Waters of LIFE

Framework of Measures and Best Practice Guidelines for the Protection and Restoration of High Status River Waterbodies

Annex 1: Agriculture

Tables of Measures for Mitigating Impacts from Significant Issues arising from Agricultural Activities in Catchment Areas where the Objective is Restoration

Waters of LIFE www.watersoflife.ie

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta
Department of Housing, Local Government and Heritage

Co-funded by the European Union

Version Control

Date	Version No	Status	Change	Author name	Reviewer name
20/1/2023	F01	Final		Donal Daly	Anne Goggin
08/8/2023	F02	Final	Measures descriptions added	Philip Murphy	Donal Daly

Acknowledgements

This measures document was developed in collaboration with RPS group, environmental consultants. The Waters of LIFE project would like to thank RPS group for their input. Their expertise and insights provided a solid foundation on which to explore new ideas and their contribution was pivotal in shaping the final outcome.

The project would like to acknowledge the input of Donal Daly, Catchment Scientist, and Philip Murphy, Agricultural Scientist.

We would also like to acknowledge the contribution of stakeholders and project partners who provided valuable input into the development of the final measures tables.

Contents

1 Introduction 1

2 Context 1

3 Explanatory Comments 2

4 Measures Guidance 25

4.1 Source reduction and control measures 25

4.1.1 A1: Farmyard management 26
4.1.2 A2: Appropriate N & P application rates 27
4.1.3 A3: Soil testing & NMP 29
4.1.4 A4: Management of farm roadways, supplementary feeders, poaching 30
4.1.5 A5: Appropriate location of supplementary drinking troughs 32
4.1.6 A6: Storage of silage bales 33
4.1.7 A7: Using low crude protein animal feeds 34
4.1.8 A8: Precision nutrient applications 35
4.1.9 A9: Management of land drainage & intensification 36
4.1.10 A10: Pesticide control & weed wiping 37
4.1.11 A 11: Reducing nitrogen loading 39

4.2 Mobilisation control measures 40

4.2.1 A12: Complying with landspreading requirements for fertilisers and soiled water 41
4.2.2 A13: Liming of mineral soils 42
4.2.3 A14: Low emission slurry spreading 43
4.2.4 A15: Cover/catch crops (tillage) 44
4.2.5 A16: Protected urea 45
4.2.6 A17: Multi-species swards 46
4.2.7 A18: Best practice N applications 47
4.2.8 A19: Application of sulphur 48
4.2.9 A20: Conservation tillage, contour ploughing & tramline management 49
4.2.10 A21: Raising water levels in peatlands 50
4.2.11 A22: Peaty soils – fertiliser spreading little and often based on crop needs 51

4.3 Pathway interception measures 52

4.3.1 A23: Fixed width buffers/setbacks 55
4.3.2 A24: Spatially targeted variable width/extended buffers 57
4.3.3 A25: Magic Margins 58
4.3.4 A26. Raised buffer/interception berm 59
4.3.5 A27: Raised buffer – overbank storage 60
4.3.6 A28: Hedgerows 61
4.3.7 A29: Wetland buffer/farm pond 63
4.3.8 A30: Swales 64
4.3.9 A31: Tile-drain fed wetland 65
4.3.10 A32: In-field sediment trap 66
4.3.11 A33: In ditch sediment trap 67
4.3.12 A34: Engineered ditch management 68
4.3.13 A35: Leaky dam 69
4.3.14 A36: Sediment filter fence 70
4.3.15 A37: Denitrifying bioreactor 72

4.3.16 A38: Woodlands (outside riparian areas) 72
4.3.17 A39: Agroforestry 74
4.3.18 A40: Integrated constructed wetlands 75
4.4 In-stream works 76
4.4.1 A41: Livestock exclusion from watercourses 76
4.4.2 A42: Bank stabilisation 77
4.4.3 A43: Invasive species control 78
4.4.4 A44: Raising the water table in groundwater dependent terrestrial ecosystems 80

List of Tables

Table 2-1: Statistics for the categories of agricultural measures including protect measures and targeted restore measures to mitigate the various *significant issues* impacting on HSO waterbodies. 2
Table 3-1: List of measures for Agricultural Activities, categorised based on location in the landscape, with guidance on the estimated effectiveness potential for pollutants and other issues of concern, where the objective is restoration to the required waterbody status or condition. 8
Table 3-2: List of measures for mitigating impacts from SEDIMENT arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 11
Table 3-3: List of measures for mitigating impacts from PHOSPHATE arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 13
Table 3-4: List of measures for mitigating impacts from NITRATE arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 15
Table 3-5: List of measures for mitigating impacts from AMMONIUM arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness. 17
Table 3-6: List of measures for mitigating impacts from BOD arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 19
Table 3-7: List of measures for mitigating impacts from MCPA arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 21
Table 3-8: List of measures for mitigating impacts from FIOs arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 22
Table 3-9: List of measures for mitigating impacts on HYDROLOGY arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness 24

List of Figures

Figure 2-1: Overview of the “Targeting Agricultural Measures” Layer on Catchments.ie. 3
Figure 3-1: Process flowchart for evaluation of measures in HSO waterbody catchments. 7
Figure 4-1: Representation of the pollutant transfer continuum. 25
Figure 4-2: Illustration of a phosphate critical source area (CSA) where water enters the watercourse along three different flow pathways. 53
Figure 4-3: PIP-P map showing an area of generally high pollution impact potential for phosphorous, with flow delivery paths and points. 54
Figure 4-4: Illustration of possible spatially targeted interception measures. 55

1 Introduction

The Waters of LIFE is a European Union funded Life Integrated Project which aims to help reverse the loss of Ireland's most pristine rivers. The ongoing loss of high-status waters is a worrying trend for water quality in Ireland. The protection and restoration of these waters is one of the key underpinning principles of the EU Water Framework Directive.

The project aims to develop, test and validate effective catchment management measures to reverse this declining trend. Six project catchments have been selected, five demonstration catchments and one control catchment. These are:

- Avonmore, Co. Wicklow - https://www.watersoflife.ie/catchments/avonmore/
- Awbeg (Kilbrin), Co. Cork - https://www.watersoflife.ie/catchments/awbeg_kilbrin/
- Graney, Co. Clare - https://www.watersoflife.ie/catchments/graney/
- Islands, Co. Roscommon / Co. Galway - https://www.watersoflife.ie/catchments/islands/
- Sheen, Co. Kerry (Control Catchment) - https://www.watersoflife.ie/catchments/sheen/
- Shournagh, Co. Cork - https://www.watersoflife.ie/catchments/shournagh/

The measures in this document were identified in the context of mitigating the issues related to agricultural pressures acting on high status objective (HSO) river waterbodies in general and the demonstration catchments in particular. However, these measures are equally applicable to river waterbodies which have been assigned a good status objective under the river basin management plan.

2 Context

Nationally, agriculture forms the principal economic land cover activity (by area) across most HSO waterbody catchments, and it has impacted on 54 of the 334 HSO waterbodies. Although encompassing a wide variety of activities, Corine Land Cover data, which subdivides agriculture into a number of subsets, indicates that pasture/livestock rearing is dominant in HSO catchments. This, and associated activities, can potentially give rise to point and diffuse pollution, thereby impacting on water quality and aquatic ecosystems.

As part of the development of Ireland's 3rd cycle River Basin Management Plan, the EPA has carried out an analysis of the types of actions that may be most beneficial in each river sub-catchment to meet the WFD environmental objectives.[1] A Targeting Agricultural Measures map[2] has been developed by the EPA to identify the types of agricultural issues that require targeted measures in each sub-catchment to support targeting the right measure in the right place to achieve water quality objectives. This incorporates EPA monitoring and characterisation data along with information from Local Authorities to assign flags to each sub-catchment which indicate the potential water quality issues. Coloured flags indicate areas where agricultural measures are needed to restore water quality:

- Navy flags are for measures to reduce phosphorus/sediment losses.
- Orange flags indicate areas to reduce nitrate losses.
- Red flags indicate that there is a potential farm point source issue.

Some sub-catchments are impacted by more than one *significant issue* arising from agricultural activities and this is indicated by a combination of coloured flags. A white flag indicates areas where

[1] https://www.epa.ie/publications/monitoring--assessment/freshwater--marine/water-quality-monitoring-report-on-nitrogen-and-phosphorous-concentrations-in-irish-waters-2022.php

[2] This map is available under the 'Maps' and 'Taking Action' headings on www.catchments.ie .

agriculture is not identified as a significant pressure and measures to protect existing good water quality are appropriate.

This information has been compiled for HSO sub basins in Table 2-1, which gives the percentage areas for each *significant issue* category arising from agricultural activities, as well as the percentage area where 'protect' farming measures are required.

Table 2-1: Statistics for the categories of agricultural measures including protect measures and targeted restore measures to mitigate the various *significant issues* impacting on HSO waterbodies.

	Targeting agricultural measures – category						
	Restore Farming Measures						Protect Farming Measures
	Navy Flag	Red & Navy Flags	Navy & Orange Flags	Red, Orange & Navy Flags	Orange Priority Flag	Orange Flag	
Number of SubBasins	27	5	22	2	5	69	204
Area (km^2)	488	103	459	47	128	1120	3850
%age area	8	2	7	1	8	13	62

Source: Source: Data from Catchment Science and Management Unit, EPA.
Note: The *significant issues* associated with farm point pressures are BOD and/or ammonium.

The Orange Priority Flag (high nitrate) and Orange Flag (risk of nitrate losses (review PIP-N map)) categories take account of transitional and coastal (TraC) waterbodies as a receptor. The Orange Flag (risk of high NO_3 losses (review PIP-N)) category is based on those areas where the downstream TraC waterbody is impacted by excess nitrate, but where there is no evidence that the nitrate is >2.6 mg/l in the HSO waterbodies, and that therefore the PIP-N maps need to be reviewed to identify appropriate measures.

While 38% of the HSO sub basin areas require farming measures to mitigate the various *significant issues*, Figure 2-1 and Table 2-1 also indicate that a high proportion of these areas – 62% – is not impacted significantly by farming. In addition, it is likely that in a substantial portion of the Orange Priority Flag and Orange Flag areas, nitrate from agricultural activities is not impacting on HSO river waterbodies. Therefore, the predominant *significant issue* category impacting on HSO river waterbodies that needs mitigation is phosphorus/sediment. Even in the sub basins where phosphate, sediment, ammonium and BOD are the *significant issues*, they will not arise throughout the sub basin areas. This highlights the importance of catchment characterisation and using the Pollution Impact Potential (PIP) maps to enable targeting of measures.

3 Explanatory Comments

- A key principle in deciding on and establishing measures is the **"right measure in the right place"**. Determining the 'right measure in the right place' is based on a number of factors, such as the following:
    i) The **issue of concern** (pollutants, hydrology (river flow), morphology (channel pattern and geometry). The main pollutants of concern are: phosphate (PO_4), Total Phosphorus (TP) (for lakes), nitrate (NO_3), ammonium (NH_4), Biological Oxygen Demand (BOD), sediment, MCPA, pH and Faecal Indicator Organisms (FIOs). Each has differing potential both in their impact and abilities to be transported in water and, in particular, to be attenuated on the land and in the landscape.

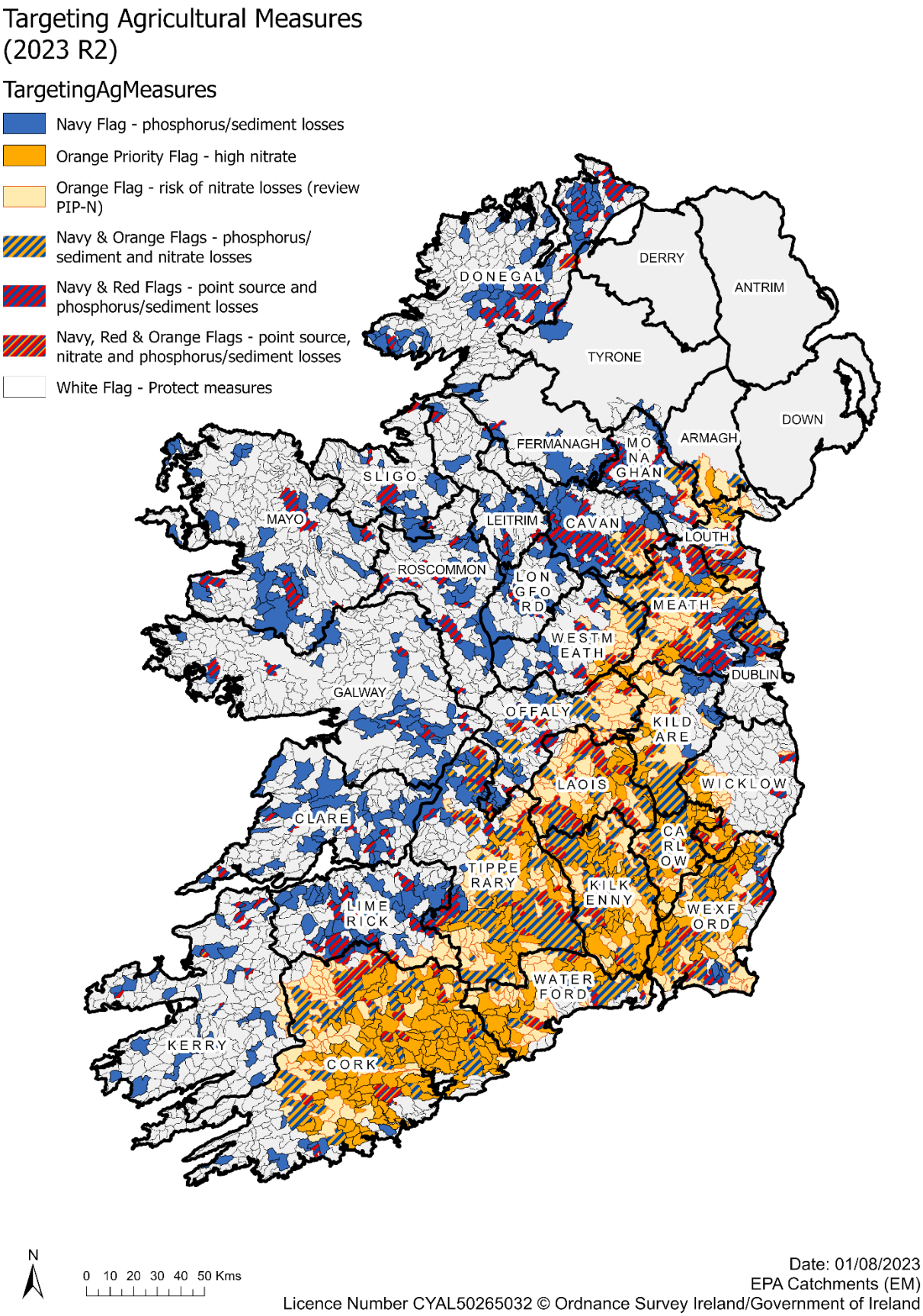

Figure 3-1: Overview of the "Targeting Agricultural Measures" Layer on Catchments.ie.

ii) The **pressure(s**) causing the issues of concern. In the case of pollutants, the relative **loading** from the pressure and the **likelihood** of the loading reaching the receptor are important factors that require consideration and assessment.

iii) The hydrogeological characteristics that determine whether the physical setting is **freely draining (FD)** or **poorly draining (PD)** as this influences the flowpaths of water and associated pollutants, and the attenuation potential.

iv) Whether the objective is to **'restore' (improve) or 'protect' (maintain**), as more stringent and resource intensive measures are likely to be needed to achieve the restore/improve objective.

Therefore, each of these factors needs to be taken into account in deciding on measures prior to their establishment, as a means of ensuring that they are efficient and effective in achieving their objectives. The catchment science and management process that encompasses these factors is shown in Figure 3-1.

- A key requirement is compliance with the measures for agricultural activities in the Good Agricultural Practices (GAP) Regulations (2022) (SI 113 of 2022 as amended by SI 393 of 2022 and SI 716 of 2022)

- Nine tables providing a menu of measures for eight issues of concern arising from agricultural activities – sediment, phosphate, nitrate, ammonium, BOD, MCPA, FIOs and hydrology (runoff and water levels) – have been compiled.
  - Table 3-1: List of measures for Agricultural Activities, categorised based on location in the landscape, with guidance on the estimated effectiveness potential for pollutants and other issues of concern, where the objective is restoration to the required waterbody status or condition.
  - Table 3-2: List of measures for mitigating impacts from **sediment** arising from agricultural activities.
  - Table 3-3: List of measures for mitigating impacts from **phosphate** arising from agricultural activities.
  - Table 3-4: List of measures for mitigating impacts from **nitrate** arising from agricultural activities.
  - Table 3-5: List of measures for mitigating impacts from **ammonium** arising from agricultural activities.
  - Table 3-6: List of measures for mitigating impacts from **BOD** arising from agricultural activities.
  - Table 3-7: List of measures for mitigating impacts from **MCPA** arising from agricultural activities.
  - Table 3-8 List of measures for mitigating impacts from **FIOs** arising from agricultural activities.
  - Table 3-9: List of measures for mitigating impacts from **hydrological impacts** arising from agricultural activities.

- The tables provide an estimate of the effectiveness of measures, that have been designed, located and established appropriately, to be used as a guide in assessing and deciding on possible measures. Four categories are given – High (H), Medium (M), Low (L), Insignificant (-).

- The measures have been categorised based on whether they are:
  i) Mandatory.
  ii) Mandatory above a stocking level.
  iii) Incentivised or voluntary.

- While many of the farming measures listed in this document have co-benefits for GHG emission reduction, carbon sequestration and terrestrial ecosystems, the primary objective is achieving

Water Framework Directive (WFD) and Habitat Directive (HD) goals, and therefore the effectiveness scoring is based on the potential to mitigate the impact of the issues of concern on aquatic ecosystems.

- In compiling the tables, the assumptions are:
  i) The receptors are surface water ecosystems.
  ii) Desk-based and field-based assessments have been undertaken in advance of decisions on measures. Therefore, the following factors are known, thereby providing the basis for decision-making on measures: a) the issues of concern arising from agricultural activities that are impacting on the ecosystems (such as sediment, phosphate, nitrate, ammonium, BOD, MCPA, FIOs and hydrology); b) the physical setting (poorly draining (mineral and peatland) and freely draining); and c) the 'story' of the catchment.
  iii) The effectiveness ratings are based on measures needed in the catchments of waterbodies in 'Areas for Restoration' where, for instance, significant reductions in pollutant loads may be required.
  iv) The High (H) rating has been reserved for measures that on their own will make a significant difference to improving the water quality.
  v) To achieve receptor restoration and the desired aquatic ecosystem objective, a suite of measures at an appropriate scale will generally need to be established.

- When considering the content of the tables, the recommended approach is to:
  i) Ensure that characterisation of a waterbody catchment has been undertaken and the following is known: a) the required objective (e.g. status) has not been achieved and the catchment is therefore an *Area for Restoration*; b) the issues of concern; c) the physical settings (hydrology/hydrogeology); and d) the pressures causing the impacts.
  ii) Start with the i**ssue of concern** (e.g. phosphate).
  iii) Keep in mind the main physical settings – **poorly draining (mineral and peatland) and freely draining** – as in the case of pollutants, for instance, these determine a) water and pollutant pathways, b) attenuation on the land and in the landscape and c) the likelihood that the pollutant and associated pressure will impact on the receptor.
  iv) Analyse each possible measure in terms of **potential to mitigate the impact** of the issue of concern arising from the specific pressure (e.g. the potential to reduce the load of phosphate entering a watercourse from pasture land), and in the process make a significant contribution to restoring the waterbody to the required objective and condition.
  v) Keep in mind that a combination of measures is likely to be needed.
  vi) Use the measures effectiveness ratings when prioritising establishment of measures.

Guidance on the 44 measures in Table 3-1 is provided in Section 4. It is recommended that the tables and guidance be considered in conjunction with the Waters of Life Measures Framework report, which provides the background catchment science understanding on which the measures are based.

Sources of information on prevention of water pollution from agricultural activities

DAFM, 2022. S.I. 113 pf 2022. European Union (Good Agricultural Practices for Protection of Waters) Regulations, 2022 and subsequent amendments. https://www.irishstatutebook.ie/eli/2022/si/113/made/en/pdf

LAWPRO/EPA (2022a). An overview of catchment science and management. A Guidance Handbook. Volume 1. Local Authority Waters Programme and Catchment Science and Management Unit, Environmental Protection Agency. https://lawaters.ie/app/uploads/2022/01/Print_CSM-Volume-1_April-2022.pdf

LAWPRO/EPA (2022b). Pressures and catchment walks. A Guidance Handbook. Volume 2. Local Authority Waters Programme and Catchment Science and Management Unit, Environmental Protection Agency. https://lawaters.ie/app/uploads/2022/09/Print_CSM-Volumes-23_April-2022.pdf

NFGWS, 2020. A Handbook of Source Protection and Mitigation Actions for Farming. Published by the National Federation of Group Water Schemes. Available for download at www.nfgws.ie. (This publication contains links to relevant sources of information on the various Actions, including links to Teagasc advice.)

O'Connor, M. (2023). Duhallow Farming for Blue Dot Catchments. Booklet of Measures. IRD Duhallow. https://www.irdduhallow.com/site15/wp-content/uploads/2023/04/Booklet-of-Measures-Interactive.pdf

RPS, 2022. Framework for Best Practices Measures and Guidelines for the Protection and Restoration of High Status Waterbodies. Report for Water of LIFE.

SMARTER_BufferZ project This EPA funded project, which is undertaken by Teagasc and the James Hutton Institute, outlines the role of riparian buffers for the effective management of Irish rivers. http://www.smarterbufferz.ie/

Water of Life, 2023a. Framework of best practice measures and guidelines on the protection and restoration of high status river waterbodies.

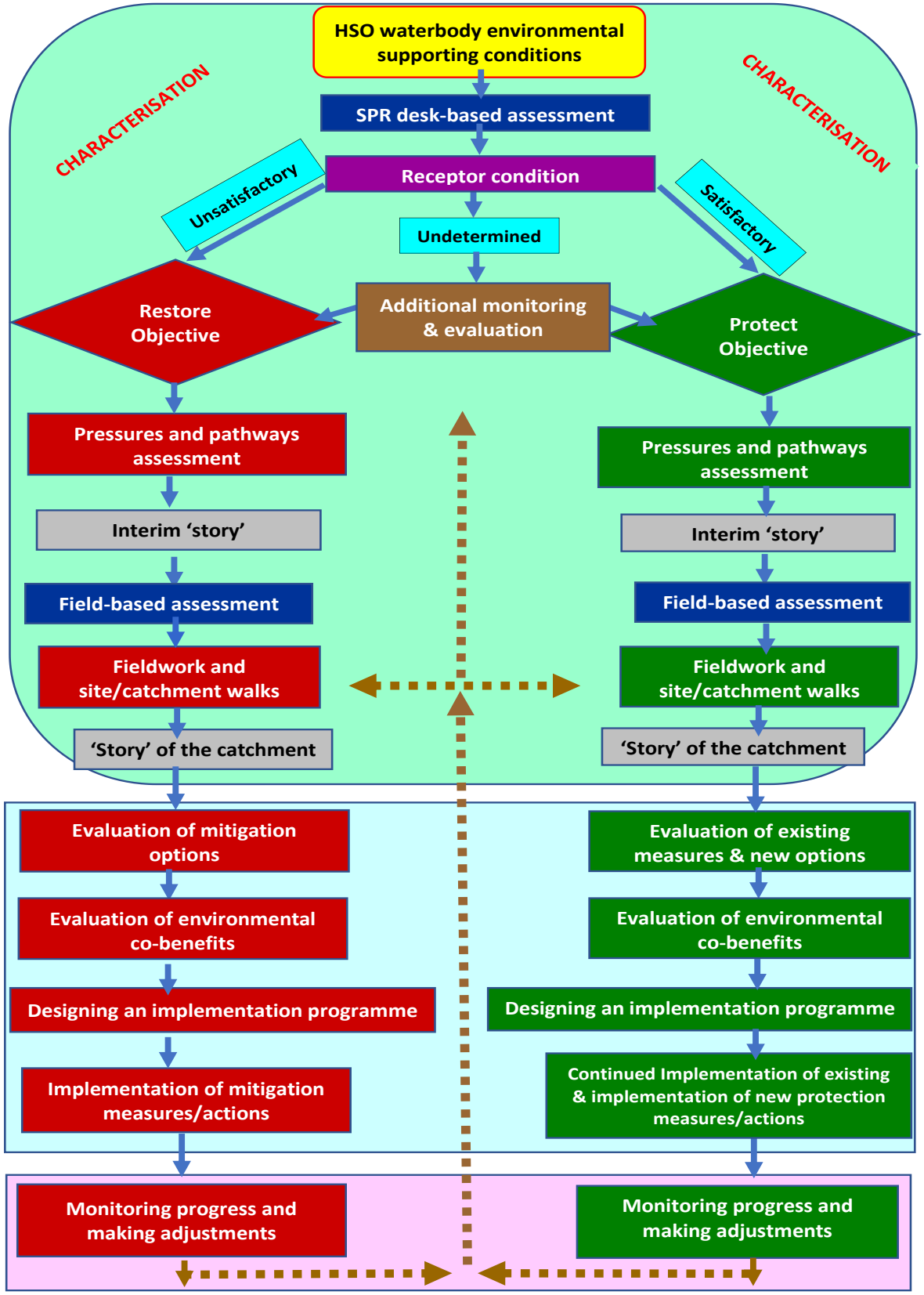

Figure 3-2: Process flowchart for evaluation of measures in HSO waterbody catchments.

