Proposed
Hurunui and Waiau River Regional Plan

And Proposed Plan Change 3 to the Canterbury Natural Resources Regional Plan

Section 42A Report
September 2012

Potential of wetlands to reduce nutrient loads from the Lowry Peaks and St Leonards Drains

Prepared by

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Kaunihera Taiao ki Waitaha

1. Introduction

My name is Christopher Charles Tanner. I hold the degrees of Master of Science with honours and Doctor of Philosophy in Biological Sciences from the University of Waikato. I am a Principal Scientist with NIWA, the National Institute of Water and Atmospheric Research Ltd, based in Hamilton. I have worked as a scientist for NIWA since its inception, 20 years ago. Previously, I was employed for 10 years in similar positions in the Research Division of the Ministry of Agriculture and Fisheries, at Ruakura Research Centre in Hamilton.

1.1 I currently lead research programmes at NIWA on the effects of land-use intensification on water quality and on the restoration of wetland ecosystems, and take part in a range of applied research and consultancy related to the assessment and management of water quality. My specific expertise is on the functioning and sustainability of ecologically-based water treatment systems such as constructed wetlands. My PhD thesis (1994) dealt with treatment performance and growth of plants in constructed wetlands receiving agricultural wastewaters, and I have authored more than 50 scientific papers and book chapters on related subjects, and led or collaborated in the preparation of five practical guidelines relating to wetland treatment and associated vegetation management. I have designed, provided advice and reviewed performance and management for more than sixty wetland and pond treatment systems in a broad range of applications for government agencies, district and regional councils, consulting engineers, industry, commercial enterprises and NZAID.

1.2 I am a member of the International Water Association, including Regional Co-ordinator of the Specialist Group on the Use of Wetlands in Water Pollution Control. I am a member of Water New Zealand, the New Zealand Land Treatment Collective, and the New Zealand Freshwater Sciences Society. I have been on the Editorial Board of the international journal *Ecological Engineering* since 1999, including guest editing two special editions on use of wetlands for pollution management. Recently, I have been lead convener of 2 international workshops/symposia on Wetland Ecosystem Services in Agricultural Landscapes (2009 and 2011)[1,2].

1.3 Although this is a Council Hearing, I have read the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note dated 1 November 2011. I have complied with that Code when preparing my written statement of evidence and I agree to comply with it when I give any oral evidence.

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1 Cooperative NZ–USA research workshop (sponsored by MoRST, MFAT and USDA) on “Wetland ecosystem services in agricultural landscapes–comparing approaches in USA and New Zealand”, Society of Wetlands Scientists Annual Conference, Madison WI, USA. June 2009.

2 International Symposium (sponsored by the OECD Co-operative Research Programme) “Bringing Together Science and Policy to Protect and enhance Wetland Ecosystem Services in Agricultural Landscapes”, held in conjunction with the 15th IWA International Conference on Diffuse Pollution and Eutrophication and the 16th International Symposium on Health-Related Microbiology. Rotorua, New Zealand. Sept. 2011.

1.4 I confirm that this evidence is written within my area of expertise, except where otherwise stated, and that I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

1.5 The scope of my evidence relates to potential mitigation of the water quality impacts of irrigated agriculture using constructed wetlands. The potential application of wetlands to reduce nutrient loads from the Lowry Peaks and St Leonards Drains on the Amuri Plains is investigated, as an indication of what may be achievable in similar situations elsewhere in the region.

1.6 The literature or other material which I have used or relied upon in support of my opinions are described in a recent report to Canterbury Regional Council (CRC)[3]. The data on which I have relied include measurements (St Leonards[4]) or estimates (Lowry Peaks[5]) of discharge and water quality for the St Leonards Drain provided by CRC and water quality samples taken at the up- and down-stream ends of the Homestead Creek tributary by Anne-Mary Benton (Amuri Dairying) on 14 April 2011 under the supervision of a Justice of the Peace[6] and submitted to a reputable laboratory for analysis[7]. Approximate flows were estimated by eye for Homestead Creek and two other small spring-fed tributaries of St Leonards Drain in January 2011.

2. Content of the officer's report

2.1 This report is prepared under the provisions of section 42A of the Resource Management Act 1991 (RMA). Section 42A allows council officers to provide a report to the hearing commissioners on the proposed Hurunui and Waiau River Regional Plan and allows the commissioners to consider the report at the hearing.

3. Explanation of terms and coding used in the report

CRC	Canterbury Regional Council or Environment Canterbury (ECan)
DIN	Dissolved Inorganic Nitrogen
DRP	Dissolved Reactive Phosphorus
TP	Total Phosphorus

[3] Tanner, C.C. (2012). Potential of wetlands to reduce nutrient loads from Lowry Peaks and St Leonard's Drains before entry into the Waiau and Hurunui Rivers. NIWA Client Report HAM2012-015 for Canterbury Regional Council. Feb 2012. 38 p.

[4] Approximately 70 monthly flow gaugings and water quality samplings (Apr 2005-Oct 2011).

[5] Limited flow measurements and no water quality data were available for the Lowry Peaks Drain. Monthly daily flows for Lowry Peaks Drain were therefore estimated (Jeff Smith, CRC) based on coincident flow records for the Waiau River at Stanton, Cheddar Valley (CRC Hydrological site #64610) for the period June 1969 – Sept 2011. Although this gave a relatively high linear correlation coefficient (R^2 = 0.917, n=8) it is probably only reasonable as an indication of intermediate flows, as the factors governing high flow events are likely to differ markedly for the two sites.

[6] D.I. Addis, JP#8263, Culverden.

[7] Laboratory Report #888499, Hill's Laboratories, Hamilton.

4. Scope of Evidence

4.1 I have been asked by CRC to prepare evidence on the potential effectiveness of wetlands in reducing nutrients entering the main-stem of the Waiau and Hurunui Rivers from the Lowry Peaks and St Leonards Drains. The purpose of this assessment was to provide information on the wetland areas, vegetation types and locations, and associated construction costs and maintenance needs, required to reduce nutrient concentrations in the Lowry Peaks and St Leonards Drains to levels that would have minimal downstream impact.

