Wright-Stow, A.E., Tanner, C., Matheson, F., Stephens, T., Quinn, J., Burger, D., Young, J., 2018. Accelerating uptake of constructed wetlands and riparian buffers by quantifying attenuation performance: a proposed national investigation. In: *Farm environmental planning – Science, policy and practice*. (Eds L. D. Currie and C. L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 31. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 5 pages.

ACCELERATING UPTAKE OF CONSTRUCTED WETLANDS AND RIPARIAN BUFFERS BY QUANTIFYING ATTENUATION PERFORMANCE: A PROPOSED NATIONAL INVESTIGATION

Aslan Wright-Stow[1], Chris Tanner[2], Fleur Matheson[2], Tom Stephens[1], John Quinn[2], David Burger[1], Justine Young[1]

[1]DairyNZ, Corner of Ruakura and Morrinsville Roads, Private Bag 3221, Hamilton, 3240
[2]NIWA, Gate 10, Silverdale Road, Private Bag 11-115, Hamilton, 3216

Email: aslan.wright-stow@dairynz.co.nz

Introduction

Many landowners are in the process of identifying and implementing mitigations to reduce diffuse contaminant loss to waterbodies, under regional limit-setting processes required by New Zealand's National Policy Statement for Freshwater Management (NPS-FM). Constructed wetlands (CWs) and riparian buffers (RBs) are at the forefront of mitigation options available to meet limits. However, there are gaps in our understanding of how they perform in different landscape settings and how to optimise their performance. Consequently, further research is needed to better quantify their environmental performance and benefits with a national scale perspective. This is needed so that landowners can claim expected contaminant load reductions through farm contaminant budgets and regulators can have confidence that specific riparian or wetland mitigations will deliver the reductions to on-farm contaminant budgets, required to meet catchment load objectives. To improve the levels of certainty around environmental outcomes, and to accelerate the uptake and acceptance of these tools by farmers and in regulation, we need a markedly increased local case-study dataset that covers all representative New Zealand landscape settings. This project will provide robust performance criteria for diffuse contaminant attenuation and scientifically-based optimised practical guidance, to accelerate the wide-scale implementation of constructed wetlands and critical source targeted riparian buffers in NZ as effective tools for managing farm and catchment contaminant loads.

Background

Constructed wetlands

Natural wetlands store, assimilate, and transform contaminants lost from the land, before they reach waterways. Constructed wetlands attempt to mimic these natural systems to treat through flowing waters (Tanner *et al.*, 2010). Typically, in constructed wetlands intercepting farm run-off and drainage, water flows through shallow (<0.5 m) flooded beds of emergent aquatic plants such as native sedges (*Carex, Schoenoplectus, Eleocharis, Macherina* species), rushes (*Juncus* species) and raupo (*Typha orientalis*).

Constructed wetlands are generally designed to remove, absorb, and store nutrient and sediment loads. They can be designed to treat surface runoff or sub-surface drainage waters.

Inflowing water is dispersed and slowed down to promote settling and deposition of suspended particles and phosphorus bound to sediment (Tanner *et al.*, 2005; McDowell and Nash, 2012). This is especially important for the treatment of surface runoff which is typically enriched with sediment and phosphorus. Wetlands are also highly productive environments for plants and beneficial microbes that promote nitrate-nitrogen removal via two main mechanisms: denitrification, in which nitrate is converted to nitrogen gas by bacteria in organically enriched, waterlogged, anaerobic wetland soils; and direct biological uptake by plants and microbes growing within the wetland whereby nitrate is assimilated into plant tissues or detrital organic pool (Rutherford *et al.*, 2017). Nitrogen taken up into plants can be later released when plants senesce and decompose, returning dissolved and particulate organic nitrogen back into the water. Nitrate removal is particularly important in the treatment of sub-surface drainage waters.

