

New Zealand publications on groundwater denitrification

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Journal Articles - Refereed (Code 12-R):

Rivas, A., Barkle, G., Stenger, R., Moorhead, B. Clague, J. (2020) Nitrate removal and secondary effects of a woodchip bioreactor for the treatment of subsurface drainage with dynamic flows under pastoral agriculture. *Ecological Engineering* 148 (2020) 105786.

<https://doi.org/10.1016/j.ecoleng.2020.105786>

Rivas, A., Singh, R., Horne, D. J., Roygard, J., Matthews, A., & Hedley, M. J., (2020). Contrasting subsurface denitrification characteristics under temperate pasture lands and its implications for nutrient management in agricultural catchments. *Journal of Environmental Management*, 272. <https://doi.org/10.1016/j.jenvman.2020.111067>

Maxwell, B., Birgand, F., Schipper, L., Barkle, G., Rivas, A., Helmers, M., and Christianson, L. (2020). High-frequency, in situ sampling of field woodchip bioreactors reveals sources of sampling error and hydraulic inefficiencies. *Journal of Environmental Management* 272, 110996.

<https://doi.org/10.1016/j.jenvman.2020.110996>

Wilson, S. R., Close, M. E., Abraham, P., Sarris, T. S. Banasiak, L., Stenger, R., Hadfield, J. (2020) Achieving unbiased predictions of national-scale groundwater redox conditions via data oversampling and statistical learning. *Science of the Total Environment* 705:135877 14pp.

<https://doi.org/10.1016/j.scitotenv.2019.135877>

Friedel, M. J., Wilson, S. R., Close, M. E., Buscema, M., Abraham, P., Banasiak, L. (2020) Comparison of four learning-based methods for predicting groundwater redox status. *Journal of Hydrology* 580: 124200. <https://doi.org/10.1016/j.jhydrol.2019.124200>

Burbery, L., Sarris, T., Mellis, R., Abraham, P., Sutton, R., Finnemore, M., Close, M. (2020) Woodchip denitrification wall technology trialled in a shallow alluvial gravel aquifer. *Ecological Engineering* 157 (2020)105966. <https://doi.org/10.1016/j.ecoleng.2020.105966>

Goeller, B.C., Febria, C.M., McKergow, L.A., Harding, J.S., Matheson, F.E., Tanner, C.C., McIntosh, A.R. (2020) Combining tools from edge-of-field to in-stream to attenuate reactive nitrogen along small agricultural waterways. *Water* 12(2):383. <https://doi.org/10.3390/w12020383>

Clague, J.C., Stenger, R., Morgenstern, U. (2019) The influence of unsaturated zone drainage status on denitrification and the redox succession in shallow groundwater. *Science of the Total Environment* 660:1232-1244. <https://doi.org/10.1016/j.scitotenv.2018.12.383>

Singh, R., Horne, D., (2019). Water quality issues facing dairy farming: potential natural and built attenuation of nitrate losses in sensitive agricultural catchments. *Animal Production Science* 60(1), 67-77. <https://doi.org/10.1071/AN19142>