Table 3-1: List of measures for Agricultural Activities, categorised based on location in the landscape, with guidance on the estimated effectiveness potential for pollutants and other issues of concern, where the objective is restoration to the required waterbody status or condition.

No.	Cat.	Measure	Measures Effectiveness (High (H), Medium (M), Low (L), Insignificant (-))															
			Sediment		PO_4		NO_3		NH_4		BOD		MCPA		FIOs		Hydrology	
			PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD
A1	Source reduction & control	Farmyard management	M	L	H	L	L	-	M	L	H	M	-	-	H	M	-	-
A2		Appropriate N & P application rates	-	-	M	L	-	M	-	-	-	-	-	-	-	-	-	-
A3		Soil testing & NMP**	-	-	M	-	-	M	-	-	-	-	-	-	-	-	-	-
A4		Management of farm roadways, supplementary feeders, poaching	H	L	M	L	-	-	L	-	M	L	-	-	H	M	-	-
A5		Appropriate location of supplementary drinking troughs**	L	-	L	-	-	-	-	-	L	-	-	-	L	-	-	-
A6		Storage of silage bales	-	-	-	-	-	-	-	-	M	L	-	-	-	-	-	-
A7		Using low crude protein animal feeds**	-	-	L	-	-	M	-	-	-	-	-	-	-	-	-	-
A8		Precision nutrient applications (e.g. using GPS technology in conjunction with NMP).	-	-	L	-	-	L	-	-	-	-	-	-	-	-	-	-
A9		Management of land drainage & intensification	H	L	L	-	-	-	-	-	-	-	-	-	-	-	L	-
A10		Pesticide control & weed wiping	-	-	-	-	-	-	-	-	-	-	H	-	-	-	-	-
A11		Reducing N loading	-	-	M	-	-	H	L	-	-	-	-	-	-	-	-	-
A12	Mobilisation control	Complying with landspreading requirements for fertilisers and soiled water (e.g. closed period).	-	-	H	-	-	M	M	-	M	-	-	-	M	-	-	-
A13		Liming of mineral soils**	-	-	M	-	-	L	-	-	-	-	-	-	-	-	-	-
A14		Low emission slurry spreading**	-	-	L	-	-	L	L	-	-	-	-	-	L	-	-	-
A15		Cover/catch crops (tillage)**	H	L	L	-	-	M	-	-	-	-	-	-	-	-	-	-
A16		Protected urea	-	-	-	-	-	L	-	-	-	-	-	-	-	-	-	-
A17		Multi-species swards	-	-	-	-	-	L	-	-	-	-	-	-	-	-	-	-

No.	Cat.	Measure	Measures Effectiveness (High (H), Medium (M), Low (L), Insignificant (-))															
			Sediment		PO_4		NO_3		NH_4		BOD		MCPA		FIOs		Hydrology	
			PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD
A18		Best practice N applications (e.g. taking account of: i) soil temperature, ii) SMD, grass growth rate, iv) rainfall, v) N content of organic fertilisers).	-	-	-	-	-	L	-	-	-	-	-	-	-	-	-	-
A19		Application of sulphur (to improve N efficiency)	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-
A20		Conservation tillage, contour ploughing & tramline management	H	-	L	-	-	L	-	-	-	-	-	-	-	-	-	-
A21		Raising water levels in peatlands	L	-	L	-	-	-	H	-	L	-	-	-	-	-	H	-
A22		Peatland soils (>20% OM) – fertiliser spreading little and often based on crop needs	-	-	M	-	-	-	L	-	-	-	-	-	-	-	-	-
A23	Pathway interception	Fixed-width buffers/setbacks	L	-	L	-	-	-	L	-	L	-	L	-	L	-	-	-
A24		Spatially targeted variable width/extended buffer	H	-	H	-	-	L	H	-	H	-	M	-	H	-	M	-
A25		Magic margin	M	-	M	-	-	-	L	-	L	-	L	-	L	-	L	-
A26		Raised buffer/interception berm	H	-	M	-	-	-	L	-	L	-	-	-	L	-	M	-
A27		Raised buffer – overbank storage	M	-	L	-	-	-	L	-	L	-	-	-	L	-	M	-
A28		Hedgerows (along a contour or alongside a watercourse)	M	-	M	-	-	-	L	-	L	-	L	-	M	-	-	-
A29		Wetland buffer/farm pond	M	-	M	-	L	L	M	-	M	-	L	-	L	-	M	-
A30		Swales	M	-	M	-	-	-	M	-	M	-	L	-	M	-	M	-
A31		Tile-drain fed wetland	L	-	L	-	-	-	L	-	L	-	L	-	L	-	M	-
A32		In-field sediment trap	M	-	M	-	-	-	-	-	L	-	-	-	L	-	L	-
A33		In ditch sediment trap	M	-	M	-	-	-	L	-	L	-	-	-	L	-	L	-
A34		Engineered ditch management, e.g. two-stage channel	M	-	M	-	-	-	L	-	L	-	L	-	L	-	M	-
A35		Leaky dam	M	-	L	-	-	-	-	-	-	-	-	-	-	-	L	-
A36		Sediment filter fence (tillage)	M	-	L	-	-	-	-	-	-	-	-	-	-	-	-	-

No.	Cat.	Measure	Measures Effectiveness (High (H), Medium (M), Low (L), Insignificant (-))															
			Sediment		PO_4		NO_3		NH_4		BOD		MCPA		FIOs		Hydrology	
			PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD	PD	FD
A37		Denitrifying bioreactor	M	-	L	-	M	M	L	L	L	-	L	-	L	-	-	-
A38		Woodlands (outside riparian areas)	-	-	L	-	-	L	L	-	L	-	L	-	L	-	-	-
A39		Agroforestry (outside riparian areas)	-	-	L	-	-	L	L	-	L	-	-	-	L	-	-	-
A40		ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	M	-	M	L	-	-	M	L	M	L	-	-	L	-	-	-
A41	In-stream works	Livestock exclusion from watercourses (drinking points, river crossings)**	M	M	L	L	-	-	L	L	L	L	-	-	M	M	-	-
A42		Bank stabilisation	L	L	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A43		Invasive species control	M	M	L	L	-	-	-	-	-	-	-	-	-	-	L	-
A44		Raising water table in groundwater dependent terrestrial ecosystems (GWDTEs)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H	H

Notes:

Mandatory measure in GAP Regulations

** Measure is not mandatory for all circumstances, e.g. below certain stocking rates – see GAP Regulations for details.

Table 3-2: List of measures for mitigating impacts from SEDIMENT arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A4	Management of farm roadways, supplementary feeders, poaching*	H
	A9	Management of land drainage & intensification	H
	A15	Cover/catch crops (tillage)*	H
	A20	Conservation tillage, contour ploughing & tramline management	H
	A24	Spatially targeted variable width/extended buffer	H
	A26	Raised buffer/interception berm	H
	A1	Farmyard management*	M
	A25	Magic margins	M
	A27	Raised buffer/overbank storage	M
	A28	Hedgerows (along a contour or alongside a watercourse)	M
	A29	Wetland buffer/farm pond	M
	A30	Swales	M
	A32	In-field sediment trap	M
	A33	In-ditch sediment trap	M
	A34	Engineered ditch management, e.g. two-stage channel	M
	A35	Leaky dam	M
	A36	Sediment filter fence (tillage)	M
	A37	Denitrifying bioreactor	M
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance).	M
	A41	Livestock exclusion from watercourses (drinking points, river crossings) **	M
	A43	Invasive species control	M
	A5	Appropriate location of supplementary drinking troughs**	L
	A21	Raising water levels in peatlands	L
	A23	Fixed-width buffers/setbacks*	L
	A31	Tile-drain fed wetland	L
	A42	Bank stabilisation	L
Freely draining			
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	M
	A43	Invasive species control	M
	A1	Farmyard management*	L
	A4	Management of farm roadways, supplementary feeders, poaching**	L
	A7	Management of land drainage and intensification	L
	A15	Cover/catch crops (tillage)*	L

	A42	Bank stabilisation	L

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration and/or terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures

Mobilisation control measures

Pathway interception measures

In-stream measures

Table 3-3: List of measures for mitigating impacts from PHOSPHATE arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A1	Farmyard management*	H
	A12	Complying with landspreading requirements for fertilisers and soiled water, e.g. closed period*	H
	A28	Spatially targeted variable width/extended buffer	H
	A2	Appropriate N & P application rates*	M
	A3	Soil testing & NMP**	M
	A4	Management of farm roadways, supplementary feeders, poaching**	M
	A11	Reducing N loading, e.g. less LUs/ha	M
	A13	Liming of mineral soils**	M
	A22	Peatland soils (>20% OM) – fertiliser spreading little and often based on crop needs	M
	A25	Magic margins	M
	A26	Raised buffer/interception berm	M
	A28	Hedgerows (along a contour or alongside a watercourse)	M
	A29	Wetland buffer/farm pond	M
	A30	Swales	M
	A32	In-field sediment trap	M
	A33	In-ditch sediment trap	M
	A34	Engineered ditch management, e.g. two-stage channel	M
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	M
	A5	Appropriate location of supplementary drinking troughs**	L
	A7	Using low crude protein animal feeds**	L
	A8	Precision nutrient applications (e.g. using GPS technology in conjunction with NMP).	L
	A9	Management of land drainage & intensification	L
	A14	Low emission slurry spreading**	L
	A15	Cover/catch crops (tillage)*	L
	A20	Conservation tillage, contour ploughing & tramline management	L
	A21	Raising water levels in peatlands	L
	A23	Fixed-width buffers/setbacks*	L
	A27	Raised buffer – overbank storage	L
	A32	Tile-drain fed wetland	L
	A35	Leaky dam	L
	A36	Sediment filter fence (tillage)	L
	A37	Denitrifying bioreactor	L
	A38	Woodlands (outside riparian areas)	L
	A39	Agroforestry (outside riparian areas)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	L

Setting	No.	Measure	Effectiveness rating
	A43	Invasive species control	L
Freely Draining			
	A1	Farmyard management*	L
	A2	Appropriate N & P application rates*	L
	A4	Management of farm roadways, supplementary feeders, poaching**	L
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	L
	A43	Invasive species control	L

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The measures ratings do not apply to the freely draining soils and permeable subsoils, which are derived from Old Red Sandstone bedrock, located close to the coast in County Cork where the geochemistry, particularly the high iron content, facilitates leaching to groundwater.
4. The ratings are intended as guidance, and they may vary depending on local circumstances.
5. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration and/or terrestrial biodiversity enhancement.
6. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
7. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
8. The measures are categorised based on their location in the landscape.

Source reduction & control measures

Mobilisation control measures

Pathway interception measures

In-stream measures

Table 3-4: List of measures for mitigating impacts from NITRATE arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A37	Denitrifying bioreactor	M
	A1	Farmyard management	L
	A29	Wetland buffer/farm pond (in riparian area)	L
Freely draining	A11	Reducing N loading, e.g. less LUs/ha	H
	A2	Appropriate N & P application rates*	M
	A3	Soil testing & NMP**	M
	A7	Using low crude protein animal feeds**	M
	A12	Complying with landspreading requirements for fertilisers and soiled water, e.g. closed period*	M
	A15	Cover/catch crops (tillage)*	M
	A19	Application of sulphur	M
	A37	Denitrifying bioreactor	M
	A8	Precision nutrient applications (e.g. using GPS technology in conjunction with NMP).	L
	A13	Liming of mineral soils**	L
	A14	Low emission slurry spreading**	L
	A16	Protected urea	L
	A17	Multi-species swards	L
	A18	Best practice N applications (e.g. taking account of: i) soil temperature, ii) SMD, grass growth rate, iv) rainfall, v) N content of organic fertilisers).	L
	A20	Conservation tillage, contour ploughing & tramline management	L
	A24	Spatially targeted variable width/extended buffer	L
	A29	Wetland buffer/farm pond	L
	A38	Woodlands (outside riparian areas)	L
	A39	Agroforestry (outside riparian areas)	L

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.

** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).

7. The measures are categorised based on their location in the landscape.

Source reduction & control measures	Mobilisation control measures
Pathway interception measures	In-stream measures

Table 3-5: List of measures for mitigating impacts from AMMONIUM arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A21	Raising water levels in peatlands	H
	A24	Spatially targeted variable width/extended buffer	H
	A1	Farmyard management*	M
	A12	Complying with landspreading requirements for fertilisers and soiled water, e.g. closed period*	M
	A29	Wetland buffer/farm pond	M
	A30	Swales	M
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	M
	A4	Management of farm roadways, supplementary feeders, poaching**	L
	A11	Reducing N loading, e.g. less LUs/ha	L
	A14	Low emission slurry spreading**	L
	A22	Peatland soils (>20% OM) – fertiliser spreading little and often based on crop needs	L
	A23	Fixed-width buffers/setbacks	L
	A25	Magic margins	L
	A26	Raised buffer/interception berm	L
	A27	Raised buffer/overbank storage	L
	A28	Hedgerows (along a contour or alongside a watercourse)	L
	A31	Tile-drain fed wetland	L
	A33	In-ditch sediment trap	L
	A34	Engineered ditch management, e.g. two-stage channel	L
	A37	Denitrifying bioreactor	L
	A38	Woodlands (beyond riparian areas)	L
	A39	Agroforestry (beyond riparian areas)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings) **	L
Freely Draining			
	A1	Farmyard management *	L
	A37	Denitrifying bioreactor	L
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	L

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.

4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures	Mobilisation control measures
Pathway interception measures	In-stream measures

Table 3-6: List of measures for mitigating impacts from BOD arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A1	Farmyard management*	H
	A20	Spatially targeted variable width/extended buffer	H
	A4	Management of farm roadways, supplementary feeders, poaching**	M
	A6	Storage of silage bales	M
	A12	Complying with landspreading requirements for fertilisers and soiled water, e.g. closed period*	M
	A29	Wetland buffer/farm pond	M
	A30	Swales	M
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	M
	A5	Appropriate location of supplementary drinking troughs**	L
	A21	Raising water levels in peatlands	L
	A23	Fixed-width buffers/setbacks	L
	A25	Magic margins	L
	A26	Raised buffer/interception berm	L
	A27	Raised buffer/overbank storage	L
	A28	Hedgerows (along a contour or alongside a watercourse)	L
	A31	Tile-drain fed wetland	L
	A32	In-field sediment trap	L
	A33	In-ditch sediment trap	L
	A34	Engineered ditch management, e.g. two-stage channel	L
	A37	Denitrifying bioreactor	L
	A38	Woodlands (outside riparian areas)	L
	A39	Agroforestry (outside riparian areas)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings) **	L
Freely Draining			
	A1	Farmyard management *	M
	A4	Management of farm roadways, supplementary feeders, poaching**	L
	A6	Storage of silage bales	L
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	L
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	L

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.

2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures	Mobilisation control measures
Pathway interception measures	In-stream measures

Table 3-7: List of measures for mitigating impacts from MCPA arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A10	Pesticide control & weed wiping	H
	A24	Spatially targeted variable width/extended buffer	M
	A23	Fixed-width buffers/setbacks	L
	A25	Magic margins	L
	A28	Hedgerows (along a contour or alongside a watercourse)	L
	A29	Wetland buffer/farm pond	L
	A30	Swales	L
	A31	Tile-drain fed wetland	L
	A34	Engineered ditch management, e.g. two-stage channel	L
	A37	Denitrifying bioreactor	L
	A38	Woodlands (beyond outside areas)	L
Freely Draining			
	10	Pesticide control & weed wiping	H

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures

Mobilisation control measures

Pathway interception measures

In-stream measures

Table 3-8: List of measures for mitigating impacts from FIOs arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A1	Farmyard management*	H
	A4	Management of farm roadways, supplementary feeders, poaching**	H
	A24	Spatially targeted variable width/extended buffer	H
	A12	Compliance with landspreading requirements for fertilisers and soiled water, e.g. closed period*	M
	A28	Hedgerows (along a contour or alongside a watercourse)	M
	A30	Swales	M
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	M
	A5	Appropriate location of supplementary drinking troughs**	L
	A14	Low emission slurry spreading	L
	A23	Fixed-width buffers/setbacks	L
	A25	Magic margins	L
	A26	Raised buffer/interception berm	L
	A27	Raised buffer/overbank storage	L
	A29	Wetland buffer/farm pond	L
	A31	Tile-drain fed wetland	L
	A32	In-field sediment trap	L
	A33	In-ditch sediment trap	L
	A34	Engineered ditch management, e.g. two-stage channel	L
	A37	Denitrifying bioreactor	L
	A38	Woodlands (outside riparian areas)	L
	A39	Agroforestry (outside riparian areas)	L
	A40	ICWs for soiled water (using DAFF specification S133 (2011) and maintenance)	L
Freely Draining			
	A1	Farmyard management*	M
	A4	Management of farm roadways, supplementary feeders, poaching**	M
	A41	Livestock exclusion from watercourses (drinking points, river crossings)**	M

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.

5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures

Mobilisation control measures

Pathway interception measures

In-stream measures

Table 3-9: List of measures for mitigating impacts on HYDROLOGY arising from agricultural activities in poorly draining and freely draining areas, with measures ranked based on an estimation of effectiveness.

Setting	No.	Measure	Effectiveness rating
Poorly Draining	A21	Raising water levels in peatlands	H
	A44	Raising water table in groundwater dependent terrestrial ecosystems (GWDTEs)	H
	A24	Spatially targeted variable width/extended buffer	M
	A26	Raised buffer/interception berm	M
	A27	Raised buffer – overland storage	M
	A29	Wetland buffer/farm pond	M
	A30	Swales	M
	A31	Tile-drain fed wetland	M
	A34	Engineered ditch management, e.g. two-stage channel	M
	A9	Management of land drainage and intensification	L
	A25	Magic margins	L
	A32	In-field sediment trap	L
	A33	In-ditch sediment trap	L
	A35	Leaky dam	L
	A33	Invasive species control	L
Freely Draining			
	A44	Raising water table in groundwater dependent terrestrial ecosystems (GWDTEs)	H

Notes:

1. Measures effectiveness ratings: High (H), Medium (M), Low (L). Measures classified as having an insignificant effect are not shown.
2. The ratings are based on consideration of measures in the catchment areas of waterbodies where the objective is restoration to the required water body status or condition.
3. The ratings are intended as guidance, and they may vary depending on local circumstances.
4. The ratings do not account for environmental co-benefits, such as GHG emission reduction, carbon sequestration, terrestrial biodiversity enhancement.
5. For optimum effectiveness, a suite of measures at an appropriate scale will generally need to be established.
6. Mandatory measures are indicated as follows:
   * Mandatory measures.
   ** Mandatory measures only when a stocking rate is exceeded (see GAP Regulations).
7. The measures are categorised based on their location in the landscape.

Source reduction & control measures

Mobilisation control measures

Pathway interception measures

In-stream measures

4 Measures Guidance

The measures for agricultural activities are categorised depending on their location along the 'pollutant transfer continuum' in the landscape (Figure 4-1):

i) Measures to reduce or eliminate the pollutants or issue of concern.
ii) Measures to reduce mobilisation of pollutants on land.
iii) Pathway interception measures.
iv) Receptor in-stream works.

In addition, account is taken of whether the pressures are located in poorly draining or freely draining settings, as this has important implications for the appropriateness and effectiveness of the measures.

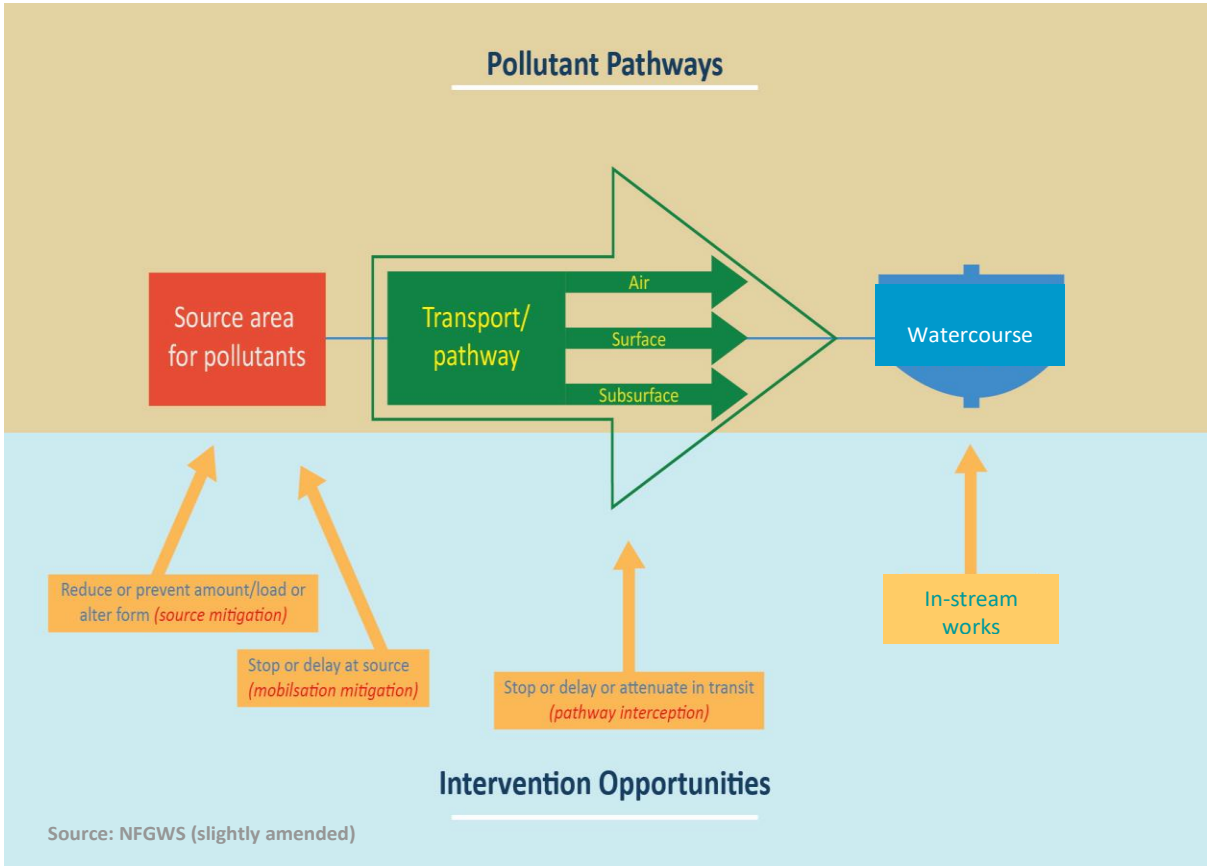

Figure 4-1: Representation of the pollutant transfer continuum.

