3D buffer strips: Designed to deliver more for the environment

Chief Scientist's Group report

October 2020

Appendices

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Professor Doug Wilson
Chief Scientist

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Appendix A1. Main sources of literature referred to, mapped across a matrix of diffuse pollution and wider benefits against interacting factors

		Diffuse pollution					Terrestrial habitat	Aquatic ecosystems	Flood management	Biomass and C storage	Amenity
		Sediments	Nitrogen	Phosphorus	Pesticide and herbicides	Pathogens					
	Field land cover and management	10	10	10			10	10	10		
	Field soil type	10, 13, 15, 27	10	10, 15, 17, 27	6, 9		10	10	10		
	Site-specific buffer placement	10, 14, 25, 27	10, 25	10, 25, 27	25	25	1, 10, 14, 28	10	10, 14	1	
	Climate and run-off volume and timing	15		15, 17	9					5	
	Buffer width	2, 4, 15	4	7, 15, 17			1, 2, 28	2, 4		1	2
	Buffer soil texture, composition	10, 16, 20, 25	10, 25	7, 10, 16, 18, 25	9, 25		10	10	10	5, 24	
	Buffer hydrology: infiltration, flowpaths, soil drainage	10, 12, 16	10, 11, 12, 26	7, 10, 11, 12, 17, 18, 19	6, 11, 12		10	10, 12	10, 12	1, 5	
	Biogeochemical transformations in the soil			7, 17, 18	9					5	
	Buffer vegetation	2, 3, 4, 10, 13, 24	2, 4, 8, 10, 24, 26	2, 7, 10, 26			1, 2, 10, 26, 28	2, 3, 4, 10, 26	10	1, 2, 5, 8, 24	8
	Livestock exclusion	20, 26					23, 29	23	29	29	
	Buffer management	2, 10, 12, 20, 30	2, 10, 12, 30	2, 7, 10, 12, 30		30	2, 10, 28	2, 10, 12	10, 12	1, 2, 5, 8, 24	2, 8

Numbering	Reference
1	Kuglerova and others, 2014
2	Broadmeadow and Nisbet, 2004
3	Hubble and others, 2010
4	Sweeney and Newbold, 2014
5	Sutfin and others, 2015
6	Chen and others, 2016
7	Dorioz and others, 2006
8	Christen and Dalgaard, 2013
9	Arora and others, 2010
10	Feld and others, 2018
11	Allaire and others, 2015
12	Dollinger and others, 2015
13	Ma and others, 2016
14	Qiu and Dosskey, 2012
15	Syversen and Borch, 2005
16	Weaver and Summers, 2014
17	Hoffmann and others, 2009
18	Roberts and others, 2012
19	Weaver and Summers, 2014
20	Pilon and others, 2017
21	Jaynes and Isenhart, 2014
22	Stutter and others, 2012
23	Muller and others, 2016
24	Ferrarini and others, 2017
25	Vidon, 2010
26	Correl, 2005
27	Thomas and others, 2016
28	Dybkjaer and others, 2012
29	Hale and others, 2018
30	Miller and others, 2015

Appendix A2. Selected options in the Countryside Stewardship scheme for protecting water habitats and associated options deemed appropriate as part of in-buffer features

Code [1]	Name	Payment rates (£/ha) [2]	Land cover[3]	Establishment notes	Management requirements
AB8 (MT)	Flower rich margins and plots	£539 (£209)	Cu	Seed mix specified	Established spring to autumn, with cut/remove or graze options for 90% area
GS1 (MT)	Take small areas out of management	£365	Ex, IG	Patch <0.5 ha per 5 ha of grassland	Cut or graze only 1 year in every 5
HS6 (MT)	Maintenance of designed/engineered waterbodies	£440	Ex, IG, Cu	For grass bank buffers (>4 m) around artificial standing water	Remove cut material
SW1 (MT)	4-6 m buffer strip on cultivated land	£353 (£79)	Cu	Can be riparian or non-riparian	Cut 1-3 m closest to crop annually (>July)
SW2 (MT)	4-6 m buffer strip on intensive grassland	£170	IG	For fields >100 kgN/ha/year; can be riparian or non-riparian	Leave uncut
SW3 (MT)	In-field grass strips	£557 (£94)	IG, Cu	Not riparian (provides a comparison); <30% of whole field	Exclude livestock, establish grass, cut annually (>July)
SW4 (MT)	12-24 m watercourse buffer strip on cultivated land	£512 (£96)	Cu	Riparian only, exclude livestock	Cut 6 m closest to crop annually (>July)
SW8 (MT)	Management of intensive grassland adjacent to a watercourse	£202	IG	For sloping fields >200 kgN/ha/year	Limited N applications, graze/cut from year 2, exclude livestock
SW10 (MT)	Seasonal livestock removal on grassland in SDA next to streams, rivers and lakes	£36	Ex, IG	For wet/poached permanent grassland	Livestock excluded Oct-Mar
SW11 (MT)	Riparian management strip	£440	Ex, IG	>4 m to <12 m, fenced, no watering access	Control INNS, exclude livestock
WT1 (MT)	Buffering in-field ponds and ditches in improved grassland	£201	IG	10-20 m, grasses, flowers, scrub, trees	Don't cut Mar-Aug
WT2 (MT)	Buffering in-field ponds and ditches on arable land	£501 (£73)	Cu	10-20 m, grasses, flowers, scrub, trees	Don't cut Mar-Aug

RP8 (HT)	Capital item: Constructed wetlands for treatment of pollution	50% of costs	IG, Cu	Areas targeted for reducing agricultural water pollution treating field and farmyard run-off	Establish pond, let heavily vegetate, restrict livestock, manage outlet water quality
SP2 (HT)	Raised water level supplement	£127	Ex, IG	10-year option, water management structures funded	
SW12 (HT)	Making space for water	£640	IG, Cu	20-year option, wetlands, channel meanders, keeping floodplain deposits	
SW15 (HT)	Flood mitigation on arable reversion to grassland	£488	Cu	Bunded water storage, floodplain reconnection	
SW16 (HT)	Flood mitigation on permanent grassland	£256	Ex, IG	Bunded water storage, floodplain reconnection	
RP32, RP33 (HT)	Capital item: Small (RP32) and large (RP33) leaky wooden dams	£461 and £764 per dam	Ex, IG, Cu	Target catchments for flood mitigation. Cascades of wood dams across channels.	
WD1 (HT)	Woodland creation maintenance (use with TE4)	£200/ha/year	Ex, IG, Cu	Link habitats, protective buffer, reduce flood risk, diffuse pollution and soil erosion	Manage to establish trees for 10 years, no herbicides if next to a watercourse
TE4 (HT)	Capital item: Supply and plant tree	£1.38/tree	Ex, IG, Cu	Requires a woodland creation plan. Can specifically target water quality or flood risk improvement	Min 0.1 ha blocks, >10 m width, > 1,600 stems/ha
WT4 (HT)	Pond management (first 100 m^2)	£103/pond	Ex, IG, Cu	On prioritised ponds	Manage vegetation and margins
WT5 (HT)	Pond management (areas >100 m^2)	£183/pond	Ex, IG, Cu	On prioritised ponds	Manage vegetation and margins

[1]MT and HT denote mid-tier and higher-tier schemes, respectively; [2]Payment rates are £/ha except where stated. The second rate is the discounted rate if the measure is part of EFA within cropland; [3]Applicability for different land covers: Ex, extensive grazing; IG, Intensive grassland; Cu, Cultivated.