- Rissmann CWF, Pearson LK, Beyer M, Couldrey, MA, Lindsay JL, Martin AP, Baisden WT, Clough TJ, Horton TW, Webster-Brown, JG (2019) A hydrochemically guided landscape classification system for modelling spatial variation in multiple water quality indices: Process-attribute mapping. *Science of the Total Environment* 672:815-833.
<https://doi.org/10.1016/j.scitotenv.2019.03.492>
- Sarris, T.S., Scott, D.M., Close, M.E., Humphries, B., Moore, C., Burbery, L.F., Rajanayaka, C., Barkle, G., Hadfield, J. (2019) The effects of denitrification parameterization and potential benefits of spatially targeted regulation for the reduction of N-discharges from agriculture. *Journal of Environmental Management* 247:299-312. <https://doi.org/10.1016/j.jenvman.2019.06.074>
- Goeller, B.C., Burbery, L.F., Febria, C.M., Collins, K.E., Burrows, N.J., Simon, K.S., Harding, J.S., McIntosh, A.R. (2019) Capacity for bioreactors and riparian rehabilitation to enhance nitrate attenuation in agricultural streams. *Ecological Engineering* 134:65-77.
<https://doi.org/10.1016/j.ecoleng.2019.03.014>
- Sarris, T.S., Close, M.E., Moore, C. (2019) Uncertainty assessment of nitrate reduction in heterogeneous aquifers under uncertain redox conditions. *Stochastic Environmental Research and Risk Assessment* 33:1609-1627. <https://doi.org/10.1007/s00477-019-01715-w>
- Burbery, L. (2018) Nitrate reactivity in groundwater: A brief review of the science, practical methods of assessment, and collation of results from New Zealand field investigations. *Journal of Hydrology (NZ)* 57 (2):51-79.
- Sarris, T. S., and L. F. Burbery, (2018). Stochastic multi-objective performance optimization of an in-stream woodchip denitrifying bioreactor, *Ecological Engineering* 124: 38-50. DOI 10.1016/j.ecoleng.2018.09.006.
- Stenger, R., Clague, J.C., Morgenstern, U., Clough, T.J. (2018) Vertical stratification of redox conditions, denitrification and recharge in shallow groundwater on a volcanic hillslope containing relict organic matter. *Science of the Total Environment* 639: 1205-1219.
<https://doi.org/10.1016/j.scitotenv.2018.05.122>
- Elwan, A., Singh, R., Patterson, M., Roygard, J., Horne, D., Clothier, B. and Jones, G., (2018). Influence of sampling frequency and load calculation methods on quantification of annual river nutrient and suspended solids loads. *Environmental Monitoring and Assessment* 190:78.
<https://doi.org/10.1007/s10661-017-6444-y>
- Woodward, S. J. R., Wöhling, Th., Rode, M., Stenger, R. (2017) Predicting nitrate discharge dynamics in mesoscale catchments using the lumped StreamGEM model and Bayesian parameter inference. *Journal of Hydrology* 552: 684-703. <https://doi.org/10.1016/j.jhydrol.2017.07.021>
- Wilson, S.R., Close, M.E., Abraham, P. (2017). Applying Linear Discriminant Analysis to predict groundwater redox conditions conducive to denitrification. *Journal of Hydrology* 556: 611-624.
<https://doi.org/10.1016/j.jhydrol.2017.11.045>
- Rivas, A., Singh, R., Horne, D., Roygard, J., Matthews, A., Hedley, M.J. (2017) Denitrification potential in the subsurface environment in the Manawatu River catchment, New Zealand: indications

- from oxidation-reduction conditions, hydrogeological factors, and implications for nutrient management. *Journal of Environmental Management* 197: 476–489.
<https://doi.org/10.1016/j.jenvman.2017.04.015>.
- Collins, S., Singh, R., Rivas, A., Palmer, A., Horne, D., Manderson, A., Roygard, J., Matthews, A. (2017) Transport and potential attenuation of nitrogen in shallow groundwaters in the lower Rangitikei catchment, New Zealand. *Journal of Contaminant Hydrology* 206: 55–66.
<https://doi.org/10.1016/j.jconhyd.2017.10.002>.
- Close, M.E., Abraham, P., Humphries, B., Lilburne, L., Cuthill, T., Wilson, S. (2016) Predicting groundwater redox status on a regional scale using linear discriminant analysis. *Journal of Contaminant Hydrology* 191: 19-32. DOI:10.1016/j.jconhyd.2016.04.006
- Goeller, B.C., Febria, C.M., Harding, J.S., McIntosh, A.R. (2016) Thinking beyond the bioreactor box: incorporating stream ecology into edge-of-field nitrate management. *Journal of Environmental Quality* 45:866-872. DOI: 10.2134/jeq2015.06.0325
- Clague, J. C., Stenger, R., Clough, T. J. (2015) Evaluation of the stable isotope signatures of nitrate to detect denitrification in a shallow groundwater system in New Zealand. *Agriculture, Ecosystems and Environment* 202:188-197. DOI: 10.1016/j.agee.2015.01.011
- Clague, J. C., Stenger, R., Clough, T. J. (2015) Denitrification in the shallow groundwater system of a lowland catchment: A laboratory study. *Catena* 131:109-118.
 DOI:10.1016/j.catena.2015.03.012
- Barkle, G.F., Stenger, R., Wöhling, T. (2014) Fate of urine nitrogen through a volcanic vadose zone. *Soil Research* 52 (7):658-670.
- Peterson, M.E., Curtin, D., Thomas, S., Clough, T.J., Meenken, E.D., 2013. Denitrification in vadose zone material amended with dissolved organic matter from topsoil and subsoil. *Soil Biology & Biochemistry* 61, 96–104. doi:10.1016/j.soilbio.2013.02.010
- Clague, J. C., Stenger, R., Clough, T. J. (2013) The impact of relict organic materials on the denitrification capacity in the unsaturated-saturated zone continuum of three volcanic profiles. *Journal of Environmental Quality* 42:145-154. DOI:10.2134/jeq2012.0239.
- Woodward, S. J. R., Stenger, R., Bidwell, V. J. (2013) Dynamic analysis of stream flow and water chemistry to infer subsurface water and nitrate fluxes in a lowland dairying catchment. *Journal of Hydrology* 505:299-311.
- Burbery, L.F.; Flintoft, M.; Close, M.E. (2013) Application of the re-circulating tracer well test method to determine nitrate reaction rates in shallow unconfined aquifers. *Journal of Contaminant Hydrology* 145C:1-9. DOI:10.1016/j.jconhyd.2012.11.006
- Thomas, S., Dann, R., Close, M. (2012) Nitrous oxide dynamics in a deep soil-alluvial gravel vadose zone following nitrate leaching. *Soil Science Society of America Journal* 76: 1333–1346.
<https://doi.org/10.2136/sssaj2011.0349>