4.2 Specifically, my evidence is based on a desk-top modelling assessment of potential treatment performance for 3 different wetland scenarios applicable to the the Lowry Peaks and St Leonards Drains:

a. Large bottom-of-catchment wetlands;

b. Small bottom-of-catchment wetlands; and

c. Wetlands targeting nitrate-rich spring-fed tributary streams and drains.

4.3 To familiarise myself with the area, I visited the site with CRC staff, Andrew Parrish and Dr Jeff Smith on 8 December 2011, and spoke on-site with local farmers, Wally Jamieson, Paul Hood and Andrew Benton. However, no geotechnical, flood risk, land ownership status or other information was readily available for the site, and therefore the potential wetland locations considered should be considered only as hypothetical scenarios for the purpose of preliminary evaluation.

5. Wetland treatment

5.1 Wetlands have been shown in numerous studies around the world to be capable of effectively removing nutrients and a wide range of other contaminants from polluted waters[8,9,10,11,12]. Results from these studies

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[8] Mitsch, W.J., Day, J.W., Zhang, L., Lane, R.R., 2005. Nitrate-nitrogen retention in wetlands in the Mississipi River Basin. Ecological Engineering 24, 267-278.

[9] Crumpton, W.G., Stenback, G.A., Miller, B.A., Helmers, M.J., 2006. Potential benefits of wetland filters for tile drainage systems: impact on nitrate loads to Mississippi River sub-basins. U.S. Department of Agriculture Project no. IOW06682, Iowa State University, Ames IA. http://www.fsa.usda.gov/Internet/FSA_File/fsa_final_report_crumpton_rhd.pdf (accessed 30 Dec 2011).

[10] O'Green, A.T., Budd, R., Gan, J., Maynard, J.J., Parikh, S.J., Dahlgren, R.A., 2010. Mitigating nonpoint source pollution in agriculture with constructed and restored wetlands. Advances in Agronomy 108, 1-76.

[11] Kadlec, R.H., 2012. Constructed marshes for nitrate removal. Critical Reviews in Environmental Science & Technology 42(9):934-1005 DOI:10.1080/10643389.2010.534711.

[12] Tanner, C.C., Sukias, J.P.S., 2011. Multi-year nutrient removal performance of three constructed wetlands intercepting drainage flows from intensively grazed pastures. Journal of Environmental Quality 40, 620-633.

[12] Tanner, C.C., Sukias, J.P.S., 2011. Multi-year nutrient removal performance of three constructed wetlands intercepting drainage flows from intensively grazed pastures. Journal of Environmental Quality 40, 620-633.

suggest that shallow surface-flow wetlands (Figure 1) vegetated with tall emergent plants such as raupo (*Typha orientalis*) are the most appropriate wetland type to consider for treatment of flows from the Lowry Peaks and St Leonards Drains, and other similar situations in agricultural catchments.

5.2 Surface-flow wetlands such as these can provide effective nitrate-N removal via microbial denitrification supplemented by plant uptake and accretion in sediments. Nitrate removal via denitrification is promoted by close contact with organic sediments and wetland plants that provide anoxic conditions and organic matter (decomposing plant litter) for denitrifying microbes. Generally the larger the wetland the better the treatment achieved, but with diminishing returns per unit area[13]. Nitrate removal performance is temperature sensitive, and will generally be poorer during winter than summer.

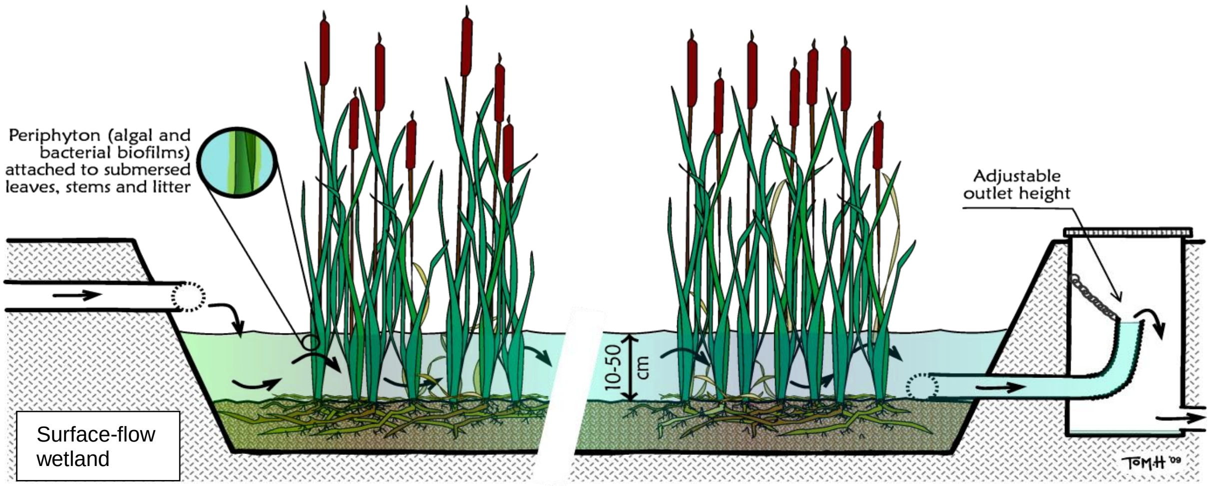

Figure 1: Cross section of a typical surface-flow constructed wetland. A range of alternative options are available to disperse inflows, collect outflows and maintain desired water levels

5.3 Wetlands can provide good removal of particulate-associated P, but generally only low levels of dissolved P removal. Particulate P removal occurs predominantly by settling, which is promoted in quiescent conditions such as occur in deep water and in areas within vegetated zones. Soluble P removal occurs via reversible soil sorption (which eventually becomes saturated) and uptake by bacterial biofilms, algae and macrophytes. Cycling through growth, death and decomposition returns much of the biotic uptake, but an important residual contributes to long-term accretion of P in newly formed sediments and soils. Dissolved P removal may be promoted by the use of P-sorbing media, including aluminium, iron and calcium-rich materials[14] , but such materials generally have a finite life, after which they must be replaced.