4.1 Source reduction and control measures

In the hierarchy of pollution prevention, the primary preference is source reduction, which is the process of minimising the load of nutrients and other potential pollutants generated at the source (whether in the farmyard or in the fields) to lessen the impact on the local environment, and specifically water quality. Source control aims to prevent or minimise pollutants leaving the source area, e.g. farmyard.

Regardless of the current or incoming policy for agriculture, there are a number of fundamental farm activities that lead to the generation of potentially polluting materials, such as livestock manures, contaminated water, silage effluent, agro-chemicals, hazardous materials and plastics. At waterbody level, the migration of these materials into water can lead to nutrient pollution (nitrate, phosphate

and ammonium), pathogen contamination (faecal matter), pesticide contamination (e.g. herbicides), and hazardous material contamination (e.g. oil, diesel).

The collection and storage of potentially polluting materials generated by farming is typically guided by policy, which sets a high standard for farmers. It is therefore important to seek out opportunities to put in place a process that can reduce the source load produced on a farm. This will not only reduce the likelihood of losses to water, but will reduce the total amount of pressure put on collection and storage infrastructure. In addition, control measures (e.g. management of farm roadways and supplementary feeders) further decreases the risk of impacting on water and aquatic ecosystems.

The following is a list of measures (A1 to A11) that could be used individually or in combination with other measures to help with source reduction and control on farms in the catchment areas of HSO waterbodies.

4.1.1 A1: Farmyard management

The aim of this measure is to provide guidance on identifying the process of generating and storing dirty water, manure, slurry and silage effluent on a farm. This includes identifying the pathways and likelihood of pollutants leaking to the nearest waterbody. Proper storage of chemicals, including fertilizers, detergents, oils and fuel, disinfectants and pesticides, and the filling of sprayers needs to be considered in this context. Farmyards pose a high risk of point source pollution when not managed correctly. Point source pollution can by-pass any potential attenuation areas and enter the waterbody in a concentrated form. For a frame of reference, the minimum basic requirements relating to farmyard management issues are stipulated in the GAP Regulations.

Implementation
Implementation of this measure is as per standard best farming practice and in compliance with the GAP Regulations and Cross Compliance, and would be expected to have an immediate effect on reducing and controlling pollutants at farm level. Additional environmental benefits from implementation are limited, but it may reduce bacterial and pesticide loads to drinking water abstraction sources, particularly local well supplies which could be on-farm.

Consider the following during and after a farm visit

- Is the volume of dirty water produced in the farmyard minimised and is clean water diverted, e.g. rainwater, so as it doesn't become contaminated?
- Is slurry, soiled water, farmyard manure, silage effluent, etc. managed through appropriate collection and storage infrastructure so that runoff or seepage to surface water or groundwater is prevented.
- Are chemicals stored in secure locations with bunding as required? Spillages must be cleaned immediately and not be washed to surface water drains. All containers and bags must be disposed of appropriately and must not be washed to surface water drains.
- Infrastructure must be in place *before* risk generating activities are undertaken.
- In poorly draining, high rainfall areas, farmyards are more likely to be problematical due to greater runoff potential, and greater connectivity to watercourses due to the presence of a high density of streams and ditches. High rainfall events in well drained areas are not exempt from this pathway however. It is worthwhile considering whether a heavy and consistent downpour event on a farmyard would mobilise pollutants that would otherwise remain in the farmyard.
- Costs are an essential element of meeting the basic requirements, and initial capital costs or major refurbishments can be significant but may be defrayed by grants. No significant additional costs accrue due to implementation, or operation.

Other notes

A high level of compliance with this measure is required in all areas, but in HSO waterbodies in particular, as these ecosystems are sensitive and can be impacted by relatively low loads of pollutant. In addition to noting measures implementation in the farmyard, a walk to and from the nearest watercourse can help to identify any pathways for pollutants to the watercourse.

Sources of information

- LAWPRO/EPA (2022b). Pressures and catchment walks. A Guidance Handbook. Volume 2, Chapter 2. https://lawaters.ie/app/uploads/2022/09/Print_CSM-Volumes-23_April-2022.pdf
- NFGWS, 2020. A Handbook of Source Protection and Mitigation Actions for Farming. Available for download at https://nfgws.ie/
- Farmyard Management to avoid pollution for the winter ahead .https://www.teagasc.ie/publications/2019/farmyard-management-to-avoid-pollution-for-the-winter-ahead.php
- Rural Environment & Sustainability – Nitrates. https://www.gov.ie/en/publication/c9563-rural-environment-sustainability-nitrates/
- Explanatory Handbook for Cross Compliance Requirements. https://www.gov.ie/en/publication/6ab3e9-cross-compliance-requirements/

4.1.2 A2: Appropriate N & P application rates

The aim of this measures is to ensure the implementation and seasonal reviewing/adjustment of a Nutrient Management Plan (NMP) on a farm. In recent years, significant weather extremes such as drought and heavy rainfall have highlighted the need to adjust application practices mid-season to both minimise economic losses and environmental impacts.

In sensitive HSO waterbodies, soil nutrient status and pH, and an assessment of risk to waters needs to be carried out in greater detail using maps and a farm walk. Accuracy of spreading and use of low emission spreading technology in line with the NMP reduces risk of leaching excess nutrients. NMPs must be fully compliant with all obligations under the GAP Regulations, and certain additional measures are required where stocking rates are >170kg/ha/year organic N. The frequency of preparation of the NMP may vary from 3 to 5 years, but it could be reviewed with the farmer annually in a HSO waterbody.

Implementation

The NMP tool is available for agricultural professionals at https://nmp.teagasc.ie. The NMP must consider the whole farm and all sources of nutrients regardless of enterprise type. It should detail timing and rates of application for all fields, and the types of fertilizer and equipment (including GPS technologies) to be used. It must be supported by an adequate soil testing programme (3-4 years or as per compliance, e.g. derogation requirements). It will likely be necessary to provide a guidance letter or referral to the farmer outlining extra steps they need to take on their farm to ensure minimal losses to a HSO WB.

Estimated costs

A NMP is likely to cost approximately €400.

Consider the following during and after a farm visit

- It will optimise economic return from nutrient applications and, in the process, can reduce the likelihood of surplus nutrients in the wider environment.
- In some instances, it may be necessary to reduce application to below optimum crop requirements where excessive soil nutrients need to be reduced – specifically for soil P levels (and Potassium (K) for agronomic reasons).
- Nutrient distribution from slurry is important across the farm; typically fields close to the farmyard receive the majority of nutrient due to proximity to slatted sheds. While an NMP would identify poorer fertility fields, in practice due to costs/time/distances, slurry is often not transported to the fields that need it most.
- Critically consider NO_3 on freely draining soils and subsoils in general, and in high nitrate Pollution Impact Potential (PIP) areas[3].
- Critically consider PO_4 on poorly draining soils and subsoils, and on peaty soils in general, and in high phosphate PIP areas in particular.
    - N losses to water are primarily an issue in freely draining areas where NO_3 is easily leached downward from soils, particularly with grazing livestock and especially due to losses from urine patches.
    - The efficiency of N uptake in grasslands may be less than 30% of applied N (seasonality of N – see sources of information below).
- Use of protected urea instead of urea and CAN reduces atmospheric losses of N (Protected Urea – see sources of information below).
- P applications to suit crop needs must be based on soil testing. While soil P index 3 is generally considered optimal, soil P index 1 and 2 may be sufficient to meet requirements in extensive farming scenarios such as occur in many HSO waterbodies.
- In all scenarios, applications must correspond with suitable weather conditions (soil temperature and expected rainfall) that help ensure maximum plant P uptake and minimal losses to the wider environment.
- PO_4 is readily adsorbed to mineral soil particles and not readily leached. It may be transported to waterways with sediments during surface flow events.
- Peaty soils cannot store P and losses can readily occur – via overland flows and shallow subsurface flow flows.
- P application on peaty soils needs to be applied by regular low-rate applications rather than a single high rate application.
- While source reduction using NMPs may moderate nutrient application and losses from soils with immediate effect, reduction of soil P reserves may take several years.
- NMPs may need to be complemented by other measures such as reduction in stocking rates. Grant support may be available through proposals of the Food Vision Beef and Sheep Group or other enterprise specific schemes. There are also potential synergies with the Organic Farming Scheme.

Environmental co-benefits

- N measures reduce greenhouse gas emissions.
- These measures help maintain quality in drinking water abstraction sources, as well as the recreation and amenity value of waters.

[3] PIP maps can be accessed at https://gis.epa.ie/EPAMaps/Water under the heading 'PRESSURES & ACTIVITIES'.

Sources of information

- Implementing NMP's - https://www.teagasc.ie/news--events/daily/environment/why-nutrient-management-planning-is-so-important-for-farmers.php
- Dept. Agricultural, Environment and Rural Affairs, NI - https://www.daera-ni.gov.uk/articles/nutrient-management-plan
- The Fertilizer Association of Ireland in association with Teagasc Technical Bulletin Series – No. 4 February 2019 - https://www.fertilizer-assoc.ie/wp-content/uploads/2019/02/The-Efficient-Use-of-Phosphorus-In-Agricultural-Soils-Tech-Bulletin-No.-4.pdf
- AFBI, The Importance of a Farm Nutrient Management Plan - https://www.afbini.gov.uk/news/importance-farm-nutrient-management-plan
- Seasonality of nitrogen uptake, apparent recovery of fertilizer nitrogen and background nitrogen supply in two Irish grassland soils – t-stor – https://t-stor.teagasc.ie/handle/11019/448
- Why You Should Use Protected Urea https://www.teagasc.ie/news--events/daily/environment/why-you-should-use-protected-urea.php

4.1.3 A3: Soil testing & NMP

The aim of this measure is to support the use of NMP. Soil nutrient testing will determine soil status and agronomic need, and is essential to inform NMPs. Crop response to fertilizer application decreases with increasing soil index class (1-3). The risk of nutrient loss to waters increases as the soil P Index increases, as this indicates that higher P loadings are present in the soil. While achieving soil P index 3 may be considered agronomically optimal, soil P index 1 and 2 may be sufficient to meet requirements in extensive farming scenarios and certain farms in the catchment areas of HSO waterbodies. Terrestrial biodiversity benefits are likely to be higher on lower P index soils.

Laboratory testing for N in soils is not undertaken. Guidance on N requirements for grassland systems is based mainly on the land use and farming system, and particularly on stocking rates. In tillage systems, N supply status depends on crops grown in previous years, previous applications of chemical and organic manures, and the requirement of the current crop and the likely crop yield.

Implementation

Soils testing should be carried out in tandem with an NMP (at least at 3-5 year intervals). Analysis should include the measurement of soil pH and organic matter content. It will inform the need for liming of mineral soils. December or January would be the most likely optimal times to soil sample for most farms. Being consistent in the sampling timing and sampling pattern will help improve the accuracy of the results.

Soil samples should be taken strategically to cover different soil types, cropping histories (grazing or silage) and field divisions. Keep a record of the order paddocks were sampled in and the date. To be representative of the area. Sampling should follow a "W" pattern. The recommended rate is one sample per 2–4 ha stratified by soil type, cropping history, known growth differences/previous performance etc. A sample normally consists of 0.25 – 0.5 kg of soil and is comprised of a minimum of 20 cores taken to a uniform depth of 10cm.

Estimated costs

The cost of soil sampling is approximately €2/ha/year over a four-year sampling cycle.

Consider the following during and after a farm visit

- What soil sampling regime has already been implemented on the farm? Has it been recorded or mapped and digitised?
- What is the distribution of crop types across the farm?
- Sample every paddock to best line up results with fertiliser application plans. Map and divide the farm into 2h or 4ha soil areas and use the same divides every sampling year.
- Identify soil type differences and topographic differences (consider the pathways for water flows) across the farm.
- Be cognisant of scheme deadlines, end of the closed period, weather and growth rates, and laboratory capacity for testing samples to ensure enough time is available to get soil test results back.

Other notes

Liming of peat soils may increase methane and carbon dioxide production, and release soluble organic carbon.

Sources of information

- Soil sampling technique - Good Agricultural Practice for Protection of Waters Regulations 2022 (S.I. No. 113 of 2022) - https://www.gov.ie/en/publication/f1d01-fifth-nitrates-action-programme-2022-2025/
- Soil Nutrient Health Scheme - https://www.afbini.gov.uk/news/soil-nutrient-health-scheme-registration-opens-zone-1
- Benefits of soil sampling, Teagasc - The importance of taking a proper soil sample

4.1.4 A4: Management of farm roadways, supplementary feeders, poaching

The aim of this measure is ensure proper construction, management and siting of farm roadways and supplementary feeders. Preventative measures can avoid mobilisation of nutrient and sediment sources to waterways. Under the GAP Regulations no direct runoff of soiled water from farm roadways is allowed into watercourses or dry drainage ditches. The degree of runoff management from both roadways and supplementary feeders in HSO waterbodies will depend on the intensity of livestock and duration/frequency the animals use the roadways and feeders throughout the year, as this will affect the source load of the pollutant and the extent of the pathways.

The DAFM "Minimum Specification for Farm Roadways' (S.199 2021) sets out the requirements. Where feasible, avoid positioning new roadways adjacent to watercourses, and include a minimum grass margin of 1.5m between the roadway fence and the top of the watercourse. Supplementary feeders should be located at least 20 m from watercourses.

Implementation

Roadways should be located at a distance from watercourses where possible. Relocation of impacting roadways and remediation of roadways in poor condition should be considered. 'Water bars' are an effective means of diverting road runoff into a field, sump or pond (see IRD Duhallow Booklet). Works should be carried out in good weather and when soils are dry. For both roadways and supplementary feeders, the implementation of measures to reduce the source load or break the pathway will yield immediate mitigation. Heavily impacted areas may need remedial works and take several seasons to repair and require assistance by other measures.

Estimated costs

The estimated contract (ex VAT) price for a 4 metre wide roadway, laid on the surface of the ground, is around €25 to €30/m for supplying materials and laying the roadway (Note this price is indexed to 2022 from 2009 costs provided by Teagasc but does not include sundry increased cost elements). Assistance may also be available through the Targeted Agricultural Modernisation Scheme (TAMS).

Consider the following during and after the farm visit

- Farm roadways are relatively impermeable and after rainfall they form a pathway for pollutants to be readily washed into watercourses and drainage ditches in the vicinity, particularly where the roadway is sloping and/or is crossing a watercourse or drainage ditch.
- Well drained tracks should have appropriate surfaces and be cambered to shed water.
- When maintained properly, drainage should be to grassed areas, soakaways or swales, not to bare soil, roads or watercourses.
- Gateways into paddocks should be moved a minimum of 6m from the top of the bank of streams or open drains.
- Check whether slopes can be avoided during construction and whether restructuring is needed? Where slopes are unavoidable, deflectors may be installed at intervals to divert flow to grassed areas etc.
- Options to prevent overland sediment and nutrient runoff include cambering of the roadway to direct water to one side and away from the watercourse; earth bunding along the side; piping runoff to a sediment trap/pond or directly on to land.
- Non-compliance with GAP regulations may incur financial penalties. Benefits to farmers will include animal welfare improvement, for instance, reduce lameness.

Environmental co-benefits

- Reduction in microbial contamination of watercourses reduces risks to drinking water abstraction sources.
- Properly sited and maintained roadways may contribute to improving biodiversity in adjacent areas, although this is not likely to be substantial unless significant planning is given to it.

Sources of information

- DAFM S.I. 199 2021. Minimum Specifications for Farm Roadways. https://www.gov.ie/pdf/?file=https://assets.gov.ie/95233/7484f243-d1d9-4b5c-a407-a3cfe2e1f380.pdf#page=null
- Teagasc (2021) The Farm Roadway Visual Assessment Booklet. https://www.teagasc.ie/media/website/publications/2021/The-Farm-Roadway-Visual-Assessment-Booklet.pdf
- IRD Duhallow Booklet of measures - https://www.irdduhallow.com/site15/wp-content/uploads/2023/04/Booklet-of-Measures-Interactive.pdf
- Teagasc – What is in runoff - https://www.teagasc.ie/publications/2020/what-is-in-farm-roadway-runoff.php
- Teagasc – Building regulations https://www.teagasc.ie/media/website/publications/2020/Buildings---New-regulations-on-farm-roadways-and-waters.pdf
- Teagasc – Dairy farm Infrastructure https://www.teagasc.ie/media/website/publications/2017/Dairy-Farm-Infrastructure-Handbook-Moorepark2017-(V3).pdf

4.1.5 A5: Appropriate location of supplementary drinking troughs

The aim of this measure is to provide an alternative for livestock water supply in a suitable area where they have to be excluded from access to watercourses. Pasture pumps and/or troughs tend to become loitering points which can lead to nutrient hot spots, increased soil compaction, greater runoff potential, and sediment and P loss. These can be particularly problematic when located in critical source areas. Excessive poaching around the pump or trough needs to be avoided.

On farms stocked at greater than 170kg organic nitrogen per ha, water troughs must be 20m from an open drain or watercourse. Pasture pumps are usually more suitable for dry stock herds (usually less animals relative to flow rate). Solar and ram pumps deployed with storage tanks and troughs may be used for dairy herds.

Implementation
Careful selection of the location and the possible use of hard pack standing at the watering point is advisable. Several optional locations may be prepared for deployment to allow the pump to be moved and prevent soil damage. Use of this measure depends on a suitable source water within reasonable distance of the pasture area. The measure deployment may be constrained in smaller fields where adequate separation from watercourses is difficult. A non-return valve is placed in the water on a post to keep it up off the river bed, thereby ensuring a clean water supply and preventing sediment build-up.

Estimated costs
Cost per location for a pasture pump, including all piping and fittings is approximately €550. Cost of solar systems vary substantially depending on specification.

Consider the following during and after a farm visit
- The water source needs to be of sufficient quality and deep enough to ensure a continuous supply throughout the year.
- Avoid locating the drinking site in a wet area or in a flow delivery pathway.
- If the river banks show obvious signs of damage due to livestock access, they should be fenced off and alternative watering sources provided at suitable locations
- There is a potential for damage to habitats at pump or trough deployment locations and these must be carefully selected and preferably used intermittently to allow recovery. Locations for intake valves should also consider damage to in-stream habitat and fauna e.g. amphibians.
- Pasture pumps may be sited 50-70m from the water source. Maximum distance depends on the head difference between water source level and pump outlet. Pasture pumps can pump up to about 7m heads. A pasture pump is sufficient for 10 to 15 animals.
- Solar pump systems can pump heads of 20m and over distances of 1.5km. They can provide volumes in excess of 3,500l per day. However, excessive water extraction may reduce flows and levels in the hydrological summer period and thereby impact on the aquatic ecosystem. Account needs to be taken of this potential impact prior to installation of the solar pump system.
- Multiple pumps can be used, or solar pumps supplying larger volumes and troughs are an alternative for larger water demands. Pumps are very robust but need to be checked regularly, particularly after floods and frosts.

Environmental co-benefits
- Reduces possible microbiological, sediment and phosphate contamination of surface water.
- Improvements to the riparian zone will result in biodiversity benefits.

Sources of information

- Grazing infrastructure incentivised - https://www.teagasc.ie/news--events/daily/grassland/grazing-infrastructure-incentivised-under-tams-3.php
- Funding may also be available from the Community Water Development Fund for local groups – Community Water Development Fund
- Solar pumps - https://solarpumpsolutions.ie/

4.1.6 A6: Storage of silage bales

The aim of this measure is to i) ensure that stored silage bales outside of farmyards are not located within 20m of watercourses (as required by the GAP Regulations) and ii) to check that there is no "dormant" pathway from silage effluent runoff. A dormant pathway could be a field drain that is dry during the summer but has water flowing in it during heavy or persistent rainfall and connects to a natural waterway. At a minimum, ensure the GAP rules are being followed precisely.

Silage effluent is a highly potent pollutant, with a high BOD (30,000-80,000 mg/l in comparison to <2 mg/l for unpolluted surface water). If allowed to enter surface water, it rapidly depletes the oxygen content, causing serious impacts such as fish kills and deterioration in waterbody status. If it enters groundwater, it pollutes nearby wells (usually indicated by the presence of manganese) and watercourses.

Implementation

Silage bales must be at least 20m away from any watercourse, be wrapped in impermeable plastic, ideally on hard-core or concrete and be stacked no more than 2 bales high. The primary goal is to ensure and review that where bales are located, effluent will not reach a watercourse. The generation of effluent can be minimised by aiming for a silage moisture content between 25% and 30% – this can be achieved by wilting silage for 2-3 days depending on weather conditions. Bale or pit silage made in wet weather will have a higher moisture content and more likely to have effluent runoff – particularly when bales are stacked 2 rows high. Buffer zones will be an extra measure that further guards against effluent runoff. The use of inoculants on silage can help preserve nutrients in the silage and reduce the growth of harmful bacteria – reducing the pollution potential of the silage but also improving the quality of the silage (protein and fibre levels).

Consider the following during and after a farm visit

- Are there fields on out-farms or silage platforms that have bales stored near a waterbody?
- Are any bales stacked more than 2 rows high?

Sources of information

- Teagasc – Silage effluent, storage, and water quality - https://www.teagasc.ie/news--events/daily/environment/silage-effluent-storing-silage--water-quality.php
- Teagasc – Sugar and nitrate levels in your silage - https://www.teagasc.ie/publications/2020/why-are-sugar-and-nitrate-levels-in-your-silage-important.php
- DAERA – Careful location choice - https://www.daera-ni.gov.uk/news/choose-location-carefully-when-storing-silage-bales-winter-period
- Irelands 5th NAP - https://www.gov.ie/en/publication/f1d01-fifth-nitrates-action-programme-2022-2025/

4.1.7 A7: Using low crude protein animal feeds

This measure illustrates that animal diet is one of the many important factors that affects the overall nitrogen balance on a farm. Protein intake by livestock is typically through grass, silage (grass or maize), and concentrate feedstuff (including by-products such as brewer's grain) – these are controllable factors (non-controllable factors include genetics, lactation stage, health, and weather conditions). Reducing the crude protein in, for instance, dairy cow diets can significantly reduce the nitrogen excretion in urine.

The Fifth Nitrates Action Programme 2022-2025 aims to address this by putting a maximum level on the crude protein content of concentrate feed used on farms. A maximum of 15% is allowed in concentrate feed fed to grazing livestock between 15 April and 30 September.

Implementation
At a minimum, follow the NAP regulations particularly if they are updated or changed. It is difficult to strictly monitor the protein intake by livestock but working out a balanced diet strategy with an animal nutritionist each year would enable confidence in the use of low protein supplements, appropriate reduction of concentrate feed, and high fibre forage. It is important to get the protein balance correct so as to respond appropriately to changing weather conditions that may affect protein levels in grass and/or change in protein requirements by animals throughout the grazing season.

Consider the following during and after a farm visit
- Are low protein feeds being used (e.g. barley vs soya)?
- Is there a dietary plan for the livestock on the farm?
- Is the feed being used at 15% protein content?