Appendix A3. Scenarios of the break-even point for turning headlands into 3D buffers

One of the arguments used in favour of buffer strips is that yield penalties around headlands, especially those where vehicle turning, and shading take place, offset the impact of not cropping these areas (Defra, 2011). The yield loss in field margins is due to a combination of additional compaction and competition for light, water and nutrients (Kuemmel, 2003, Defra, 2012). Yield losses in cereal crop headlands of 3-19% (mean 7%) have been observed in monitoring of commercial farms (Sparkes and others, 1998a). In sugar beet (a typical root crop), losses were 19-41% (mean 26%). If trees already occurred in field hedgerows for example, yield decline in field margins was larger than when they do not (Sparkes and others, 1998b).

Evidence for the increase of crop yields, especially pulses, associated with introduction of wildlife friendly habitats at the field margin is also emerging (see Figure A3.1 taken from Pywell and others, 2015). These authors considered the impact on yields of removing 3 or 8% of land at the field edge from production to create wildlife habitat in 50–60 ha patches over a 900 ha commercial arable farm in central England, and compared to a business as usual control (no land removed). In the control fields, crop yields were reduced by as much as 38% at the field edge. Habitat creation in these lower yielding areas led to increased yield in the cropped areas of the fields, and this positive effect became more pronounced over 6 years. Consequently, yields at the field scale were maintained and, indeed, enhanced for some crops, despite the loss of cropland for habitat creation. These results suggested that over a 5-year crop rotation, there would be no adverse impact on overall yield in terms of monetary value or nutritional energy.

Offsetting economic disadvantages of headlands
It is, therefore, valuable to consider the economic disadvantages of turning headlands into 3D buffers, to assess how much weight this argument should hold in considering new buffer strip arrangements such as 3D buffers, along with other arguments for habitat creation. We can do this by quantifying the area of land considered, the likely potential value of yield losses associated with headlands, and the costs of production foregone by not cultivating.

Example: The area of land previously occupied by turning headlands into 3D buffers depends on the size and shape of the field and turning requirements. A typical turning zone could be 18 m wide (Sparkes and others, 1998). If these were at either end of a square 4 ha field, they would represent 18% of field area. This fraction decreases with the square root of field area for square fields and decreases for fields with the ratio of long to short side of the field (assuming the short side is used for turning).

Consider first the installation of an uncropped field margin, which can still be used for turning. There will be a break-even point for the pre-modification yield losses in turning headlands, where the variable costs foregone balance the yield foregone, so that gross margin is unaffected by not cropping. Table 1 shows 2 examples of such analysis, using cereal crop gross margin data for the UK (Redman, 2017) and Ireland (TEAGASC, 2018). This shows that for cereal crop headlands with crop yield losses close to the upper end of the range observed, non-cropped turning headlands are economically viable, but only where gross margins are small, as is the case in Ireland. In the UK, there would need to be quite large losses, well above the 3-19% observed, to make non-cropping of cereal headlands economically viable without some other benefits.

Consider now the installation of a 3D buffer. If the wooded element of a 3D buffer extends into the field, turning zones will need to be shifted and shading impacts will also move further into the field. The extent of these depends on the structure of the 3D element of the buffer, especially trees.

Table A3.1. Analysis of when not cropping turning headlands is economically justifiable, based on yield value foregone equalling variable costs foregone. The analysis uses (a) data from Redman (2017) for UK, and (b) from TEAGASC (2018) for Ireland

	Variable costs £/ha	**Target yield tonnes/ha**	**£/tonne**	**Break even yield foregone on area on which buffer created (assuming turning still feasible)**
(a) Redman (2017)				
Winter wheat	460	8.6	140	62%
Spring wheat	336	6	146	62%
Feed winter barley	533	7	128	41%
Winter malting barley	339	6.2	142	61%
Spring malting barley	282	5.7	150	67%
Winter oats	299	6.3	130	63%
Spring oats	294	5.5	190	72%
(b) TEAGASC (2018)				
Winter wheat	1076	11	123	20%
Spring wheat	920	9	123	17%
Winter barley	992	10	114	13%
Spring barley	810	8	114	11%
Malting barley	815	7.5	141	23%
Winter oats	861	9	114	16%
Spring oats	797	7.5	114	6%

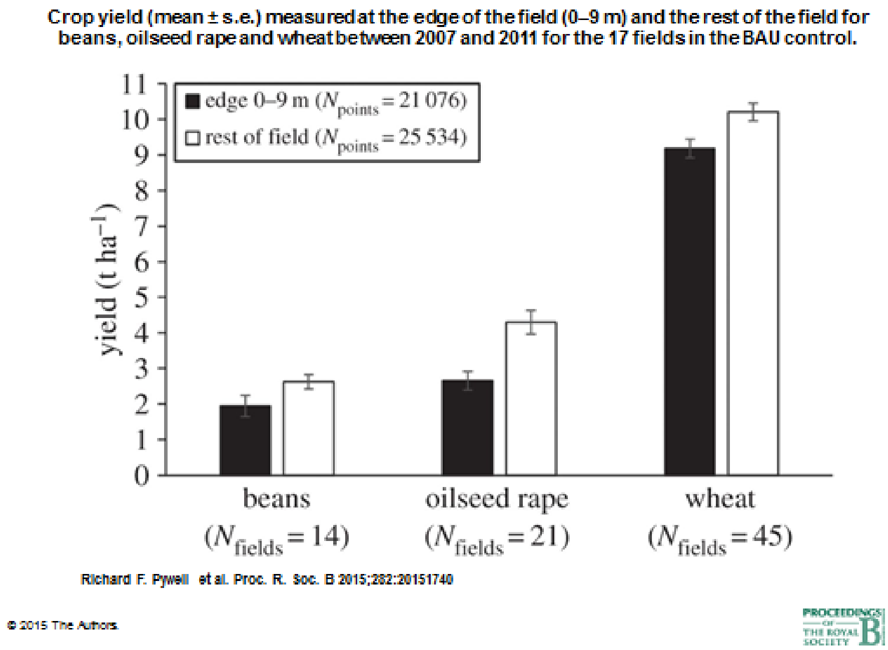

Figure A3.1. Crop yield measured at the edge of a field (0-9 m) and the rest of the field for beans, oilseed rape and wheat between 200 and 2011 for the 17 fields in the BAU control (taken from Pywell and others, 2015).