5.4 From a practical point of view, optimal wetland treatment conditions for both N and P removal are created through provision of wetland areas, depths and

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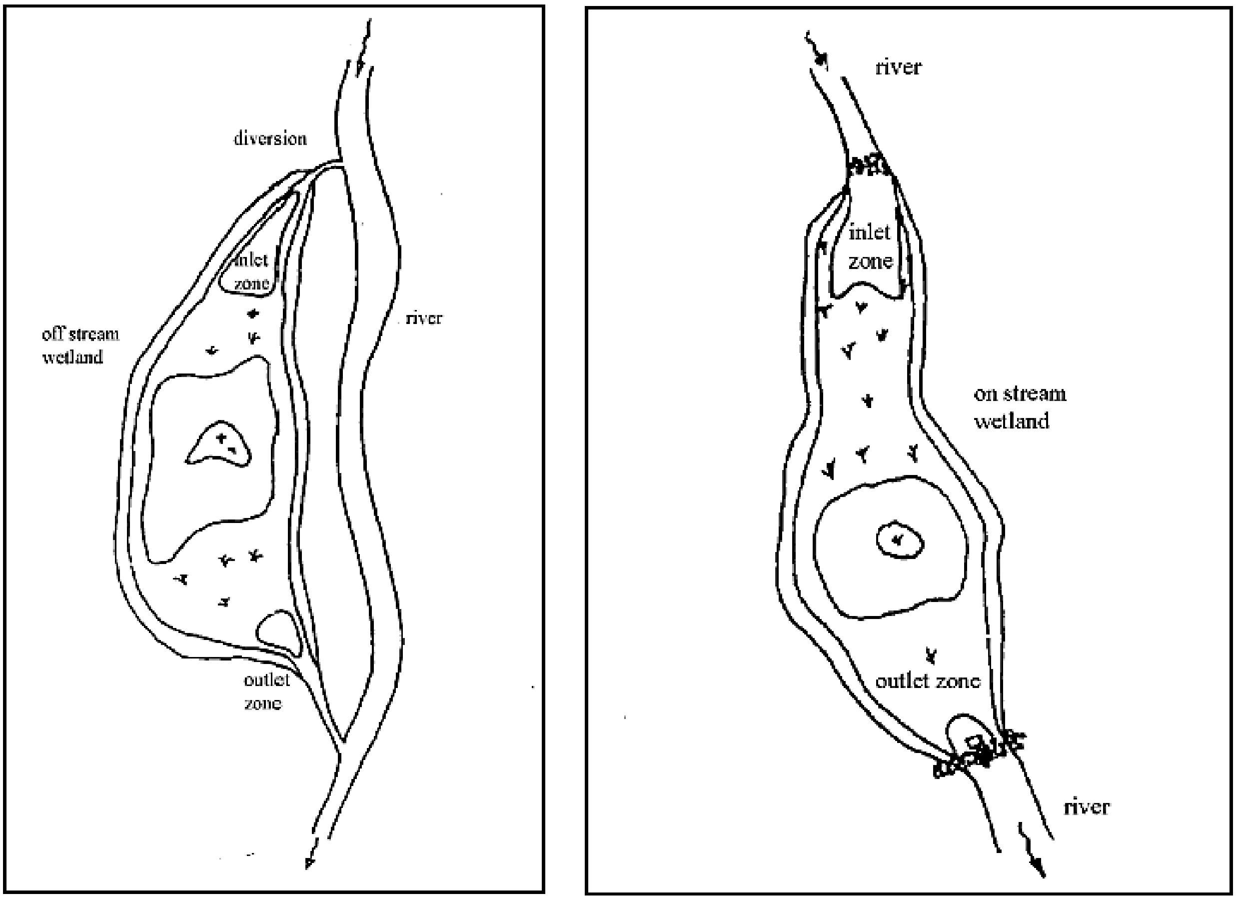
[13] Tanner, C.C.; Sukias, J.P.S.; Yates, C.R. (2010). New Zealand Guidelines for Constructed Wetland Treatment of Tile Drain Flows from Grazed Pasture. NIWA Information Series No. 75. NIWA, Hamilton, NZ. http://www.niwa.co.nz/our-science/freshwater/tools/tile-drain-wetland-guidelines

[14] Ballantine, D.J., Tanner, C.C., 2010. Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff: A review. New Zealand Journal of Agricultural Research 53, 71-95.

length to width ratios that provide sufficient wetland assimilative area, efficient hydraulic characteristics and conditions suitable for establishment of dense growths of desirable vegetation. For systems constructed to treat stream flows, provision must also be made for management of storm and low flows, siltation, and fish passage. Wetlands built off-stream (Fig 2) have significant advantages in this respect, because the original stream channel remains intact and can be used to convey a proportion of flood flows. However, off-stream wetlands are not always practically achievable, requiring provision for routing of flood-flows around (or through an armoured floodway within) the wetland. Wetlands receiving flood flows may require more frequent maintenance and specific rehabilitation after large flood events.



a. Off-stream wetland. b. On-stream wetland.

Figure 2 1: Comparison of (a) off-stream (in parallel) and (b) on-stream (in-channel) treatment wetlands[15]**.**

6. Methods

Wetland performance assessment

6.1 For preliminary assessment purposes, wetland nitrogen and phosphorus removal performance was assessed for surface-flow wetlands using a well-established first order kinetic modelling approach[16]. Mean nutrient removal

[15] Bendoricchio, G.; Cin, L.D.; Persson, J., (2000). Guidelines for free water surface wetland design. *EcoSys Bd. 8*: 51–91.

