Constructed Wetland Options in the Upper Waituna Catchment

Prepared for Dairy NZ

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Executive summary

An extensive range of potentially viable constructed wetland sites was identified in upper Waituna Creek catchment in the vicinity of Oteramika, suggesting wetlands would have wide applicability for interception and attenuation of nutrient and other pollutant losses.

Wetlands located in natural swales and gullies in mole and tile drained areas of the upper catchment are estimated to be able to intercept 60-90% of the surface and subsurface run-off from their subcatchments.

Constructed wetlands areas equivalent to 2-3% of the contributing catchments would be required to reduce annual nitrate-N losses by ~30-40%. The percentage nitrate-N removal would be highest for flows occurring in the warmer months. Suspended solids and particulate P loads would also be substantially reduced.

A major constraint is that many of the most feasible areas identified for wetland construction were former wetlands that have recently been drained – many in the last 5 years or less. Farmers are understandably less than keen to convert such areas back into wetlands.

Three potential wetland trial sites and a potential site for a wood-chip filter beds were identified and preliminary engineering design and costing was undertaken in association with John Scandrett.

Three of the wetlands were 0.2-0.4 ha in size, and likely to cost an estimated $32-64K to construct ($160-180 K/ha). An excellent site for a larger wetland of ~3 ha in size treating the losses from ~130 ha was estimated to cost ~$300K to construct (~$100K /ha). Based on these cost estimates the overall implementation costs per ha of farmed catchment for constructed wetlands would be in the order of $2K-5K, with costs lowest for medium to large-scale systems.

The proposed wood-chip filter is likely to be constructed this summer and its performance monitored as part of a DoC-Fonterra/DairyNZ/NIWA trial. This system treating a catchment of ~9ha was estimated to cost ~$17.8K or around $2K per ha of catchment mitigated.

The cost of constructing wetlands or alternatives such as wood-chip denitrification filters is relatively high, suggesting the potential value of maintaining and enhancing remaining natural wetland areas in the catchment.

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1 Brief

Dairy NZ contracted NIWA to undertake an assessment of potential sites for implementation and demonstration of constructed wetlands within the Waituna catchment to reduce nutrient and sediment flux to the Waituna lagoon. The specific services requested were:

1. Identify low-cost constructed wetland design options and locations in the upper Waituna Catchment.
2. Determine their feasibility in terms of engineering/construction costs and nutrient and sediment removal efficacy.
3. Provide an expert opinion on the suitability of wide-scale application of constructed wetlands to reduce catchment nutrient loads in the Waituna catchment, including key design criteria that need to be considered when identifying suitable locations and their likely efficacy rate.
4. Of the sites identified, recommend a suitable location and design for a subsequent constructed wetland pilot study.
5. Investigate and identify a suitable site for testing of a denitrification filter.

Key deliverables include:

- A written report summarising (a) the results of the field assessment, estimates of engineering costs and wetland efficacy for each site, (b) expert recommendations on the suitability of future wide-scale constructed wetland application in the Waituna catchment as well as considerations for site selection, design and treatment efficacy, (c) recommendations for a suitable location and design for a subsequent constructed wetland pilot study.
- The results of any third-party engineering assessments.
- Supporting photographs and maps.

2 Report outline

The project builds on a previous preliminary study done in association with Environment Southland and DairyNZ to identify locations and types of constructed wetlands that could be implemented in the Waituna catchment to intercept nutrients and sediments (Tanner et al. 2013a). The present study has involved a series of iterative site assessments to determine in more detail the most appropriate sites for implementation of wetlands in the upper catchment (an area identified to have high nitrate losses) and to identify specific sites for pilot-scale demonstration trials of constructed wetlands and a denitrification filter. We have focussed the main body of this report on addressing the broader feasibility of constructed wetlands in the catchment for contaminant attenuation, identification of suitable trial sites and estimation of associated construction costs. For completeness, detailed information from preliminary site assessments which informed the selection of these sites are included as appendices.

3 Feasibility of wetlands in the upper catchment

The upper Waituna catchment is a slightly to moderately undulating landscape dissected by natural swales and gullies feeding the upper tributaries of the Waituna Creek. The common placement of tile drains within or linking into these natural drainage channels provides multiple opportunities to integrate wetlands into the natural landscape. As an estimated 60-90% of run-off (including both subsurface drainage and episodic surface flows) is expected to be transported through these areas (Hughes et al. 2013), they also offer the potential to intercept a substantial proportion of nutrient losses from the catchment. The real challenge is to retrofit constructed wetlands into the current highly modified drainage network in a way that maintains upstream drainage function and is acceptable to farmers.

Over the years the main course and tributaries of the Waituna Creek have been extensively channelized, straightened and deepened. Mole and tile drainage networks have gradually been implemented across the landscape to overcome impeded drainage. Dairy conversions and intensification has more recently led to significant additional investment in drainage within the catchment, reducing areas of poor drainage and gradually whittling away at remnant wetland areas in the landscape. This intensification of drainage will cumulatively have considerably increased the rate of soil drainage, and deepened ground-water tables and channel bed depths across large areas of the landscape. In this landscape, creation of constructed wetlands requires excavation below the level of the drainage system to avoid impacts on the drainage of upslope land. Although this is practically achievable, it significantly increases the cost of wetland construction, particularly in low gradient areas.

A common issue we encountered during our investigations in the upper Waituna catchment was that farmers had recently spent substantial amounts of money draining the very areas where wetland construction was most feasible (see examples; Figure 3-1 and Figure 3-2). In many cases these had been the last and most difficult low-lying areas to drain and farmers understandably were reticent to see these hard-won areas converted back into wetland, and forego the expected payback on their investment. So, although it would still be practically feasible to build wetlands in these areas, there would likely be significant antipathy from farmers, creating a significant hurdle to future application of constructed wetlands in such areas across the catchment. We estimate that this may affect in the vicinity of half of all potential wetland sites in the areas of the upper Waituna Catchment where our investigations were focussed. This emphasises the need for early intervention before farmers have invested large sums of money into wetland drainage, as well as the need to foster greater awareness of the potential value of natural wetlands for contaminant attenuation of intercepted run-off. The cost of re-constructing such wetland areas is significant, as becomes evident below (see Section 5.3).

2003

2009

2013

Figure 3-1: Location 1: Example of recent wetland drainage in the upper Waituna Catchment. Prospective sites investigated for wetland construction during the current project are marked.

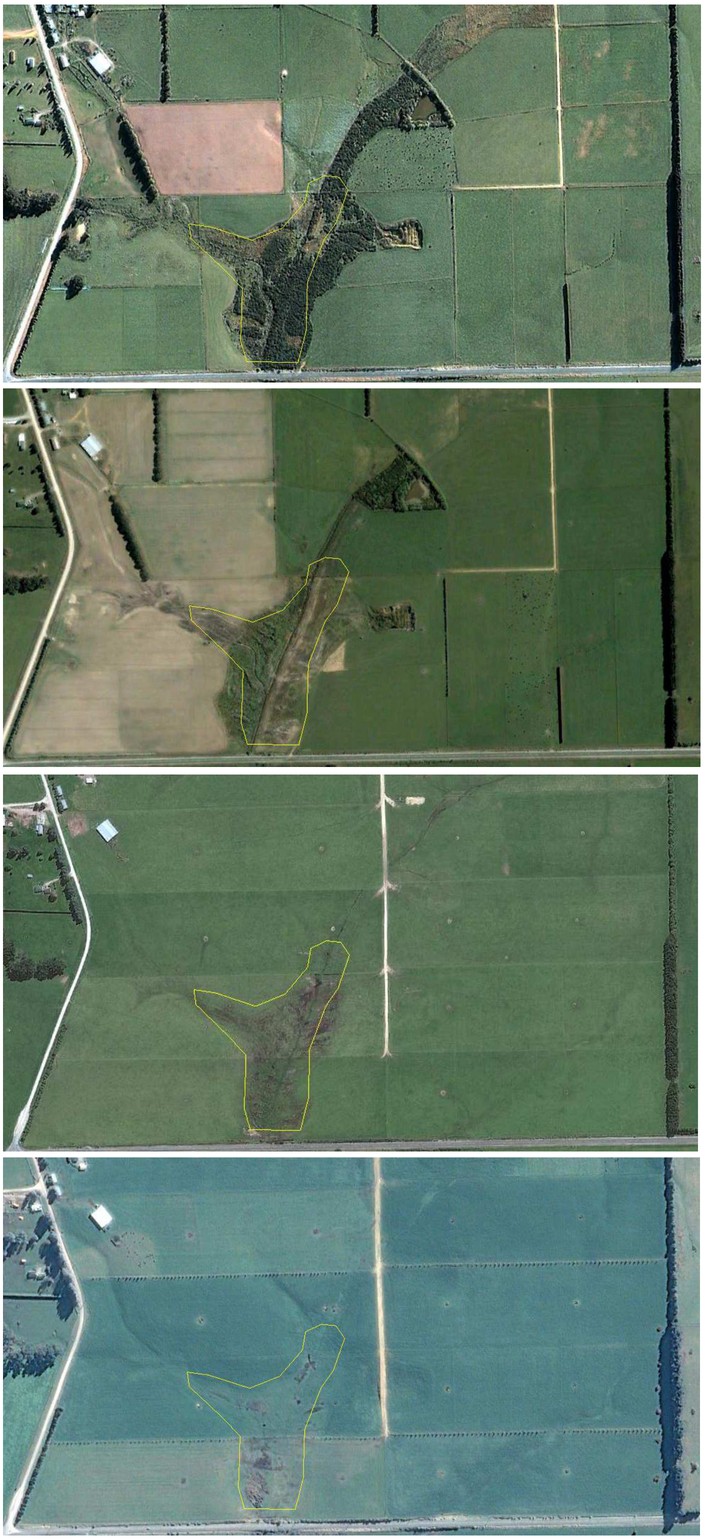

Figure 3-2: Location 2: Example of recent wetland drainage in the upper Waituna Catchment. Prospective sites for wetland construction investigated in the present study are marked. Various episodes of drainage works are visible in 2003 (not shown), 2004 and 2009 views.