Appendix A4. Farmer preferences for buffer associated measures as determined by (Collins and others, 2016) using a survey of attitudes to 86 measures by farmers within the demonstration test catchments

	Farm business backgrounds			
	Cereals	**Lowland livestock**	**Dairy**	**Mixed farmers**
High current uptake (>75%)	Establish riparian buffer strips; Maintain field drainage systems		Maintain field drainage systems	
Medium to low uptake, with positive future attitudes			Fence off rivers and streams; Ditch management	Maintain field drainage systems
Medium to low uptake, with mixed future attitudes		Establish permanent woodland; Fence off rivers and streams	Establish riparian buffer strips	Establish permanent woodland; Fence off rivers and streams; Establish riparian buffer strips
Medium to low uptake, with negative future attitudes	Establish and maintain artificial wetlands; Grow biomass crops	Establish and maintain artificial wetlands; Construct bridges for livestock; grow biomass crops	Allow field drainage to deteriorate; Establish permanent woodland; Grow biomass crops	Grow biomass crops; Establish and maintain artificial wetlands

Appendix A5. Expert workshop

A workshop was held (London, 29 March 2018) to gain expert input into the knowledge base for buffers with the specific objectives of:

1. Capturing the current baseline of buffer practice in England, how and where this leaves field edge and riparian function lacking, and drivers for and barriers to change.

2. Consulting experts and practitioners on a range of integrated buffer design options for England to address water quality and related pressures.

3. Considering the relative environmental effectiveness of the different designs, maintenance needs, wider ecosystem service provision, and fit with farm business and landscape setting, take stock of responses and revise designs accordingly to inform position report

A5.1. Attendees

Name	Organisation	Experience	Buffer opening statement
Jamie Letts	Environment Agency	Environment Agency, but with secondment in Forestry Commission for aligning woodland and water goals.	Buffers are not the panacea they're often considered to be
Tom Nisbet	Forest Research	Forest hydrology.	Woodland buffers do work. However, their effectiveness is often limited by being too narrow. They don't work where they're not respected, for example by machinery or managed appropriately
Rachael Dils	Environment Agency	Agricultural risk and policy evaluation, Science background on P dynamics and hydrology in arable drained systems.	How can the effectiveness of buffers be evaluated in the wider landscape, and how can they be incorporated into future land management schemes?
Dominic Coath	Environment Agency	Natural biodiversity team, experience of fens management.	Need to align ecological with other objectives. Not always in the right place.
Chris Stoate	Game and Wildlife Conservation Trust	Farmland ecology and soil management. Farming background.	Field drains are an issue for bypassing buffers.
Paul Quinn	Newcastle University	Senior lecturer in hydrology. Interested in engineering aspects of catchment measures.	Buffers ignore hydrology. Make space for the environmental processes in-field and in field margins and make them work
Adrian Collins	Rothamsted Research, North Wyke	Leads the BBSRC soil to nutrition project 3 optimising sustainable intensification at multiple scales.	Strategic scale analysis is needed as buffers are generally in the wrong place relative to pollutant pressures and physiographic/landscape factors affecting their performance.

Mark Wilkinson	James Hutton Institute	Flood risk management, natural flood management and agricultural mitigation.	Buffers can be made to do more; they can be in the wrong place and hydrological flows bypass them.
Marc Stutter	James Hutton Institute	Soil science to water quality, mitigation and river corridor resilience processes.	The variable evidence for effectiveness shows the very site-specific nature of buffer functions.

Apologies: Lydia Burgess Gambell (Environment Agency), Richard Gooday (ADAS), Andrew Lovett (University of East Anglia), Louise Webb (Natural England), Kirsten Foot (Environment Agency), Paul Newell-Price (ADAS), Phil Haygarth (Lancaster University).

A5.2. Agenda

Session	Time	Activity	*Lead*	Obj	Notes
Coffee	10-00				
Introduction	10-10	Round table introductions			
Background	10-20	Background to the project	*Jamie Letts (EA)*		
	10-25	Aims of the day	*Marc Stutter (JHI)*		
The state of current buffer practice: issues, extent and BMP from England, UK and wider	10-35	Quick overview talks: (i) Drivers for, and barriers to, change; (ii) Issues for buffer functioning and targeting; (iii) Buffer zones: where and when; (iv) Lessons from the Allerton project;	 *Jamie Letts (EA)* *Adrian Collins (RRes)* *Paul Quinn (Newcastle Uni);* *Chris Stoate (GCT)*	1	(i)
Design features for incorporation into buffers	11-15	Review and discussion of design features	*Mark Wilkinson (JHI), Tom Nisbet (FRes)*	2	(ii)
Assessing benefits in the context of place and pressures (1)	12-25	Introduction to a matrix of landscape biophysical context vs pressures	*Marc*	3	(iii)
Lunch	12-40	Lunch task: flip chart to capture key literature to review			
Assessing benefits in the context of place and pressures (2)	13-10	Qualitative assessment 'scoring' of benefits, constraints vs opportunities of context, capital and management	*Marc /Mark*	3	(iv)
	14-30	Putting it together 'bundling measures' for key buffer units.	*Marc/Mark*	3	
Key gaps, priorities and targeting	15-00	Discussion: (i) agree key gaps in knowledge & application; (ii) how best to achieve effective targeting (e.g. by water status, by field risk assessment)	*All*	1	
Wrap up and next steps	15-30 (15-45 finish)		*Jamie*		
Notes: (i) We ask four key invitees to present having 8 mins plus 3 mins for questions; (ii) A basic common format (one slide/one page) will be used for the presentation of possible buffer features. A number of these will be brought to the meeting pre-prepared to go through. Then we ask the participants to suggest others that we draw on the same format on pre-printed A1 paper templates. The outcome is a set of design features that we have agreed as a workshop to take into the afternoon's assessment. This session should also aim to identify any sites/BMP examples of any features in the UK presently; (iii) This matrix will be a simple four landscape typologies against which the buffer features will be assessed; (iv) This is the main activity and outcomes of the day. We work through the design features agreed before lunch and we qualitatively score effectiveness (1-5), confidence (1-3) and applicability (1-3) on a common grid of multiple benefits. Other notes to be made against each feature will include capital outlay vs maintenance, combining features and some gut-feeling scoring.					