Burbery, L.F. and Wang, F. (2010) A Re-Circulating Tracer Well-Test Method for Measuring Reaction Rates in Fast-Flowing Aquifers: Conceptual and Mathematical Model. *Journal of Hydrology* 382: 163-173.

Barkle, G.F., Schipper, L.A., Burgess, C.P., Painter, B.D.M. (2008) In situ mixing of organic matter in sand aquifers decreases hydraulic conductivity in denitrification walls. *Ground Water Monitoring and Bioremediation* 28 (1): 57–64. doi:10.1111/j.1745-6592.2007.00185.x.

Stenger, R., Barkle, G.F., Burgess, C., Wall, A., Clague, J. (2008) Low nitrate contamination of shallow groundwater in spite of intensive dairying: the effect of reducing conditions in the vadose zone – aquifer continuum. *Journal of Hydrology (NZ)* 47(1): 1-24.

Zaman, M., Nguyen, M.L., Gold, A.J., Groffman, P.M., Kellogg, D.Q., Wilcock, R.J., 2008. Nitrous oxide generation, denitrification, and nitrate removal in a seepage wetland intercepting surface and subsurface flows from a grazed dairy catchment. *Australian Journal of Soil Research* 46, 565–577. doi:10.1071/SR07217

Painter, B.D.M., and Milke, M.W. (2007). Comparison of factorial and scenario analysis methods for assessing uncertainty in the design of Permeable Reactive Barriers. *Ground Water Monitoring & Remediation Journal* 27 (3): 102-110.

Barkle, G., Clough, T., Stenger, R. (2007) Denitrification capacity in the vadose zone at three sites in the Lake Taupo catchment, New Zealand. *Australian Journal of Soil Research* 45:91-99.

Conference Proceedings Full Conference Paper – Refereed (Code 5-1-R):

Greer, G., Wilson, S. (2015). Groundwater denitrification - can we afford to ignore it? Contributed paper prepared for presentation at the 59th Australian Agricultural Resource Economics Society Annual Conference, Rotorua, NZ, February 2015.

Woodward, S. J. R., Stenger, R., Bidwell, V. J. (2011) Using a simple 2-D steady-state saturated flow and reactive transport model to elucidate denitrification patterns in a hillslope aquifer. *MODSIM 2011 – Proceedings of the International Congress on Modelling and Simulation*. 12-16 December 2011, Perth, Australia.

Conference Proceedings Full Conference Paper – Non Refereed (Code 5-1-NR):

Note: This selection focusses on easily accessible papers; all FLRC conference proceedings papers are freely available at: <http://flrc.massey.ac.nz/publications.html>.