4 Conceptual design for intercepting sub-surface drains while maintaining upstream drainage

Two different broad types of suitable constructed wetland locations have been previously identified (Tanner et al. 2013a):

1. Large-scale on-stream wetland in main stream channels, and
2. Smaller wetlands within the contributing catchment, that either:
   - A. Utilise or supplement existing farm ponds or gravel pits, or
   - B. Intercept natural flow channels (swales and gullies) and subsurface drains. In this region subsurface drains are often laid in natural drainage channels, so wetlands in these situations will therefore intercept both subsurface drainage and surface runoff.

This report focusses on type 2B and medium-scale type 1 wetlands. These are widely applicable across the catchment, with the former likely to the most appropriate scale to undertake an affordable demonstration trial in the catchment. One medium sized on-stream wetland is also evaluated. Farm ponds, often created for recreational duck shooting, are widely distributed across the landscape. Incorporation of wetlands into the outlet zones of these ponds or wetlands treating their discharge could provide additional treatment benefits. Environment Southland has set-up a demonstration wetland system in association with an existing duckpond within the catchment (type 2A). Further information on these other wetland options is available in Tanner et al. (2013a).

To maintain drainage function compatible with agricultural use in the surrounding land, partial or full excavation will generally be required at the wetland site to ensure that the land immediately upslope and surrounding the wetland is still able to drain effectively. On low gradient land substantial excavation is likely to be required to avoid constraints on drainage of upstream and surrounding farmland (Figure 4-1). As the gradient increases and natural swales and gullies constrain the lateral extent of inundation, there is greater potential for use of dams and bunds to impound flows and only partial excavation between the inflow and outflow levels is required to maintain the functioning of upstream land areas (Figure 4-2).

Excavation of a pond at the upstream end of constructed wetlands is recommended to trap coarse sediment deposits (that would otherwise gradually fill in the wetland) where they can be mechanically removed periodically. This can also provide habitat for waterfowl and associated recreational activities. The outflow structure should preferably be designed to retain flows and slowly release them, promoting creation of a reasonably permanent wetland.

In-stream wetlands need to be built to withstand major floods, and would likely require high flow diversion channels to maintain flow passage and limit damage to the wetlands. Ideal locations for wetland construction occur where there are constrictions in valleys (reducing the size and cost of any dams required and enabling anchoring of them into firm ground) and where land surrounding the flood plain rises relatively steeply to delimit the wetland margins.

Only in-stream options have been considered in the present study, but off-stream wetland options might be appropriate in some areas. They have the disadvantage that they would generally only intercept a proportion of the flow, and so receive and remove less contaminant(s), however they would help maintain fish passage in situations where there is valuable upstream fish habitat.

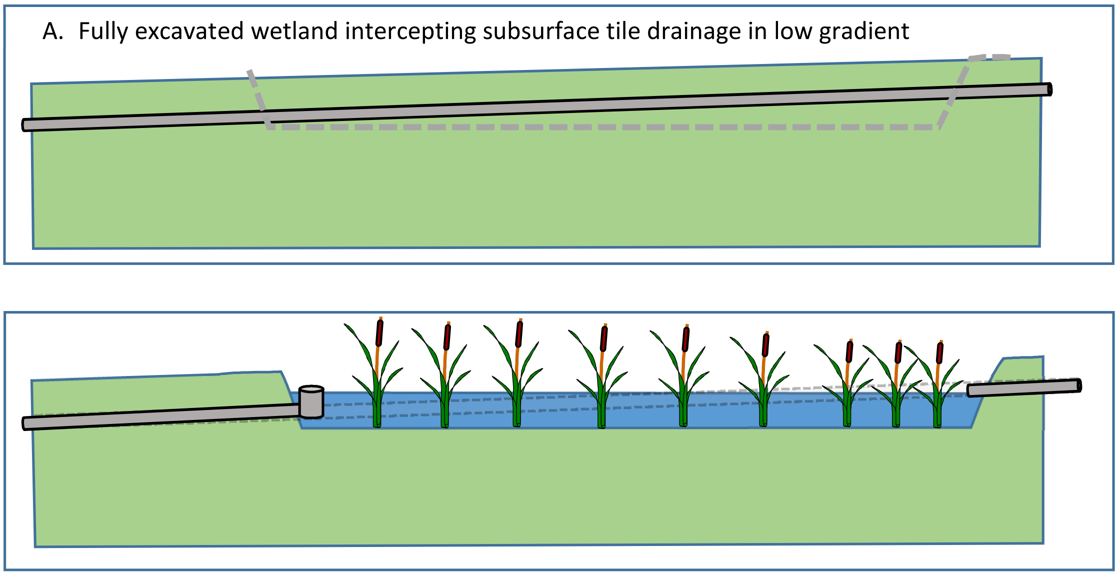

Figure 4-1: Illustration of wetland creation in low gradient, tile-drained situations. Note that to maintain the functioning of the upstream land areas the whole wetland needs to be excavated to below the upstream drain depth to maintain functioning of upstream drains.

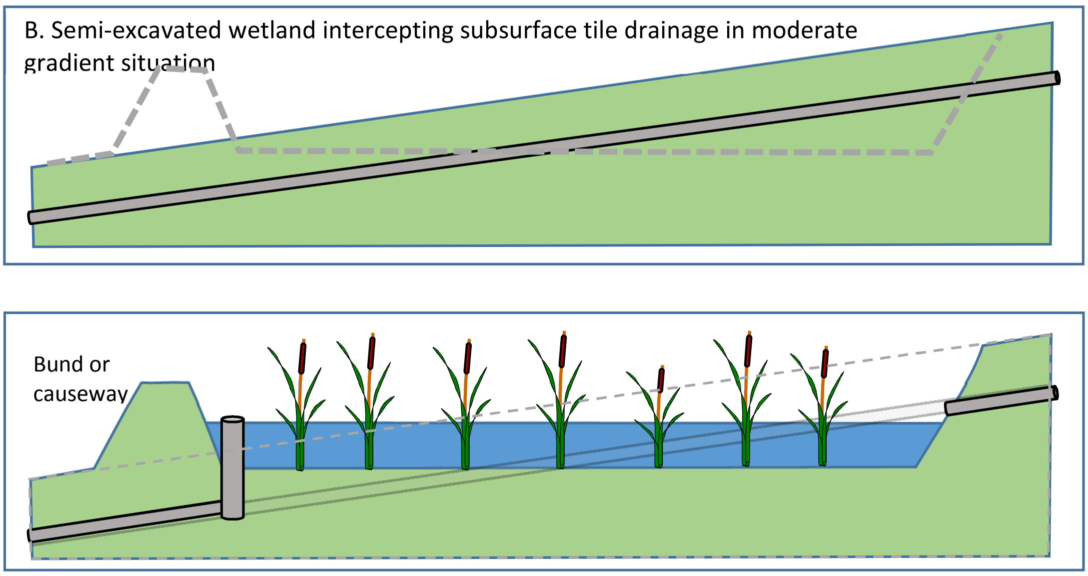

Figure 4-2: Illustration of wetland creation in moderate gradient, tile-drained situations. Note that in this case a bund can be used, reducing excavation requirements whilst maintain the drainage of upstream land.

5 Potential sites for wetlands intercepting sub-surface drains

5.1 Criteria

The following criteria were developed at the beginning of the assessment process to guide site investigations:

- Tile drain flows are the dominant flow path, expected to contribute 60-90% of run-off (Hughes et al. 2013).
- Tile drains commonly follow natural drainage channels, wetlands sited in these locations are also likely to intercept a high proportion of surface run-off during large events.
- Target areas expected to have high nitrate-N export. Use flow and drain nitrate concentration estimates from Tanner et al (2013).
- Wetland should occupy 2-3 % of catchment area, ideally utilising natural landscape features and lower value land to maximise cost:benefit (Tanner et al. 2013a).
- If we assume wetland construction costs in the order of $100K/ha and a construction budget of $25-30K, we should look for demonstration wetland area of around 0.25-0.3 ha, which translates to a catchment area of 10-12 ha (for wetland occupying 2.5% of catchment).

Sites also needed to be generally representative of and applicable across a significant area of the catchment, and be reasonably accessible, to facilitate demonstration of these mitigation options to other farmers. Additionally, the sites chosen needed to involve farmers receptive to trialling the concept of wetland attenuation and agreeable to use of their land for a demonstration trial.

5.2 Method

A six step method was used within the vicinity of Oteramika in the upper Waituna Creek catchment:

1. Initial satellite imagery search.
2. Check landowner willingness.
3. Desktop GIS analysis.
4. Site visits (9 sites).
5. Preliminary engineering assessment (6 sites).
6. Detailed feasibility, design and costing assessment (4 sites).

Google Earth satellite imagery was used to identify potential locations for wetlands. Prime wetland sites were commonly found along swale or gully systems that provided natural boundaries for wetland construction and ground levels below those of the surrounding pastures.

DairyNZ and/or Environment Southland staff spoke with the land owners involved and assessed whether they were prepared to be involved. For sites where general agreement to proceed was provided by the landowner, a desktop GIS analysis was done to gain further detailed information on the topography and contributing catchment areas.

Contributing flow networks and catchment areas were calculated in ArcGIS on Lidar elevation data (1 m^2 cell size) provided by Environment Southland. A network of convergent flow areas was delineated using output from the ArcGIS Flow Accumulation tool. The Flow Accumulation Tool generates a raster layer of the number of upslope cells that flow into each cell. By applying a threshold value (500 m^2) to the results of the Flow Accumulation Tool, a virtual stream network was delineated. Although, in reality, an actual stream may not exist in many places, an area of convergent flow will exist during rainfall events and subsurface drainage will typically either be connected to or follow these flow pathways. These inferred surface drainage networks, supplemented with farmer knowledge of farm drainage systems (where available), were then used to estimate catchment areas above the prospective wetland sites and calculate the appropriate wetland areas required. These were then compared with the apparent wetland areas that could be feasibly constructed within the natural landforms. Lidar maps showing elevation contours, supplemented by strategically located cross-sectional profiles, were used to characterise the natural landforms.