Other notes
The farm animal will naturally regulate the amount of protein it requires and so excess or surplus protein in the diet is expected to be lost from the cow by dung and urine which ultimately adds to the likelihood of nitrogen loss – i.e. protein contains nitrogen (in the form of urea which can be converted to ammonia).

Sources of information

- Teagasc – Dairy Manual - https://www.teagasc.ie/publications/2016/teagasc-dairy-manual.php
- Teagasc – Grazing management for NUE - https://www.teagasc.ie/news--events/daily/dairy/grazing-management-to-increase-n-use-efficiency-on-irish-dairy-farms.php#:~:text=The%20current%20average%20NUE%20is,to%20both%20water%20and%20air
- AFBI – Animal nutrient and NUE – https://www.afbini.gov.uk/news/local-animal-nutrition-companies-partner-afbi-improve-nitrogen-use-efficiency-dairy-cows#:~:text=Dairy%20cow%20diets%20contain%20nitrogen,being%20converted%20into%20milk%20protein.
- NFGWS, 2020. A Handbook of Source Protection and Mitigation Actions for Farming. Section 5.6. www.nfgws.ie.

4.1.8 A8: Precision nutrient applications

The aim of this measure is to identify opportunities for a farmer to increase their use of GPS technology and precision information for informing nutrient applications. GPS connected machinery, soil sensors, yield mapping, mobile apps, and variable rate technology has been available for some time. However, their adoption has always been limited. It would be expected that arable farmers are better adopters of precision technology than grassland farmers – this is down to scale of operation, crop diversity, available time, and economics. Valuable options for precision nutrient technology and precision information gathering (including farm system modelling tools) are available to grassland farmers and their adoption is encouraged where feasible.

Implementation

Ensuring the widest level of GPS technology uptake will be through demonstrating the benefits of them. Contact professional users, advisors, or farmers who use the technology and hold a discussion group or demonstration day. Alternatively, seek out events that aim to promote and demonstrate the viability of GPS technology for grassland and arable farms. Minimise the complexity and communicate the balance in the costs of adopting such technology. Ensure an advisor is available to the farmers during the earliest stages of technology adoption as the main issues and troubleshooting is expected at that time. If possible, encourage a group of farmers to partake in a new technology and enable a platform for them to ask questions and provide feedback.

Estimated costs

Costs vary substantially between the different options, and subscription-based services may be necessary.

Consider the following during and after a farm visit

- Identify farmers who already use GPS related technology or have made efforts to use precision technology or to collect precision information.
- Identify stakeholders who can help with practice adoption and demonstrations of such technology.

Other notes

- Grass measuring/budgeting would be an introductory level to precision nutrient application technology.

Sources of information

- Teagasc - precision farming - https://www.teagasc.ie/animals/dairy/research/livestock-systems/precision-farming-systems/
- Teagasc – automation and technology - https://www.teagasc.ie/animals/dairy/research/livestock-systems/precision-farming-systems/automation-and-technology/
- Teagasc – LESS - https://www.teagasc.ie/publications/2020/spreading-the-benefits--low-emission-slurry-spreading-less.php
- AFBI – Precision grassland platform - https://www.afbini.gov.uk/news/afbi-launches-unique-precision-grassland-platform

4.1.9 A9: Management of land drainage & intensification

The aim of this measure is to identify opportunities on a farm to avoid land drainage where it will lead to a significant environmental impact locally and to promote correct installation of new drainage systems to ensure nutrient loss, sediment loss and waterlogging issues are minimised. Installing new drainage systems will alter the landscape of the farm and affect habitat condition. This can result in habitat change and an impact on plant, bird and insect species.

Local knowledge and expertise can be captured in the planning process, but they also benefit from advisory support to ensure that natural attenuation features are retained and exploited. Careful investigation of the site supported by appropriate expertise, and due consideration of environmental factors are all essential. High risk hydrologically connected locations may be difficult to identify, e.g. areas overlying field drains, and advisory support to produce drainage and soil management plans may reduce risks and allow selection of appropriate set back distances for particular scenarios.

Drainage of high organic content soils is no longer climate smart and any drainage should focus on appropriate mineral soils. The future for organic soils will include their role in climate change mitigation. In this context, further drainage of peaty soil or peat cannot be justified and a significant programme of water table management needs to be considered on those organic soils that were previously drained.

Implementation

Consideration must always be given to downstream receptors in the landscape, such as lakes, streams, rivers, estuaries or protected terrestrial ecosystems. Care must be taken to ensure that drainage channels do not become pathways for losses of nutrients and a range of mitigation measures need be applied, as outlined in this document. In particular, it is important to ensure that drainage stone doesn't come to the ground surface and that there a good covering of soil on any sub-surface drains to ensure that they don't provide a direct pathway for pollutants to watercourses. Drainage and soil management must be based on systematic investigations on a field by field basis, including existing drains and watercourses, soil type and permeability, geology, topography, water table level and local habitats. The measure applies to the whole farm area, in particular land which, due to natural limitations related to soil type, topography, relief and climate, are poorly drained. Drainage of peaty soils, vulnerable habitats and wetlands should be avoided. Drainage of mineral soils must consider the potential environmental impacts on watercourses and vulnerable wetland habitats downstream of the drainage water.

Existing drainage of peaty soils can be addressed through alternative strategies that manage water table levels. Drainage management planning should consider a range of mitigations including silt traps in drains, settlement ponds, wetland retention, buffer strips and road management.

Estimated costs

Costs of preparing a farm scale drainage and soil management plan is likely to be of the order of €1,000. Implementation will vary substantially depending on the measures required and setting.

Consider the following during and after a farm visit

- What environmental receptor is the recipient of the drainage water from the farm? What condition is that receptor in?
- As sediment is likely to pose the greatest threat, are measures being taken to reduce overland flows directly to watercourses after heavy rainfall?
- Are there significant changes to habitats adjacent and downstream of the drainage system?
- Have best practices in installation and maintenance been implemented?
- Is there opportunity to restore some of the drainage area through water table management?

Environmental co-benefits

While mitigation of damaging drainage impacts and restoration of water table levels may take some time to revert to satisfactory conditions, there are significant co-benefits. CAP may include measures targeted at raising the water table in organic soils in liaison with landowners, and thereafter managing existing drainage features on selected sites to manipulate the depth of the water table. This will reduce CO_2 emissions to the atmosphere. However, the drainage of high organic content or peat soils will result in substantial CO_2 emissions to the atmosphere and losses of ammonium to watercourses. Although drainage is often associated with negative impacts on biodiversity, appropriate management of existing surface drainage systems can provide a variety of small-scale wetland habitats for aquatic and terrestrial plants and animals. Open drains can play a role in habitat connectivity, acting as wildlife corridors. Water table management will also help prevent the release of sediment, carbon and nutrients, and have benefits for biodiversity.

Sources of information

- Teagasc – Manual on Drainage (2nd edition). 2022. https://www.teagasc.ie/media/website/environment/soil/Teagasc_Drainage_Manual_2022.pdf
- Department of Agriculture Food and Marine – Environmental Impact Assessment (Agriculture) Regulations - Guide for Farmers. https://www.gov.ie/en/service/161a7-environmental-impact-assessment-screening-service/

4.1.10 A10: Pesticide control & weed wiping

In general, the principles of Integrated Pest Management should be applied in relation to minimising the use of pesticides. The herbicides MCPA and glyphosate are widely used, in particular for rush control. MCPA use is prevalent in areas of marginal and upland agricultural land where it is also most vulnerable to loss due to soil and drainage characteristics (due to its high solubility and poor adsorption to the soil matrix). While it is known that MCPA degrades under aerobic conditions, negligible breakdown can occur in anaerobic environments, potentially creating a legacy in saturated soils which may be subsequently mobilized. MCPA is detected widely in waterbodies and drinking water supplies. MCPA has been reported as highly toxic to aquatic organisms. Mitigation measures include alternative rush control methods (non-chemical), and reducing prevalence of rushes by avoiding poaching or overgrazing. If spraying is used, it should only be on dry ground and when no rain is forecast, with designation of buffer zones where pesticide spraying cannot occur.

Sheep-dips (diazinon, cypermethrin, amitraz) are highly toxic to aquatic invertebrates. Use of pour-ons, or injectables are preferable to dipping. Strict adherence to best practice is essential.

Any use of plant protection products must be in accordance with Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides. The Directive requires i) provisions for the training and certification of distributors, advisors and users, ii) the testing and certification of application machinery, iii) the drafting of National Action Plans (NAP), iv) the protection of the aquatic environment and other environmentally sensitive areas, and v) general principles of Integrated Pest Management (IPM) as set out in Annex III. In all instances, use needs to be in accordance with restricted use of plant protection products in designated areas as specified in S.I. No. 155/2012 Sustainable Use of Pesticides.

Implementation

Where possible, alternatives to pesticide use are preferred. These include sustainable biological, physical or other non-chemical methods and appropriate management regimes are preferred to chemical methods if they provide adequate control. Pesticide use should be minimised alongside

watercourses, in close proximity to drains, drainage ditches, in critical source areas and areas where surface runoff is focused. Such areas can be protected by buffer zones that are a minimum of 5m wide, but may be considerably larger for sensitive receptors. Where pesticides must be used, best practice is essential in relation to storage, handling, mixing rates, filling of equipment, appropriate equipment and precision application, weather and terrain conditions and disposal of containers. Weed wiping is recommended as an application method (see Section 5.10 in NFGWS, 2020 and Stranooden GWS, 2023)

Estimated costs

This measure will result in savings insofar as it aims to reduce pesticide usage. However, alternative physical control methods will incur costs and may be more labour intensive. Based on information from the weed-wiping pilot project at Stranooden GWS, glyphosate cost was €3 per ha, while MCPA cost was €15 per ha.

Consider the following during and after a farm visit

- Where pesticides may be applied in close proximity to watercourses, critical source areas, drains and drainage ditches and where runoff is focused, every effort must be made to ensure no pesticide enters the waterway directly or indirectly.
- MCPA may remain in soils for some years and result in pollution long after application has ceased, therefore this must be taken into account during decision making.

Other notes

The Organic Farming Scheme employs many relevant non-chemical agronomic weed and pest protection methods such as protection of natural enemies; the choice of species, varieties and heterogeneous material; crop rotation; cultivation techniques such as biofumigation, mechanical and physical methods, and thermal processes. In 2022, the European Commission adopted its proposal for a new Regulation on the sustainable use of Plant Protection Products (SUR). The rules encourage reducing pesticides through integrated pest management and alternatives to chemical pesticides. The measure can deliver significant benefits for drinking water abstraction and treatment. It may also yield biodiversity returns.

Sources of information

- DIRECTIVE 2009/128/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:en:PDF
- S.I. No. 155/2012 - European Communities (Sustainable Use of Pesticides) Regulations.
- STRIPE - Surface Water Tool for Reducing the Impact of Pesticides in the Environment. https://www.irishstatutebook.ie/eli/2012/si/155/made/en/pdf
- National Action Plan for the Sustainable Use of Pesticides 2013. Pesticide Registration & Control Division, Department of Agriculture, Food and the Marine. https://www.pcs.agriculture.gov.ie/media/pesticides/content/sud/Irish%20National%20Action%20Plan%20for%20the%20Sustainable%20Use%20of%20Pesticides%20-%20February%202019.pdf
- NFGWS, 2020. A Handbook of Source Protection and Mitigation Actions for Farming. Section 5.10. Available for download at www.nfgws.ie.
- Stranooden GWS, 2023. Section 7, Source Protection Pilot Project Final Report. https://stranoodengws.ie/images/pdf/PHASE-II-FINAL-REPORT.pdf
- Teagasc – Controlling rushes and protecting water - https://www.teagasc.ie/publications/2018/controlling-rushes-and-protecting-drinking-water-go-hand-in-hand.php

4.1.11 A 11: Reducing nitrogen loading

Nitrate losses from agricultural activities are posing significant threats to aquatic ecosystems in estuarine and coastal waters, and to water quality in certain drinking water sources. These arise in freely draining soils areas where the farming is relatively intensive. In Table 5, 22 measures are listed. This is the only one that is given a high (H) effectiveness rating.

For pasture based enterprises, the nitrogen (N) loading arises from inorganic fertilisers, concentrates, clover-fixed N and, in certain circumstances, from imported slurry and/or silage. Mineralisation of organic matter in the soil in the Autumn and after ploughing and reseeding causes mobilisation of nitrate; however, they are not primary sources. For tillage enterprises, the N loading arises from inorganic fertiliser, N fixed by legumes in catch crops and, in certain circumstances, imported manure.

In the freely draining areas where nitrate arising from farming activities are impacting on a waterbody, the key target is to reduce the surplus N[4] (at any scale – field, farm, catchment). The main ways of achieving this are: i) increasing the nitrogen use efficiency (NUE) and ii) reducing the N load. The generally quoted NUE for dairying is 25% currently; this leaves a high surplus N load. A proportion of this surplus load is available to leach to groundwater and increase the nitrate concentrations in watercourses. Many of the source reduction measures – A2, A3 and A8 – and mobilisation control measures – A12, A14, A15, A16, A17, A18 and A19 – described in this report are aimed at increasing the N use efficiency and thereby reducing the surplus N load. However, even if all these measures are implemented effectively, the NUE is unlikely to increase to more than 35-40% where dairying is the *significant pressure*. The N load reduction in kg/ha required in watercourses vary, depending on the physical setting and the N load on the land – for instance, the load reductions needed to achieve the EQS of 2.6 mg/l in several of estuaries have been estimated by the EPA (2021)[5]. This increase in NUE may, in many circumstances, reduce the nitrate concentrations sufficiently so that aquatic ecosystems will improve and return to their required status. However, where the reduction from these measures is not sufficient, consideration will need to be given to reducing the N loading. This could, for instance, mean a reduction in stocking rate in the case of dairy farming.

In many circumstances, a combination of a suite of measures chosen from the other 18 measures listed in Table 5 may reduce nitrate leaching sufficiently to achieve required water quality objectives. However, there are likely to be circumstances where the required reduction in leached N load is greater than can be achieved by these measures.

Implementation
On the grazing platform of dairy farms, the total (combined inorganic and organic) N load can often be substantially higher than 500kg/ha. As this is a particular 'hot spot' area for leaching in freely draining soils and subsoils, reducing the N loading by reallocating slurry to the silage block would be an effective way of reducing leaching from the grazing area, and thereby whole farm losses to groundwater.

Overall, this is the most challenging of all the measures listed for nitrate to achieve. Where large reductions in N losses to water are required, it is likely to result in a reduction in farm productivity and therefore profitability. Achieving progress in establishing this measure requires further consideration and discussion.

[4] N surplus is calculated as N imports-N exports. For dairy farms, N imports are the N from inorganic fertiliser, N from the concentrate, clover-fixed N and N from silage purchases. N exports are calculated as N from milk, N from meat export and N from silage sold. NUE is calculated as N export/N import.
[5] https://www.catchments.ie/assessment-of-the-catchments-that-need-reductions-in-nitrogen-concentrations-to-achieve-water-quality-objectives/

Environmental co-benefits

- The main co-benefit from this measure is a reduction, probably significant, in GHG emissions.
- Some benefits for carbon sequestration and terrestrial ecosystems are likely.
- Along the south coast where, due to the geochemistry of the soils, leaching of phosphate to groundwater occurs, a reduction on the N loading may also result in a reduction in phosphate loading.

Other notes

Following implementation of this measure, a reduction in nitrate concentrations in watercourses is likely to commence within months where the soil/subsoil is less than 2 m thick. However, it is likely to take a number of years (perhaps 4-5) before concentrations are reduced sufficiently to achieve the required concentration in the watercourse and a further short period (1-2 years generally) for the ecosystem to recover.

Sources of information

- EPA Catchments Unit, 2021. Assessment of the catchments that need reductions in nitrogen concentrations to achieve water quality objectives - https://www.catchments.ie/assessment-of-the-catchments-that-need-reductions-in-nitrogen-concentrations-to-achieve-water-quality-objectives/
- Teagasc – Soil type and nitrogen application - https://www.teagasc.ie/publications/2020/review-of-the-influence-of-chemical-nitrogen-application-rate-soil-type-and-agroclimate-location-on.php
- Teagasc – Impact of N strategies on dairy farms, report published in July 2021 - https://www.teagasc.ie/publications/2021/the-impact-of-nitrogen-management-strategies-within-grass-based-dairy-systems.php
- Teagasc – Impact of N strategies on dairy farms, report updated in March 2023 - https://www.teagasc.ie/media/website/publications/2023/The-Impact-of-Nitrogen-Management-Strategies-within-Grass-Based-Dairy-Systems.pdf

4.2 Mobilisation control measures

The application of nutrients on land is an essential element of farming. While source reduction and control measures have a vital role in reducing losses to water, measures to reduce mobilisation of nutrients on the land are an important additional means of hindering and reducing losses to water.

Mobilisation control in the context of nutrient transfer refers primarily to the ability of plants to regulate the release of nutrients from their tissues into the soil. Where excess nutrients are available a plant will not absorb them and they may be left vulnerable to movement in the soil solution. In the context of water quality protection, mobilisation refers to the commencement of movement of these nutrients and/or sediment from the soil beyond the root zone along and a pathway to a receptor. A number of crop and nutrient management measures can be put in place to reduce the likelihood mobilisation of nutrients and/or sediment by rainfall.

Weather conditions and one-off extremes like flooding or drought always cause a burden to a farmer's livestock, crop or soil health management strategy. Mobilisation control measures are aimed at continuing best practice with crop management but with strong consideration for these extreme events and a contingency plan that allows the farmer to adjust their management strategy in an effort to pre-empt a change in weather conditions. Long term planning for weather and climate conditions

enables farmers to build resilience into their crop management systems so as to minimise economic and environmental impacts. Examples of these measures include using catch crops, multi-species swards, low emission spreading and conservation tillage.

The following is a list of mobilisation control measures (A12 to A22) that could be used individually or in combination with other measures to help with minimising nutrient and sediment mobilisation on farms in the catchment area of a HSO waterbody.

4.2.1 A12: Complying with landspreading requirements for fertilisers and soiled water

The aim of this measure is to ensure awareness of the latest changes to the rules relating to the Good Agricultural Practices (GAP) Regulations, the Nitrates Action Programme (NAP) and their iterations. The GAP Regulations set out specific legal requirements for farmers including farmyard management, nutrient management planning, stocking rates, and land application of fertilisers. Complying with all GAP measures is a legal requirement, and this section focuses on closed periods, land spreading requirements and soiled water.

Implementation

There are times of the year when you must not spread any fertiliser, manure or soiled water on your land. These are called the prohibited spreading periods or "closed periods". Research has shown that prohibited periods are necessary to prevent nutrient losses to water during the most environmentally risky time of the year. The difficulty is in predicting the weather. Therefore, well timed advice on implementation is needed to enable the farmer to be in a nutrient management scenario that is of least risk to nutrient losses at the start and end of the closed periods.

The GAP Regulations divide the country into zones with different rules about minimum storage capacity and the prohibited spreading periods for each zone.

Details on the measures are given in the DAFM Nitrates Explanatory Handbook and the DAFM Information Note on the Nitrates Regulations and 5th Nitrates Action Programme (see Sources of Information).

Consider the following during and after a farm visit

- In the lead up to a closed period date (start or end), is the farmer going to be in a nutrient storage surplus or deficit scenario?
- What measures can be carried out within 4 weeks of the closed period dates to avoid a nutrient management scenario that has a high likelihood of nutrient losses?

Sources of information

- DAFM, Rural Environment & Sustainability – Nitrates - https://www.gov.ie/en/publication/c9563-rural-environment-sustainability-nitrates/
- DAFM, Nitrates explanatory handbook 2022 - https://www.gov.ie/pdf/?file=https://assets.gov.ie/240494/04af2e95-3550-4074-b22a-7e8b03812d9a.pdf#page=null
- DAFM Information Note on the Nitrates Regulations and 5th Nitrates Action Programme – https://www.gov.ie/pdf/?file=https://assets.gov.ie/235985/4ea15982-7696-4c18-82e9-fa9e69f6a834.pdf#page=null
- ACP, Nutrient loss and closed periods - https://www.teagasc.ie/news--events/daily/environment/nutrient-loss--the-closed-period-for-spreading-manure.php
- EPA, 2006, A model to predict N fluxes in Irish grasslands - https://www.epa.ie/publications/research/water/Final-Report-LS-2311-(Section-3-of-3----NCYCLE_IRL)-for-web.pdf

4.2.2 A13: Liming of mineral soils

This measure aims to reduce nutrient application to land by optimizing soil nutrient availability using lime as a soil conditioner. Liming of mineral soils can maximise the availability of applied nutrients and release nutrients that are "locked up", through pH adjust. This measure will fall in line with NMP implementation and soil testing, and together the measures is likely to increase farm level nutrient use efficiency.

Liming of peaty soils[6] is not recommended as it may result in increased Dissolved Organic Carbon (DOC) and N leaching as well as increased loss of soil organic carbon. Certain habitats require low pH to allow specific plant species to grow and so liming is not a necessity.

Implementation
Use soil test results to determine the farms lime requirement. Lime sections of the farm in rotation. Lime can be applied all year round, but grazing and sowing of sensitive crops may need to be delayed post application. Slurry or urea application must wait 3 months after lime application, or 10 days after slurry or urea is applied before applying lime. Lime should be applied after ploughing or to fields with little grass cover. Calcium ground limestone is most commonly used but magnesium (Dolomitic) ground limestone, and granulated lime are also available. Ground limestone (35%) works fast and will react slowly and to help maintain soil pH for a number of years. Normal fertiliser spreading equipment can be used and must be set up and calibrated correctly.

Lime should not be applied to peaty soils. Soils that are heavier textured (clay soils) or higher organic matter levels tend to have higher buffering capacities and higher lime requirements as a result.

Estimated costs
It can cost €27/tonne of lime, but this is depending on where in the country lime is being purchased. Generally, there are no substantial costs above normal nutrient management programmes. Cost of lime spreading is offset against reduced nutrient requirements and increased grass production.

Consider the following during and after a farm visit
- Measures to improve nutrient use efficiency will only have an effect if nutrient application rates are actually adjusted relative to the soil nutrient status (N, P, and K).

Other notes
Lime spreading on peaty soils may increase GHG emissions.

Sources of information
- Teagasc – Liming on beef farms - Teagasc. Grassland Advice on Liming for Beef Farms.
- Soil profile handbook - EPA/ERTDI/STRIVE (2008). Soil Profile Handbook. (2007-S-CD-1-S1) Final Technical Report 10.
- Teagasc – Soil fertility FAQ https://www.teagasc.ie/crops/soil--soil-fertility/faq/lime-faq/

[6] The location of peaty is are shown on the National Soils Hydrology map which can be accessed at https://gis.epa.ie/EPAMaps/Water under the heading 'WATER, LAND & SOIL'.

4.2.3 A14: Low emission slurry spreading

All measures involving slurry spreading needs to take into consideration soil test results and the implementation of a NMP so that a farmer and advisor can be confident that nutrients are being applied in the most agronomic and environmentally suitable fields on the farm. Furthermore, within the context of mobilisation control, the timing of slurry application is crucial for minimising nutrient losses to the environment and maximising nutrient availability to the crop. Therefore, nutrient efficiency from different methods of slurry spreading is still bound by local weather conditions and climate events.

Low emission slurry spreading (LESS) has benefits for nutrient efficiency (nutrient availability and fertiliser replacement rate) in that it reduces ammonia losses to air and helps reduce nitrogen requirements from other sources (provided adjustments are made in the NMP to account for the N load difference).

While this measure primarily suits atmospheric emissions reductions, it is expected to reduce the amount of slurry that can be lost via runoff to waterways due to the smaller surface area each method uses.

