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DIVERSE SOLUTIONS FOR MITIGATION OF DIFFUSE CONTAMINANT LOSSES: WHICH GOES WHERE, FOR WHAT?

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Extended abstract

Interceptive mitigation options implemented at the edge of fields and along flow pathways can complement preventive in-field management of agricultural land-use to reduce diffuse contaminant losses to surface waters. They can provide farmers and land managers with an additional range of tools to manage contaminant losses and achieve nutrient limits. The pathways by which run-off and associated contaminants travel from land to water determine the types of contaminants mobilised, their form (e.g., dissolved or associated with particulates), where they can be intercepted and the suitability of different mitigation options (Figure 1).

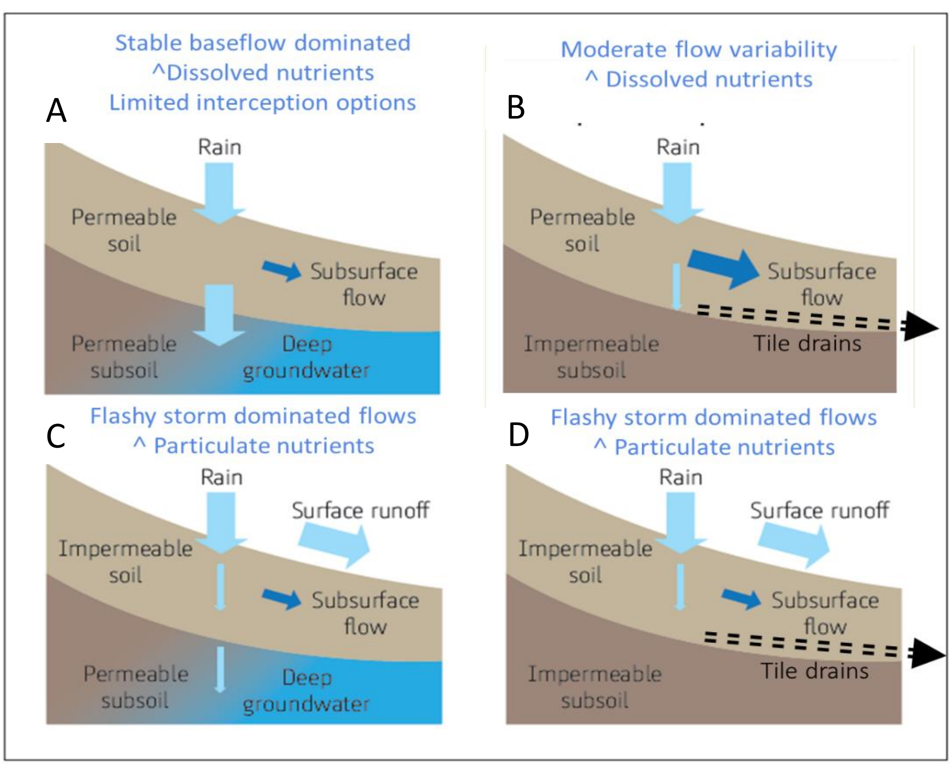


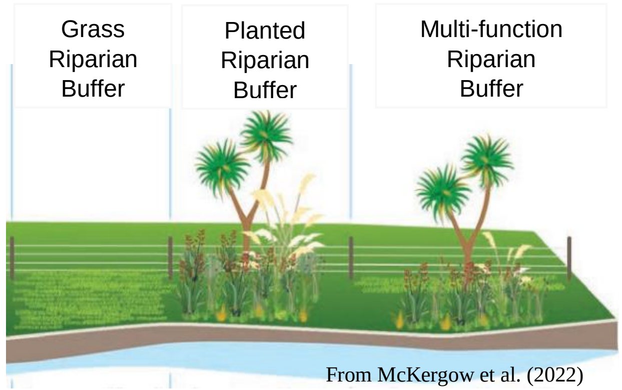
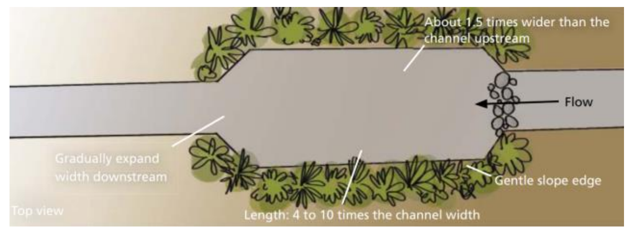
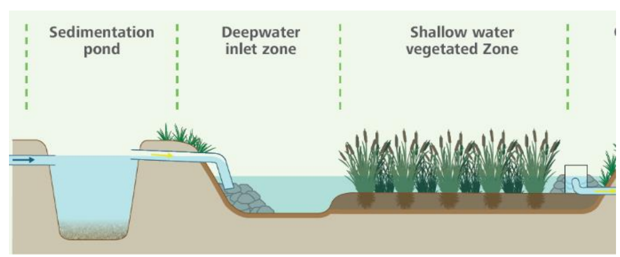
Figure 1. The four basic hydrologic landscape types (HLTs; modified from USEPA, 2015). All soil types will produce surface run-off on slopes during high intensity storms. Installation of subsurface tile drainage in low permeability soils (primarily types B and D) can reduce surface runoff and associated particulate contaminant losses, but increase dissolved nutrient losses.