A5.3. Background and context sessions

Session 1: Background to the project and aims

Talk 1: 3D field margins: background to the project and workshop (Jamie Letts, Environment Agency)

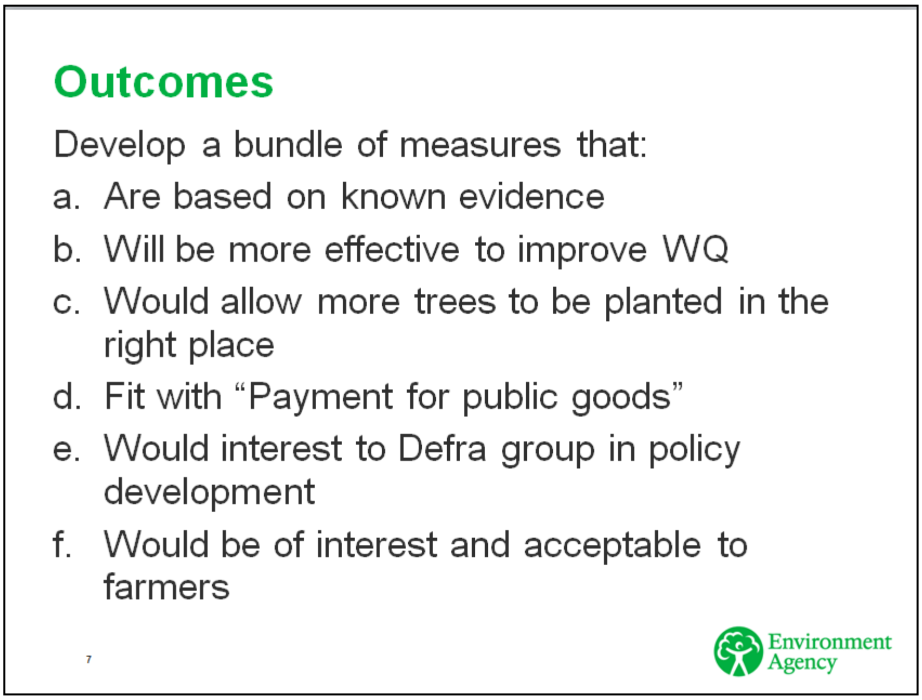

Fig. A1. Example slide from J Letts on the required outcomes for the 3D buffers project

- Buffers are still the most popular environmental measure in Environmental Stewardship schemes and farmers understand them

- There were 23,000 buffer agreements (at 2014) equivalent to 42,000 ha (includes field margins as well as buffers), with around 5,500 ha next to watercourses.

- The Environment Agency has suggested that 1.5 Mha of land use change would be required to achieve water quality obligations. What are the alternatives with features like improved buffers?

- The good side: they can be effective for sediment bound phosphorus (P) and pesticides.

- The bad side: they need to be managed correctly. They are not very good on slopes owing to compaction issues on surrounding soil.

- So, what if this 42,000 ha provided even more services for the public good and the same land could host trees, ponds, swales, access and bring income via biofuels? [a statement to open the day]

Questions/comments: Should there be a *de minimis* for buffers? (Dominic).
An outline of the aims and process for the day was given:

What & how

Objectives

- To capture the current baseline of buffer practice in England, drivers for and barriers to change and opportunities.
- To consult on integrated buffer design options for England and assess ability to address water quality and related pressures against landscape contexts.

How?

- Short position talks
- Discussion
- Introducing measures – individually and as 'systems'
- Assessing them – scoring (effectiveness/confidence), annotating drawings
- Drawing consensus on key aspects: targeting, knowledge gaps
- Generating a report

Fig. A2. Example slide from M Stutter on the aims and process for the day of the 3D buffers workshop

<u>Session 2: Context talks</u>

The aims of this session were to understand the state of current buffer management practice, issues and opportunities (focussing on the context in England).

Talk 2: Buffer zones: An Opportunity to manage water quantity and quality. Where and when to intervene (Paul Quinn, Newcastle University)

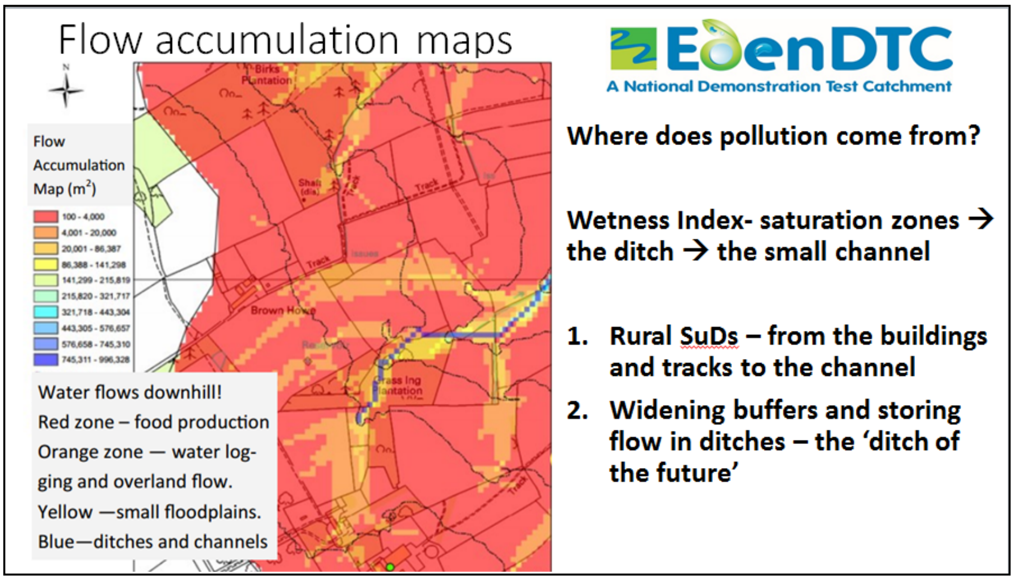

Fig. A3. Example slide from P Quinn on flow routing and scaling in aspects of where to intervene with buffers in-field and utilising ditch channel space

- An underpinning hydrological basis is needed with flowpaths and building in soil wetness indices. Terrain analysis - identifying flow pathways. Identifying source zones and developing source buffers.

- There is a strong temporal aspect – lessons from natural flood management (NFM) studies/application show periods of large volumes of water.

- Then a set of example NFM/water quality measures were introduced as designs that maximised holding water in the landscape:

  - Bunds – experience showed that instead of crop yield reductions on ground temporarily wetted behind the bund, crops benefitted from the extra fertility of sediment nutrients

- It is important to remember that water comes out of infiltration zones during floods. Therefore, it is about holding water in the landscape.

- A proposal was given for a 5% future - we need to engineer a 5% zone of the landscape (and typically of a field) for mitigation.

- Dig out ditches; create sediment traps - so why not widen the ditch into the buffer. Well designed, well managed systems will deliver water quality benefits.

- The demonstration test catchment projects show big problems with overland flow paths - therefore widen the ditch; create cascades of ponds. Standing water > Water table goes up > therefore more buffering is required.

Main messages

- Consider the hydrology in space and time.

- Sustainable intensification requires space for farmers to farm (an example of a 5% 'deal' where we can 'engineer' the required edge of field mitigation and 95% space is left to farm, subject to additional technological assistance to make further improvements in that 95% space).

- Use the hillslope buffer and channel together: Buffers can comprise bottom of the hillslope measures but also work across ditches in headwaters to utilise the channel as part of buffering (for example, sediment trap cascades).

Questions/comments

- We should practice prevention as well as cure (Tom).

- Is there a size for which consent to manipulate the channel is allowable? (Marc)

- Sediment trap effectiveness is limited for fine particles from clay soils? (Chris). Not if designed properly (Paul). 'Proper' designs work when receiving surface run-off (coarse material) but not field drain/ditch discharges (WFF project, Chris).