CWs are one of the most promising tools available for managing farm contaminant loads. For example, guidelines for the treatment of sub-surface tile/mole drainage through CWs have estimated that on average, between 22 and 53% (+/- 15%) of total annual catchment nitrate removal is possible from wetlands that cover 1% and 5% of total catchment area, respectively (Tanner *et al.*, 2010). Despite this, encouragement of CW implementation through regulation is often limited by uncertainty in treatment performance and water quality outcomes. Many councils currently rely on the OVERSEER^{TM} nutrient model to quantify benefits of nitrogen mitigations, but nutrient loss reductions possible using CW are currently poorly represented in this model. Widespread uptake of CWs by landowners is unlikely to occur unless councils give credit for the nutrient reductions they provide. Although the use of CWs is well understood in principle, they still lack specific practical guidance and certainty on optimal design and performance.

Existing research has quantified wetland performance at a limited number of NZ CW case study locations for subsurface-flow tile drainage (Tanner *et al.*, 2010; Sukias and Tanner, 2011), but performance for surface drainage containing a higher proportion of particulate contaminants, and variability in efficacy due to differences in design or environmental, climatic and farming conditions has not been addressed, especially between regions. Expected CW removal under New Zealand pastoral farming conditions has been estimated (McKergow *et al.*, 2007), and some catchment-scale assessments of wetland nutrient attenuation made (Hamill *et al.*, 2010; Tanner, 2012; Hughes *et al.*, 2013; Tanner *et al.*, 2015). However, until a wider range of case studies are established and evaluated, including catchment-scale assessments, the uncertainties will remain and their wide-scale uptake by landowners and incorporation of wetland tools in the regulatory framework will continue to be limited.

Riparian buffers

Riparian buffers are arguably the most widely used "edge-of-field" mitigation tool for reducing the impacts of landuse on waterways. A riparian zone is described scientifically, as the zone of direct interaction between land and water (Gregory *et al.*, 1991). New Zealand has a long history of using riparian buffers to reduce impacts on aquatic values with the first riparian catchment schemes dating back to the 1970s (McKergow *et al.*, 2016).

Buffer widths on permanently flowing streams in agricultural catchments are generally a compromise between maintaining productive farming land and delivering water quality and ecosystem benefits. In New Zealand buffers of 2-5m wide are commonly employed to exclude livestock and intercept contaminants. Where planting is undertaken, buffer widths are typically wider (5 m), and generally comprise a relatively low diversity of species (Renouf and Harding, 2015).

Riparian management can help reduce the load of nutrient, sediment and faecal microbes (*E. coli*) entering the water by intercepting, transforming and/or storing contaminants (Parkyn, 2004; Dosskey *et al.*, 2010; Vidon *et al.*, 2010; McKergow *et al.*, 2016). For instance, livestock exclusion on Southland dairy farms has been linked to a 20 percent reduction in *E. coli* contamination of adjacent waterways and a 40 percent reduction in phosphorus loss (Goldsmith *et al.*, 2013). An international review found that grass filters of five meters can reduce nitrogen, phosphorus and sediment losses by 54-74 percent (Dillaha *et al.*, 1989), while a study in the Bay of Plenty reported grass filters of three metres can reduce nitrogen, phosphorus and sediment loads by 35-87 percent (McKergow *et al.*, 2008). Riparian vegetation has also been demonstrated to create more habitat diversity, temperature regulation, habitat to support invertebrate and fish life-cycle stages, food web stability and diversity and refuge from predators and floods (Quinn *et al.*, 1997; Parkyn and Collier, 2004; Greenwood *et al.*, 2012; Olsen *et al.*, 2012; McKergow *et al.*, 2016).

Despite much riparian research, there are still many uncertainties around how riparian buffers are best designed and implemented. For example, there has been limited validation and national guidance on buffer performance under environmental and farming settings. This has created a mix of policy provisions for minimum buffer width that vary regionally. It is critical that this knowledge gap is addressed as significant national-scale investment is, and will be made in riparian restoration projects over the next 5-10 years. Without more robust riparian buffer performance information and guidance, it remains uncertain what the quantifiable catchment-scale benefits are or what riparian set-backs are required to meet farm or catchment objectives. We also risk missing a key opportunity to generate most benefit by targeting riparian buffers at runoff “hot-spots” (i.e., to maximize flow and contaminant attenuation where beneficial effects are disproportionate) thereby enabling a better return on this substantial investment, as well as greater certainty around outcomes.