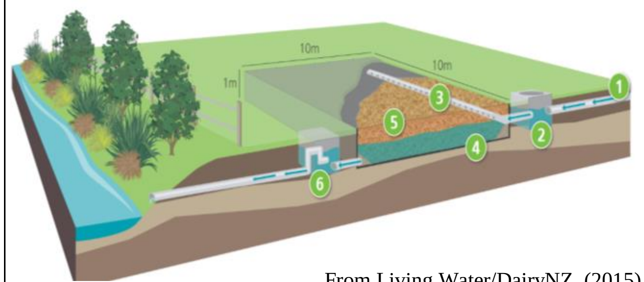
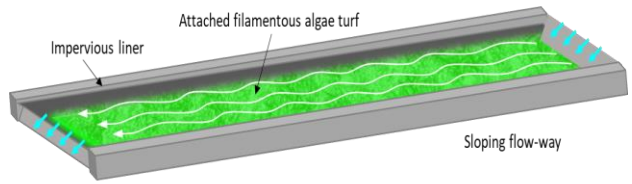
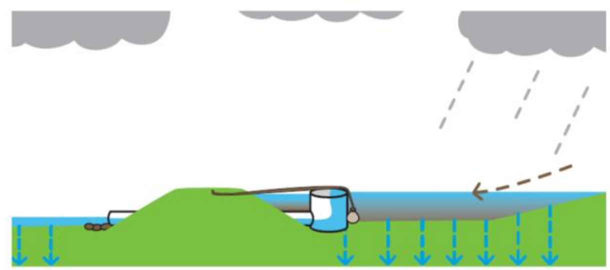
Each mitigation option has its niche in terms of contaminant(s) and flow path(s) able to be targeted, efficacy, cost, longevity, operation and maintenance requirements, ancillary benefits, landscape fit, and consenting requirements. However, it is often not clear to users which mitigation option is appropriate for their situation, where it could be located, what contaminant reductions and benefits can be achieved, and what it would cost to implement, maintain and operate. The applicability of 8 mitigation options with wide applicability on pastoral farms in New Zealand are overviewed in Table 1, and their basic attributes summarised in Table 2. For further information on this approach see Tanner et al. (submitted)

Table 1. Suggested suites of cost-effective mitigation practices to consider, depending on hydrologic pathway, HLT, and key contaminant category. The importance of different pathways for each HLT is indicated by shading. Coding: none=absent/minor; yellow=present; green=dominant/co-dominant. Abbreviations for mitigations are- GRB: grass filter riparian buffer; PRB: planted riparian buffers; MRB: multi-function riparian buffers; CW: constructed wetlands; DB: detainment bunds; ST: sediment traps; FANS: filamentous algae nutrient scrubbers; WB: woodchip bioreactors.

HLT		Flat/undulating (< 7°)				Rolling/hilly (7-25°)			
Pathway	Key contaminants targeted	A	B	C	D	A	B	C	D
Ephemeral runoff	Particulate	GRB	GRB MRB	GRB MRB	GRB DB[7] PRB MRB	GRB DB PRB MRB	GRB DB PRB MRB	GRB DB PRB MRB	GRB DB PRB MRB
Surface drains/ ditches[1]	All	FANS CW ST GRB[4]	FANS CW ST GRB[4]	FANS CW ST GRB[4]	FANS CW ST GRB[4]			CW ST GRB[4]	CW ST GRB[4]
Tile drains	Dissolved (NO_3)		WB CW FANS	WB CW FANS	WB CW FANS				WB CW FANS
Seeps/springs[2]	Dissolved (NO_3)		PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB	PRB[5] MRB CW[6] WB
Streams[3] (stable flows)	Dissolved (NO_3) >particulate	PRB MRB CW FANS	PRB MRB CW FANS			PRB MRB CW FANS	PRB MRB CW FANS		
Streams[3] (flashy flows)	Particulate >dissolved		GRB MRB CW	GRB MRB CW ST	GRB MRB CW ST	GRB MRB CW	GRB MRB CW ST	GRB MRB CW ST	GRB MRB CW ST