Nine general sites were initially identified and visited with Environment Southland and Dairy NZ staff in April 2014 (See Appendix A for further details). Following field assessment of these sites, six specific sites (including some new ones identified during site visits) were then short-listed for preliminary investigation by an experienced agricultural engineer. These were sites that could feasibly accommodate a wetland of the required wetland to catchment ratio of 2-3% and where possible involved lower value land. In particular we focussed on smaller sites suitable for a pilot-scale demonstration trial (See Appendix B for specific details).

The preliminary engineering assessments involved a visual assessment and GPS marking, supplemented by insertion of a metal rod into the soil to provide information on subsurface materials (e.g., presence and depth of peat, sand, gravel, clay, hard-pans etc.). Results of these preliminary engineering investigations (undertaken in May 2014) are summarised in Appendix C.

On the basis of this information, 4 wetland sites were prioritised for more detailed field assessment including preliminary engineering feasibility, design and costing (Table 5-1 and Appendix D). Additional costs to plant out the proposed wetlands were estimated and added to the construction costs to provide an overall mid-range cost estimate. All costings are based on preliminary field assessments by an experienced agricultural engineer with considerable local knowledge, however they should only be considered as “rough order” estimates within ± 30% of likely costs. Work rates (and concomittant costs) assume good weather and soil conditions for construction and do not make allowance for possible groundwater intrusion during construction. An allowance for engineering supervision appropriate to the scale and complexity of the proposed construction has been included, but no allowance is made for the cost of new fencing around the wetlands.

5.3 Selected trial sites and cost estimates

5.3.1 Three smaller wetland sites

Three adjacent wetland sites (31-33; Figure 5-1) ranging in size from just under 0.2 to 0.4 were subjected to further engineering assessment. Dimensions and estimated construction and planting costs are summarised in Table 5-1. Development costs for the three wetlands ranged from $32-64K each (~$160-170K per hectare), which would translate to $4.1-4.8K per ha of catchment mitigated. The two smaller wetland sites (31 and 33) provide sufficient area to construct wetlands comprising 2.5-2.8 % of their estimated drainage catchments. Site 32 had a larger catchment and only provided sufficient readily available area for construction of a wetland comprising 1.7% of its land area (below the ideal ratio for a trial). Because of the general lack of surface flows at these sites, fish passage is not expected to be a concern.

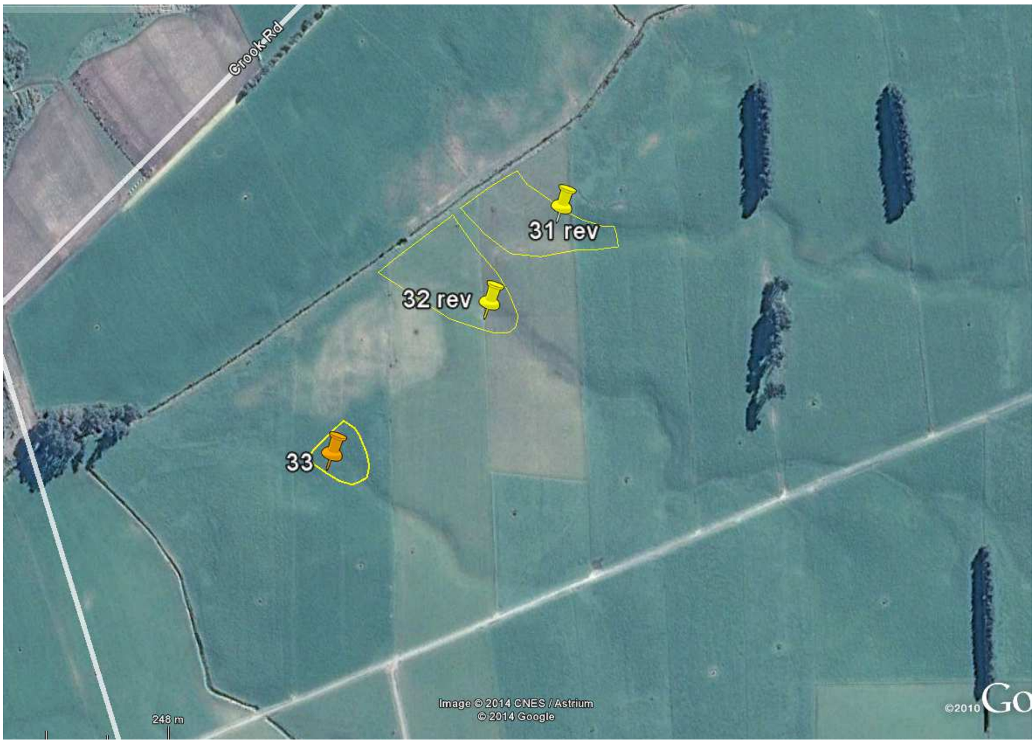

Figure 5-1: Three prospective small wetland trial sites. Sites 31-33 on the Anray Farm ranging in size from ~0.2 to 0.4 ha in size.

5.3.2 Medium in-stream wetland trial site

Site 21 to the north of Drake-Hill Rd offers an ideal site for construction of an elongated ~3ha wetland (Figure 5-2) which would comprise ~2.3% of its estimated 130 ha catchment area. The wetland proposed would require construction of 2 low dams across the existing relatively straight section of channel and adjacent flood-plain to occupy the base of valley (see cover photo). A wetland constructed at this site would occupy land in the base of the valley that appears to be of relatively lower agricultural value than the surrounding uplands. The open channel only continues ~250m further north of the proposed wetland to a culvert under Rimu Seaward Downs Rd. Above the culvert water flows predominantly through subsurface drains, suggesting limited fish habitat above the proposed wetland. Construction of a wetland at this site was estimated to be cheaper per hectare at just under $100K than the other sites investigated or around $300K in total (i.e., $2.3K/ha of catchment mitigated).

Figure 5-2: Prospective larger wetland trial site. A 3 ha wetland on Murray Clarke's farm comprising 2.3 % of catchment area at Site 21.

Table 5-1: Summary of final selected wetland sites and costings. Detailed geotechnical assessment of the sites has not been undertaken. The costs shown are rough order estimates ± 30% based on preliminary investigations of the site by an experienced agricultural engineer.

Site	Property	Site description	Wetland area ha)	Catchment area (ha)	% of catchment	Comments	Overall site assessment score (1-9)	Establishment costs ($K)					
								Construction	Design, supervision & administration	Planting	Total	Per hectare of wetland constructed	Per hectare of farm mitigated
33	Anray	South side of Creek, West of Kapuka North Rd	0.19	6.7	2.8	Better drained requiring care to seal wetland base	7	19.5	5	7.6	32	169	4.8
31	Anray	South side of Creek, West of Kapuka North Rd	0.32	12.4	2.6	Better drained requiring care to seal wetland base	7	33	5	12.8	51	159	4.1
32	Anray	South side of Creek, West of Kapuka North Rd	0.40	22.9	1.7	Insufficient suitable area harder to construct and seal than adjacent sites.	6	41	7	16	64	160	2.8
21	Murray Clarke	N of Drake-Hill Rd, and South of Rimu Seaward Downs Rd	3	129.5	2.3	Generally good site, Would need to allow for flood-flow passage	7.5	156	21	120	297	99	2.3

5.4 Wider applicability of wetland site assessment method

Our approach provides a practical means to identify potential wetland locations on farms in similar landscapes and soil types elsewhere in Southland. Google Earth satellite imagery or equivalent high resolution aerial photography provides a ready means to view the main drainage channels and swales across the landscape and initially identify potential locations for interception of flows and wetland construction. Lidar elevation data provides a basis to infer surface drainage networks to supplement farmer knowledge (where this is available) of farm drainage systems and determining where wetlands would most optimally be situated. Farm advisors and/or Regional Council Land Management Officers would potentially be able to assist farmers with generation of suitable maps from Lidar elevation data.

6 Denitrification filter

Denitrification filters are buried beds of woodchips (or other slow-release carbonaceous materials) constructed to intercept and filter nitrate-rich drainage (Schipper et al. 2010; Van Driel et al. 2006). In addition to supply of organic substrates, the beds must be maintained fully saturated to exclude oxygen and so promote microbial denitrification of dissolved nitrate-N to dinitrogen gas (and limit potential nitrous oxide production) (Warneke et al. 2011). Ideally some sort of weir system is required to divert flow from drainage lines into the bed and control the water level in the bed, whilst retaining the option of partial bypassing of excess flow (see Figure 6-1).