Implementation
Trailing shoe, injection, and dribble bar are the low emission slurry spreading options available to famers currently. Injection method may be the most effective for minimising overland flow to waterways. Splash plate technology the least effective way of applying nutrients from slurry to crops.

Application can be in early growing season (provided weather conditions allow and growth rates are appropriate) prior to closing fields for used for silage harvesting later in the year.

Estimated costs
Savings are expected to be made through reduced chemical fertiliser use (fertiliser replacement value). Some grants may still be available to aid in the purchase of low emission slurry spreading technology.

Consider the following during and after a farm visit

- Which low emission slurry technology would be most suitable for the farm taking account of soil type, slope, grassland management, and livestock management.
- On grassland, is there an opportunity to apply to higher sward covers e.g. via trailing show so as to avoid high risk rainfall events early in the growing season?
- Is there an economic opportunity to adjust the NMP and chemical fertiliser use by replacing a chemical application with a low emission spreading application?
- Could low emission slurry be used where odours could be an issue for the general public.

Other notes

- The 5th Nitrates Action Programme planned a phased approach for Low Emission Slurry Spreading (2023-2025) for farms above 100kg/ha and must also be used for the application of pig slurry.
- Research estimates that the typical value of 1,000 gallons of cattle slurry applied by low emission slurry spreading (LESS) method in springtime has an available N-P-K content equivalent to a 50 kg bag of 9-5-32.
- Research estimates that there is an increase of fertiliser replacement value of slurry by using LESS of + €2-3 in N fertiliser replacement value per 4.5 m^3 of cattle slurry.

Environmental co-benefits

- Reduced losses of ammonia to air.

Sources of information

- Teagasc – Benefits of LESS - https://www.teagasc.ie/publications/2020/spreading-the-benefits--low-emission-slurry-spreading-less.php
- DAFM – LESS equipment scheme - https://www.gov.ie/en/service/d4b800-low-emission-slurry-spreading-less-equipment-scheme/

4.2.4 A15: Cover/catch crops (tillage)

The aim of this measure is to identify the opportunity to plant a cover crop on an arable farm or between crop rotations on a grassland farm (in a rented field for example or where maize is grown). In a water quality context, this measure is expected to reduce nutrient run-off by keeping "armour" on the soil with plant leaves and stems, and by reducing nutrient leaching by keeping living roots in the soil. It also increases water infiltration which again reduces the risk of run off as well as increasing the likelihood of attenuation. Bare soil is the high risk scenario for sediment run-off, which is detrimental to invertebrates and the health status of local waterbodies. Also, sediment is expected to carry phosphorus to a waterbody.

Implementation

Cover/catch crops are planted between production crops so identifying the opportunity to use them will require knowledge of a crop rotation plan for the farm. It is important to select appropriate cover crops for the goal in question – weed suppression, breaking disease cycles, nutrient capture, or winter forage production.

Brassicas, legumes, Phacelia, grass and cereals can all be used as catch crops for breaking rotations. Legumes fix nitrogen via rhizomes on their roots and so the risk of nitrogen leaching may still be present.

Catch crops should be sown soon after cereal harvesting to optimise the take up of surplus nitrogen. In addition, in freely draining areas where nitrate is a significant issue, use of legumes in the catch crop is not advisable unless an allowance is made for this in inorganic fertiliser applications subsequently.

Best practice establishment and seedbed conditions are important as the quality of the catch crop and the extent of its benefits may be affected.

Consider the following during and after a farm visit

- Is the environmental benefit intended to be:
  - i) Reducing nitrate leaching in the late Autumn and Winter period in freely draining areas?
  - ii) Reducing sediment and associated P losses, primarily in poorly draining areas?
- Is the catch crop in place being managed as a forage crop in a field that is prone to poaching and run off?
- Always consider catch crop destruction in the context of water quality. Is a pesticide expected to be used and is it necessary? Is ploughing the only option for establishing a new crop? Can additional actions or measures be implemented to further minimise the end of a catch crop cycle?
- Would a catch crop benefit the crop rotation?

Environmental co-benefits

There are substantial benefits to soil structure that can be gained from using catch crops, but it depends on the practices used (minimum tillage practices, over seeding, or ploughing). Minimising disturbance is important for minimising carbon emissions and leaching impacts.

Sources of information

- Teagasc 2021, catch crops and water quality - https://www.teagasc.ie/news--events/daily/environment/catch-crops-for-water-quality.php
- EPA Catchments unit 2020, https://www.catchments.ie/catch-crops-improving-soil-structure-and-water-infiltration-and-reducing-nitrate-and-soil-loss/
- Teagasc 2020, benefits of cover crops - https://www.teagasc.ie/news--events/daily/crops/the-function-and-benefits-of-cover-crops.php
- Teagasc – Cover crops - https://www.teagasc.ie/crops/crops/cover-crops/

4.2.5 A16: Protected urea

Protected urea uses a urease inhibitor to slow down the rate of nitrogen release from the fertiliser. The inhibitor also reduces the amount of nitrogen lost by volatilisation to the atmosphere. By inhibiting the hydrolysis, it results in delaying the release of ammonium and nitrate to the plant and potentially better matching nutrient release to growth rate. This is expected to reduce the risk of nitrogen loss by leaching also. This measure would contribute towards increasing the overall nitrogen use efficiency on a farm. Slow-release fertilisers are suitable for grassland management in all HSO waterbodies.

Implementation

Use protected urea instead of urea and CAN. Normal fertiliser spreading equipment can be used and must be set up and calibrated correctly.

Estimated costs

No substantial additional costs above normal nutrient management programmes apply. Use of protected urea can give substantial cost saving (12-15%) compared to CAN and urea. It is cheaper and more cost effective when N losses are taken into account. Cost savings may accrue due to reduced input management systems.

Consider the following during and after a farm visit

- GAP Regulations stipulate comprehensive conditions in relation to fertiliser use and spreading, i.e. timing, accuracy and amount of fertiliser applied, land and meteorological conditions, closed periods, nature of equipment used, and consideration of vulnerability of area.
- Buffers and critical source areas must be avoided.

Environmental co-benefits

- Reduction in GHGs emissions.

Sources of information

- Teagasc – Protected Urea - https://www.teagasc.ie/crops/soil--soil-fertility/protected-urea/#:~:text=reduce%20farm%20emissions-,Protected%20urea%20(protected%20with%20a%20urease%20inhibitor)%20is%20cheaper%20than,a%2012.0%25%20lower%20spreading%20rate.

4.2.6 A17: Multi-species swards

Multispecies swards may be comprised of grasses, herbs, brassicas and legumes such as white and red clover. The latter fix atmospheric nitrogen and can significantly reduce the need for inorganic N fertilizer. White clover in the sward can replace 40% inorganic nitrogen (100 kg N/ha) and not affect herbage production compared to a grass-only sward receiving 250 kg N/ha.

The persistence of such swards and their ability to out-compete weed species may also reduce herbicide application requirements although this is not the primary aim of the measure and direct controls of pesticide use in sensitive areas are more appropriate in this regard. The deeper rooting systems of elements of the sward (e.g. plantain) promotes infiltration and are less prone to be impacted by droughts.

Implementation

A multi-species sward is best established as part of a full reseed as the small seeds of some species struggle to establish in an existing sward. Over sowing may be less successful. Early sowing allows better establishment before the winter, which is important for root development. Weed control before sowing is important, however, a good multi-species sward that establishes quickly will generally outcompete most weeds. Reseeding may be needed more frequently relative to ryegrass.

The composition of multi-species swards is selected based on landuse objectives e.g. summer grazing, silage, sheep or beef. Species mixtures must also be selected to suit wet or dry soil conditions. Common constituents are Ryegrass, White and Red Clovers, Plantain, Chicory and Timothy grass. Clovers are the key nitrogen providing component of the sward.

This measure may be used particularly on freely draining soils and subsoils in general, and high nitrate PIP areas, in particular. Use of sward mixtures for wet soils may also reduce ammonia losses. Establishment of swards is best in spring but may be done from April to August.

Estimated costs

Teagasc estimate the cost of reseeding at approximately €600/ha. Significant savings in N fertilizer can be realised to offset this.

Consider the following during and after a farm visit

- Chemical nitrogen application may be reduced when the sward is established and reaches 20-25% clover composition.
- Fertiliser application should be strongly reduced in summer (May-September) when nitrogen from clovers is provided.
- This measure should be used for existing high N-demand grasslands and not to increase the area of improved grassland at the expense of other valuable habitat types, such as semi natural grassland.

Environmental co-benefits

A Multispecies Sward Measure has been introduced by the DAFM to promote environmentally sustainable methods of farming. The measure increases carbon sequestration and reduces nitrous oxide emissions. The measure is subject to adherence to the EIA (Agriculture) Regulations 2011.

Sources of information

- Teagasc 2022, Multi-species swards - https://www.teagasc.ie/publications/2022/establishing-multi-species-swards-on-your-farm.php
- The Bride project - https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf

4.2.7 A18: Best practice N applications

The objective of this measure is to ensure optimal use of N fertiliser applications in facilitating crop growth with minimal losses of N to water and air. Factors that influence: i) the application loads and timing, ii) uptake by crops and iii) nitrogen use efficiency (NUE) are as follows:

- Soil temperature – growth does not commence until the temperature is >5°C.
- Soils moisture deficit (SMD)[7]. SMDs of >50 mm increasingly limits grass growth and therefore N demand and uptake, with drought conditions occurring when the SMD is >75 mm[8]. A negative SMD indicates a water surplus, which will be drained over time through either infiltration or overland flow or both. (See link to Met Éireann details on SMD and grass growth given below.)
- Soil type – freely draining soils warm up earlier in Spring than poorly draining soils.
- Soil pH – the recommended pH for grass is 6.3.
- Crop growth – grass measurement ('You Can't Manage What You Don't Measure!'[9]).
- The N content of organic fertilisers.

Implementation

- Access and use the information on soil temperature, SMD and rainfall in 'Latest Farming Commentary' on the Met Eireann website.
- Follow Teagasc advice on crop growth in the context of weather conditions.
- Take account of soil drainage categories of fields on the farm from the National Soils Drainage map[10] and farmer knowledge.
- Measure grass growth using the Teagasc recommended approach.
- Take account of the estimated N content of slurry. If possible, use a slurry hydrometer to determine the N content. Alternatively, either use a local laboratory or use the values in the GAP Regulations for organic manures.
- Analysis of herbage for N levels periodically during the growing season enables identification of the trend in N uptake.

Consider the following during and after a farm visit

- Is there a history of N applications available?

[7] See https://www.met.ie/climate/services/agri-meteorological-data for details and explanations on SMD and Field Capacity.

[8] The drought in 2018 resulted in a slow-down in the growth of crops across Ireland. Due to this lack in growth, there was minimal or no uptake of fertiliser applied both pre-drought and during the drought by the plants. This resulted, for instance, in decreased grass growth and a build-up of nitrate in the soils. In freely draining areas, leaching to groundwater occurred after the soils reached field capacity (SMD = 0) in the Autumn. As a consequence, nitrate concentrations in groundwater and surface water rose in the following Winter and Spring.

[9] https://www.teagasc.ie/crops/grassland/grass10/grass-measurement/

[10] https://gis.epa.ie/EPAMaps/Water

- Is the soil type distribution known?
- Is the farmer measuring grass and recording grass growth rates?

Other notes
- Relevant advice is also given for measures A2, A3, A8 and A12 in this report.
- The Irish Farmers Journal is a good source of information and advice on the implications of the weather on crop growth.

Sources of information
- Met Éireann – Farming forecast – https://www.met.ie/forecasts/farming
- Teagasc – Soil fertility - https://www.teagasc.ie/crops/soil--soil-fertility/organic-manures/
- Teagasc – Water quality and nitrogen inputs - https://www.teagasc.ie/environment/water-quality/water-quality-week/utilising-nitrogen-inputs-efficiently/
- Met Éireann – Drought definitions - https://www.met.ie/drought-summary
- Agri-meteorological data – https://www.met.ie/climate/services/agri-meteorological-data
- Irish Statute Book – SI 113 of 2022 - https://www.irishstatutebook.ie/eli/2022/si/113/made/en/pdf
- Teagasc – Grazing management to increase N use efficiency – https://www.teagasc.ie/media/website/publications/2021/Grazing-management-to-increase-N-use-efficiency-Mick-ODonovan-Mike-Egan-Elodie-Ruelle-Moorepark21.pdf
- Teagasc – Grass measurement – https://www.teagasc.ie/crops/grassland/grass10/grass-measurement/

4.2.8 A19: Application of sulphur

The aim of this measure is to improve the nitrogen use efficiency (NUE) by enabling actions to ensure sulphur levels in grassland and arable farms are sufficient for efficient crop production. Sulphur (S) is a macronutrient that is essential for crop growth and should be considered in the same context as P and K. However, there is no soil test to determine the level of sulphur in soil, although it can be determined from analysis of herbage. Irish research estimates that sulphur application can make a significant improvement in NUE in freely draining soils.

Implementation
The timing of S application is important – early spring applications of S prior to N application is effective in improving N use efficiency. It was also found that the application of N and S together can be effective as it enables a dual support of plant formation and nutrient uptake.

Consider the following during and after a farm visit
- What is the legacy of sulphur use on the farm?
- Can a benefit be gained from using sulphur to improve nitrogen use efficiency? Which fields would benefit most?
- Protein content in grass is expected to be reduced where sulphur is deficient.

Other notes
- Sulphur is lost by leaching in a similar manner to nitrogen so sandy soils are the most vulnerable.

Sources of information

- Teagasc – Sulphur importance - https://www.teagasc.ie/environment/soil/research/site-specific-sulphur-deficiency/
- Teagasc – Sulphur advice - www.teagasc.ie/publications/2020/sulphur-deficiency-potential-to-boost-growth-and-advice.php
- Teagasc – Why all the fuss about sulphur – https://www.teagasc.ie/news--events/daily/grassland/why-all-the-fuss-about-sulphur.php
- Teagasc – Role of sulphur - https://www.teagasc.ie/media/website/crops/soil-and-soil-fertility/The-Role-of-Sulphur-in-Crop-Production.pdf

4.2.9 A20: Conservation tillage, contour ploughing & tramline management

The aim of this measure is to identify opportunities to reduce soil erosion, increase water infiltration, improve soil structure and resilience through conservation tillage practices. This measure mainly revolves around minimal disturbance of the soil by leaving crop residues on the surface and eliminating or reducing the practice of deep soil cultivation.

Generally, the aim is to increase the level of organic matter on the soil surface. Organic matter in the form of crop residues minimises the chance of heavy rainfall dislodging soil and leading to sediment or pesticide runoff. Slowing down the flow and momentum (speed and volume) of runoff or water in a field increases the opportunity to infiltrate leading to increases in nutrient capture by the living roots. Soils with more organic matter hold water and nutrients longer and so enable higher resilience of the plant during prolonged weather events such as drought. Contour ploughing[11] will also slow the flow of surface run-off by breaking the momentum of it. Caution must be exercised when carrying out contour ploughing as it typically requires moving across a slope rather than up and down a slope. Tramline management[12] again is an action that aims to reduce the momentum of surface water flow in a field by reducing the surface area of soil that gets compacted.

Implementation

Don't leave soils bare by ensuring living roots and plant residues are left in the field for as long as possible. If soil needs to be left bare, make sure it is for as short a period as possible and avoid severe weather events such as heavy rainfall. Consider if ploughing is absolutely necessary and, if so, what would be the best way to avoid letting the momentum of water build up in a field. Consider where the nearest waterbody is relative to the field and the most likely pathway to it if ploughing or tramlines were to connect it. Long term planning is required of conservation tillage before soil health benefits become measurable.

Consider the following during and after a farm visit

- Is conservation tillage already being practiced on this farm? Are there opportunities to introduce it?
- Is there an opportunity long term to convert to conservation tillage practices?

[11] Contour ploughing is the farming practice of ploughing and/or planting across a slope following its contour lines instead of up- and downward.

[12] Tramlines are tracks in tillage fields used by farm machinery and separated from the crop. They can become compacted due to regular and heavy machinery trafficking and provide pathways for soil and water to run off fields, and eventually find their way into watercourses. Therefore, they need to be located and managed to prevent direct runoff to watercourses.

- Are there specific areas of the farm that would benefit from conservation tillage, contour ploughing, or tramline management?

Other notes
Lower fuel consumption is an advantage from implementing conservation tillage practices.

Sources of information

- Teagasc – Conservation tillage - https://www.teagasc.ie/crops/crops/grass-weeds/enable-conservation-tillage-ect/conservation-tillage/
- Teagasc – Crop establishment systems - https://www.teagasc.ie/crops/crops/grass-weeds/enable-conservation-tillage-ect/crop-establishment-systems/
- Teagasc – Conservation tillage project - https://www.teagasc.ie/crops/crops/grass-weeds/enable-conservation-tillage-ect/

4.2.10 A21: Raising water levels in peatlands

The aim of this measure is to minimise the impact of drainage of peatland and peaty soils on water quality. Drainage of peat allows the entry of air which enables slow breakdown and decomposition of the organic matter with the release of carbon dioxide to the air, and ammonium and dissolved organic carbon (DOC) to watercourses. Drained peaty soil is a 'wasting asset' for farmers that is indicated by subsidence and, in certain circumstances, complete loss eventually of the peat content of soil by decomposition. By raising the water table to 30-40 cm below ground level (bgl), it decreases peat decomposition and prolongs the asset value of the soil for farmers, while reducing carbon dioxide losses to air, and ammonium and DOC losses to water. By raising the water table further – to less than 10 cm of the surface – losses will be minimised and the peatland habitat will change to a more biodiverse one with restoration of the natural hydrological processes such water storage and flood mitigation.

Implementation
An initial step is to identify areas on the farm where there are significant area of peatland and/or peaty soils – by examining the National Soils Hydrology map or the GSI Subsoils map[13] and undertaking a walk-over survey.

A hydrological assessment of the site is needed with the assistance of an appropriate expert. This will identify the best course of action to manage the water levels in-situ. Blocking of drains is the most common measure. It may be necessary to remove invasive species if they are present. Monitoring of the site to assess the success of the effort is recommended. It may be necessary to seek out funding resources and engage local stakeholders to ensure the success of this measure.

Consider the following during and after a farm visit

- Check for the presence of peaty soils on the farm.
- Check the size of the area designated for the measure.
- Check water levels in drains and decide on the level that is achievable and is agreed with the landowner.
- Identify if collaboration with neighbouring landowners in carrying out this work is feasible.

[13] https://gis.epa.ie/EPAMaps/Water

Environmental co-benefits

Raising the water levels is one of the most important means of reducing losses of carbon dioxide to the atmosphere. In addition, where the water level is within 10 cm of the surface, it enables carbon sequestration. However, there is the potential for methane release during the initial raising of the water table.

Sources of information

- EPA 2022, - Peatland Properties Influencing Greenhouse Gas Emissions and Removal https://www.epa.ie/publications/research/climate-change/Research_Report_401.pdf
- NPWS, National Peatland Strategy - https://www.npws.ie/sites/default/files/general/Final%20National%20Peatlands%20Strategy.pdf
- Bord na Móna - www.bordnamona.ie/peatlands/peatland-restoration/
- EU LIFE Peat Restore project - https://cinea.ec.europa.eu/news-events/news/restoring-peatlands-5-eu-countries-2022-07-20_en
- IPPC - http://www.ipcc.ie/advice/peatland-management-diy-tool-kit/restoration-of-drained-peatlands/

4.2.11 A22: Peaty soils – fertiliser spreading little and often based on crop needs

High organic matter soils cannot store phosphorus and therefore losses can readily occur if over-applied at rates that crops cannot use. A soil with 20% or greater organic matter is considered peaty/high organic matter. The National Soils Hydrology map will enable identification of peaty soil types; however, a soil sample for organic matter levels at farm or field scale would be a more accurate approach. Significant differences in the P sorption mechanisms in high organic matter soils is due to a lack of availability of "sorption sites" in the soil – making it vulnerable to P loss.

Phosphorus is removed from the soil by plant uptake, runoff and erosion, and leaching. In general, phosphorus loss by leaching is minimal compared to surface runoff. Surface runoff is the major pathway for phosphorus loss from soils. Runoff water carries away both soluble (dissolved) phosphorus and particulate (eroded soil particles) phosphorus from soil surface. Phosphorus is the "limiting nutrient" of surface water macrophytes and so aquatic plants respond strongly to increased P levels in the water.

Implementation

A key point is that peat soils cannot build P levels. It's not economically feasible (crop production and fertiliser costs) to do so. This is regardless of whether the phosphorous is applied as inorganic or organic.

Always match the application with the growth/development of the crop. Follow best practice nutrient management guidelines – avoid application in wet conditions or before heavy rainfall. In grassland peat soils, a little and often approach is recommended to ensure applied P is taken up by the grass crop and not lost to waters.

Consider the following during and after the farm visit

- Identify peaty soils from soils maps[14] and farm walks.

[14] National Soils Hydrology map at this link: https://gis.epa.ie/EPAMaps/Water.

- Consider P and sediment mobilisation factors like weather – rainfall and temperatures, and landscape – gradient, vegetative buffers, and attenuation ponds.
- Consider overland pathways and connectivity between field drains and local waterways.
- Carry out soil sampling to test for organic matter levels.
- Speak to an advisor about Index P levels and the agronomic and environmental risks with nutrient management on vulnerable parts of the farm.

Sources of information

- The Fertiliser Association of Ireland – The Efficient Use of Phosphorus in Agricultural Soils - https://www.fertilizer-assoc.ie/wp-content/uploads/2019/02/The-Efficient-Use-of-Phosphorus-In-Agricultural-Soils-Tech-Bulletin-No.-4.pdf
- Teagasc – Phosphorus management in organic soils for sustainable agriculture - https://www.teagasc.ie/environment/soil/research/phosphorus-management-in-organic-soils/
- Teagasc – Phosphorus use on peat soils - https://www.teagasc.ie/publications/2020/phosphorus-use-on-peat-soils-.php#:~:text=Firstly%2C%20just%20apply%20the%20phosphorus,term%20advantage%20to%20the%20soil.

4.3 Pathway interception measures

The role of pathway interception measures in mitigating inputs of pollutants to watercourses depends on the pollutant of concern and the physical land setting:

- Losses of nitrate to water occurs in freely draining areas where it infiltrates downwards from the soil to groundwater. Therefore, pathway interception is not feasible, and the key measures are source reduction and mobilisation control.
- In the poorly draining areas where the pathway is in overland and near surface, the pollutants of concern are phosphate, Total P, sediment, ammonium, MCPA and microbial pathogens. As these pose a threat to water at low concentrations, source reduction and mobilisation control measures, while beneficial, will often not be sufficient to mitigate significant impacts on water quality. Therefore, pathway interception will often be essential as an additional measure.

Pathway interception aims to slow runoff and break hydraulic connectivity thereby intercepting phosphorus and orthophosphate, sediment, ammonium, pesticides and pathogens, and enabling nutrient take up. In poorly draining settings, due the low permeability of the underlying geological materials, particularly the soil, a high proportion of effective rainfall must 'run off' either as overland or shallow subsurface flow from all of the area, irrespective of slope. Slope dictates i) where the water flows 'horizontally' in the landscape, ii) the degree of flow concentration in certain areas and iii) the delivery/areas/zones/points of water to watercourses. As a consequence, there are three landscape scenarios for entry of water (and pollutants) to watercourses and drainage ditches (Figure 4-2)[15]:

i) At focussed flow delivery points, where there is varying slopes/topography.
ii) Dispersed flow delivery, where the topography is relatively flat.
iii) No surface water inputs, where the slopes/topography sheds water laterally into focussed flow delivery paths or flat areas.