- There could be implications for ecology (Dominic); but (Chris) suggest there could be benefit to ecology as these systems are not clean water areas to begin with.
- Suggest we could do this in first and second order channels (Paul).
- There is money in NFM so this must be considered - linked funding sources (Paul).

Talk 3: Strategic assessment of the spatial mismatch between buffer uptake and water quality risk or non-compliance (Adrian Collins, Rothamsted Research, North Wyke)

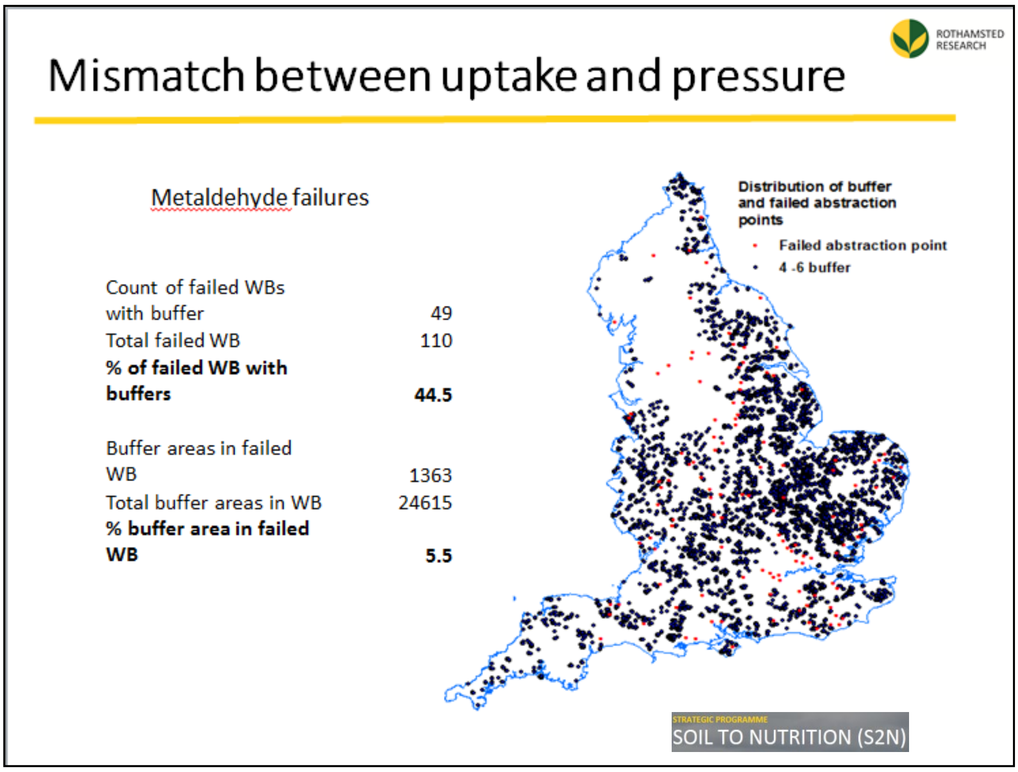

Fig. A4. Example slide from A Collins on the mismatch between current buffer practices and pressures on waterbodies

- ➢ Need to take a strategic view of buffer placement at the macro-scale to understand effective uptake and targeting currently.
- ➢ Examined 2016 rural development options uptake for 4-6 m and 12-24 m riparian buffer classes. Examples of mismatches between the water quality responses, land pressures, landscape pathways and the uptake of buffers

were presented (presented as % of the total number of buffer claims that are on the NE records):

   - metaldehyde water quality compliance
   - modelled pollution load estimates
   - prevalence of artificially-drained land

- A study had looked at sub-lethal impacts of sediment on fish versus buffer and tramline management. Critical windows of time were evident for ecology that necessitated temporal understanding of the mitigation actions and the best buffer performance does not match well with the critical early life stages windows for some fish species (for example, salmonids).

- A study (Collins and others, 2016) on farmer preferences showed that riparian buffers were not preferred mitigation measures. However, farmer focus groups show farmers are keen to benchmark environmental performance against neighbours.

Main messages

- At a national level there is a mismatch between uptake of buffer options in the English rural development programme and landscape risks, processes, water quality and compliance.

Questions/comments

- This analysis underscores some of the problem with current targeting and the problem will apply to other measures as well.

- (Tom) Is it not likely that the farmers who are keener on using buffers will also be those that manage their soil/land better and therefore have less impact on the water environment? Is there any evidence that stronger uptake in non-failing water bodies is the reason why these waters are at good status?

Talk 4: Allerton Project Buffer Strips (Chris Stoate, Game and Wildlife Conservation Trust)

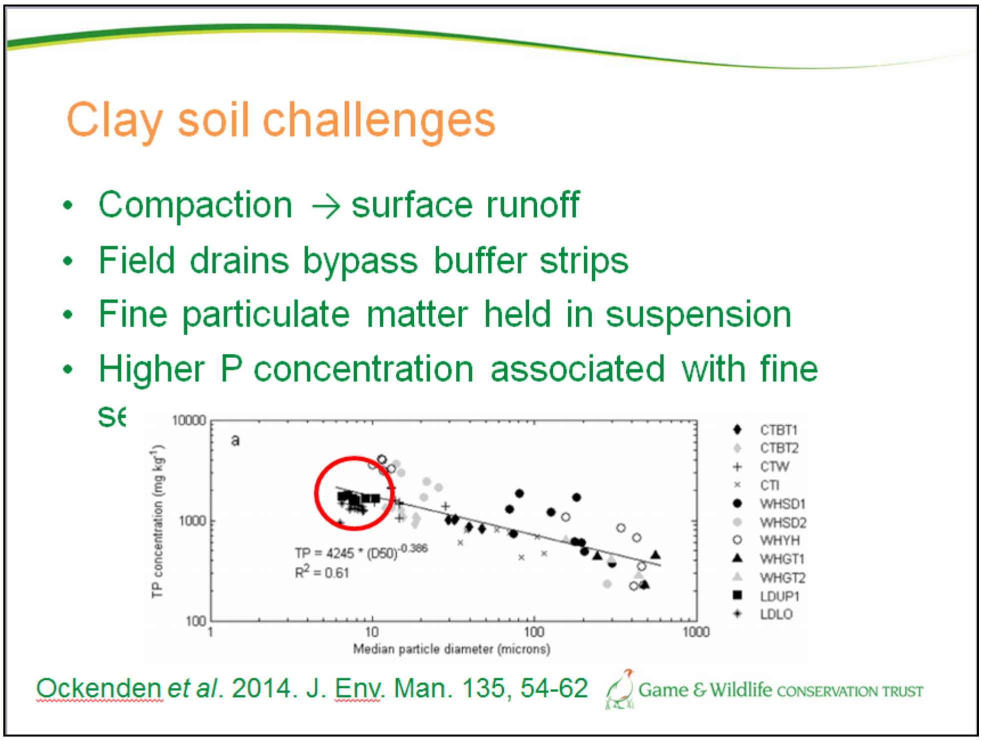

Fig. A5. Example slide from C Stoate highlighting the issues of transport of fine particles and bound contaminants for clay soils

- There are particular challenges for buffers with clay soils due to enhanced P carrying capacity of fine, clay soil-derived, particles (reference to the study by Ockenden and others, 2014).
- Improvements can be made in important biological services in buffers, for example greater earthworm abundance in margins increased infiltration compared with the field (under minimum tillage).
- Vegetation management can increase buffer benefits, whereby improving grass margins with flowering plants and grass mixtures improves multiple benefits for water quality and pollinators.
- Some sediment reduction scenarios were then presented and buffer scenarios and no-till scenarios found comparable to the extreme land change case of conversion to 100% forestry.
- Loddington farm soil is common to much of lowland England - compaction and run-off are issues on clay soils.