[16] Kadlec, R.H., Wallace, S., 2009. Treatment wetlands. CRC Press, Boca Raton, FL.

rates and temperature coefficients were derived from comprehensive reviews of available international and New Zealand data for constructed wetlands treating diffuse agricultural drainage[8,17,18].

6.2 As nitrate-N comprised the majority of Dissolved Inorganic N (DIN) measured in St Leonards Drain, its removal was assumed to be representative of overall DIN removal. In practice, there is likely to be some minor ammonium-N generation in the wetland as a result of mineralisation of organic-N released by decaying plants. This would likely contribute to the DIN load exiting the wetland, slightly reducing overall DIN reduction levels below those predicted here for nitrate-N.

6.3 To account for seasonal variation in nitrogen removal predictions were made for average annual (mean temperature, 12 °C), summer (95th percentile temperature, 16 °C) and winter (5th percentile temperature, 8 °C) water temperatures recorded for St Leonards Drain.

6.4 Phosphorus removal was assessed for Total P, rather than only the dissolved reactive forms (DRP) for which specific targets have been set. This was done because estimated wetland removal rates for TP are better established and more reliable than for DRP.

6.5 For preliminary assessment performance was predicted at median flow and the hydraulic efficiency of the wetlands was assumed to be equivalent to that of well-designed and vegetated surface-flow constructed wetlands. It should be noted, however, that different wetland systems show a range of performance depending on their specific flow and loading regime, design, age, vegetation type and cover, and local climate and site conditions[19].

<u>Wetland construction and maintenance cost assessment</u>

6.6 Costs for constructing wetlands have been estimated using the approach proposed by Kadlec and Wallace (2009)[20], calibrated for New Zealand conditions based on the inflation adjusted costs for construction of the Lake Okaro wetland in Rotorua[21,22]. They do not include any allowance for purchase or leasing of land. These cost estimates necessarily rely on broad

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[17] Reddy, K.R., Kadlec, R.H., Flaig, E., Gale, P.M., 1999. Phosphorus retention in streams and wetlands: a review. Critical Reviews in Environmental Science and Technology 29, 83-146.

[18] Tanner, C.C., Sukias, J.P.S., 2011. Multi-year nutrient removal performance of three constructed wetlands intercepting drainage flows from intensively grazed pastures. Journal of Environmental Quality 40, 620-633.

[19] Kadlec, R.H., 2012. Constructed marshes for nitrate removal. Critical Reviews in Environmental Science and Technology 42(9):934-1005 DOI:10.1080/10643389.2010.534711.

[20] Kadlec, R.H., Wallace, S., 2009. Treatment wetlands. CRC Press, Boca Raton, FL.

[21] Tanner, C.C., Caldwell, K., Ray, D., McIntosh, J., 2007. Constructing wetlands to treat nutrient-rich inflows to Lake Okaro, Rotorua. 5th South Pacific Stormwater Conference, Auckland, NZ.

[22] Hamill, K., MacGibbon, R., Turner, J., 2010. Wetland feasibility for nutrient reduction to Lake Rotorua. Opus International Consultants Report to Bay of Plenty Regional Council.

assumptions and should be considered only as “rough order” costs within ± 30% of expected costs. Cost estimates are shown in my Table 2.

Water quality targets for wetland treatment

6.7 The wetland treatment targets used for this assessment are based on water quality targets proposed by CRC[23]. They are a load reduction of 50% for Dissolved Inorganic Nitrogen (DIN; nitrate-N + nitrite-N + ammonium-N) and a load reduction of 25% for Dissolved Reactive Phosphorus (DRP) from current levels. As noted above, due to limitations in accurately predicting wetland DRP removal performance, we have for preliminary assessment purposes assumed a 25% reduction in TP will result in an equivalent reduction in DRP.

7. Results

Characteristics of the Lowry Peaks and St Leonards Drains

7.1 The Lowry Peaks and St Leonards Drains are situated on the Amuri Plains east of Culverden. Their catchments are estimated to be 9,868 and 6,525 ha respectively (Figures 3 and 4). The Lowry Peaks Drain flows northwards to the Waiau River and the St Leonards Drain flows southwards to the Pahau River, near its confluence with the Hurunui River.

7.2 The median flows estimated for both Lowry Peaks and St Leonards Drains are roughly similar at around 110,000 and 80,000 m^3 /d respectively. The flow record for St Leonards Drain, which is the most reliable, shows flow normally varying between about 60,000 and 170,000 m^3/d with a peak of just under 245,000 m^3/d. Because of irrigation activities in the catchment flows occur throughout the year without any clear seasonal pattern.

7.3 Water quality data was only available for the St Leonards Drain (Table 1) This was assumed to also be representative of water quality in the Lowry Peaks Drain. The drain outflows were generally well oxygenated and showed neutral to slightly alkaline pH and low turbidity, with median Total Suspended Solids (TSS) concentrations of 12 g/m^3. The drains showed moderate faecal bacterial contamination with median and 95 percentile *E.coli* levels of 375 and 1865 MPN/100 mls respectively. In terms of key nutrients, the median nitrate-N concentration was 3.1 g/m^3 and comprised the majority (99%) of the DIN measured in the drain flows. The median TP concentration was about 0.3 g/m^3 with 45% present in dissolved reactive forms (DRP).

7.4 Evidence provided by Andrew and Anne-Mary Benton of Amuri Dairying suggest that the small spring-fed streams such as Homestead Creek exhibit elevated nitrate-N concentrations (approximately double those in the main drains), but relatively low DRP and TP concentrations. Further flow and water quality sampling are warranted to verify this and better characterise these flows.

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[23] Kelly, D., 2011. Water quality data and suggested load reductions on St Leonards and Lowry Drain. Memorandum to Andrew Parrish , Environment Canterbury, Christchurch.