Project aims

This project aims to provide robust, scientifically-based practical guidance to accelerate the wide-scale implementation of constructed wetlands and targeted riparian buffers in NZ as tools for managing farm and catchment contaminant loads. Specifically, we plan to provide sufficient guidance and certainty of expected contaminant reductions to enable farmers and regulatory agencies to account for riparian and wetland effects within farm nutrient management plans and regional planning responses to the NPS-FM.

This project will:

1. Develop a set of provisional performance and design guidelines for immediate use by councils
2. Design, establish and monitor a range of CW and riparian buffer systems across NZ to quantify and compare performance in different landscape and climate settings, and use this to refine and validate provisional performance and design guidance
3. Aim to encourage and incentivise wide-scale implementation of appropriate wetland and optimised riparian buffers as contaminant management tools

Methods

For step 1 we will gather existing information from local and international sources and then work with a wider industry and government group to agree on a set of preliminary guidelines for councils to use in the short-term.

For step 2, in each of the main dairying regions in NZ (Northland, Waikato, Taranaki, Canterbury, Southland) we will establish whole-of-catchment riparian fencing & planting project treatments to establish optimal design. At each site we will identify a suitable paired catchment to implement and compare the performance of a standard fixed width buffer (e.g., 1 m width as signalled by recent policy) with that of a variable width buffer which is made wider in locations along the riparian margin where runoff is more strongly focused. Conceptually, targeting these runoff hotspots with a wider buffer should improve flow and contaminant attenuation and thus enhance overall buffer performance at catchment scale. However, that principle lacks empirical evidence and has not been tested at the catchment scale.

Across these regions, we will also establish and monitor five new and five existing CWs. Controlling the wetland and riparian design will enable robust scientific testing ("before-after-control-impact") to separate direct effects of project design and management (e.g., fixed width vs targeted (i.e., variable & critical source area focused) width buffers) from confounding environmental effects. Such an experiment has not been undertaken in NZ or internationally.

Outcomes

This project delivers science to guide on-land activity to meet water quality limits. The outcomes are principally focussed on reduction of the primary water quality contaminants (sediment, nitrogen, phosphorus and faecal microbes) through optimal CW and RB design and implementation. Ancillary benefits include flow buffering, biodiversity & habitat enhancement, and climate change mitigation for water quality (e.g., stream shading & water temperature). The programme also supports robust reporting for the NPS-FM by regulatory agencies on managing to freshwater objectives in regional plan policy responses and provides certainty of performance to catchment decision makers, industry, rural advisors and land-owners. Collectively, these components are intended to make on-farm change more cost-effective and better manage stakeholder expectations, as well as ensure that these wide-spread edge-of-field solutions are scaled to work optimally in the landscape setting that they are implemented.

References

Dillaha, T., Reneau, R., Mostaghimi, S., Lee, D., 1989. Vegetative filter strips for agricultural non-point source pollution control. Transactions of the American Society of Agricultural Engineers 32, 491-496.

Dosskey, M.G., Vidon, P., Gurwick, N.P., Allan, C.J., Duval, T.P., Lowrance, R., 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams1. JAWRA Journal of the American Water Resources Association 46, 261-277.

Goldsmith, R., Olsen, D., Ryder, G., 2013. Environmental Effects of Activities within the Riparian Zone: Technical Review. Ryder Consulting.

Greenwood, M.J., Harding, J.S., Niyogi, D.K., McIntosh, A.R., 2012. Improving the effectiveness of riparian management for aquatic invertebrates in a degraded agricultural landscape: stream size and land-use legacies. Journal of Applied Ecology 49, 213-222.

Gregory, S.V., Swanson, F.J., McKee, W.A., Cummins, K.W., 1991. An Ecosystem Perspective of Riparian Zones. BioScience 41, 540-551.