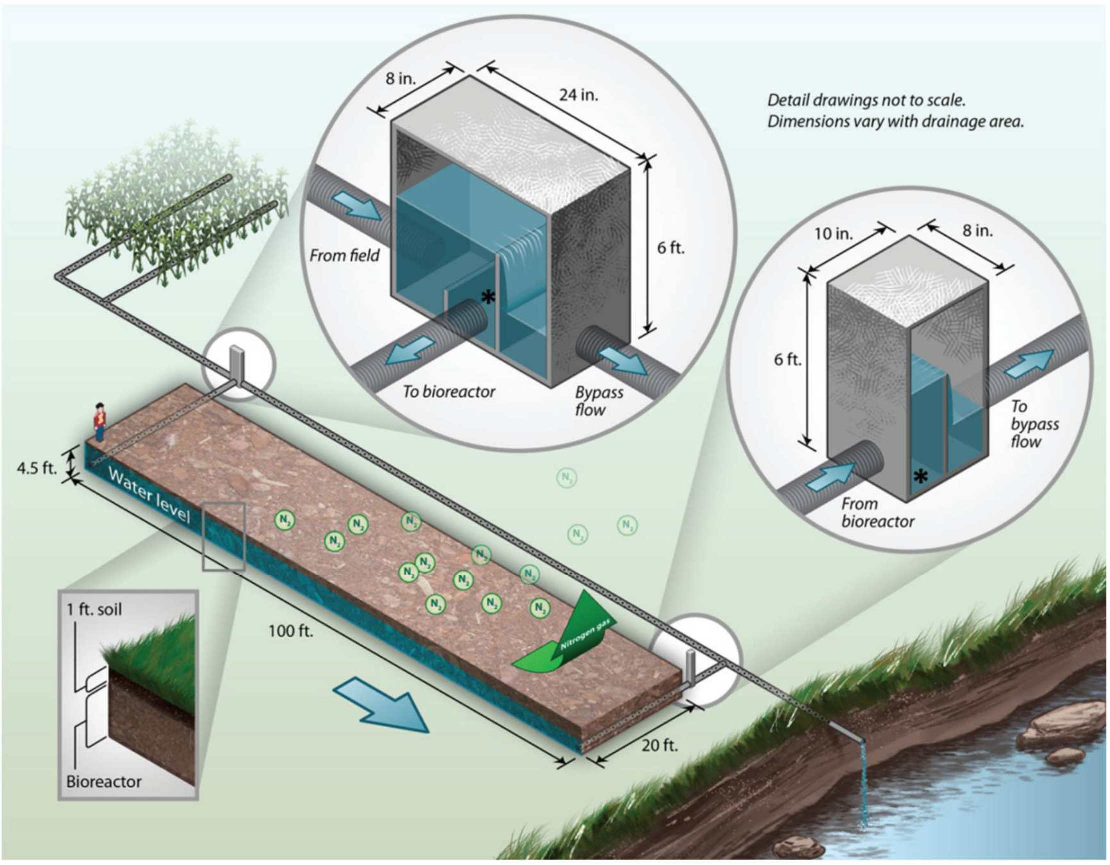

Figure 6-1: Basic concept for wood-chip denitrification filters. Diagram from (Christianson et al. 2012).

6.1 Criteria and method

We used the site selection method developed for the wetlands (see Section 5.2) with the following initial criteria developed at the beginning of the assessment:

- Focus on intercepting tile drain flows, excluding surface run-off with high TSS.
- Target areas with significant nitrate export. Use flow and drain nitrate concentration estimates from Tanner et al (2013).
- If using lined shipping containers (prelim estimate $5-6K delivered to site) set into ground and designed to capture 50% of mean winter nitrate load (flow and concentrations as used in previous NIWA Waituna wetland assessment report; (Tanner et al. 2013b).
- A 20 ft container (33.2 m^3) filled with woodchip could treat 3.1 ha drainage catchment, and
- A 40 ft container (67.6 m^3) could treat a 6.3 ha drainage catchment.
- Assuming woodchip available locally at $100/m^3 delivered to site and $1000-1500 for excavation etc., plus $1000 for pipework, lining and plumbing, capital cost = roughly $10,300 ($3,322 per ha of treated catchment) for 20 ft container, and $15,300 for 40 ft container ($2,429 per ha of treated catchment).
- If using excavated lined pits of 1 m depth (beneath drain level), would need 11 m^3 (and 11 m^2 of land) per ha of drained catchment. For 3.1 ha catchment estimate $3,410 for 33 m^3 of woodchip (plus 33 m^2 of land), $2430 for liner and plumbing (95.4 m^2 of liner @ $15/m^2 plus piping and plumbing of $1000), plus excavation costs of say $1000 = $6,840 ($2,206 per ha of treated catchment).
- A recent GNS report assessing the suitability of in-situ filters and bioreactors in Southland (Cameron et al. 2014) appears to calculate a similar volume of woodchips per ha for our assumed mean drain NO_3-N concentration of 3.2 g/m^3 (although based on a different set of assumptions about flows).
- Likely we would also need to allow for fencing to exclude livestock from surface of bed and possibly a cover to exclude rainfall?

6.2 Selected trial site and cost estimates

A site identified on the Pirie Farm (Pirie C; Figure 6-2) was investigated and deemed suitable for a denitrification filter demonstration trial. The basic layout for the proposed denitrification filter is shown in Figure 6-2. Before going ahead with construction of the filter at this site further monitoring is recommended to ensure that this drain is in fact a significant source of N export. A preliminary costing of ~ $7.3 K was estimated for construction of the denitrification filter excluding the cost of purchase and transport of suitable wood-chip media for the proposed 105 m^3 filter, which would treat subsurface drainage from a ~9 ha catchment. Based on our preliminary estimate of $100/m^3 for supply of woodchip material to the site this would add $10.5K to the cost, increasing the implementation cost to ~$17.8K or $1,978 per ha of catchment mitigated.

Figure 6-2: Proposed woodchip denitrification filter trial site Pirie C. Filter dimensions 5 m by 21 m x 1 m deep (105 m^3) receiving subsurface drainage from a 9 ha catchment.

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7 Acknowledgements

The success of this project has depended to a large extent upon the co-operation of farmers within the Waituna Catchment. This has been facilitated by the liaison undertaken by Environment Southland staff (James Dare and Katrina Robertson) and Dairy NZ staff (David Burger). We would like to thank all parties involved in this phase of the project.

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Appendix A Stage I. Initial sites and preliminary assessments

Initial sites visited on April 3-4 are shown below. These sites were identified on the basis of previous reconnaissance within the area and perusal of Google Earth satellite images. They were investigated for their potential for implementation of a constructed wetland or restored wetland areas, primarily for nutrient removal. In the upper catchment area, soils are more mineral in character, and thus tend to leak more nitrogen. In the lower catchment area, sites tend to be more organic/peaty, and thus tend to leach more phosphorus. Key deciding factor as to the appropriateness for any site in this early stage of assessment were:

1) Likely feasibility and cost of construction (related to total size of wetland and necessary earthworks), and

2) Percentage area of catchment occupied by the wetland. Ideal is around 2-3 %[1].

Extensive research within NZ (Tanner and Sukias 2011) and internationally (Kadlec 2012) have shown a strong relationship between treatment performance and wetland size relative to the contributing catchment. Larger wetland areas achieve better performance with regard to nutrient removal. However, pragmatically wetlands within the range of 2-3 % of catchment are generally considered to provide the ideal balance between cost and performance for most New Zealand pastoral dairy farming areas. Practical guidance on constructed wetland construction and expected performance relative to wetland size for farm tile drainage are provided in Tanner et al. (2010)

Sites which are too large will exceed the budget for this project. Sites which are too small a percent of the catchment will be less effective, thus less suitable as a demonstration site. The table below shows total wetland and catchment areas as well as percentage of catchment.

Initial site locations are shown in Figure A-1 and assessments are shown in Table A-1Table A-1.

Table A-1: Stage I: Potential sites for investigation

Site	Wetland area (ha)	Catchment area (ha)	% of catchment	Site suitability score
4	0.13	11.1	1.2	4
6	0.72	153.0	0.5	
13	2.02	53.4	3.8	2
13b	0.25	38.4	0.7	
21	3.0	129.5	2.3	1
26	0.8	240.3	0.3	
22b (Clinton)	3.06	100.5	3.0	5
28	0.05	2.1	2.4	3
29	1.5	242.0	0.6	6

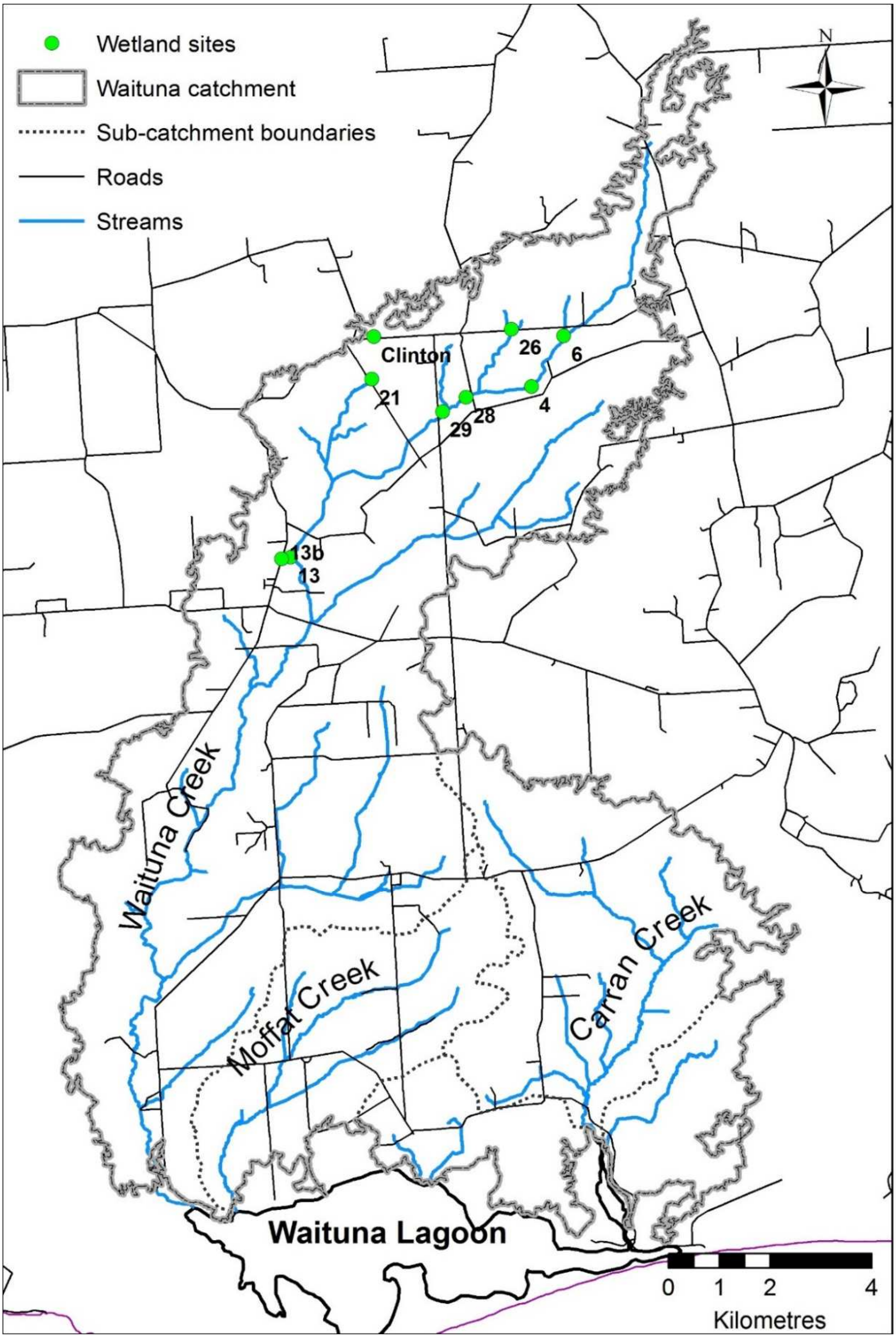

Figure A-1: Site locations (initial assessment).