[15] Source: LAWPRO/EPA (2021a)

During wet weather, it is likely that most flow inputs would be in flow delivery zones and points, with slower flows and lower inputs generally from dispersed delivery zones. In addition, runoff quantities are likely to correspond with pollutant, particularly phosphate, load inputs to watercourses. Therefore, in areas with a high pollutant loading, e.g. high PIP-P areas, pathway interception will be more effective when located along flow delivery pathways and at flow delivery points.

EPA maps can be used to locate:

i) Susceptible areas for losses of phosphate to watercourses[16].
ii) CSAs for phosphate using the PIP-P map;
iii) Focussed flow delivery paths and points.

Figure 4-3 shows a phosphate critical source area (CSA) – the high PIP-P areas – together with the focussed flow delivery paths and points[17]. The PIP maps should be used for guidance, and field checking is required. For optimum effectiveness, it is recommended that pathway interception measures focus on the flow delivery paths and points within the larger catchment areas. Examples of targeted interception actions in poorly draining areas are shown in Figure 4-4[18].

It is recommended that account be taken of the features mentioned above when considering establishment of the 18 pathway interception measures – A23 to A40 – described in the following sections.

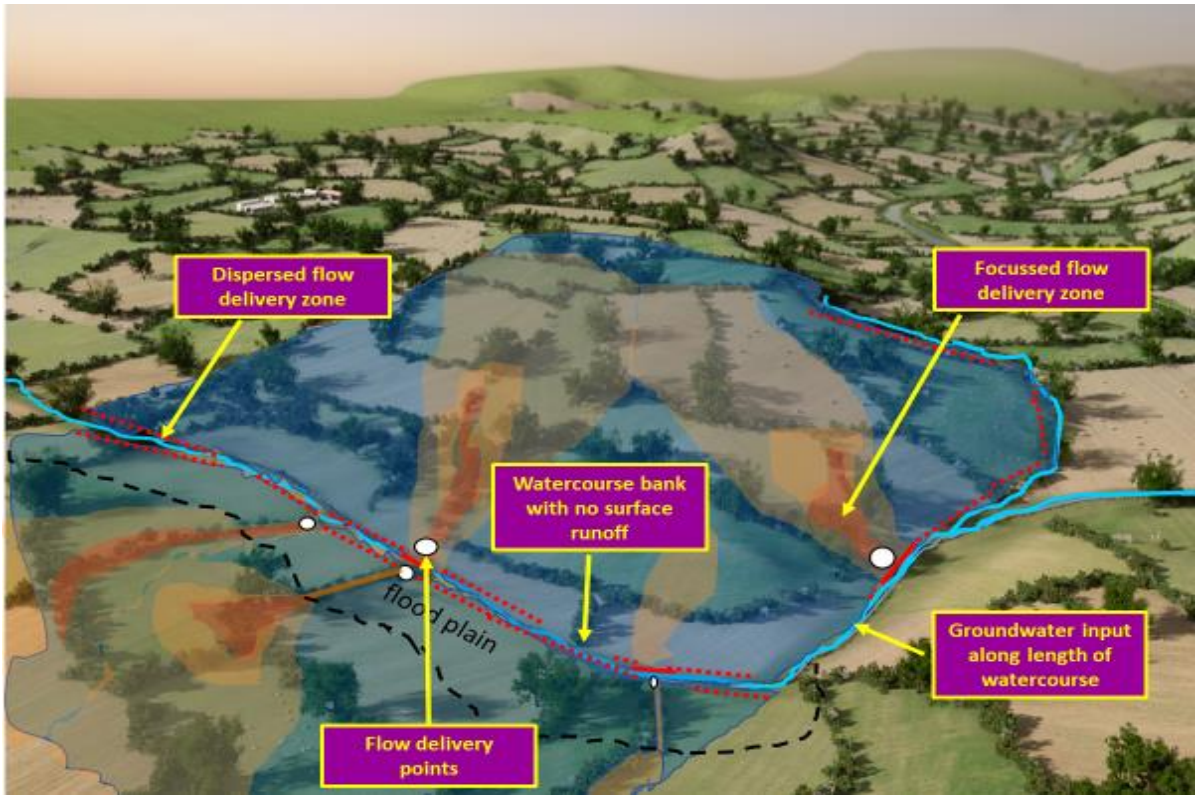

Figure 4-2: Illustration of a phosphate critical source area (CSA) where water enters the watercourse along three different flow pathways.

[16] The 'Near Surface Phosphate Susceptibility' map can be accessed under the Water, Land and Soil heading at https://gis.epa.ie/EPAMaps/Water.
[17] Source: https://gis.epa.ie/EPAMaps/Water
[18] Source: LAWPRO/EPA (2021a).

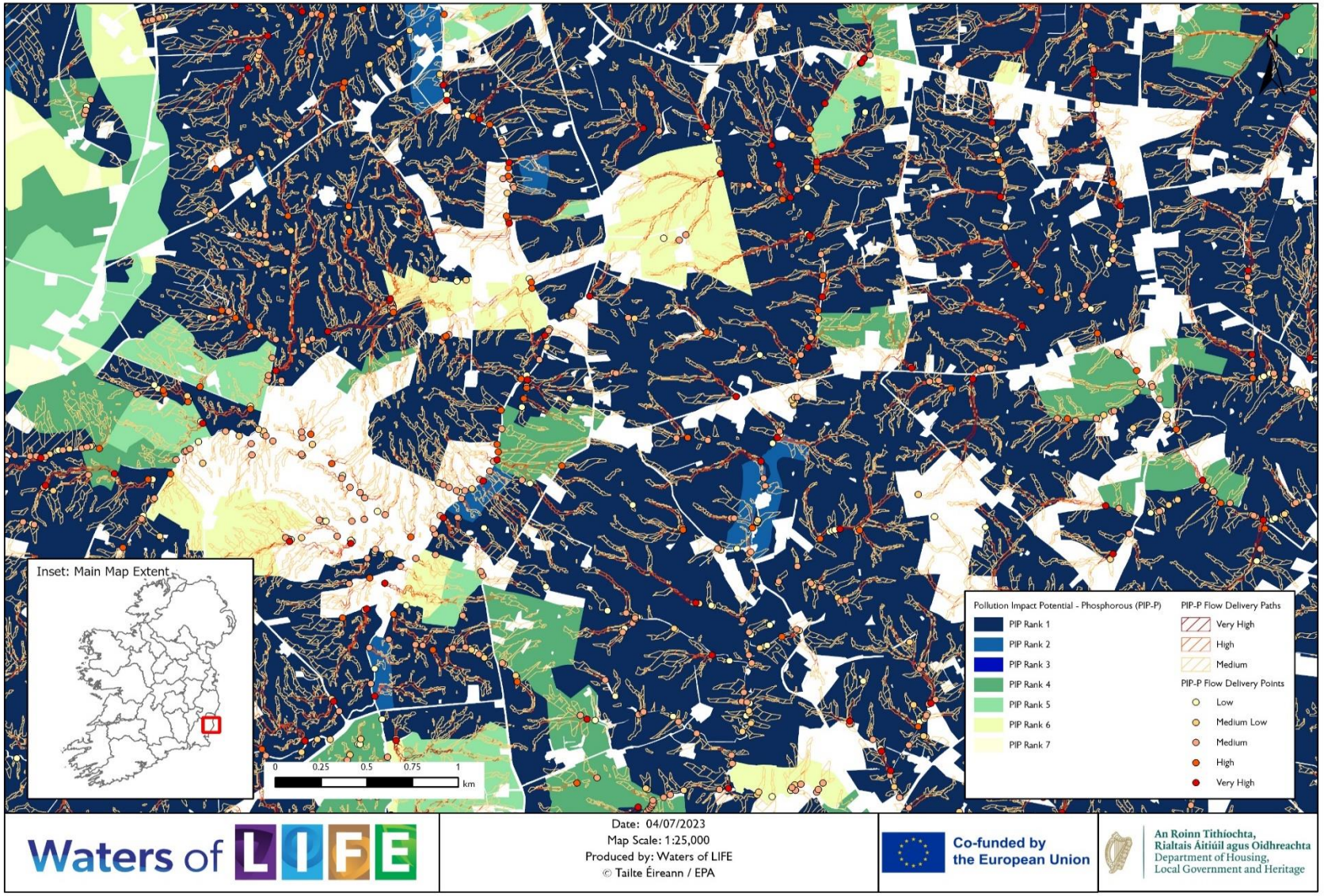

Figure 4-3: PIP-P map showing an area of generally high pollution impact potential for phosphorous, with flow delivery paths and points.

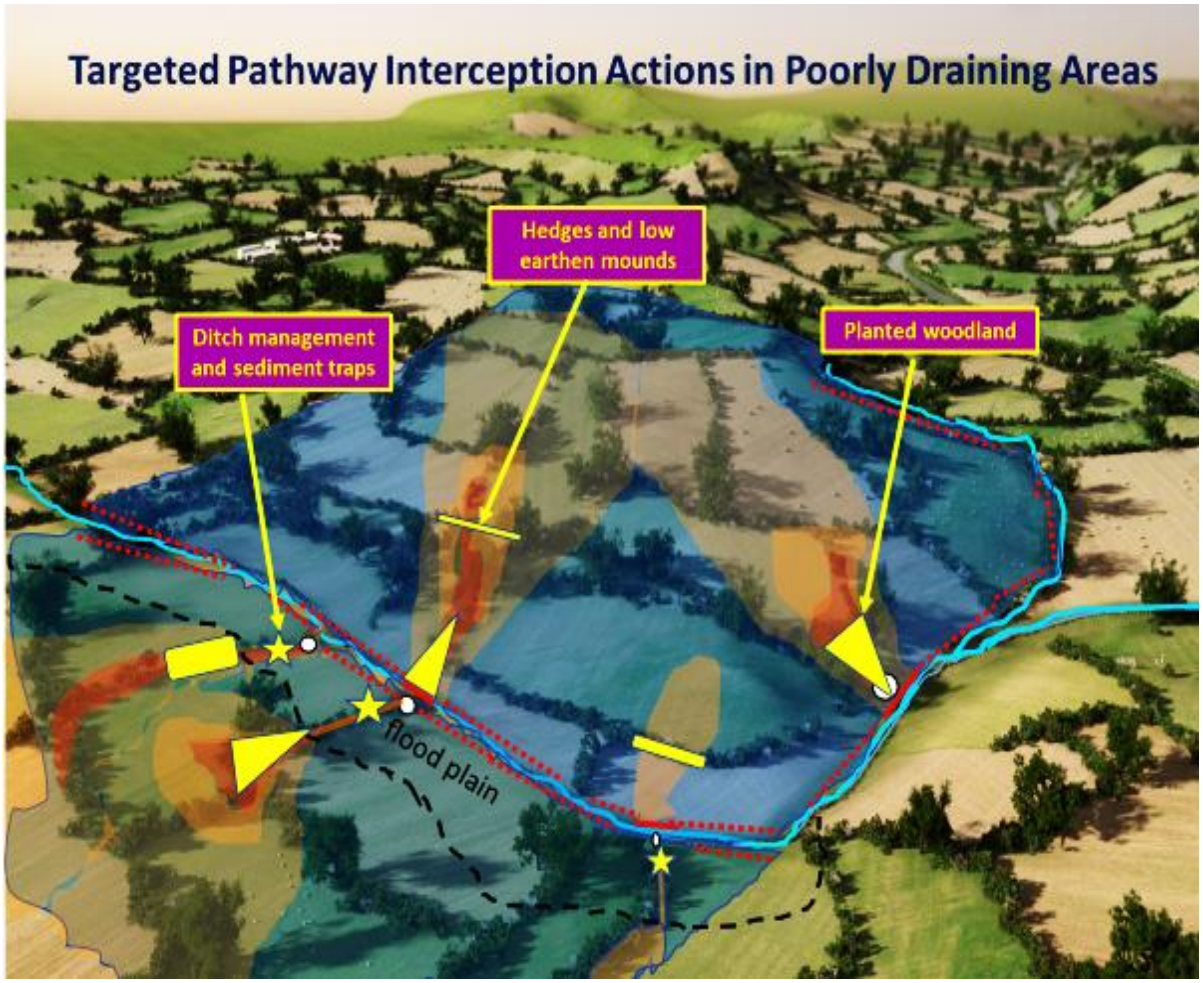

Figure 4-4: **Illustration of possible spatially targeted interception measures.**

4.3.1 A23: Fixed width buffers/setbacks

Setback distances are set out in the GAP Regulations for various farming activities. Their aim is to provide protection of water quality by maintaining a distance between the location of the pollutant load and the watercourse. This creates capacity for attenuation to occur as water and pollutants flow across the setback distance or buffer zone. The fixed width buffers specified in the GAP regulations are of limited benefit for water quality in free draining areas as the pathways for water to watercourses are underground, thereby bypassing the attenuating and interception capacity of the buffer. While they are of some benefit in poorly draining areas, bypassing of the relatively narrow GAP regulation fixed-width buffers is common, thereby limiting their effectiveness somewhat.

It is important that farmers know and observe the setback distances in the most up to date GAP Regulations.

Establishing vegetated and unfertilized “buffer zones”, that are retained as non-productive features alongside water courses, can reduce erosion and stabilize their banks. They may also protect against diffuse losses of nutrients, sediment and chemicals, such as pesticides. Plants growing in the buffer strip will remove nutrients through uptake and growth. They enable interception of sediment particulates in diffuse runoff and pollutants, such as P, that may be adsorbed to them. They may also improve infiltration and the removal of N (depending on the species of plant used and other site-specific factors). Subsequent removal of plants during strip management also removes contained

nutrients. Deep rooted and woody perennial plants improve infiltration, hydraulic roughness and soil stability.

Riparian buffer zones may provide valuable mitigation for receiving waters in areas where grazing impacts are obvious in the contributing lands, or where erosional features are evident. They provide mitigation during soil disturbance from tillage or grass re-seeding events. Where riparian zones have been heavily damaged there may be a need for some re-profiling of banks and planting suitable riparian vegetation for effective early greening. In most areas colonisation and spread of existing local riparian species will establish a diverse riparian strip as it matures. The measure is generally implemented in conjunction with fencing for maximum effect in areas with livestock grazing.

Implementation

On grassland, watercourses must be fenced to 1.5 m on farms stocked above 170 kg/ha organic N. Selected setback distances are given in Table 4-1. Farmers can demonstrate the implementation of setback distances most clearly with slurry application as this is visible. Chemical fertiliser is more difficult to see but a tractor GPS and a calibrated spreader could be used to ensure the 3m setback is being implemented. Setback distances can be underestimated so it is important to use some method for indicating the distance, for example something very simple like a number of pegs inserted into the ground as markers can be effective.

Environmental co-benefits

- Buffer zones have benefits for terrestrial biodiversity and GHG emission reduction.

Table 4-1: Selected setback distances in the Regulations

Chemical fertiliser (S.I. No. 716/2022 (Amendment))	
3m	From any surface waters.
Organic fertiliser or soiled water & drinking water supplies (S.I. No. 113/2022)	
200m	From a water supply such as an abstraction point of any surface waters, borehole, spring or well used for human consumption in a water scheme serving 500 people or more.
100m	From a drinking water supply like above serving 50 people.
25m	From any drinking water supply .
Organic fertiliser or soiled water & surface waters (S.I. No. 113/2022)	
20m	From a lake shoreline or a turlough likely to flood.
15m	From exposed karstified limestone features (such as swallow-holes and collapse features)
5m & 10m	5m from any surface waters (other than a lake like mentioned above or a surface waters specified as a drinking supply like mentioned above) 10m for two weeks before after the start of the fertiliser closed period.
Specific scenarios	
Other conditions and alterations can occur when technical assessment is carried out by local authorities and sufficient evidence is provided to deem it necessary to adjust the distance of the setback.	

Sources of information

- DAFM, 2022. S.I. 113 pf 2022. European Union (Good Agricultural Practices for Protection of Waters) Regulations, 2022. https://www.irishstatutebook.ie/eli/2022/si/113/made/en/pdf
- DAFM, 2022. S.I. no. 716 of 2022 European Union (Good agricultural practice for protection of waters) (AMENDMENT) (No. 2) Regulations 2022. https://www.irishstatutebook.ie/eli/2022/si/716/made/en/pdf
- LAWPRO/EPA (2022a). An overview of catchment science and management. A Guidance Handbook. Volume 1. Appendix 10. https://lawaters.ie/app/uploads/2022/01/Print_CSM-Volume-1_April-2022.pdf
- BRIDE Project, Farm Habitat Management - https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf
- Catchment based approach, natural flood management measures - https://catchmentbasedapproach.org/learn/natural-flood-management-measures-a-practical-guide-for-farmers-north-west/
- Natural Water Retention Measures EU - http://nwrm.eu/
- Mitigation options for reducing nutrient emissions from agriculture, Wageningen University - https://www.cost869.alterra.nl/Report2141.pdf
- NFGWS, 2020. Section 7.1. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/

4.3.2 A24: Spatially targeted variable width/extended buffers

In circumstances where the mandatory fixed-width buffer zones (Measure A23) do not or are not likely to intercept pollutants, such as phosphate and sediment, adequately in runoff in poorly draining areas, spatially targeted extended buffers, located, designed and shaped to suit the local topographic situation are a means of increasing pollutant interception and attenuation, thereby reducing the threat to water quality. Interception measures located in these buffer zones, such as farm ponds, tree and shrub planting (see Section 4.3.16) and creation of mini-wetlands (see Section 4.3.7), are possible options for consideration.

Implementation

The EPA PIP-P maps[19] provide a guide to the location of flow delivery paths and points (see Figure 3-4). They also indicate where fixed-width buffers are likely to be inadequate during wet weather when runoff is greatest, and therefore where spatially targeted extended buffers provide greater effectiveness. For optimum effectiveness, the recommended location for pathway interception should focus on the flow delivery paths and points within the larger catchment areas to flow delivery points. Field checking is required to ensure that the correct locations are chosen.

Estimated costs

There is some cost in terms of usage foregone in riparian zones – the amount of which will depend on the areal extent and productivity of the buffer zone.

Consider the following during and after the farm visit

- Ground truth the flow delivery pathways and points on the farm that were identified using the PIP-P maps.

[19] https://gis.epa.ie/EPAMaps/Water under "PRESSURES & ACTIVITIES".

- Planting appropriate trees in the buffer area where phosphate is the pollutant of concern and the installation of ponds where sediment is the pollutant of concern.
- Making before and after observations and note the beneficial effects as they occur over time.
- Checking for land drainage pipes as these would enable bypassing of the buffer zone by water.

Environmental co-benefits

- The measure will give rise to an increase in natural habitats and species diversity, including habitats for farmland birds, mammals and beneficial insects, and food sources for pollinators.
- Reduces the risk of flooding downstream (by slowing the flow in storm events)
- Captures carbon and lowers farm carbon footprint.
- Improves aesthetics, as vegetative buffers are attractive features.

Sources of information

- Appendix 10, LAWPRO/EPA (2021a). https://lawaters.ie/app/uploads/2022/01/Print_CSM-Volume-1_April-2022.pdf
- Deel Spatially Targeted Buffers EIP End of Project (2023). https://www.ballyhouradevelopment.com/european-innovation-partnership-deel-river

4.3.3 A25: Magic Margins

Magic margins are a series of ridges and mini-infiltration dams parallel to the slope (Smarter_BufferZ project). This is a measure for arable/tillage fields, but could also be used on sloping grassland. The aim is to incorporate a "system of barriers" along the flow pathway of a sloping field to intercept the movement of water along the surface and to encourage infiltration. The barriers will also minimise or reduce soil erosion and sediment losses to watercourses. Incorporation of vegetation increases the effectiveness of the measure and adds biodiversity to the area.

Implementation

Use a potato drill plough and, if available, a tied ridger. Sow grass or preferably native wildflowers or a mix with the intention of preventing runoff of nutrients and sediment, and increasing biodiversity.

Estimated costs

Likely to be low, but this depends on the availability of appropriate machinery and the amount of area given to this measure as this will increase the amount of wildflower seed needed.

Consider the following during and after the farm visit

- Use the PIP flow pathway and delivery point maps to identify the areas that would most cost and environmentally effective for implementation.
- Plan with the farmer when to carry out the works around the arable operations and when weather and soil conditions allow.

Environmental co-benefits

- Farm biodiversity is enhanced.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/HandbookTool.pdf
- Hutton University – Magic Margins - https://www.hutton.ac.uk/news/%E2%80%9Cmagic-margins%E2%80%9D-win-innovation-award-rspb-nature-scotland-awards
- RSPB – Magic margins - https://community.rspb.org.uk/ourwork/b/scotland/posts/magic-margins

4.3.4 A26. Raised buffer/interception berm

This is a low bund, usually constructed of soil, placed across an overland flow pathway, thereby disconnecting the pathway and temporarily storing water (Smarter_BufferZ project). The feature needs to have a designed spillway (in case of overtopping) and usually a pipe is placed through the bund to aid with draining. At its simplest, it is low earthen mound that intercept flows, retains water and entrains sediment. The retained water infiltrates the soil, evaporates or slowly diffuses along near surface pathways. More elaborate structures serving larger areas may require specialist design in relation to the contributing catchment area, capacity and freeboard, overflow provision and deployment location. Berms should be aligned along contours and sited in areas of coalescing flows that transport sediment, or where rill or gully erosion may occur. Vegetation with grasses provides extra stability to the bunds.

In-field grass berms, which are permanent grass covered features parallel to contours, provide similar physical interception of surface flows.

This measure is suitable for catchment areas on gentle to moderate slopes that are vulnerable to rill or gully erosion, and areas with clearly identifiable flow concentration that lead to soil erosion. They may not be suitable in flow delivery paths with focussed high velocity runoff after intense rainfall as erosion of the berm might occur.

Implementation

Berms may require specialist design in relation to contributing catchment area, capacity, emergency overflow provision and location. High resolution topographic data will assist in identification of key deployment sites. If they are not sized and shaped correctly, flows may regularly exceed their capacity. In addition, inspections, especially after storm events, are advisable.

Consider the following during and after the farm visit

- Low earthen mounds may be established along watercourses and ditches in critical source areas.
- Use the PIP flow and delivery maps and discussion with the land owner when considering locations for berms to identify preferential flow paths and gradients. The contributing catchments should be relatively small and preferable no greater 2ha.
- Berms are most often deployed in arable settings. Berms may not be suitable for large areas with very impervious soils, but constructing them in series along slopes may be an option.

Other notes

- Berms will provide immediate mitigation on completion of construction.
- Adverse impacts are unlikely in properly deployed measures.
- Herbicides should not be used in site preparation or in maintenance of measures.

Environmental co-benefits

- Berms may provide some biodiversity benefits in tillage areas by increasing permanent grassland.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/HandbookTool.pdf
- Natural Water Retention Measures EU - http://nwrm.eu/
- Wageningen University – Mitigation options for reducing nutrient emissions from agriculture - Mitigation options for reducing nutrient emissions from agriculture. A study amongst European member states of Cost action 869.
- Dairy NZ – On farm actions - DairyNZ. Critical Source Areas.
- Farming for a better climate (collaboration) - Best Management Practices — Controlling Soil Erosion on the Farm — A practical guide.
- Royal Society for the Protection of Birds - RSPB. Farming and Crofting for Wildlife. Beetle Banks.
- Catchment based approach, natural flood management measures - https://catchmentbasedapproach.org/wp-content/uploads/2018/11/North-West-NFM-handbook.pdf
- Rural Sustainable Drainage Systems (RSuDS) - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291508/scho0612buwh-e-e.pdf

4.3.5 A27: Raised buffer – overbank storage

The difference between a 'raised buffer/interception berm' and a 'raised buffer – overbank storage' is that the latter stores water after a flood event, with emptying occurring 24-48 hours later, trapping sediment in the process. A low earthen bank (usually max. 1m high) is constructed in a flood plain area of a field – somewhere that begins to flood first and holds water longer than other parts of the field (Smarter_BufferZ project).