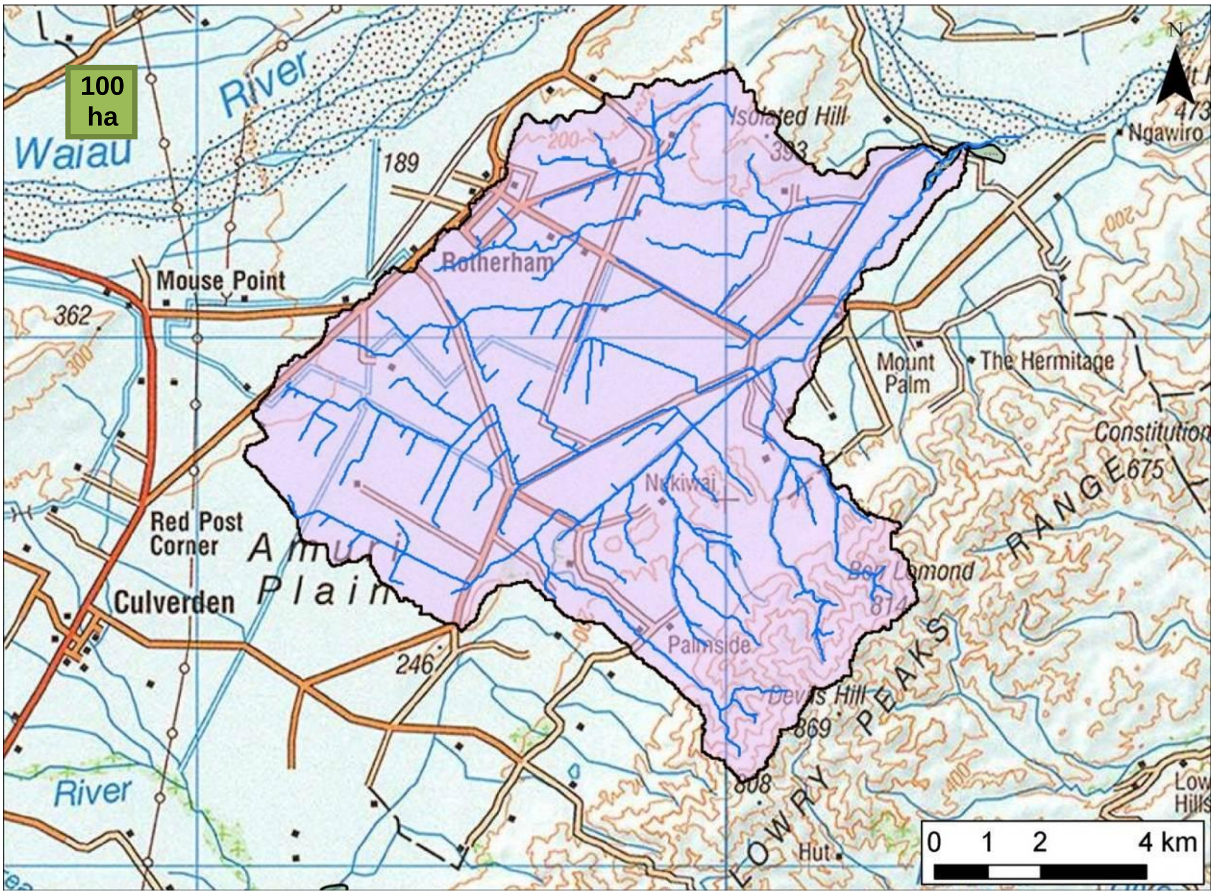

Figure 3: Map showing location of Lowry Peaks Drain and catchment. The surface catchment area is based on the NIWA River Environment Classification (REC). For comparative purposes, the green square in the top left hand corner of the map represents the relative area occupied by100 ha (1 km^2)