Main messages

- Buffer actions must also consider soil management.
- Field drains are an issue as they bypass buffers.
- Clay soils present challenges in dealing with compaction and surface run-off issues.

Questions/comments

- Comparing buffer effectiveness for sediment reductions with a scenario of total land conversion to forestry it depends on the forest management regime/stage and how this is modelled (Tom).
- There is a risk of ecological trade-offs that should be considered. For example, trade-offs between requirements to manage vegetation and loss of functions, such as cutting to maintain biodiversity and the roughness of an effective water quality filter strip (Dominic). Marc: but that has other aspects of helping to remove P in vegetation where there are no alternative loss pathways (unlike N with a gas phase).
- Clay proportion of sediments will be the hardest to manage, however, it flocculates - therefore un-flocculated particles could to be filtered within a ditch at lower flow situations.
- Ponds need to be managed in order to extract the sediment (Paul).
- Do permeable reactive barriers work (Rachael) – (Paul) it’s not the chemistry, it’s the physical part that is in question, such as trapping sediments.

Talk 5: 3D Field margins: Policy and other drivers (Jamie Letts, Environment Agency)

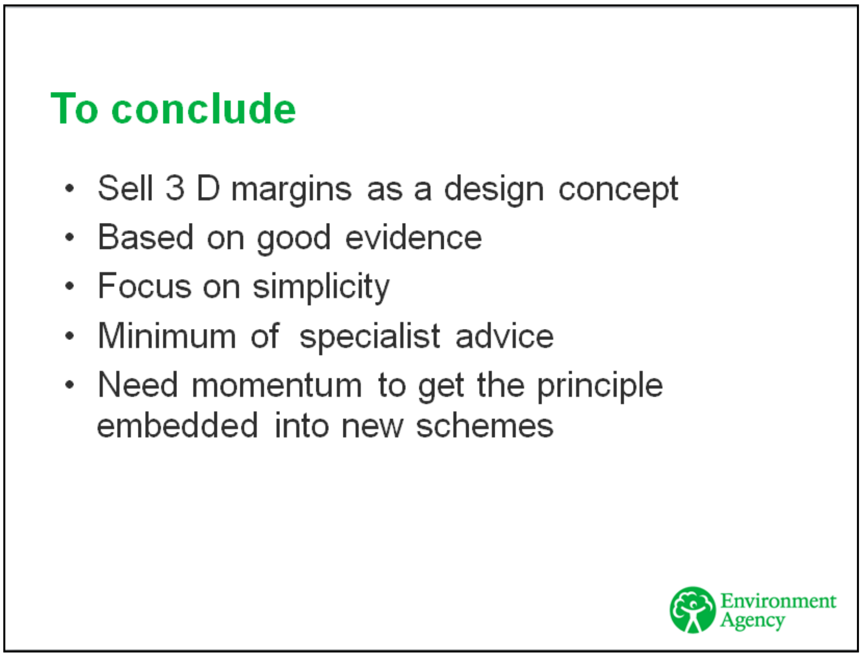

Fig. A6. Example slide from J Letts summing up the requirements of a new '3D approach' to buffer zones

- Jamie Letts (Environment Agency) set out main environmental targets, for example to increase woodland from 10 to 12% by 2060 (England). Measures in stewardship are already complex. How do we package buffer options, so they are not too complex? There's also a requirement for parts of the schemes to be light on specialist advice.

- We need to sell 3D margins as a concept to a possible future management scheme that replaces current pillar 1 and 2 schemes.

Main messages

- Aspiration to set aside around 5% land field areas providing many opportunities for buffer space.

- Basic payment scheme will most likely disappear (Brexit), so the management scheme will need to do more.

Questions/comments

- The 3D margin approach sounds like a second tier above a baseline level of good practice. This second tier should come in to 'fix' an 'issue' catchment for water quality and other aspects like flood risk (Paul).

- Can we pool resources/budgets for outcomes across different schemes/departments that cover water quality, flood risk, woodland planting etc?

A5.4. Measures assessment sessions

Session 3: Measures: options

The aims of this session were to: (i) introduce a set of pre-prepared templates of buffer individual to 'system' measures, (ii) to fill in templates with additional measures, (iii) to agree a set of measures to go forward to assessment in the afternoon

The group considered some measures divided between cross slope (intercepting flow pathways) and watercourse buffers (watercourse used instead of 'riparian' since often this is taken as riparian when considering higher order rivers and we are to consider buffers from ditch sizes upwards). Field edge buffers parallel to flow pathways were not considered.

Main messages

- If we are considering cross slope buffers how close on the slope should the management be to the source of the problem (point of erosion mobilisation etc)?
- We must take good practices on the field in terms of source controls, good soil condition and managing mobilisation as a prerequisite when considering the edge of field actions (some may relate to 'end of pipe' or 'last resort') buffer reliance as this is part of the current false buffer 'panacea'.
- On the other hand, we must accept some degree of soil degradation and losses of sediment N, P from fields as part of food production. So all parts of the treatment train are worth pursuing and buffers also bring multiple benefits for ecology and aquatic resilience. Treatment trains should consider the dominant hydrological pathways and processes, rather than simply targeting highly visual evidence.
- Considering this, we considered that future schemes have 2 tiers: (1) that basic good practice is mandatory and could include providing space for buffers such that a basic, for example 6 m watercourse buffer be provided as part of good practice, (2) that a future tier 2 approach builds on this space to include more bespoke, site-specific designs requiring additional resource (advice, support to be considered separately).
- The term raised bunds should be referred to as 'bunded' measures.
- Project should not be constrained in the options recommendations for what can be achieved under current funding mechanisms. Instead we should use presently funded, or favoured options, as a basis for augmentation or redesign to make better fit for purpose in improving buffer outcomes.

A full set of measures can be seen in Appendix 1. As a result of the above main points, the list of considered measures was condensed and allocated to either tier 1 or tier 2 approaches (shown in Table A1).

A typologies approach was introduced that aimed to classify landscape practices associated with 4 main model farm, soil type and drainage and climate groupings and their resulting pressures (Table. A5.2). Scores were applied to the measures against these typologies applicability, in the afternoon's assessment. The rationale and questioning in using such a typologies approach was:

- Are underlying design aspects of buffers typology-specific (soil, LU, climate)?
- This affects macro-scale targeting scenarios (funding/recommendations)
- Are target goals the same for all typologies with general principles applying across all?
- ➢ If buffers are active can we 'engineer' the functions into any landscape?