Potentially suitable sites

Site 22b (Clinton farm)

The catchment above the wetland area was ~80 ha. A bund across the valley would be required to form a wetland. Agricultural contractor frequently used by Environment Southland, Joe Chisholm, suggested costs to excavate/reform a wetland here in the order of ~$130K, with a proviso in all instances that this is a very preliminary estimate, and requires on site assessment and test pits dug to give a more definite price.

Figure A-2: Potential wetland location on farm site 22b.

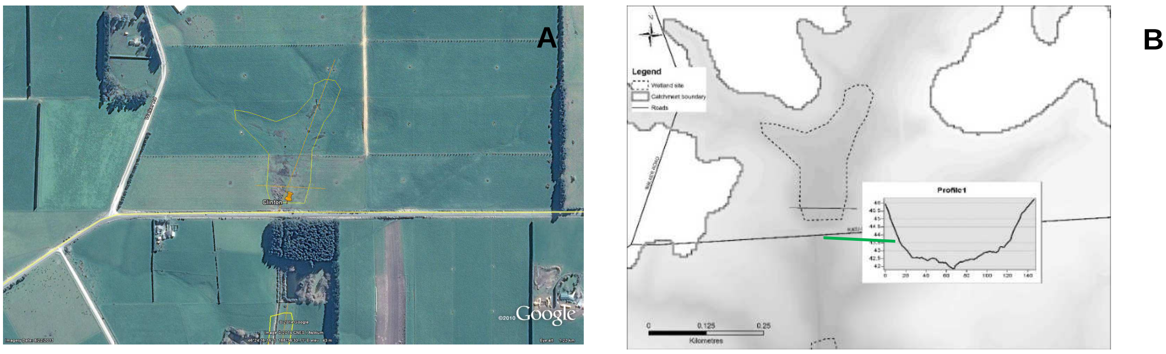

Figure A-3: Site 22b. A. Satellite photo of site. B. LiDAR contours and cross-section. Potential bund shown in green with cross-section of contours shown.

Site 13

Site 13 (100m N of Mokotua Garage) has a large area of scrubby land which could potentially be utilised as a wetland (at the time of the visit, the potential value of this was not as apparent, so no photos directly of the site). Potential for south and north drains emerging from catchments on other side of the road to be routed into this area. Likely to require a mix of bunding and excavation. Careful on-site assessment will be required.

Figure A-4: Looking west from road. Main drain emerging from culvert under road, with potential wetland area 13 just visible on the far left of the photo.

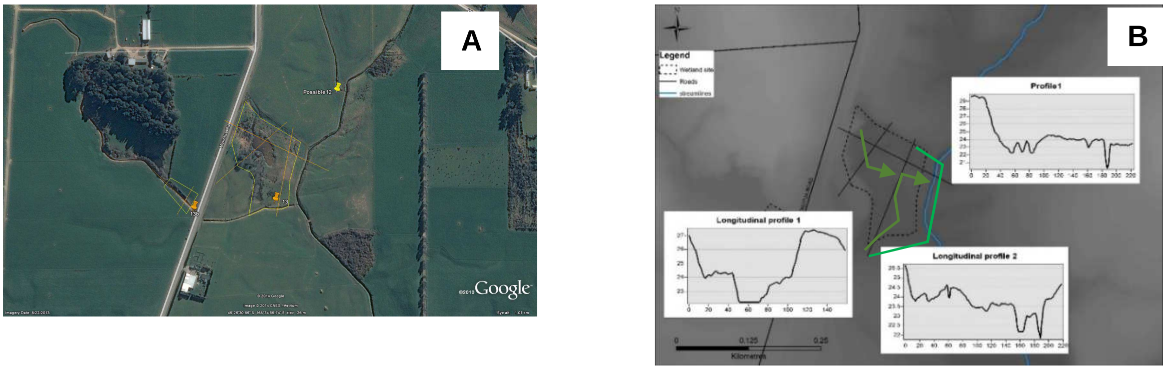

Figure A-5: A. Satellite photo of site. B. LiDAR contours. Potential wetland shown with dashed line, and bund shown in green. Flow paths shown in orange. The distance along Longitudinal profile 2 (from wetland border area to wetland border area).

Site 28 (Red tussock sites)

The patches of red tussock are mostly “toe-slope” seepage areas with little potentially for further development. A potential area for a wetland was a valley swale coming down between remnant red tussock patches. This was a reasonably well-developed pasture area, so may not be ideal from farmer point of view. However its small size and facilitative landscape features would potentially provide a good site for cost-effective small-scale trial. Note, historical Google Earth imagery shows a small pond/dam which is no longer present. The tussock patches are remnants which at times appear to have undergone significant periods of grazing as they appear absent from some past images.

Wetland could be created by 1-2 m high dam across mouth of swale and partial excavation further up into valley.

Figure A-6: Patch of red tussock.

Figure A-7: A. Red tussock site. B. view looking up swale which is a potential wetland impoundment site.

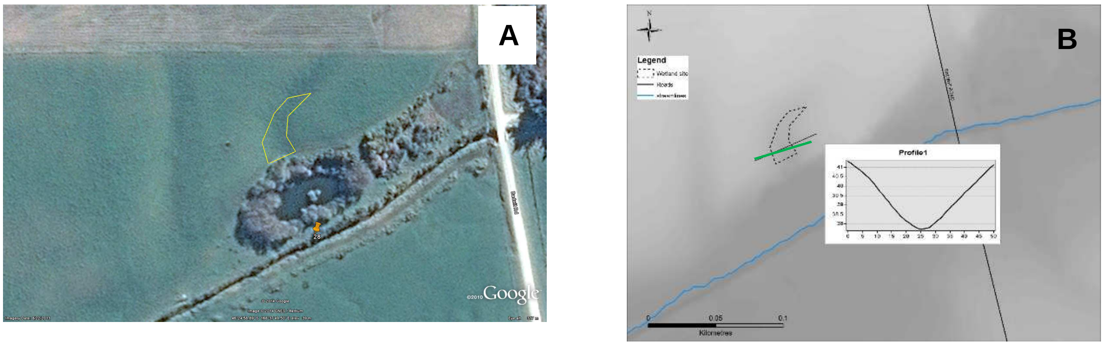

Figure A-8: A. Satellite photo of site. B. LiDAR contours. Potential bund shown in green. Bund may need to be >2.5m.

Site 21

Long straight surface drain (maintained by ES) with side swales (with subsurface drains), sited inside a fence along the drain. Paddock on true left side quite rough, less so on other side. Potential lower bund shown in green and proposed wetland area shown by dashed line. Likely to require 2-3 bunds and significant excavation on either side to form shallow wetland and allow for unimpeded drainage from side drains and along main drain.

Joe Chisholm estimated ~$130K to build such a wetland at this site.

Figure A-9: Site 21 looking upstream from Drakes Hill Rd. Potential wetland location shown along stream banks.

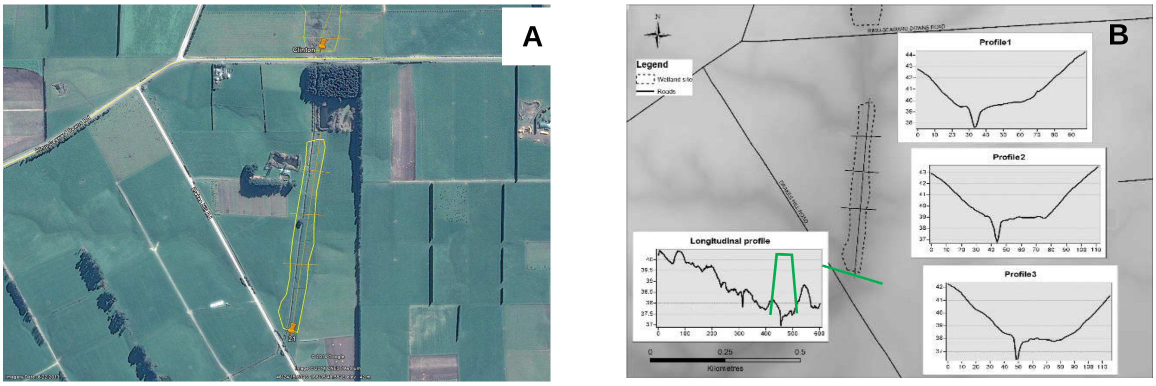

Figure A-10: Site 21 A. Satellite photo of site. B. LiDAR contours and cross-sections. Potential bund shown in green.

If bund is 2.5m high, and water 2m behind bund, water will extend back to about the point of profile 2. Therefore may require second bund at about this point.

Site 4

Duck Pond on Botting Farm, which appears to be perched above and not connected to surface drain inflows. Uncertain where flow into pond is coming from. Likely tile drains extend down adjacent valley beside pond area and discharges to Waituna Creek. Ideally wetland intercepting this drain would need to be twice the size indicated in Figure A-12 A to provide the desired wetland to catchment ratio. Would require significant excavation down to intercept tile and form wetland that does not impede drainage of surrounding land. May require 2 tier wetland up into valley. There is only potential to treat the first arm, but pond may be doing reasonable job anyway, if it is connected with the main flow.