Implementation

- A suitable area for the installation needs to be located where floodwaters can be directed towards topographic depressions or relatively flat areas on the floodplain (to maximise amount of storage and minimise the volume of soil needed for the bund).
- A drainage outlet pipe needs to be incorporated into the design.
- This measure may require a lot of space to be effective – bund width could be around 6 m to 8 m. However, the area of this measure can still be farmed. Moreover, it is essential to manage sediment accumulations. The bund will require inspections especially after storm events.
- Consultation with LAWPRO, EPA and OPW for larger measures is recommended.

Consider the following during and after the farm visit

- Use OPW flood mapping[20] to identify if there are any flood plain areas on the farm or the GSI subsoil map[21], which shows river alluvium. Use in combination with PIP flow and delivery maps too.

[20] https://www.floodinfo.ie/map/floodmaps/

[21] https://gis.epa.ie/EPAMaps/Water under "WATER, LAND AND SOIL" or https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=7e8a202301594687ab14629a10b748ef

- Measure out the area of the flood plain and estimate how often it floods. Seek advice from specialists if necessary.
- Ground truth the area.
- Develop a sediment management plan with the farmer.
- Adjustments may be required at a later time.
- Identify a contractor specialised in constructing bunds and berms.

Other notes
- Can be vegetated with a mix of grasses for extra stability to the bund.
- Usually fenced off in a livestock field to ensure livestock do not damage bund.

Environmental co-benefits
- The variability of wetter and drier soil conditions around the features aids habitat diversity.

Sources of information
- Smarter Bufferz - http://www.smarterbufferz.ie/HandbookTool.pdf
- Information on building UK bunds in the video at https://vimeo.com/217366315
- Examples of bunds from the SLOWater project in Ireland at https://youtu.be/sBsmx_d6crs and https://youtu.be/aUpmOTp1EBc

4.3.6 A28: Hedgerows

Planting of hedgerows alongside watercourses, along contours or in natural gullies breaks the hydrological connectivity of the landscape and mitigates surface runoff, soil erosion, suspended and export of sediment and associated pollutants. Hedgerows contribute to mitigating nutrient losses by intercepting runoff, increasing infiltration (depending on the vegetation age and type), and by utilising nutrients for plant growth.

Hedgerow establishment is not suitable for heath, bog or scrub/woodland habitats and should not replace valuable existing or protected habitats.

Implementation
Our recommendations are as follows:
- Align hedgerows along contours, if feasible. In addition, they have a greater benefit when sited across areas of coalescing flows that may transport sediment and nutrients, or where rill or gully erosion may occur.
- Plan to have hedgerows that are at least 2m wide, although widths of 3-4 m will be more beneficial.
- A suitable planting density is 6 plants per metre in a double row 0.8m to 1.2m apart.
- Use native species, with at least two woody species in each 10m of hedge, and at least 4 species per 50m length. Suitable species include oak, willow, hawthorn, blackthorn, hazel, spindle, guelder rose, dog rose and woodbine. Plant different tree species intermittently, e.g. mountain ash, crab apple and hazel depending on soil (Note: Ash is not suitable currently due to ash dieback disease).
- Plant between December and March.
- Where hedgerow planting is on an earthen bank, it should be to the side of the bank rather than on top.
- Newly planted hedgerows may require protection against grazing by deer, rabbits or livestock.

- Avoid using herbicides in site preparation or maintenance – particularly if near a watercourse or near a drain that could carry water to a watercourse.

Estimated costs

Installation costs are relatively low – less than €15 per metre. Some maintenance costs will accrue during establishment for replacing failed plants and topping, but again this is small. Where fencing is required to protect against grazing, additional costs will accrue of the order of €10/m for post and wire, or €5/m for permanent electric fencing.

Consider the following during and after the farm visit

- Identify if the farm meets the "space for nature" requirement for the Eco Scheme.
- Identify where hedgerows would be best placed to break the hydrological connection across the landscape – use PIP-P maps showing flow delivery paths and points, and ground truth them.
- Look out for slopes that show or appear vulnerable to rill or gully erosion.

Other notes

Hedgerows are slow to establish and take a number of years to mature. Rules around removal and planting hedgerows can change depending on regulations and agri-environment schemes, so be aware of the latest information.

Environmental co-benefits

- Enhanced biodiversity by creating habitats for farmland birds, mammals and beneficial insects.
- Provides habitat and a food source for pollinators and nesting sites for birds.
- Shading for rivers.
- Reduced downstream flooding.
- Lowers farm carbon footprint.
- Enhanced landscape aesthetics.

Sources of information

- NFGWS, 2020. Section 7.3. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/
- BRIDE Project - https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf
- Catchment based approach - https://catchmentbasedapproach.org/wp-content/uploads/2018/08/EA-NFM-Toolbox-Final-Draft.compressed.pdf
- Catchment based approach - https://catchmentbasedapproach.org/learn/natural-flood-management-measures-a-practical-guide-for-farmers-north-west/
- Natural Water Retention Measures EU - http://nwrm.eu/
- Biodiversity Ireland - https://www.biodiversityireland.ie/wordpress/wp-content/uploads/Farmland-Actions-to-Help-Pollinators.pdf
- Teagasc – Biodiversity - https://www.teagasc.ie/media/website/environment/biodiversity-countryside/teagasc_farmhedge_management.pdf

4.3.7 A29: Wetland buffer/farm pond

The aim of this measure is intercept water flows off the land and in the process intercept sediment and attenuate pollutants such as phosphorus and microbial pathogens. It can also be used to intercept land drains. Also, as these areas are groundwater discharge zones, denitrification of nitrate in groundwater can be beneficial. There may be some nutrient attenuation, but this would require a robust approach to manage nutrient input and nutrient retention capacity. Note that not all "pollutants" are suitable for attenuation by ponds, so consider the type/source and quantity of pollutant in the context of the capacity of the pond to attenuate it and reduce the wider environmental risk. In all cases, a wetland buffer or farm pond requires monitoring and maintenance. Additionally, the initial construction stages may be impactful through sediment releases, habitat change, or physical changes to natural flows (hydromorphology) and this must be considered in the context of water quality issues locally.

Implementation

The geology/hydrogeology of a proposed site is critical to the success of the pond. To maintain water in the pond for all or most of the year either the subsoil needs to have a low permeability and/or the pond is located in a low lying area in the vicinity of a watercourse that is frequently wet where the water level in the pond is the same as the water level in the watercourse. As these areas are groundwater discharge zones, denitrification of nitrate in groundwater can be beneficial.

It is worthwhile consulting a professional about a detailed plan that includes size, shape, depth, and risk of erosion, or overflow, or bank failure. Ensure the design meets the priority function of the pond whatever that may be – attenuation of nutrients/biodiversity/sediment. Excavation will require clearing off the surface vegetation and digging to the planned depth. Machinery needs be suitable for the soil type in-situ to minimise damage.

Farm ponds can be an important addition in spatially targeted extended buffer areas, particularly for intercepting sediment. Also, planting with native vegetation to capture nutrients is recommended.

Consider the following during and after the farm visit

- Ensure the site is suitable for a wetland or pond by considering the soil type, slope and hydrology of nearby waterways.
- Is the farm in a protected are (SAC, SPA) and are any permissions needed?
- Ensure a monitoring and maintenance plan is agreed with the land owner.
- If desired, monitor the changes in biodiversity by carrying out a baseline survey and updating it annually or seasonally. Water quality can be monitored but will require professional assistance from private water testing companies or government agencies that are involved in local projects.

Environmental co-benefits

- Biodiversity enhancement.
- Flood mitigation.
- Water storage/supply for livestock on your farm.
- Aesthetic – they are an attractive feature.

Sources of information

- NFGWS, 2020. Section 7.9. Handbook of Source Protection and Mitigation Actions for Farming - https://nfgws.ie/nfgws-source-protection-publications/
- Farming for nature - https://www.farmingfornature.ie/your-farm/resources/best-practice-guides/building-a-wildlife-pond-on-your-land/
- Biodiversity Ireland - https://biodiversityireland.ie/projects/ponds-for-biodiversity/
- Norfolk ponds project - https://www.norfolkfwag.co.uk/norfolk-ponds-project/
- Teagasc – Biodiversity - https://www.teagasc.ie/news--events/daily/environment/protecting-wildlife-habitats-to-increase-biodiversity-on-farm.php
- UK constructed farm wetland advice - https://www.wwt.org.uk/uploads/documents/1429707026_WWTConstructedFarmWetlands150422.pdf
- Scotlands centre of expertise for waters (CREW) https://www.crew.ac.uk/sites/www.crew.ac.uk/files/sites/default/files/publication/Rural%20SuDS%20Design%20and%20Build%20Guide%20December%202016.pdf

4.3.8 A30: Swales

Swales are broad, shallow, linear vegetated channels which can store or convey surface water and remove pollutants. Swales can be used to manage water flow, reduce erosion, and enable filtration or nutrient retention to minimise or slow down an impact on a local waterway.

Swales can be installed to move water to a storage feature like a pond or wetland. The swale diverts water from runoff pathways. A swale can also be designed to hold runoff, utilising vegetation and low gradients to slow the flow. Additionally, a swale can be used to treat and reduce runoff by increasing infiltration. They are best suited on gradual gradients, but if designed carefully can be scaled up to landscape level with appropriate planning.

Implementation

- Consider combining with wetland buffer/farm pond when undertaking this measure. Assistance in swale design from a professional may be needed.
- Regular maintenance is recommended.

Maintenance details

Maintenance	
Activity	**Frequency**
Inspect swales to make sure vegetation is adequate and slopes are not eroding. Check for rilling and gullying. Repair eroded areas and revegetate.	The first few months after construction and twice a year thereafter.
Mow dry swales. Wet swales may not need to be mowed depending on vegetation.	As needed.
Remove sediment and debris manually	At least once a year
Re-seed	As necessary

Consider the following during and after the farm visit

- Installation is a similar process to the wetland buffer/farm pond measure.

- Identify opportunities to use natural gradients as much as possible. Use the PIP-P flow delivery paths and points map to guide this decision and walk the areas to ground truth it.

Other notes
Swales can be divided into two categories – wet and dry.

Environmental co-benefits
- Terrestrial biodiversity.
- Flood mitigation.
- Aesthetic.

Sources of information
- Natural Water Retention Measures EU - http://nwrm.eu/measure/swales
- Farm Advisory Service, Scotland - https://www.fas.scot/downloads/water-management-on-your-farm-slowing-the-flow/
- Massachusetts Clean Water Toolkit - https://megamanual.geosyntec.com/npsmanual/waterqualityswales.aspx#:~:text=Water%20quality%20swales%20are%20vegetated,Wet%20Swales
- Scotlands centre of expertise for waters (CREW) https://www.crew.ac.uk/sites/www.crew.ac.uk/files/sites/default/files/publication/Rural%20SuDS%20Design%20and%20Build%20Guide%20December%202016.pdf

4.3.9 A31: Tile-drain fed wetland

The aim of this measures is to identify an opportunity to intercept water from subsurface artificial drainage and, in certain circumstances, surface runoff (Smarter_BufferZ project).

Implementation
Intercepting small tile drains will depend on the landscape position, the nature of the drainage being intercepted and the areas required based on design principles on residence time for water flow rates. Cutting back small tile drains to an existing or enhanced mini-wetland area may be more proportionate management but water quality benefits would need to be judged against habitat change in the semi-natural small wetland. Efficiencies vary greatly depending on design (aspect, ratio of size to catchment affecting hydraulic residence time, carbon availability).

Consider the following during and after the farm visit
- Ask the landowner for details on past drainage installations.
- Look for evidence of pipes in drainage ditches and watercourses.

Environmental co-benefits
- Terrestrial habitat diversity.
- Minor flood mitigation.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/HandbookTool.pdf
- CREW – Rural SuDs guidance document - http://www.crew.ac.uk/publication/rural-sustainable-drainage-systems-practical-design-and-build-guide-scotlands-farmers
- The UK High Water Common Ground project explains tile drainage solutions - https://vimeo.com/217023901

4.3.10 A32: In-field sediment trap

The aim of a sediment trap is to utilise or build a landscape feature to capture and settle out sediment contained in run-off from fields or potentially farmyards (but the type of pollutant in question is important to consider) (Smarter_BufferZ project). Sediment traps are good for extreme erosion situations, such as steep slopes or exposed soil.

For areas where sediment and sediment transported contaminants degrade water quality, a sediment trap is a useful point-based measure placed in an existing buffer zone up slope of the watercourse banks. The measure is an engineered feature (or enhancement of an existing landscape depression), designed to hold back muddy run-off from fields and tracks, allowing time for suspended sediments to settle, and usually has an outlet pipe or controlled spillway to spills excess flow (Smarter_BufferZ project).

Implementation

Consideration of the function and design is essential when deciding on the implementation/installation process. Sediment traps are constructed as shallow depressions or basins at the lower end of slopes or along drainage paths. They need to be positioned to intercept runoff at a manageable rate (taking into account surges of rainfall for example). In-field sediment traps need to have an outlet to release the treated water and a sediment collection area that is accessible for maintenance.

It is usually better to have large surface areas as this allows more time for sediment to settle. Sediment traps may be placed upslope of another measure (e.g. a habitat measure) to protect it from a pollution burden and provide a managed point for extracting captured sediment. Research indicates that sediment traps in the sequence (2 to 3) are more effective in mitigating P loads as finer particulates had longer time to settle.

Similar to the wetland buffer/farm pond and swale measures – carry out excavations according to the design plan. Establish vegetation and agree on a monitoring and maintenance plan.

Consider the following during and after the farm visit

- Similar process to the wetland buffer/farm pond measure – ensure the site is suitable, enquire if licenses or permits are needed, expect some damage during initial construction, have an agreement on monitoring and maintenance and if desired measure the changes in habitat or water quality over time.
- Identify opportunities to use natural gradients as much as possible. Use the PIP-P flow delivery paths and points map to guide this decision and walk the areas to ground truth it.

Other notes

The effectiveness is improved with larger surface areas of water, however, this takes a greater area of land. Sediment traps need management e.g. they need to be emptied.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/
- CREW – Rural SuDs guidance document - http://www.crew.ac.uk/publication/rural-sustainable-drainage-systems-practical-design-and-build-guide-scotlands-farmers
- Netherton, Northumberland shows examples - https://research.ncl.ac.uk/proactive/netherton/naturalrunoffmanagementscheme/
- Video from Norfolk Rivers Trust - https://www.youtube.com/watch?v=gYXk94QlB-Y
- Minnesota stormwater manual - https://stormwater.pca.state.mn.us/index.php?title=File:Siting_and_Design_Considerations_for_Sediment_Traps.tif.jpg

4.3.11 A33: In ditch sediment trap

The aim is to slow the water in the drainage ditches so that sediment settles out and can be removed. Options include installing a physical barrier of media such as wood, stone or a widened ditch to decrease flow velocity leading to local sedimentation in the channel and protection of downstream watercourses. However, they are more suitable for coarser sediment than fine clayey sediment, which may not settle out.

Traps can be installed to enhance existing areas of sediment accumulation (at slope breaks). They can accompany other source controls to limit both runoff and sediment mobilisation. All sites must have access for machinery to clean out sediment periodically, with access from the bank without having machinery in the channel.

Implementation

The size and nature of the trap dimensions, the location and incorporation of any filtration medium can be altered for a given site. Trap sizing depends on particle sizes, water volumes and water velocities.

Maintenance to clean out sediment is important and can be done easily at times the ditch is dry. If the ditch has flow in all seasons, then windows of cleaning must be selected during suitable weather and low flows, avoiding key seasons when aquatic species in downstream waters are vulnerable.

The following best management principles apply: prevent release of sediments downstream (e.g. a temporary silt fence can be used), avoid disturbing riparian vegetation, machinery must work from the bank not in the channel, work from one bank, remove dredged material a safe distance from the bank and ideally take back to fields. For the initial sediment trap construction, the same principles apply.

Consider the following during and after the farm visit

- Combine this measure with other pathway interception measures where suitable.
- Incorporate natural slopes where possible but speak to professionals about planning and design.
- Identify if multiple landowners are needed to cooperate to ensure maximum mitigation potential.
- Use online tools, such as PIP-P flow delivery paths and points map, to achieve optimum locations for the sediment traps.
- Ensure all relevant licenses and permits are sought prior to installation.
- Ensure a monitoring and maintenance plan is put in place – review every 6 to 12 months.

Other notes
Ensure expert advice is sought for this measure.

Environmental co-benefits
- Minor flood mitigation.

Sources of information
- Smarter Bufferz - http://www.smarterbufferz.ie/
- Factsheet from British Columbia - https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/soil-nutrients/600-series/641310-1_sediment_traps-drainage_guide_factsheet_no9.pdf
- Rural sustainable drainage systems - Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS).
- Video from Canterbury Uni, New Zealand - https://www.youtube.com/watch?v=BMUJn9zL2y8
- Videos from the UK High Water Common Ground project on leaky is-stream dams including what they are (https://www.youtube.com/watch?v=GvFYDiTMLto) and the process of building them (https://vimeo.com/217155967).

4.3.12 A34: Engineered ditch management

The aim is to slow the water in the ditches by reprofiling over short distances (e.g. length 4 to 10 times the channel width) and widening with both shallow and deep components. The shallow channel sides hold water and pollutants following high flows to increase the potential of capture and retention of a pollutant.

In contrast to a traditional ditch, which has steep sides and a “V”, or trapezoidal profile, two stage ditches include the modification of the banks by addition of mini shallow floodplain benches on each side to mimic small natural floodplains but in engineered channels. In some circumstances, it may be more feasible to have one shallow bench. One main issue with traditional ditches is that they are often oversized for small flows and so during high flows a flushing out of stored sediment occurs.

The floodplain benches allow the water to spread onto the vegetated mini floodplains during times of higher flows. The aim of this is to promote channel stability overall and deposit some of the load of sediments and bound nutrients. The feature takes little additional space out of agricultural production but may require long channel lengths to make a significant contribution.

Implementation
The optimal location for re-profiling a ditch to a two stage channel is where channel benches (shoulders) are forming naturally. The principles of design are that: the channel is sized to convey the discharge effectively, with excavated benches (the 'second stages') serving as the floodplain for the smaller inset channel, and are of adequate width to prevent flow overtopping the ditch and flooding surrounding land. The designs seek to mimic features of a natural stream in adding roughness, slowing flows, providing channel stability and sedimentation.

Estimated costs
Costs can increase if excessive tree roots are encountered or excavated material has to be removed from site.

Consider the following during and after the farm visit

- Identify if the landowner has capacity to carry out this measure and determine the total length of channel that they could use.
- Seek out professional expertise and identify if any licenses or permits are needed.
- Focus on the pollutant that is being addressed in the downstream waterbody and consider the timing of the excavations to minimise sediment release.

Other notes

There is a capital cost for digging the new channel profile and removal of material and some land is required to be utilised to widen the ditch top. However, since the inset channel maintains faster flow than the benches the inset channel remains self-flushing and may require less period regular dredging.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/
- Landscape Conservation Cooperatives factsheet at https://lccnetwork.org/sites/default/files/Resources/Practice%20%233%20Two%20Stage%20Ditches%20-%20Formatted.pdf
- RSuDS - Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS).
- Factsheet and video on case study - https://www.indianawatershedinitiative.com/two-stage-ditch.html
- Two drainage ditch Wiki page - https://en.wikipedia.org/wiki/Two-stage_drainage_ditch
- Mitigation measure catalogue for targeting Agri-environmental scheme nutrient management is available from the Danish Knowledge Centre for Agriculture (SEGES) https://northsearegion.eu/media/18874/mitigations-measures-nutrients-danish-catalog.pdf
- Duhallow Life project - https://www.duhallowlife.com/sites/default/files/C4%20Final%20Technical%20Report%20-%20Provision%20of%20Silt%20Traps.pdf
- Horizons projects literature review, Government NZ – search "*Mitigating nutrient loss and OVERSEER® - measures not included, or well represented*"
- Chapter 2, Volume 3 in Local Catchment Assessment Guidance at this link: https://lawaters.ie/app/uploads/2022/09/Print_CSM-Volumes-23_April-2022.pdf
- NFGWS, (2020). Section 7.7. Handbook of Source Protection and Mitigation Actions for Farming https://nfgws.ie/nfgws-source-protection-publications/

4.3.13 A35: Leaky dam

Leaky dams can occur naturally when large sections of tress fall into and across river channels, holding back water in the channel during high flows or encouraging it to spill on to the banks. In this way, they can slow the flow and reduce downstream flood peaks. These processes can be replicated by building leaky dams using a variety of different methods.

By reducing flow velocity, these structures can reduce erosion risk and increase sediment deposition, thereby reducing transportation to downstream receptors. This measure may also help decrease P loss, as it can be adsorbed on to sediment/soil particles.

Professional expertise is required for advising on and designing this measure.

Implementation
The key process is to slow the water flow. This can be achieved by installing a "leaky" physical barrier. Structures may be placed in multiple locations, if practicable. Sediment removed from structures needs to be spread on the land at a distance of a few metres from the drain.

In general, it is recommended that dams be located in low gradient sections of watercourses and drainage ditches, and that local depressions, unsound banks and obstacles such as tree roots be avoided. Structures may require maintenance to ensure that they do not cause issues further downstream. After each significant high flow event, it is recommended that each structure be checked for debris, Integrity, and condition or need for repair.

There are a number of guidance documents available on the siting, design and construction of leaky dams (see sources of information below). These dams may be placed in drainage ditches or in river channels, but any works in stream or river channels will require consultation with the local Inland Fisheries Ireland officer.

Estimated costs
Cost of installation of structures is generally low. Maintenance is required and occasional replacement of structures by the landowner may be necessary. Periodic removal and spreading of sediment can be undertaken by the landowner at minimal cost.

Consider the following during and after the farm visit
- Identify the distribution of soil type across the farm as sediment erosion is greatest in poorly drained scenarios where surface flow paths dominate.
- Upstream and downstream landowners must be considered so this measure may require outreach and stakeholder engagement.

Environmental co-benefits
Leaky dams can provide co benefits for biodiversity, by providing habitat for wildlife.

Sources of information
- Yorkshire Dales Rivers, Leaky dams - https://www.ydrt.org.uk/wp-content/uploads/2021/04/NFM-Leaky-Dams-guide.pdf
- Catchment based approach, natural flood mitigation measures - https://catchmentbasedapproach.org/wp-content/uploads/2018/11/North-West-NFM-handbook.pdf
- Farm Advisory Service, Scotland - https://www.fas.scot/downloads/water-management-on-your-farm-slowing-the-flow/

4.3.14 A36: Sediment filter fence

In tillage fields with erosion risk (e.g. sloping, sandy textured soils, compacted soils with cultivation practices that greatly enhance soil loss potential (e.g. potato crops)), a sediment filter fence may be an effective temporary measure at a suitable location at the bottom of a slope. The fence consists of geotextile material which contains the sediment but lets the water through (Smarter_BufferZ project).

Where tillage activities are part of a crop rotation, the risks will be greatest in the Autumn each 4-5 years. In this circumstance, the filter fence is a temporary mitigation measure that can be set-up and moved.

Implementation

The drainage area above any fence should not exceed about 1500 m^2 (0.15ha). Avoid overly long runs by using multiple overlapping fences if necessary. Fences run parallel to contours and should have ends turned upslope to create ponding and settlement areas. Fencing material must use appropriate geotextile and be of sufficient durability to prevent rupture. Adequate staking and toe-in of the textile base are crucial to prevent by-passing of the fence material. Where operations in vulnerable zones (riparian or critical source areas) are unavoidable, silt curtains may provide short term mitigation – silt curtains are used in aquatic environments. A combination of both may be best practice.