Table A5.1. Summary of considered measures that fed into measures scoring and assessment in the later session.

Measure	Considered for tier 1	Considered for tier 2	Considered not in the current scope
Vegetated grass buffer: cross slope	Yes, prescribed as the space onto which additional measures are built in tier 2		Grouped together as cross slope and watercourse.
Vegetated grass buffer: against watercourse			
Designed vegetation buffer		Yes	
Wooded buffer: cross slope		Yes	Grouped together as cross slope and watercourse.
Wooded buffer: against watercourse			
Raised buffer: cross slope			Not in scope: broader farm measure and is part of the good management of the upslope field area that is implied alongside choice of riparian measures
Raised buffer: against watercourse		Yes	
Magic margins (cross slope ridging in toe slope)		Yes	
BufferTech three zone engineered ditch and tree design		Yes, subject to design issues with drainage being addressed	
Sediment traps		Yes, grouped and considered a new augmented buffer class (like Rural SUDs options)	
Swales			
Ponds and wetlands			
Controlled drainage			Not in scope: considered other ways to manage the water table in buffers
Cut back field drains (for example, into mini-wetlands)		Yes	
Augmented ditches (designs of cascades of sediment traps in-ditch)		Yes, subject to constraints on where in-watercourse measures are allowed/applicable	

Table A5.2. Landscape typologies used for assessing buffer applicability (adapted from MacLeod and others, 2012)

<table>
<tr><th>Model system</th><th>1. Cropland (light soil)</th><th>2. Cropland (heavy soil)</th><th>3. Intensive grassland</th><th>4. Upland grassland</th></tr>
<tr><td>General landform</td><td>Shallow slopes</td><td>Shallow slopes</td><td>Undulating lowland to hills</td><td>Upland, steeper</td></tr>
<tr><td>Climate</td><td colspan="2">Low rainfall (<800 mm/yr), milder</td><td>Moderate rainfall (>800 mm/yr) & temperature</td><td>Higher rainfall (>1,200 mm/yr), cooler</td></tr>
<tr><td rowspan="2">Soils</td><td>Sandy to loamy, freely drained</td><td>Heavy clay, imperfectly drained</td><td rowspan="2">Flatter (poorly draining) to steeper (freer draining), 10% fields re-sown annually (lighter machinery), moderate SOC</td><td rowspan="2">Mineral to organic relatively thin soils, limited mechanical disturbance, permanent vegetation</td></tr>
<tr><td colspan="2">Depleted (SOC), cultivated (heavy machinery), bare ground autumn</td></tr>
<tr><td>Soil water flow paths</td><td>Deeper, slower, natural drainage, strong groundwater connectivity</td><td>Surface flows and common artificial drainage</td><td>Surface flows and common artificial drainage</td><td>Flashy run-off, surface dominated</td></tr>
<tr><td>Biodiversity</td><td colspan="2">Limited, homogeneous landscapes</td><td>Heterogeneous to homogeneous biodiversity</td><td>Heterogeneous, becoming specialised by climate</td></tr>
<tr><td rowspan="2">Field pressures</td><td colspan="2">Chemical fertiliser, pesticides/herbicides, low biodiversity, low SOC</td><td rowspan="2">Chemical fertilisers, manures, slurry, FIOs, bank erosion, flooding, habitat decline</td><td rowspan="2">Bank erosion, water colouration/DOC, habitat decline, FIOs, flash floods</td></tr>
<tr><td>soil erosion, pollution leaching to groundwater</td><td>Soil compaction, muddy floods</td></tr>
<tr><td>Typical stream forms</td><td>Modified natural channel, pool/riffle channel</td><td>Large reinforced drainage channel, modified natural channel, pool/riffle channel</td><td>Modified natural channel, inactive single thread channel, plane bed channel</td><td>Step/pool channel to wandering larger channel</td></tr>
<tr><td>Riparian factors</td><td>Strong groundwater connectivity, low to moderate slopes</td><td>Artificial drainage, incised streams, low to moderate slopes</td><td>Artificial drainage, incised streams, low to moderate slopes, fencing versus watering access</td><td>Steeper slope, natural channel</td></tr>
</table>

Session 4: Measures assessment

The aims of this session were to: (i) score the main measures, commenting on effectiveness, applicability and issues against context, (ii) recommend main buffer 'systems' from bundled measures.

What we achieved

Building on the concept of tier 1 (an implied space given by a basic grass buffer) and tier 2 levels of buffering (vegetation/tree management, additional design features built into that given space) we undertook scoring of a matrix of effectiveness, confidence and applicability of that buffering action against landscape typologies for:

1. A 6 m grass buffer (considered the baseline against which to assess tier 2 additional benefits).

2. The same grass buffer but with management of non-woody (flower, herbs) vegetation to improve habitat and pollinator services.

3. The same space but with typical tree planting (minimum 1,600 stems/ha, broadleaved, and managed accordingly to address water issues.

4. The 6 m grass buffer with a site-specific package of design features comprising (i) bottom of the hillslope features (bunds, raised buffers, blind ditches).

5. The 6 m grass buffer with a site-specific package of design features comprising (ii) bottom of the hillslope features and in-ditch to online pond storage and mini-wetlands (for example, on cut-back field drains).

In this the assumption was that basic good in-field management was a requirement alongside all levels.

It was not resolved as to the degree to which the 6 m scenario we assessed was firmly 'linear' space or whether the same land take could be modified locally (from wider to a minimum) to accommodate local risk and certain tier 2 features requiring greater space.

General aspects:

- Longevity in measures (that is, long effective lifespan) provides better value for funding.

- Correct soil management will limit overland flow (for example, into a buffer). Compaction, for example, is decreasing the slope angles needed to initiate sheet flows in arable systems. Therefore, the minimum cut-off for run-off risk in cross compliance has been reduced from 3 degrees to 2 degrees.

Tables A5.2 (a-e). Measures assessment undertaken by expert judgement scoring. In all cases effectiveness is depicted numerically as 5 (very good) to 1 (very limited) and both confidence in evidence and applicability to farm types are all scored using low (L), medium (M) and high (H).