Figure A-11: Site 4 photos. A-C. Pond and surrounds. D. Potential wetland area.

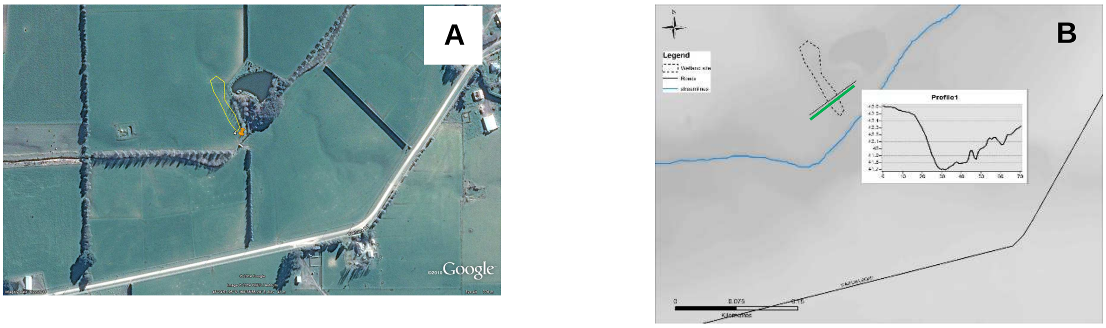

Figure A-12: Site 4. A. Satellite photo of potential wetland site. B. LiDAR contours. Potential bund shown in green.

Site 6

Site 6 had a catchment of ~187 ha. The site included an old gravel pit. The stream has two major arms that connect immediately below pit. Upstream N loads appear low. Some recent drainage work was apparent. Ability to direct flows from drain into pit area would require more extensive excavation than at present as pit not down into groundwater.

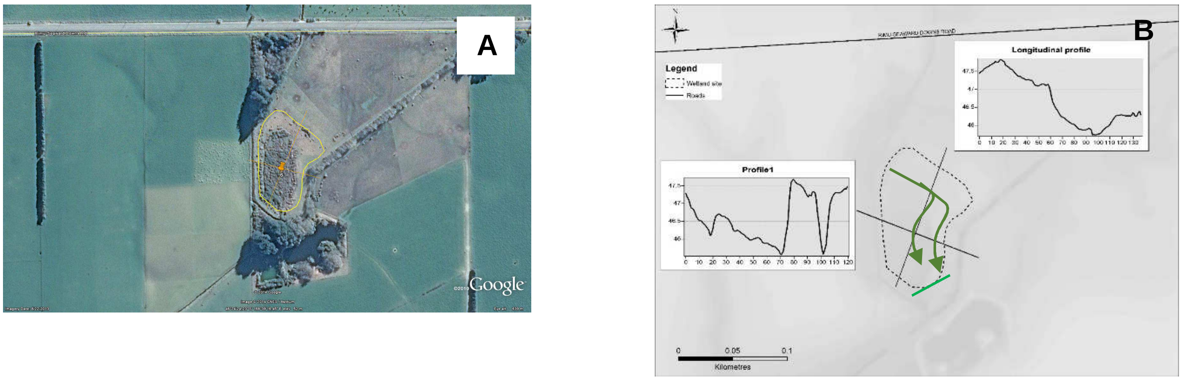

Figure A-13: Site 4. A. Satellite photo of potential wetland site. B. LiDAR contours. Potential bund site shown in green. Excavation of site would be required to induce flow distribution with sinuous path as shown in orange.

Figure A-14: Site 6 photos. Showing stream along edge of site, recent subsurface drain installation and general site layout.

Non-suitable sites

Sites in this section were visited, but were considered not suitable at the time of the assessment under the criteria outlined at the beginning of this section.

Site 26 (Additional 1)

Unsure of owner. Scrub area identified by James Dare. Seems to be a pond there. The area to the left of the photo (Figure A-15) which contains a pond (Figure A-16) appears perched above the stream level and thus not suitable to link this as a pond/wetland.

Figure A-15: Photo of Site 26 showing scrub area alongside stream.

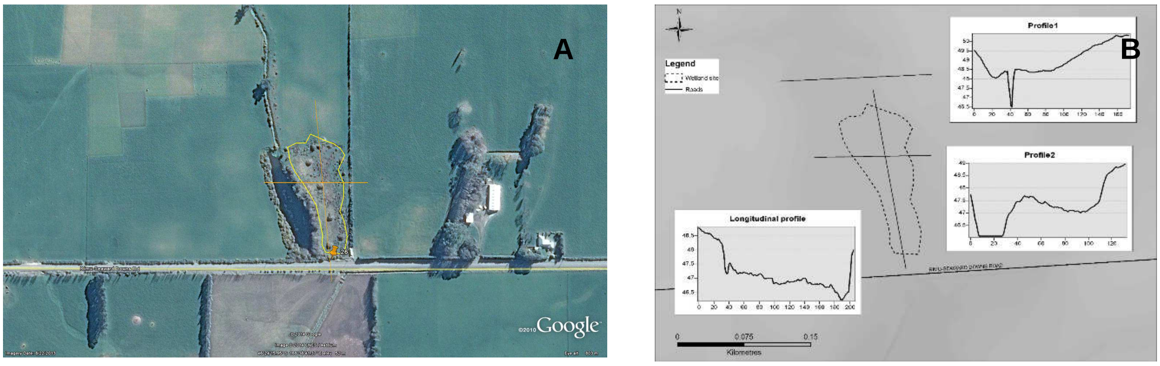

Figure A-16: Site 26 A. Satellite image of potential site. B. LiDAR contours and cross-sections.

Site 29

This site was not directly viewed. Like the tussock sites at Site 28, these appear to be toe-slope seepage areas, and thus not easy to impound. As can be seen from the profiles below, any bund would need to pass along the eastern edge (distance >460 m) of the wet areas and then up the sides They may still be performing a useful nutrient control function for the water passing through them.

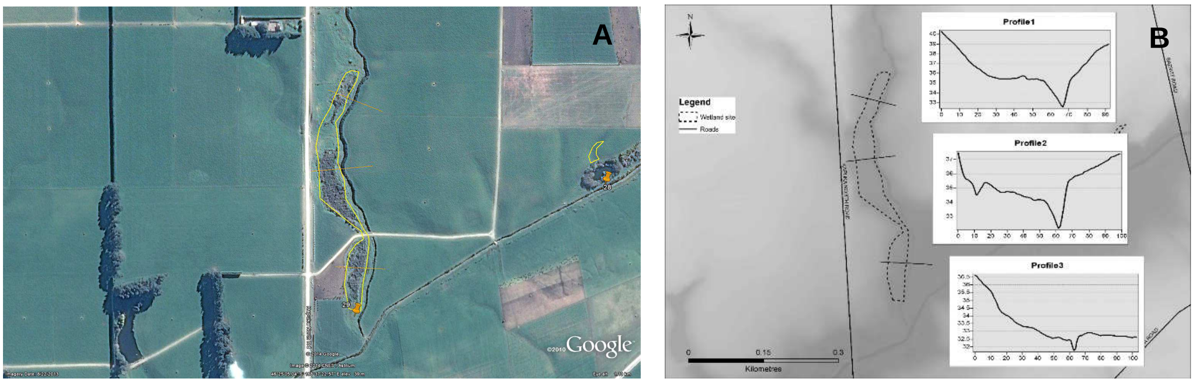

Figure A-17: Site 29. A. Satellite image of potential site. B. LiDAR contours and cross-sections. Toe-slope wetland areas alongside stream.

Site 13b

This site is across the road from Site 13. Slope is better with less apparent unintentionally affected areas of drainage. The catchment on this site is much larger than was apparent at the time of the visit, thus any single wetland will be too small. A series of smaller wetlands may be an acceptable solution, but would require up to 3 bunds.

Figure A-18: Photo of Site 13b looking upstream.

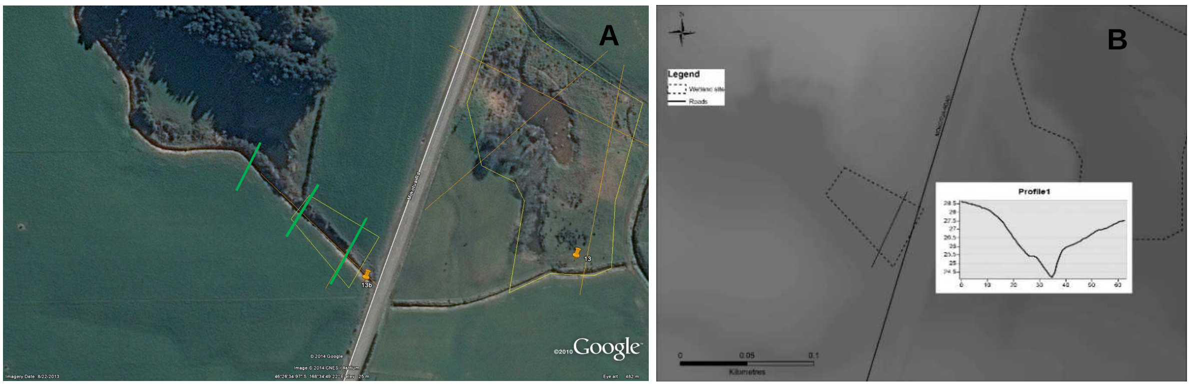

Figure A-19: Site 13b. A. Satellite image of potential CW site. B. LiDAR contours and cross-sections. Note potential bund sites.

Due to the "good" slope on this site, it may be necessary to include a series of small wetlands along the length of the drain rather than a single bund/wetland in order to achieve an appropriate ratio of % area of catchment treated.

Site 23

Gorse slope site neighbor of Warnocks. Toe of slope with little potential to achieve more than at present.