- Barkle, G., Stenger, R., Clague, J., Rivas, A., and Moorhead, B. (2020). Understanding contaminant export pathways is prerequisite for implementing effective nutrient attenuation options. Nutrient Management in Farmed Landscapes: 33rd Annual FLRC Workshop: Nutrient Management in Farmed Landscapes. Occasional Report No. 33. 11-13 February 2020, Massey University, Palmerston North, 9 pages.
- Rivas, A., Barkle, G., Maxwell, B., Moorhead, B., Stenger, R., Schipper, L., Birgand, F., and Clague, J. (2020). Determining the spatial variability of nitrate removal in a woodchip bioreactor through high frequency monitoring at multiple locations. Nutrient Management in Farmed Landscapes: 33rd Annual FLRC Workshop: Nutrient Management in Farmed Landscapes. Occasional Report No. 33. 11-13 February 2020, Massey University, Palmerston North, 11 pages.
- Stenger, R., Rivas, A., Wilson, S., Friedel, M., Barkle, G., Clague, J., Wöhling, T., Moorhead, B., Lilburne, L., Eger, A., McDowell, R., Morgenstern, U., Fuller, R., Journeaux, P., and Kusabs, I. (2019). Critical Pathways Programme: unravelling sub-catchment scale nitrogen delivery to waterways. In: Nutrient loss mitigations for compliance in agriculture. (Eds L.D. Currie and C.L. Christensen). Occasional Report No. 32. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 8 pages.
- Collins, S.B., Singh, R., Rivas, A., Horne, D., and Roygard, J., (2019). Spatial and temporal variability of groundwater chemistry and redox conditions in an agricultural landscape. In: Nutrient loss mitigations for compliance in agriculture. (Eds L.D. Currie and C.L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 32. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 12 pages.
- Rivas, A., Barkle, G., Moorhead, B., Clague, J., and Stenger, R., (2019). Nitrate removal efficiency and secondary effects of a woodchip bioreactor for the treatment of agricultural drainage. In: Nutrient loss mitigations for compliance in agriculture. (Eds L.D. Currie and C.L. Christensen). Occasional Report No. 32. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 10 pages.
- Woodward, S.J.R., Stenger, R., (2017). Using monthly stream water quality data to quantify nitrate transfer pathways in three Waikato catchments. In: Currie, L.D., Hedley, M.J. (eds) Science and policy: nutrient management challenges for the next generation. <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 30, Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 9 pages.
- Barkle, G.F., Stenger, R., Moorhead, B., and McKelvey T., (2017). Export of Nitrogen and Phosphorus from artificially drained dairy pastures in the Hauraki Plains. In: Science and policy: nutrient management challenges for the next generation. (Eds L. D. Currie and M. J. Hedley).

- <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 12 pages.
- Singh, R., Elwan, A., Horne, D., Manderson, A., Patterson, M., Roygard, J., (2017). Predicting land-based nitrogen loads and attenuation in the Rangitikei River catchment – the model development. In: Science and policy: nutrient management challenges for the next generation. (Eds L. D. Currie and M. J. Hedley). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 13 pages.
- Collins, S., Singh, R., Rivas, A., Palmer, A., Horne, D., Roygard, J., and Matthews, A. (2016). Assessment of nitrogen flow pathways and its potential attenuation in shallow groundwaters in the Lower Rangitikei catchment. In: Integrated nutrient and water management for sustainable farming. L. D. Currie and R. Singh, eds. Occasional Report No. 29. Palmerston North, New Zealand: Fertilizer and Lime Research Centre, Massey University. 14 pages.
- Stenger, R. et al., (2016). Transfer Pathways Programme (TPP) – New Research To Determine Pathway-Specific Contaminant Transfers From The Land To Water Bodies. In: Integrated nutrient and water management for sustainable farming. (Eds L.D. Currie and R. Singh). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 6 pages.
- Canard H. (2015). The role of current and future groundwater research in collaborative management of water quality. In: *Moving farm systems to improved attenuation*. (Eds L.D. Currie and L.L. Burkitt). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 7 pages.
- Stenger, R., Clague, J., Woodward, S., Morgenstern, U., Clough, T. (2015). Multi-pronged approach to elucidate nitrate attenuation in shallow groundwater. In: *Moving farm systems to improved attenuation*. (Eds L.D. Currie and L.L. Burkitt). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 7 pages.
- Elwan, A., Singh, R., Horne, D., Roygard, J., Clothier, B. (2015) Nitrogen Attenuation Factor: Can it tell a story about the journey of nutrients in different subsurface environments? In: *Moving farm systems to improved attenuation*. (Eds L.D. Currie and L.L. Burkitt). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 12 pages.
- Rivas, A., Singh, R., Horne, D., Roygard, J., Matthews, A., Hedley, M. (2015) An Assessment of the Denitrification Potential in Shallow Groundwaters of the Manawatu River Catchment. In: *Moving farm systems to improved attenuation*. (Eds L.D. Currie and L.L. Burkitt). Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 15 pages
- Woodward, S.J.R., Stenger, R., Hill, R.B. (2014) Land-to-water transfer of nutrients: What knowledge can be gained by combined analysis of river water quality and flow records?. In: 21st Century

Watershed Technology Conference and Workshop, 3-6 November 2014, The University of Waikato, Hamilton, New Zealand.