(a) A 6 m grass margin (reference system)

Functions		Effective-ness	Confidence	Arable (light soil)	Arable (heavy soil)	Intensive grass-land	Rough grass-land
Diffuse pollution	Soil loss control & sediment retention	2	M	L	H	H	L
	Phosphorus capture & retention	1	M	L	H	H	L
	Nitrogen capture, uptake, loss	1	M	H	M	M	L
	Pesticide/herbicide capture & breakdown	1	M	H	H	M	L
	FIO retention	3	H	L	L	H	M
Ecosystem	Aquatic processes: shading, leaf litter	1	H	L	L	L	L
	Terrestrial habitat diversity	2	M	H	H	M	L
	System C retention: biomass, soils	1	M	L	L	L	L
	Hydro/geomorphic improvement	1	H	L	L	L	L
Flood	Flood water retention/slowed flows	1	M	L	L	L	M
Infrastructure	Field processes: pollinators, pests	2	M	H	H	M	L
	Biomass: feed/food/fuel/green manure production	1	NA				
	Required access: vehicles/cattle crossing	1	H	L	L	L	L
Amenity	Visual landscape enhancement	2	L	H	H	M	L
	Public access & recreation	3	L	H	H	H	L

Notes on scoring:
The functionality for FIO retention in grassland requires a fenced buffer and this brings management issues for provision of off-stream animal watering. Scoring on terrestrial habitat functions especially depends on the buffer location and vegetation type. Biomass harvesting was considered not applicable (NA) since this reduced hydraulic roughness and worsened run-off control (although it was recognised biomass harvesting can provide P removal). Occasional access by animals was considered appropriate but use for vehicular access was likely to be negative.

(b). A 6 m wooded margin.

Functions		Effective -ness	Confide nce	Arable (light soil)	Arable (heavy soil)	Intensiv e grass-land	Rough grass-land
Diffuse pollution	Soil loss control & sediment retention	3	M	H	H	H	H
	Phosphorus capture & retention	3	M	H	H	H	L
	Nitrogen capture, uptake, loss	3	H	H	H	M	L
	Pesticide/herbicide capture & breakdown	4	M	H	H	M	L
	FIO retention	3	M	L	L	H	M
Ecosystem	Aquatic processes: shading, leaf litter	5	H	H	H	H	H
	Terrestrial habitat diversity	4	M	H	H	H	M
	System C retention: biomass, soils	3	H	H	H	H	M
	Hydro/geomorphic improvement	4	H	H	H	H	H
Flood	Flood water retention/slowed flows	4	M	H	H	H	H
Infrastructure	Field processes: pollinators, pests	3	M	H	H	M	L
	Biomass: feed/food/fuel/green manure production	2	H	H	H	H	H
	Required access: vehicles/cattle crossing	1	H	L	L	L	L
Amenity	Visual landscape enhancement	4	M	H	H	H	H
	Public access & recreation	3	L	H	H	H	L

Notes on scoring:
The model considered is broad-leaved trees at 1,600 stems/ha.
The functionality for FIO retention in grassland requires a fenced buffer and this brings management issues for providing off-stream animal watering. Shading functions were considered dependent on the ratio of tree height to watercourse width. Benefits for pests and pollinators were considered to depend on tree and understory vegetation types and could be lower than a grass buffer. It was recognised that carefully-controlled stock access can benefit mosaic habitat creation among understory vegetation. Biomass functions scored low due to a desire not to harvest trees to maintain other functions.

(c) A 6 m designed herbaceous vegetation margin.

Functions		Effective-ness	Confidence	Arable (light soil)	Arable (heavy soil)	Intensive grass-land	Rough grass-land
Diffuse pollution	Soil loss control & sediment retention	2	M	L	H	H	L
	Phosphorus capture & retention	1	M	L	H	H	L
	Nitrogen capture, uptake, loss	1	M	H	M	M	L
	Pesticide/herbicide capture & breakdown	1	M	H	H	M	L
	FIO retention	3	H	L	L	H	M
Ecosystem	Aquatic processes: shading, leaf litter	3	H	L	L	L	L
	Terrestrial habitat diversity	4+	M	H	H	M	L
	System C retention: biomass, soils	1	M	L	L	L	L
	Hydro/geomorphic improvement	1	H	L	L	L	L
Flood	Flood water retention/slowed flows	1	M	L	L	L	M
Infrastructure	Field processes: pollinators, pests	4	M	H	H	M	L
	Biomass: feed/food/fuel/green manure production	2	M	M	M	M	L
	Required access: vehicles/cattle crossing	1	H	L	L	L	L
Amenity	Visual landscape enhancement	3	L	H	H	M	L
	Public access & recreation	3	L	H	H	H	L

Notes on scoring:
The functionality for FIO retention in grassland requires a fenced buffer and this brings management issues for providing off-stream animal watering.
Biomass harvesting was considered applicable for this designed vegetation system. Occasional access by animals was considered appropriate but use for vehicular access was likely to be negative.

(d) A 6 m grass margin with augmented run-off measures on the slopes within the buffer scored for effectiveness and confidence, but not for applicability to the farming types (it is recognised that the measures within the package will be adapted to on-site conditions).

Functions		Effectiveness	Confidence
Diffuse pollution	Soil loss control & sediment retention	3	L
	Phosphorus capture & retention	3	L
	Nitrogen capture, uptake, loss	2	L
	Pesticide/herbicide capture & breakdown	2	L
	FIO retention	3	L
Ecosystem	Aquatic processes: shading, leaf litter	1	H
	Terrestrial habitat diversity	3+	M
	System C retention: biomass, soils	1	M
	Hydro/geomorphic improvement	3	H
Flood	Flood water retention/slowed flows	3	M
Infrastructure	Field processes: pollinators, pests	3	M
	Biomass: feed/food/fuel/green manure production	1	M
	Required access: vehicles/cattle crossing	1	H
Amenity	Visual landscape enhancement	2	L
	Public access & recreation	2	M

Notes on scoring:
In addition to a grass buffer a range of options of bunded features for temporary water retention were considered available for placement on the slopes within the buffer. The functionality for FIO retention in grassland requires a fenced buffer and this brings management issues for providing off-stream animal watering.

(e) A 6 m grass margin with augmented run-off measures on buffer slopes and across the channel scored for effectiveness and confidence, but not for applicability to the farming types (it is recognised that the measures within the package will be adapted to on-site conditions).

Functions		Effectiveness	Confidence
Diffuse pollution	Soil loss control & sediment retention	4	L
	Phosphorus capture & retention	4	L
	Nitrogen capture, uptake, loss	4	L
	Pesticide/herbicide capture & breakdown	3	L
	FIO retention	3	L
Ecosystem	Aquatic processes: shading, leaf litter	3	L
	Terrestrial habitat diversity	4+	M
	System C retention: biomass, soils	2	M
	Hydro/geomorphic improvement	4	H
Flood	Flood water retention/slowed flows	4	M
Infrastructure	Field processes: pollinators, pests	4	M
	Biomass: feed/food/fuel/green manure production	1	H
	Required access: vehicles/cattle crossing	1	H
Amenity	Visual landscape enhancement	2	L
	Public access & recreation	2	M

Notes on scoring:

The design considered comprised a grass buffer with options of bunded features for temporary water retention, plus designs to intercept artificial and slow artificial drain water. All these could be considered on both the buffer slopes and across and utilising the channel itself. The scores given comprise an upper cap dependent on the designs chosen for a given place.

It would be considered that measures that utilised the channel itself of a stream or ditch would be subject to a certain stream size above which consent to alter channel form would be prohibitive.

The functionality for FIO retention in grassland requires a fenced buffer and this brings management issues for providing off-stream animal watering. Benefits for recreation were depended on designs and satisfactory health and safety concerning areas of wet or ponded ground.

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