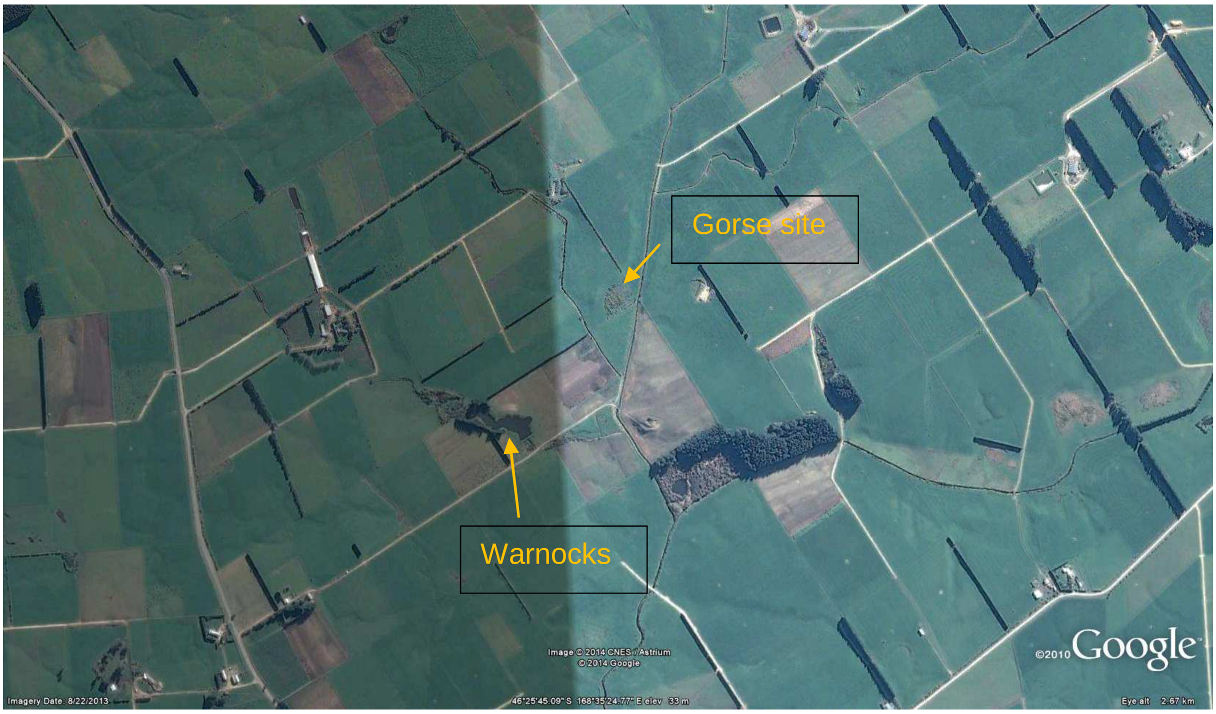

Figure A-20: Satellite image of Site 23.

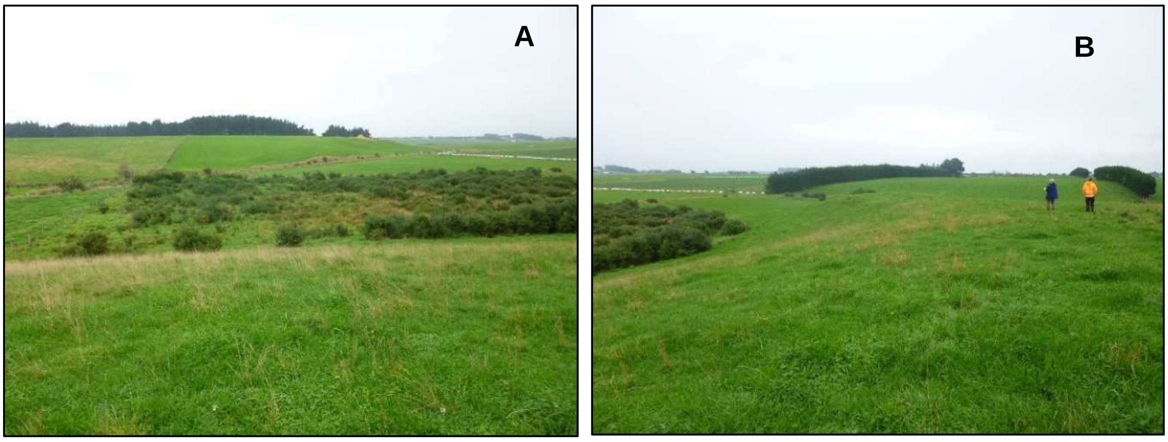

Figure A-21: A and B. Panorama of gorse areas at toe-of-slope.

Pirie C – N filter site

Potential site for woodchip denitrification filter.

Figure A-22: Satellite image of potential denitrification site. Red rectangle denotes potential site.

Figure A-23: Potential denitrification filter site.

Pirie B – Herb meadow.

This toe slope site was probably intercepting only a small amount of flow. Currently there is some grazing occurring. The site had a surprising amount of biodiversity including *Sphagnum* moss, *Gunnera prorepens* and other unidentified species.

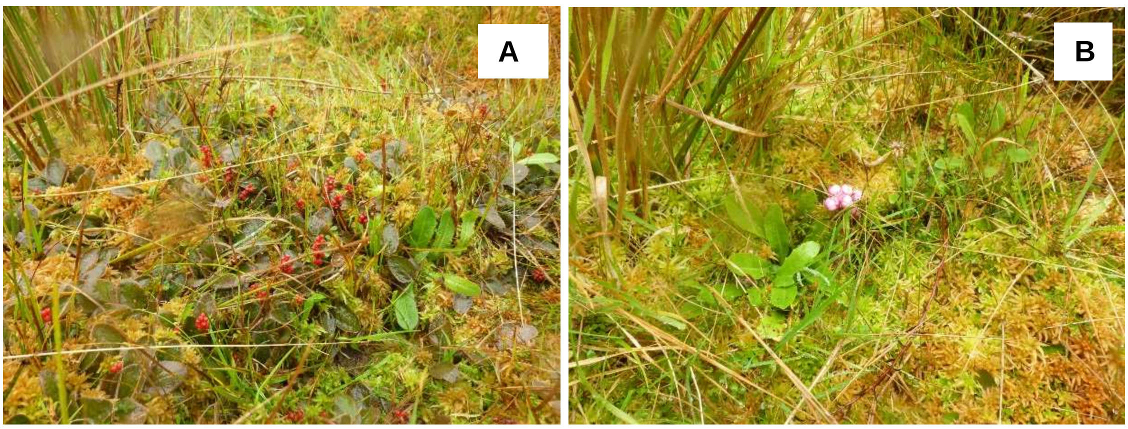

Figure A-24: A. *Gunnera prorepens*. B. Area of *Sphagnum* moss with wetland herbs.

The biodiversity of this site suggests it is worth fencing to exclude stock. The presence of *Sphagnum* suggests a low nutrient environment which may not provide much nutrient removal benefit.

Winter grazing farm

Large area of winter grazing. The farmers are developing area of manuka scrub but are willing to undertake remediation actions. This site was considered atypical, thus not suitable for p-remediation. However seems very suitable for sedimentation trap installation. We should pursue this as a really suitable option but slightly outside the scope of current work.

Figure A-25: A and B. Views of site under development for cropping and winter grazing.

Appendix B Stage II. Short-listed sites and additional assessment criteria

Selected sites for further assessment

Based on the initial assessment as outlined in Appendix A and after further discussions with Dairy NZ and Environment Southland personnel, a set of short-listed sites was established for further investigation by a sub-contracted agricultural engineer (John Scandrett, Dairy Green Ltd). The following 6 sites were short-listed

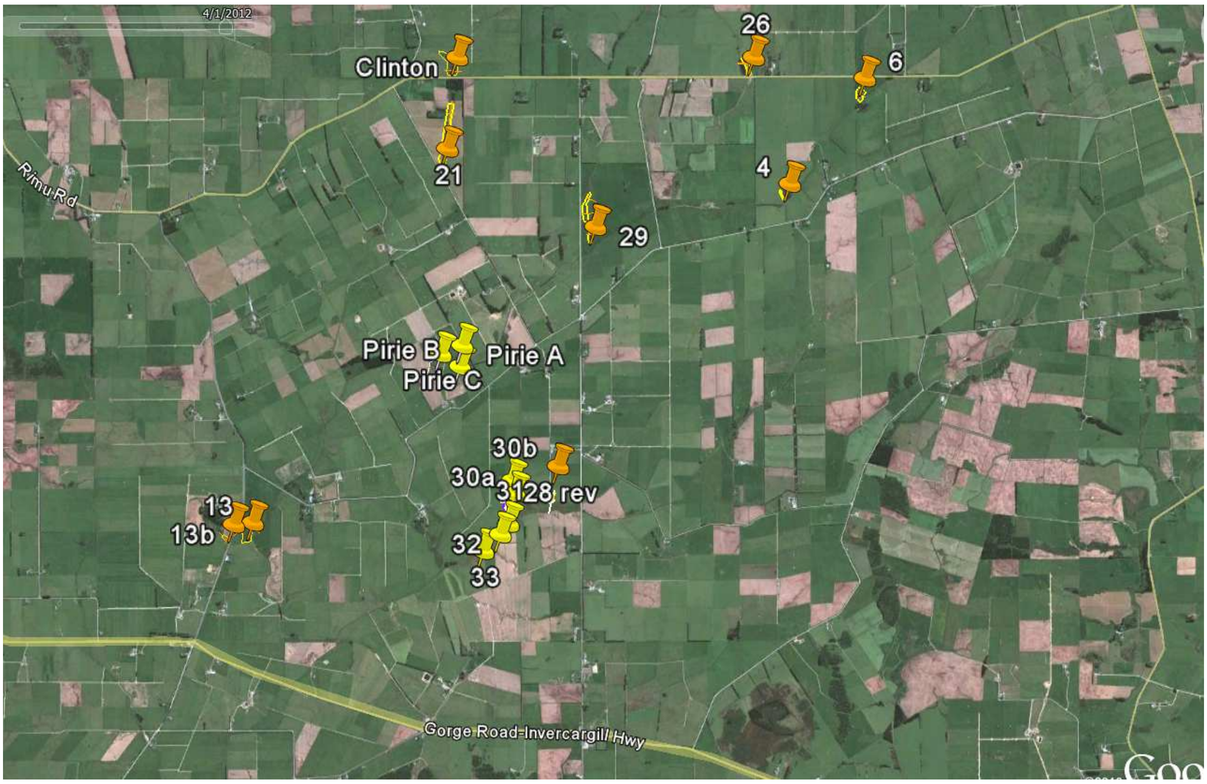

Figure B-1: Google Earth view showing additional sites (marked in orange) investigated in early April 2014 in upper Waituna Catchment. Investigated sites shown in orange. Yellow marked sites are additional sites either investigated previously or worth further investigation in the future.