Table 2: Descriptions of the 8 interceptive mitigation options considered and key information sources for New Zealand

Mitigation system		**Key information sources**
Riparian buffers (RB): Perennial vegetation strips placed along/above streambanks. Following McKergow et al. (2022), we divide riparian buffers into three classes, including grass-filter riparian buffers (GRB) focused on intercepting and filtering ephemeral runoff; planted riparian buffers (PRB) comprised of a mix of trees and ` which can intercept shallow subsurface flows; and multi-function riparian buffers (MRB) combining a GRB and a PRB. Buffer widths and species composition vary with HLT, contributing catchment area or slope length and management goals. As well as runoff and shallow groundwater interception reducing sediment, nutrients, and faecal contaminants, additional benefits may include soil carbon accretion, enhanced biodiversity, and landscape aesthetics.	 From McKergow et al. (2022)	Riparian Buffer Design Guide (McKergow et al., 2022) Riparian management: A restoration tool for New Zealand streams. (McKergow et al. 2016)
Sediment traps (ST): Deep (> 2m) pools installed by excavation and impoundment along intermittent and perennial flow-paths to slow water movement and encourage settling of particulates. Recurrent maintenance to excavate and remove accumulated sediment is required.	 From Hudson (2005)	In-channel coarse sediment trap best management practice (Hudson, 2002) A review of the effectiveness of sediment traps for New Zealand agriculture (Smith and Muirhead 2023)
Constructed wetlands (CW): Shallow (<0.5 m) impoundments vegetated with emergent aquatic plants that intercept and pond water. Most effective for removal of nitrate (through microbial denitrification) and moderate sediment and particulate P loads (through settling). They can be employed at multiple scales, including at the bottom of catchments before flows enter lakes and estuaries, and can provide ancillary habitat/biodiversity, carbon sequestration, aesthetic and cultural benefits.	 From Tanner et al. (2022)	Constructed Wetland Practitioner Guide (Tanner et al., 2022) Multi-year nutrient removal performance of three constructed wetlands intercepting drainage flows from grazed pastures (Tanner et al. 2011)

Woodchip bioreactors (WB): This mitigation diverts nitrate-bearing drainage water into and through a buried bed of porous high-carbon materials, typically woodchips. This creates conditions of high carbon availability and low oxygen concentration, which encourages nitrate to be converted to nitrogen gas by microbial denitrification.	 From Living Water/DairyNZ, (2015)	Using denitrifying bioreactors to improve water quality on Queensland farms (Wegscheidl et al. 2021) Conservation practice standard. (USDA, 2020) Effectiveness of denitrifying bioreactors on water pollutant reduction from agricultural areas (Christianson et al., 2021)
Filamentous algal nutrient scrubbers (FANS): Shallow channels seeded with attached or suspended filamentous algae that intercept surface flows. They will generally be located off-line and fed by partial diversion of perennial flowing drains or streams. The algal biomass is harvested regularly to remove accumulated nutrients which can be spread on land as a slow-release organic fertiliser or used as a feed supplement for livestock.		Utilising periphytic algae as nutrient removal systems for the treatment of diffuse nutrient pollution in waterways (Sutherland and Craggs, 2017) Performance of Filamentous Algae Nutrient Scrubbers for the treatment of agricultural drainage (Hariz et al., 2023)
Detainment bunds (DB): Low bunds placed along ephemeral flow-paths. Runoff is pooled temporarily to encourage trapping of sediment, particulate phosphorus, and bacteria. Pooled runoff will either infiltrate (in permeable soils), be released gradually via a constrained orifice or after a few days by removing a plug. This allows pasture and normal farming activities to be maintained in the ponding area between ponding events. Flows greater than the capacity of the ponding over-top the riser pipe, or in extreme cases the spillway, routing excess water downslope. This practice also mitigates concentrated flow erosion (i.e., gully formation) below the bund.	 From Paterson et al. (2020)	Detainment Bund[PS120]: A guideline for on-farm, pasture-based, storm water run-off treatment (Paterson et al., 2020) The ability of detainment bunds to decrease sediments transported from pastoral catchments in surface runoff (Levine et al. 2021)

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