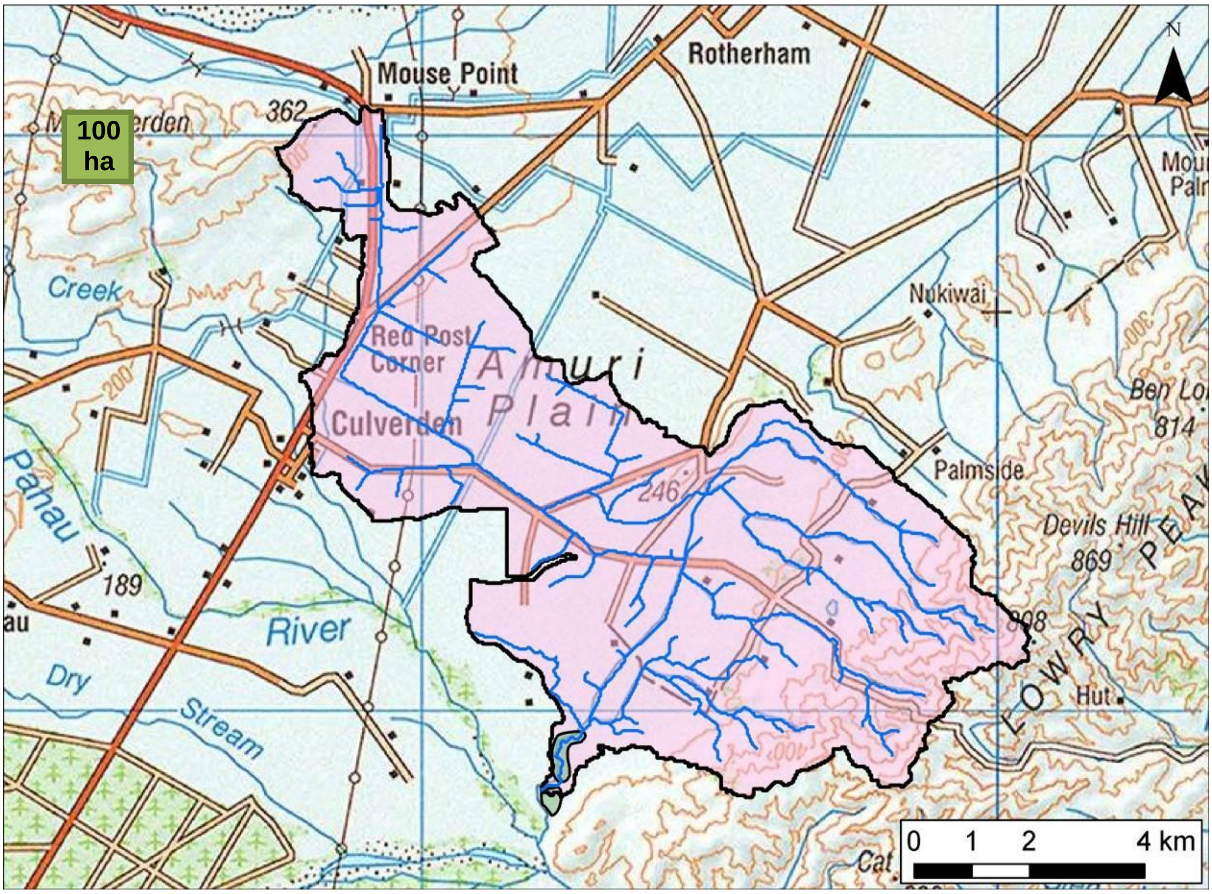

Figure 4: Map showing location of St Leonards Drain and catchment. The surface catchment area is based on the NIWA River Environment Classification (REC). For comparative purposes, the green square in the top left hand corner of the map represents the relative area occupied by100 ha (1 km^2)

Table 2: Summary of expected wetland construction and annual maintenance costs. "Rough order" estimates ± 30%.

	Construction costs				Annual maintenance costs	
Wetland area	Fully constructed wetland		Facilitated wetland			
(ha)	($K/ha)	$M	($K/ha)	$M	($/ha)	($)
2	314	0.6	157	0.3	214	428
10	191	1.9	95	1.0	130	1298
20	154	3.1	77	1.5	105	2094
50	116	5.8	58	2.9	79	3940
100	93	9.3	47	4.7	64	6357
200	75	15.1	38	7.5	51	10255

Table 1: Summary of water quality statistics for the St Leonards Drain. (Environment Canterbury data; April 2005 - October 2011).

Statistic	Ammonium -N*	Nitrate + Nitrite-N	Dissolved Inorganic-N	Total N	Dissolved Reactive P	Total P	Total Suspended Solids	Dissolved Oxygen Saturation	pH	Water Temperature	*E coli*
	g/m^3	g/m^3	g/m	g/m^3	g/m^3	g/m^3	g/m^3	%		°C	MPN/100mL
mean	0.018	3.29	3.31	3.6	0.015	0.038	16	92	7.6	12.0	564
median	0.016	3.10	3.13	3.3	0.013	0.029	12	90	7.6	11.9	375
maximum	0.090	6.50	6.55	7.2	0.065	0.240	120	119	8.1	16.7	2400
95%ile	0.033	4.70	4.72	5.2	0.042	0.090	41	107	8.0	16.0	1865
5%ile	0.004	2.26	2.28	2.5	0.004	0.012	5	80	7.2	8.0	43
n	73	73	73	73	70	73	74	74	74	74	70

*The limit of detection for ammonium-N was 0.005 g/m^3. The five data points reported as less than this limit were replaced by half the detection limit to facilitate statistical analysis

Wetland treatment performance and costs

Scenario 1: Large bottom-of-catchment wetlands.

7.5 At median flows and concentrations the Lowry Peaks and St Leonards Drains are estimated to currently export around 265 and 361 kg/d of nitrate-N, respectively, which corresponds to 97 and 132 tonnes N/yr.

7.6 To treat the full drain flows to meet the desired water quality targets for DIN (50% reduction) wetland areas in the range of 100-200 ha would be required. This would, respectively, correspond to about 1-2% of the surface catchment area of the Lowry Peaks Drain and 1.5-3% of the surface catchment area of the St Leonards Drain.

7.7 At median flow wetlands of around 200 ha are predicted to be able to provide long-term nitrate-N load reductions of 63% from the Lowry Peaks Drain and 53% from St Leonards Drain. This would remove about 166 and 191 kg N/d (61 and 70 tonnes N/yr), respectively, from these drain flows.

7.8 For 200 ha wetlands seasonal temperature variations are likely to cause nitrate-N load reduction at median flows to range seasonally between winter and summer from 52-73% at Lowry Peaks and 42-64% at St Leonards.

7.9 Wetlands of 200 ha wetlands are estimated to reduce TP loads from the Lowry Peaks and St Leonards Drains by ~17 and 14%, respectively, at median flows. This is below the target reduction of 25% sought.

7.10 The costs involved for constructing large wetlands of 100-200 ha are substantial, amounting to ~$9-15 M for fully constructed wetlands and ~$5-7.5 M for wetlands created by damming existing gullies and valleys ("facilitated" wetlands). Associated annual maintenance costs of ~$6,000-10,000/yr are expected for wetlands of 100-200 ha. Costs for a range of different sized wetlands are shown in Table 2.

Scenario 2: Smaller bottom-of-catchment wetlands

7.11 This option investigates the potential efficacy of one or two smaller wetland areas of 12-27 ha situated near the end of the main drains. These areas were identified during the site visit as areas potentially suitable for wetland construction. An example is shown for Lowry Peaks Drain (Figure 4), where "facilitated" wetlands would appear to be able to be readily formed within existing natural land-forms.

7.12 Even when combined, these smaller bottom-of-catchment wetlands are only predicted on average to reduce the median nitrate-N load from the main drains by ~15% and TP by 4%. This would result in removal of 41 and 54 kg/d of nitrate-N from the Lowry Peaks and St Leonards Drain discharges, respectively, at median flow and concentrations.

7.13 Wetlands of 20 ha in extent will likely cost about twice the price per ha compared to 200 ha wetlands, with overall costs of ~$3M and $1.5M, respectively, for fully constructed and facilitated situations.