Hamill, K., MacGibbon, R., Turner, J., 2010. Wetland feasibility for nutrient reduction to Lake Rotorua. Retrieved from the Bay of Plenty Regional Council website: https://www.boprc.govt.nz/media/99878/wetland_feasibility_for_nutrient_reduction_to_lake_rotorua.pdf.

Hughes, A., Semadeni-Davies, A., Tanner, C.C., 2013. Nutrient and sediment attenuation potential of wetlands in Southland and South Otago dairying areas. NIWA Client Report HAM-2013-016 prepared for Pastoral 21 Research Group under contract to AgResearch, Hamilton, NZ.

McDowell, R.W., Nash, D., 2012. A Review of the Cost-Effectiveness and Suitability of Mitigation Strategies to Prevent Phosphorus Loss from Dairy Farms in New Zealand and Australia. Journal of Environmental Quality 41, 680-693.

McKergow, L.A., Costley, K.J., Timpany, G., 2008. Contour grass filter strips: hydrology and water quality. NIWA Client Report: HAM2008-134.

McKergow, L.A., Matheson, F.E., Quinn, J.M., 2016. Riparian management: A restoration tool for New Zealand streams. Ecological Management & Restoration 17, 218-227.

McKergow, L.A., Tanner, C.C., Monaghan, R.M., Anderson, G., 2007. Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems (Report No. HAM2007-161). Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd (NIWA).

Olsen, D., Tremblay, L., Clapcott, J., Holmes, R., 2012. Water temperature criteria for native aquatic biota. Auckland Council Technical Report 2012/036.

Parkyn, S.M., 2004. Review of Riparian Buffer Zone Effectiveness. MAF Technical Paper No:2004/05.

Parkyn, S.M., Collier, K.J., 2004. Interaction of Press and Pulse Disturbance on Crayfish Populations: Flood Impacts in Pasture and Forest Streams. Hydrobiologia 527, 113-124.

Quinn, J.M., Cooper, A.B., Davies-Colley, R., Rutherford, K., Williamson, R., 1997. Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. New Zealand Journal of Marine and Freshwater Research 31, 579-597.

Renouf, K., Harding, J.S., 2015. Characterising riparian buffer zones of an agriculturally modified landscape. New Zealand Journal of Marine and Freshwater Research 49, 323-332.

Rutherford, K., Hughes, A.O., McKergow, L.A., 2017. Review of Nitrogen Attenuation in New Zealand Seepage Wetlands. NIWA report prepared for DairyNZ. NIWA Client Report No: 2017241HN.

Sukias, J., Tanner, C.C., 2011. Surface flow constructed wetlands as a drainage management tool – long term performance. In L.D Currie & C.L. Christensen (Eds.), Occasional Report No. 24 Adding to the knowledge base for the nutrient manager (pp. 1-16).

Tanner, C.C., 2012. Potential of wetlands to reduce nutrient loads from Lowry Peaks and St Leonards Drains before entry into the Waiau and Hurunui Rivers. NIWA Client Report HAM2012-015 for Environment Canterbury, Hamilton, NZ.

Tanner, C.C., Nguyen, M.L., Sukias, J.P.S., 2005. Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. Agriculture, Ecosystems & Environment 105, 145-162.

Tanner, C.C., Sukias, J., de Winton, M., Larned, S., Sutherland, D., Hughes, A., 2015. Wetland Nutrient Attenuation Assessment for Inflows to Te Waihora / Lake Ellesmere. NIWA Client Report HAM2015-040 prepared for Whakaora Te Waihora. April 2015., Hamilton, NZ.

Tanner, C.C., Sukias, J., Yates, C.R., 2010. New Zealand guidelines: Constructed Wetland Treatment of Tile Drainage. NIWA Information Series No. 75 National Institute of Water & Atmospheric Research Ltd.

Vidon, P., Allan, C., Burns, D., Duval, T.P., Gurwick, N., Inamdar, S., Lowrance, R., Okay, J., Scott, D., Sebestyen, S., 2010. Hot Spots and Hot Moments in Riparian Zones: Potential for Improved Water Quality Management1. JAWRA Journal of the American Water Resources Association 46, 278-298.