Consider the following during and after the farm visit

- Consider the crop rotations strategy of the farm and plan on where and when this measure would be most effective.
- Consider the need for monitoring the fence for breaks.
- Allow time for moving the fence and filter at appropriate times.
- Allow time to move the sediment upslope.

Other notes

Filter fences comprise a geotextile material that is used for erosion control in construction and forestry projects to mitigate soil loss to watercourses.

Trials at the base of sloping field (10% slope) used for potato cultivation in Scotland showed capture of 80 tonnes of soil (60-70 kg P) from a 17 ha field on one season (Nov-Feb). The accumulated sediment had similar chemical composition and bulk density to field soil (both high soil P status) but the trapped sediment was finer textured than in-situ soils. The sediment containing the highest P content was closest to the fence.

Benefits are maximised if trapped soil (and inherent nutrient content) is economically viable to be moved back upslope onto the field, or it resides in a higher risk near watercourse location at slope base and must be stabilised by permanent vegetation.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/
- Video from LEAF Linking Environment and Farming - https://www.youtube.com/watch?v=Zh_OOiQd-QM
- Video from commercial company Allstakes - https://www.youtube.com/watch?v=u2PeLrxY-_A
- SSI Environmental - https://ssienvironmental.ie/product/silt-fence/
- Massachusetts Clean water toolkit - https://megamanual.geosyntec.com/npsmanual/sedimentfence.aspx
- Agricology UK - https://agricology.co.uk/resource/filter-fences-catching-sediment-prevent-run/

4.3.15 A37: Denitrifying bioreactor

This is an engineering approach where high nitrate water is introduced through a bed of suitable media with high available organic matter to encourage microbial denitrification and reduce nitrate concentrations (Smarter_BufferZ project). The treatment bed can comprise of woodchip or experimental prototypes dosing with highly bioavailable liquid carbon sources. Often the media is mixed with gravel/soil to tune the infiltration and water residence times. Substrates may be open to air or buried with soil etc. and the base is generally sealed with a non-permeable membrane.

Implementation

U.S. Department of Agriculture (USDA) guidance provides the following advice:

Planning decisions: Do water samples show there is a need to reduce nitrate-nitrogen concentration in subsurface drainage flow? Is there a good location at the edge of a field near an outlet pipe for a bioreactor?

A bioreactor should be designed to: Treat peak flow from a 10-year, 24-hour drain flow event. Treat >15% of the peak flow from the drainage system and >60% of the long-term average annual flow; Achieve >30% annual reduction in the nitrate-nitrogen concentration of water flowing through the bioreactor.

Media Chamber: Use a medium for a carbon source that is reasonably free from dirt, fines, and other contaminants. Distribute the media within the bioreactor for a uniform flow path. Use geotextile or plastic lining for the bottom, sides, and top of the bioreactor. Design the bioreactor for an expected life of at least 10 years.

Water Control Structures: Design water control structures to provide the required capacity and hydraulic retention time. Evenly distribute and collect water in the upstream and downstream ends of the media chamber. Allows for completely draining the media chamber to facilitate management and maintenance.

Consider the following during and after the farm visit

- This measure may require consideration at a scale larger than an individual farm or field.

Other notes

Nutrient removal efficiencies show strong variation between studied sites of differing N loads, bioreactor design and age. Issues can be: water flows short circuiting the reactor substrate, inadequate sizing and in design of monitoring. Many of the studied bioreactors are currently smaller experimental facilities.

Sources of information

- Smarter Bufferz - http://www.smarterbufferz.ie/
- Natural Resources Conservation Service, USDA - https://www.nrcs.usda.gov/resources/guides-and-instructions/denitrifying-bioreactor-no-605-conservation-practice-standard

4.3.16 A38: Woodlands (outside riparian areas)

Woodlands slow and reduce surface runoff, increase infiltration, reduce connectivity to watercourses and intercept/trap pollutants. The aim of this measure is to identify areas of the farm where establishment of woodland is suitable and is achievable for the landowner. Ideally it would be best

placed adjacent to a watercourse to maximise water quality protection but if a riparian woodland has already been established there are several benefits to gain from having woodland elsewhere on the farm.

Including a woodland area on the farm will reduce the total grazing area on a farm (and ultimately the total nutrient balance) which may or may not be a concern for the landowner depending on their goal. Any potential financial gains may take substantial time to accrue because of the longer timeframe for timber to be harvested and the initial establishment costs. Costs may be offset by environmental schemes or grants. There will also be monitoring and maintenance costs to take into account. In addition, this measure can diversify farm income through timber production if it is of significant size.

Implementation

Seek out professional advice on planting and the economics of the measure. Define the goals for the woodland – timber production, biodiversity, habitat creation, carbon capture. Establish the size and location but also the soil type and weather/climate to ensure its suitable for a healthy woodland. Speak to a professional about site selection, species selection and species diversity. The initial establishment may require removing existing vegetation, controlling weeds and cultivating the soil.

Consider the following during and after the farm visit

- Develop a long term management plan for the woodland – monitoring, maintenance and timber harvesting.

Other notes

- Early monitoring efforts may identify weed, pest, or disease issues. Pesticides may be required so consider best practices and distances and connectivity to watercourses. Bat and bird boxes should be installed as early as possible.

Environmental co-benefits

- Increased native woodland biodiversity.
- Riparian restoration enhances biodiversity by creating habitats for farmland birds, mammals, pollinators and other beneficial insects.
- Habitat linkage within the wider landscape.
- Regulation of flood water.
- Captures carbon and lowers farm carbon footprint.

Sources of information

- NFGWS, 2020. Section 7.6. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/
- Management Guidelines for Ireland's Native Woodlands (July 2017), https://www.agriculture.gov.ie/forestservice/publications/
- Teagasc - Forestry - https://www.teagasc.ie/crops/forestry/research/small-woodlands-on-farms/
- Farming for Nature - https://www.farmingfornature.ie/your-farm/by-habitat/woodlands/
- COFORD – Forest road manual guidelines - http://www.coford.ie/media/coford/content/publications/projectreports/management-requirements.pdf

4.3.17 A39: Agroforestry

Agroforestry is the practice of combining forestry and agriculture in a mutually beneficial way. It changes the nutrient balance on a farm by adjusting the total grazing or arable area, while benefiting the nutrient cycling and reduction. Deep rooting trees access nutrients in the subsoil and reduce the risk of leaching to waterways. The canopy cover also helps intercept rainfall leading to reduced nutrient runoff and erosion.

Depending on the site of the selected area, it may act as a buffer for pollutants and sediment by filtering and intercepting them before they enter a waterway. Tree roots and shrubs if included will give stabilisation to the soil on areas that slope towards a waterbody.

Implementation
The landowners goal will determine the type and design of the agroforestry. Options include alley cropping, silvopasture, or windbreaks and each will be suited to different soil and weather conditions. Professional expertise will be required for the planning, species selection, and best practice management strategies.

Consider the following during and after the farm visit
- Site selection.
- Tree selection.
- Collaboration and stakeholder agreement may be needed.

Other notes
- It is necessary to consider the long-term commitment to this measure.
- Substantial grants are available from DAFM (see link in Sources of Information).

Environmental co-benefits
- Increases in native woodland biodiversity.
- Provides plants for pollinators.
- Habitat linkage within the wider landscape.
- Captures carbon and lowers farm carbon footprint.
- Improves soil quality.

Sources of information

- NFGWS, 2020. Section 7.6. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/
- https://www.gov.ie/en/service/b9742e-agroforestry-grants/
- Teagasc – Forestry - https://www.teagasc.ie/crops/forestry/advice/management/agroforestry/
- Agroforestry, Forest and tree - https://www.forestandtree.ie/forestry-planting/agroforestry
- Submission with regard to the public consultation on proposed interventions for Ireland's CAP Strategic Plan 2023-2027, Irish forestry forum - https://assets.gov.ie/230485/80a7bb4f-7755-40ea-bb20-3003d349faa9.pdf
- Teagasc – Forestry - https://www.teagasc.ie/crops/forestry/grants/establishment-grants/agroforestry/
- Soil Association Agroforestry Handbook - https://www.soilassociation.org/media/19141/the-agroforestry-handbook.pdf
- Woodland trust UK – Tree planting - https://www.woodlandtrust.org.uk/publications/2014/04/tree-planting-for-poultry/

4.3.18 A40: Integrated constructed wetlands

Integrated Constructed Wetlands (ICWs) are artificial systems which function by mimicking the water treatment properties of natural wetlands. Wastewater is treated through a complex range of processes which occur within the wetland and which include sedimentation, uptake of nutrients by plants and reduction of pathogens through exposure to sunlight UV.

These systems are approved by DAFM for the treatment of soiled water generated on farms, but are not suitable for the treatment of concentrated wastes such as slurry or silage effluent.

These are engineered structures which, if incorrectly sited or constructed, can create a significant risk of ground and/or surface water pollution. Strick adherence to the relevant guidelines, standards and regulations is therefore required. However, when properly installed, they can provide a useful means of treating soiled runoff from farmyards, thereby potentially reducing pressures on local watercourses.

All Integrated Constructed Wetlands require planning permission and a licence to discharge under the Waters Pollution Acts.

Implementation
A Site Assessment Report must be completed by a suitably qualified professional and the ICW designed to cater for the predicted volume and type of effluent to be treated. Detailed guidance is provided in *"Integrated Constructed Wetlands: Guidance Document for Farmyard, Soiled Water and Domestic Wastewater Applications*" (DEHLGH 2010).

An application for both planning permission and a discharge licence must be made to the relevant local authority and construction should not commence until both have been granted. In addition, the design and construction of the ICW should comply with DAFM publication: *"S133 Minimum specification for Integrated Constructed Wetlands (ICW's) (June 2011)".*

Consider the following during and after the farm visit
- Consider the potential of using this measure to treat soiled water generated on a farm where it may be creating a pressure on water quality.
- Some locations will be unsuitable for ICWs, by virtue of the presence of shallow bedrock; the presence of permeable subsoils such as sand or gravel; high water tables; or other adverse conditions. Trying to remedy these issues may prove to be expensive or impractical. A conventional soiled water handling system may be a better and more economic choice in such cases.
- Ensure regulatory compliance at all stages.
- Develop a maintenance plan and a follow-up routine.

Other notes
- The use of integrated constructed wetlands to treat soiled water is permitted under the GAP regulations, subject to strict compliance with DAFM specification S133 mentioned above.

Environmental co-benefits
- Aquatic and terrestrial biodiversity by creating new wetland habitats.

Sources of information

- DAFM - S133 Minimum specification for Integrated Constructed Wetlands (ICW's) (June 2011) contains all the technical specifications of ICW's.
- Society for ecological restoration - Integrated Constructed Wetlands: Guidance Document for Farmyard Soiled Water and Domestic Wastewater Applications

4.4 In-stream works

In-stream works or "receptor rehabilitation" actions will typically refer to measures that aim to address pressures which may be impacting on the river channel or river banks. In-stream works may include structural changes such as modifying weirs for fish migration or the use of woody debris for creating riffles and diverse, beneficial habitats for animals (particularly fish), plants and insects. However, this document focuses on measures which are more likely to be within a landowner's control, such as livestock management (A41), bank stabilisation (A42), invasive species control (A43) and water table management (A44). Some in-stream works may require permission and/or licenses from relevant authorities (e.g. Inland Fisheries Ireland or NPWS) before any action is carried out.

Fencing requirements within the NAP aim to minimise direct risk to waterbodies from livestock but this is dependent on stocking rates. Agri-environmental schemes such as ACRES incentivise waterbody protection through fencing and riparian management. Additional actions are expected where a HSO waterbody is significantly impacted. The expected issues are microbial pathogens (from livestock) and sediment (from exposed banks or animal/machinery access).

4.4.1 A41: Livestock exclusion from watercourses

The aim of this measure is to minimise or prevent the addition of nutrients and microbial pathogens to watercourses from livestock faecal matter, and sediments from the banks of access points. HSO waterbodies are particularly sensitive to pollutants and so must be considered in this context when identifying potentially suitable areas for this measure. Where drinking points or river crossings are present, it usually results in localised damage to the banks and substrate of the waterbody. In most cases an individual drinking point or river crossing may not impact the waterbody significantly, but its location relative to the monitoring point and the number of animals using the location can lead to significant impacts on sensitive species of invertebrates in HSO waterbodies.

Appendix 1 in LAWPRO/EPA (2022b) provides excellent advice on assessing cattle access points.

Implementation

This measure is intended to prevent cattle access to watercourses (as identified on 1:5000 OSi mapping or better) on farms with a grassland stocking rate of 170 kg organic N/ha or above. This measure has been effective from 1st January 2021.

The requirement is to erect a bovine proof fence 1.5 meters out from the top of the watercourse bank. Any fence closer than this will either have to be moved out or another fence placed outside it at the correct distance. A temporary fence (pigtail stakes and flexible wire) is sufficient. No bovine access is allowed for drinking. If bovines have to walk through a watercourse for access to an isolated land parcel the crossing must be fenced both sides so that the bovines cannot walk up or down the watercourse.

Consider the following during and after the farm visit

These rules apply to:

- All Derogation farmers.
- Farmers who exported organic manure to come back under the 170 kg N/ha in 2020.
- Tillage farmers with grassland, where that grassland is stocked at greater than 170 kg organic N/ha.

Sources of information

- LAWPRO/EPA (2022b). See Appendix 1 'A Guide to Assessing Animal Access Points'. https://lawaters.ie/app/uploads/2022/09/Print_CSM-Volumes-23_April-2022.pdf
- NFGW, 2020. Section 8.1. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/
- Teagasc – Bovines and watercourses - https://www.teagasc.ie/publications/2020/the-impact-of-bovines-on-watercourses--creating-a-farm-database-for-policy-analysis.php
- Teagasc – New water protection measures - https://www.teagasc.ie/news--events/daily/environment/new-water-protection-measures.php
- EPA – Cattle exclusion from watercourses - https://www.epa.ie/publications/research/water/research-330-cosaint-cattle-exclusion-from-watercourses-environmental-and-socio-economic-implications.php
- EPA – Cattle exclusion from watercourses literature review - https://www.epa.ie/publications/research/land-use-soils-and-transport/Research_Report_260.pdf

4.4.2 A42: Bank stabilisation

While riverbank erosion is a natural process that is important in the functioning of river ecosystems, excessive erosion as a result of land management practices and livestock access to the river can cause the degradation of a watercourse channel and have a direct impact on water quality by contributing sediment and phosphorus that is bound on the sediment, thereby impacting on macroinvertebrates, juvenile pearl mussels and salmonoid fish. Prevention is necessary. Nature based solutions, such as planting vegetation along the banks and establishing a buffer zone, are recommended. Ideally, native plant species with deep rooting systems should be selected (willow is commonly used). On banks with high erosion, rock armouring may be needed.

Implementation

Firstly, eliminate the cause of the bank de-stabilisation if it is controllable – e.g. animal access, water abstraction points for sprayers, vehicle access. Seek out professional input in undertaking the site assessment, design and planning. Vegetation establishment may require the removal of existing cover before seeding or planting samplings or live cuttings. The amount of vegetation and/or armour will be determined by the force of water flow and potential for erosion at the site.

Consider the following during and after the farm visit

- Identify the areas of the bank that are most vulnerable or potentially vulnerable.
- Agree on the extent of the area that requires stabilisation and whether nature based solutions would be sufficient.
- Where relevant, seek collaboration with stakeholders in the catchment area.
- Agree a monitoring and maintenance plan.

Environmental co-benefits

- Riparian restoration enhances biodiversity by creating habitats for farmland birds, mammals and beneficial insects.
- Adds an aesthetic value to the local area.

Sources of information

- NFGWS, 2020. Section 8.2. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/
- Duhallow Life – Reducing bank erosion - https://www.duhallowlife.com/sites/default/files/C1%20Final%20Technical%20Report%20-%20Reduction%20of%20Bank%20Erosion.pdf
- Scotland EPA - https://www.sepa.org.uk/media/219450/bank_protection_guidance.pdf
- Natural Water Retention Measures EU - http://nwrm.eu/measure/natural-bank-stabilisation
- West Cumbria rivers trust, Pearls in peril - https://westcumbriariverstrust.org/projects/pearls-in-peril/pip-projects/willow-spiling
- Stranooden GWS, 2023. Section 8.0, Source Protection Pilot Project Final Report. https://stranoodengws.ie/images/pdf/PHASE-II-FINAL-REPORT.pdf

4.4.3 A43: Invasive species control

Invasive alien plant species (IAS), such as Himalayan balsam (*Impatiens glandulifera*), Giant hogweed (*Heracleum mantegazzianum*) and Japanese knotweed (*Fallopia japonica*), can rapidly establish within the riparian margins of watercourses. These plants typically outcompete native flora, resulting in dense monospecific (i.e. one species) stands. These stands die back during the winter months, leading to bare, exposed banks that are more vulnerable to erosion and the consequent loss of sediment and attached phosphorus. Other IAS may be encountered in the riparian zone. Some of them may be widespread e.g. Montbretia (*Crocosmia x crocosmiiflora*) and could have local impact through displacement of native riparian vegetation. Montbretia forms extensive linear monocultures along banks. However, these are stable and the overwintering corms retain bank stability. Butterfly bush (*Buddleja davidii)* is an invasive plant that spreads readily in riparian areas where it can crowd out native vegetation and change the local ecosystem.

The aim of this measure is to control the IAS and re-establish native vegetation to prevent large areas of exposed soil in winter months and reduce the risk of erosion, but it also has co-benefits for biodiversity as IAS can have serious impacts on biodiversity through direct competition with native biota, alteration of habitats or introduction of parasites and pathogens.

The National Parks and Wildlife Service (NPWS) is the competent authority for Invasive Alien Species management. It is advisable to seek out professional experience for this measure.

Implementation

A coordinated approach is required for effective intervention. A number of resources for identifying IAS and recording their occurrence are available (see Sources of Information below), along with Best Practice Management guidance for specific species, and biosecurity Codes of Practice for certain activities. Control is best undertaken when stands are small or numbers of plants are low. Co-ordinated control measures may be required so that spread of the target IAS or a different IAS from nearby sites is not facilitated.

Control and eradication measures may require specialist contractors or experts where chemical methods and specialist equipment are used. Physical control may be possible with some species e.g. Himalayan Balsam, but may be labour intensive and cost prohibitive (unless voluntary actions are undertaken) where extensive populations of IAS have developed.

Once introduced, control, management and eradication where possible of invasive species can be difficult and time consuming; therefore, preventive measures, early detection and control are desirable. A local waterbody survey will establish the presence of IAS, their abundance and locations in the waterbody. A programme of prevention, control, and eradication can then be developed. Many IAS spread readily by water and therefore control measures need to begin at upstream locations.

Estimated costs

Costs will depend on the species involved, the method used and the duration for which control is required. Costs may be substantial when IAS have become widely established. Control of widespread populations will pose significant resource challenges.

Consider the following during and after the farm visit

- Preventive measures can stop introduction of IAS. Control measures may require multi-annual implementation depending on seed reserves in soils, or persistence of vegetative propagules such as rhizomes.
- Transport Infrastructure Ireland (TII) oversees management of IAS in relation to the national road and light rail networks. There may be opportunities for liaison in relation to control and management measures.

Other notes

It is also advisable that landowners and residents in the catchment area of the waterbody be made aware of the IAS that occur locally, and the practices that may promote their spread e.g. transport of contaminated soils, strimming of stands and disposal of waste, planting of IAS as ornamental exotics.

Environmental co-benefits

- Improves riparian biodiversity and enhances wildlife habitats, as native species will have an opportunity to re-establish.
- Invasive species such as Giant hogweed and Japanese knotweed can grow to heights ranging from 2m–5m, thus potentially causing excess shading along waterbodies.
- Avoids potential impacts on infrastructure.

Sources of information

- Transport Infrastructure Ireland – Invasive species management - The Management of Invasive Alien Plant Species on National Roads – Technical Guidance GE-ENV-01105 December 2020 .
- EPA, Invasive alien species control - EPA Research Report No. 368. Prevention, Control and Eradication of Invasive Alien Species Authors: Frances E. Lucy, Joe Caffrey, Jaimie T.A. Dick, Eithne Davis and Neil E. Coughlan
- Nature and biodiversity topics, invasive alien species, EU - REGULATION (EU) No 1143/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species.
- Invasive species Ireland - Invasive Alien Species Ireland.
- The Tweed Invasives project, Tweed Forum - https://tweedforum.org/wp-content/uploads/2020/05/TF_invasives_manual_web-FINAL.pdf
- Duhallow life project - https://www.duhallowlife.com/sites/default/files/INVASIVES%20BROCHURE.pdf
- LAWPRO/EPA (2022b). Section 12 - https://lawaters.ie/app/uploads/2022/09/Print_CSM-Volumes-23_April-2022.pdf
- NFGWS, 2020. Section 8.3. Handbook of Source Protection and Mitigation Actions for Farming. https://nfgws.ie/nfgws-source-protection-publications/

4.4.4 A44: Raising the water table in groundwater dependent terrestrial ecosystems

Certain terrestrial ecosystems are groundwater dependent. Where of high ecological significance, they are Special Areas of Conservation (SACs), which are listed on the Register of Protected Areas required by Article 6 of the WFD. Examples of GWDTEs are certain raised bogs, blanket bogs, alkaline fens, machairs, dune slacks and turloughs.

GWDTEs are reliant on the supporting geohydrological and hydrochemical conditions. Significant changes to these conditions due to human activities can cause ecological damage. A key requirement is achieving and maintaining the environmental supporting conditions. The water level in GWDTEs is a critical supporting condition.

The water level requirements are as follows:

- Raised bogs: within 10 cm of ground surface for approximately 90% of year (Gill *et al*. 2022).
- Blanket bogs: within 10 cm of surface in Winter and 20 cm in Summer (Flynn *et al*. 2021).
- Fens: 2.9 to 28 cm above ground level, sustained for at least 60% of the year, with the mean annual water level always above the surface (Gill *et al*. 2022).
- Machairs and dune slacks: <1 m from surface and probably significantly less for some plant species. (The LIFE on Machair Project[22] will enable a greater understanding of the environmental supporting conditions.)

Implementation

- The existing water levels and vegetation conditions need to be checked. This may require the installation of piezometers (a small diameter borehole constructed for measuring water levels).
- Where water levels are satisfactory, then maintenance of these levels is needed. Therefore, activities that might drop the water levels, such as drainage or deepening of existing drains needs to be avoided.
- Where the water levels are lower than those given above, the vegetation is likely to be damaged and unsatisfactory. Therefore, water levels in nearby drains and watercourses need to be raised. This can be achieved by drain blocking and, perhaps, by engineered ditch management.
- Obtaining professional advice is recommended.

Consider the following during and after the farm visit

- The specific environmental supporting conditions for the GWDTE present on the farm.
- Providing an understanding of the value of the GWDTE and on the developments that could have a detrimental impact.
- The water levels present relative to those required for the GWDTE.
- Practical measures to either restore or maintain, as appropriate, the water levels.
- Practical measures to monitor the water levels.
- Facilitation of inputs from specialists to provide advice and assistance.

Environmental co-benefits

- Increases in terrestrial biodiversity
- Provides plants for pollinators.
- Captures carbon.
- Aesthetic value.

[22] https://lifeonmachair.ie/

Sources of information

- Flynn *et al.* 2020. Towards the Quantification of Blanket Bog Ecosystem Services to Water. https://www.epa.ie/publications/research/water/Research_Report_378.pdf
- Gill *et al*. 2022. *Ecometrics* – Environmental Supporting Conditions for Groundwater-dependent Terrestrial Ecosystems. EPA Research Report No. 403. https://www.epa.ie/publications/research/water/Research_Report_403.pdf