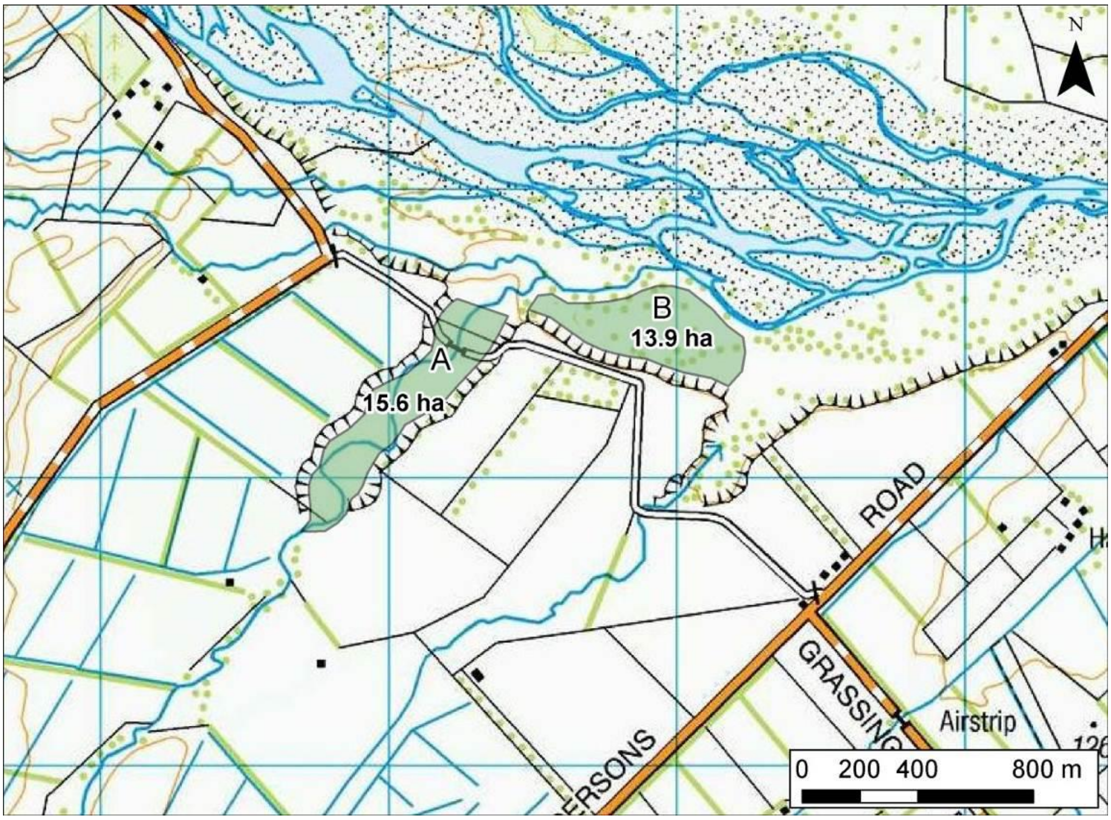

Figure 5: Example showing potential wetland areas at the end of Lowry Peaks Drain. Note the wetland areas shown (green shaded areas A and B) are hypothetical and are included only to provide an indication of the potential areas that may be amenable to wetland establishment. No geotechnical or engineering investigations have been made with respect to their potential suitability.

Scenario 3: Wetlands targeting nitrate-rich spring-fed creeks

7.14 A number of spring-fed tributaries were identified that flow into St Leonards Drain (see Figures 6 and 7). These small spring-fed creeks and drains were collectively estimated to be contributing about 20% of the median flow in the St Leonards Drain during our site visit in December 2011. Based on the limited water quality data available (an upstream and downstream sample from Homestead Creek collected on a single day), they were estimated to be contributing around 40% of the median DIN load of St Leonards Drain. This makes them potential “hot spots” to target wetland treatment.

7.15 Wetlands targeting the nitrate-rich spring-fed flows in Homestead Creek have the potential to remove a greater mass of nitrate-N per ha than those treating flows in the main drain (approximately double). Around 20 ha of wetland area would be needed to remove 50% of the loads carried by Homestead Creek (i.e., removal of 39 kg/d or 14 tonnes/yr), which would represent around 11% of the estimated median load of the St Leonards Drain.

7.16 These wetlands (~20 ha in extent) will have similar costs to the small bottom of catchment wetlands noted above (~$3M and $1.5M, respectively, for fully constructed and facilitated situations), but will provide greater efficiency in terms of mass removal of nitrate-N per ha of wetland.

7.17 Further investigations of these spring-fed inflows are warranted to properly evaluate the potential cost-effectiveness of such targeted wetland treatment.

Figure 6: Riparian areas associated with Homestead Creek. The existing stream valley could be readily developed into facilitated wetlands.