- Barkle, G. and Stenger, R. (2014). Prerequisites for incorporating groundwater assimilative capacity as a legitimate treatment component of a land based waste treatment system. In: *Managing contaminants at a catchment scale – back to basics*. New Zealand Land Treatment Collective, Proceedings for the 2014 Annual Conference. P. 118-130.
- Stenger R, Clague, J., Woodward, S., Moorhead, B., Wilson, S., Shokri, A., Wöhling, Th and H Canard, (2014). Root zone losses are just the beginning. In: *Nutrient management for the farm, catchment and community*. (Eds L.D. Currie and C L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 27. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 8 pages
- Stenger, R., Woodward, S., Shokri, A., Hill, R. (2014). N and P concentration-discharge relationships across a range of Waikato catchments. In: *Nutrient management for the farm, catchment and community*. (Eds L.D. Currie and C L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 27. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 8 pages
- Rivas, A., Singh, R., Horne, D., Roygard, J., Matthews, A., and Hedley, M. (2014). Characterization of denitrification in the subsurface environment of the Manawatu River catchment, New Zealand. In Proceedings of the 21st Century Watershed Technology Conference and Workshop, The University of Waikato, Hamilton, New Zealand. DOI: 10.13031/wtcw.2014-029.
- Rivas, A., Singh, R., Bishop, P., Horne, D., Roygard, J., Hedley, M. (2014) Measuring denitrification in the subsurface environment of Manawatu River catchment. In: *Nutrient management for the farm, catchment and community*. (Eds L.D. Currie and C L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 27. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 13 pages
- Singh, R., Rivas, A., Espanto, P., Elwan, A., Horne, D.J., Matthews, A., Clothier, B. (2014). Assessment of transport and transformation of nitrogen in the subsurface environment of Manawatu River catchment – work in progress. In: *Nutrient Management for the Farm, Catchment and Community*. (Eds L.D. Currie and C L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Fertilizer and Lime Research Centre. Massey University, Palmerston North, New Zealand. 11 pages.
- Barkle, G. F., Stenger, R., Wöhling, Th., Moorhead, B., Wall, A., Clague, J. (2013) Fate of a dairy cow urine pulse in a layered volcanic vadose zone. In *Accurate and efficient use of nutrients on farms* (Eds L. D. Currie and C. L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No.26. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 15 pages
- Stenger, R., Clague, J., Woodward, S., Moorhead, B., Wilson, S., Shokri, A., Wöhling, Th., Canard, H. (2013) Denitrification – the key component of a groundwater system’s assimilative capacity for nitrate. In *Accurate and efficient use of nutrients on farms* (Eds L. D. Currie and C. L.

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- Woodward, S., Stenger, R., Bidwell, V. (2013) Using stream flow and chemistry data to estimate catchment scale groundwater and nitrate fluxes. In *Accurate and efficient use of nutrients on farms* (Eds L. D. Currie and C. L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No.26. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 15 pages
- Stenger, R., Clague, J. C., Woodward, S. J. R., Moorhead, B., Burberry, L., Canard, H. (2012) Groundwater assimilative capacity – an untapped opportunity for catchment-scale nitrogen management? In *Advanced Nutrient Management: Gains from the past – Goals for the future* (Eds L. D. Currie and C. L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No.25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 10 pages
- Stenger, R., Clague, J and Wall, A. (2009) Groundwater nitrate attenuation in a volcanic environment (Lake Taupo, New Zealand). *Proceedings of HydroEco 2009, Vienna, Austria, 20-23 April 2009*.
- Stenger, R., Barkle, G., Wall, A., and Clague, J. (2007) Low groundwater N contamination in spite of high land use intensity – the Toenepi dairying catchment experience. In *Designing sustainable farm: Critical aspects of soil and water management* (Eds L.D. Curry and L.J. Yates). Occasional Report No.20. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. pp 86-94.