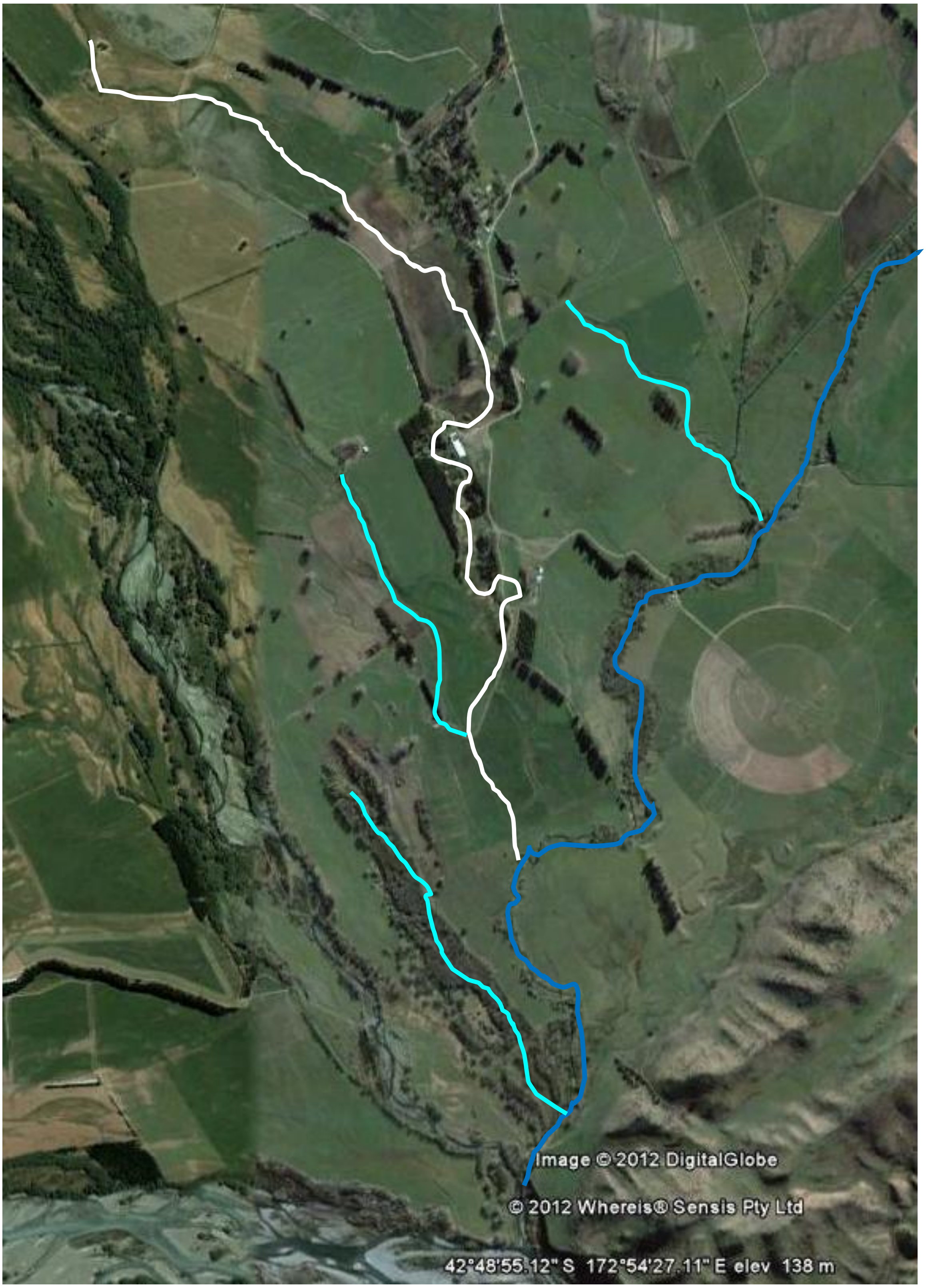

Figure 7**:** Location of Homestead Creek and other small spring-fed creeks that flow into the downstream section of St Leonards Drain. St Leonards Drain is shown in blue, Homestead Creek in white and other small spring fed streams in aqua. Locations are approximate, based on sketch map provided by Andrew Benton.

8. Conclusions

8.1 Wetlands are a potentially viable mitigation measure to reduce nutrient losses from irrigated agricultural landscapes. For the Lowry Peaks and St Leonards Drains, relatively large wetlands approaching 200 ha, comprising 2-3% of surface catchments, would be required to sustainably reduce dissolved inorganic nitrogen (DIN) loads by around 50% over an annual period. For 200 ha wetlands nitrogen removal performance during the warmer summer months would be expected to rise to 73 and 64%, respectively, for the Lowry Peaks and St Leonards Drains. Conversely during winter nitrogen removal would be expected to decline to 52 and 42% respectively for wetlands of this extent. Summer is the period when nutrient-related environmental impacts in downstream rivers are likely to be more prevalent due to lower and more stable summer flows (providing extended periods of periphyton biomass accrual) combined with longer daylight hours and higher temperatures (stimulating periphyton growth rates). Wetlands of 200 ha are predicted to reduce total phosphorus (TP) loads from these drains by 17 and 14%, respectively, for the Lowry Peaks and St Leonards Drains. This is less than the target sought of 25% reduction. This target could likely be achieved by addition of P-retentive materials either directly into the wetland sediments or as porous filter materials after the wetland. This would entail additional costs and require further investigation to identify the most cost-effective approach.

8.2 Wetlands of 100-200 ha are estimated to cost $9-15M to construct in the absence of facilitatory natural landscape features (i.e. fully constructed). Where natural landscape features are present that facilitate wetland construction (facilitated wetlands) costs are expected to be reduced by around half to $ 5-7.5M. These cost estimates do not include any allowance for land purchase or leasing costs. Associated annual maintenance costs are estimated to be in the range of $6-10K per year. Appropriately designed wetlands are likely to have a lifetime in excess of 30 years before significant refurbishment is necessary, so benefits and costs would be spread over an extended time period.

8.3 There is scope for construction of smaller wetlands that fit within natural features of the landscape. These could be sited close to the downstream end of the drains or used to specifically target small spring-fed inflows to the drains that contain elevated DIN concentrations. Wetlands of 10-20 ha in size placed near the outflow of the main drains would be able to reduce overall drain DIN loads by 5-10% respectively. Fully constructed wetlands of 10-20 ha are estimated to cost about $1.9-3.1 M and facilitated wetlands $1-1.5 M, respectively, with annual maintenance costs of $1.3-2 K per year. Wetlands targeting spring-fed tributaries containing roughly twice the concentration of DIN as the main drains (based on limited data available for Homestead Creek), would be able to remove around double the mass of DIN per unit area at a similar cost. Further monitoring of the flow and water quality of these spring-fed streams would be warranted to better evaluate the potential nutrient reductions able to be provided by wetlands targeting these flows.

8.4 In addition to removal of nutrients and other key contaminants such as suspended solids and faecal microbes, suitably designed wetlands could provide significant flow attenuation, and supplementary ecological, aesthetic and recreational benefits within this predominantly agricultural landscape. In particular, wetlands would enhance biodiversity and provide valuable habitat for water fowl, mahinga kai and other aquatic life. These wider ecosystem services should ideally be taken into account when considering the costs and benefits of wetland mitigation.

C Tanner

14 September 2012