Table B-1) as potential trial wetland sites on the basis that they:

- Provided the desired wetland to catchment area ratio of 2-3%.
- Where possible used lower value land.
- Appeared practically feasible.

As many of the suitable sites as identified in Table A-1 have been discussed in Appendix A, this section only discusses "additional sites" as identified in discussions with DNZ and ES. A further site on the Pirie farm (Pirie C) was also identified for potential installation of a wood-chip filter.

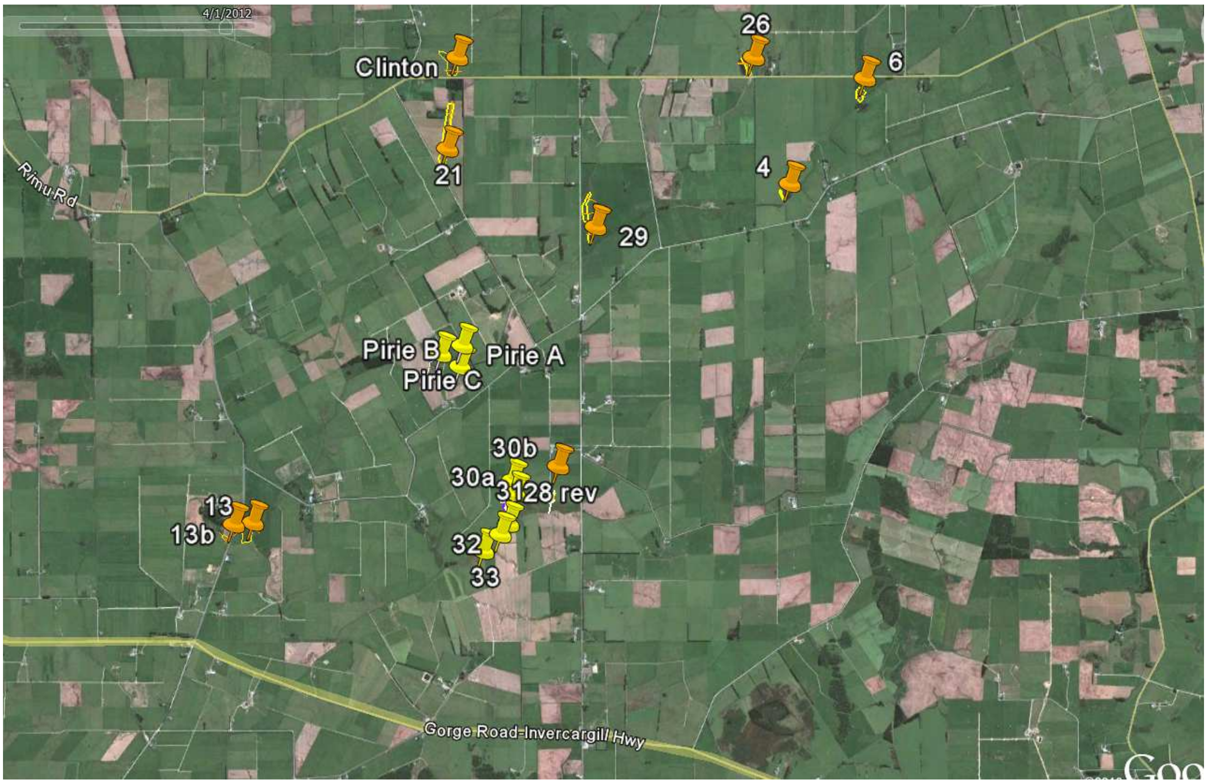

Figure B-1: Google Earth view showing additional sites (marked in orange) investigated in early April 2014 in upper Waituna Catchment. Investigated sites shown in orange. Yellow marked sites are additional sites either investigated previously or worth further investigation in the future.

Table B-1: Stage II Short-listed sites for further investigation.

Site	Property	Wetland area (ha)	Catchment area (ha)	% of Catchment	Notes
28 (originally site 18)	Winy Van Rossum, Kapuka Rd Nth	0.27	12.4	2.1	Potential site for small-scale trial application, would involve use of moderately high productivity land in base of valley.
4	Rex Botting	0.13	11.1	1.2	Need to look at potential additional area above that marked to double wetland area to ~2.5% of catchment. Potential site for small-scale application. Would involve use of moderately high productivity land in base of valley.
33	West of Kapuka North Rd	0.19	6.69	2.8	Site not visited yet. Potential site for small-scale application. Would involve use of moderately high productivity land in base of valley.
13	Brian Mathews 100m N of Mokotua Garage (East side of Rd)	2.02	53.4	3.8	Potential site for medium-scale application. Would occupy area of rough ground.
21	Murray Clarke, Drakes Hill Rd	3	129.5	2.3	Potential site for medium-scale application. Would mainly occupy area of rough ground.
22b	Clinton	3.06	100.5	3.0	Potential site for medium-scale application. This area has been subject to significant additional drainage works over the last 6 years which has likely increased its value to farmer. Included for comparison with site 21 option.

Site 28 (additional sites)

The initial site investigated has had further LiDAR contours added, and additional potential sites added. These were not investigated during our visit in April and are marked to the west.

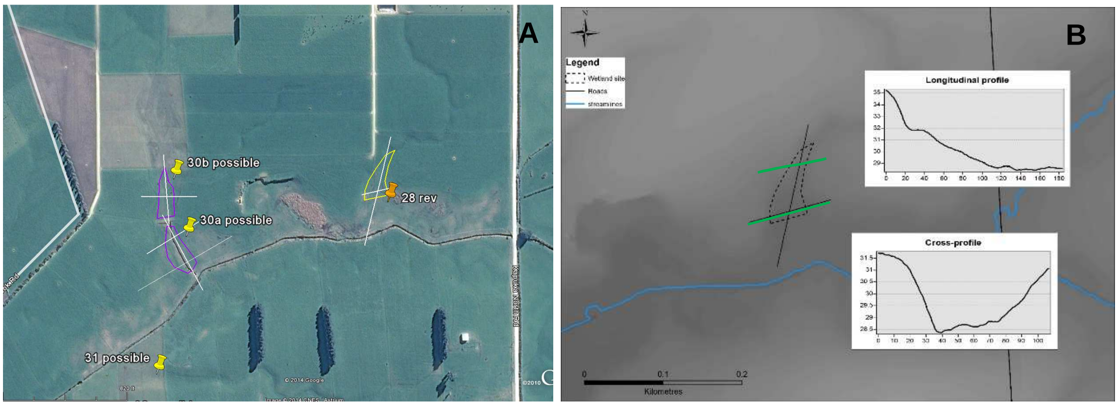

Figure B-2: A. Google Earth image of site 28 in August 2013. B. LiDAR contours and cross-sections. Potential bunds shown in green and proposed wetland area shown by dashed line.

Site 33

This site was not visited during our field assessment in early April, but has been subsequently identified from satellite and LiDAR imagery. The downstream section of the swale valley at this site appears to be conducive to wetland construction. Sites 31 and 32 to the northeast show very similar characteristics but have larger catchments relative to feasible areas for wetland construction, making them less suitable as demonstration sites.

Further investigation of this site is warranted.

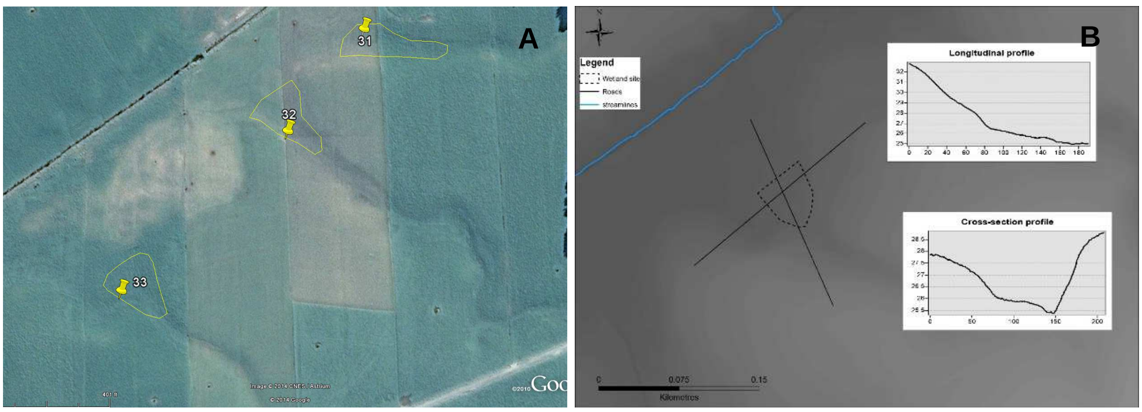

Figure B-3: Sites 31-33 showing potential wetland areas at the end of swale valleys. B. LiDAR contours and cross-sections.

Sites for N filter

Pirie C – N filter site

Potential site for woodchip filter intercepting subsurface drain flow. Propose woodchip material in filter to be 1 m deep (saturated), lined and covered with good quality liner material with water-tight pipe connections (to enable accurate monitoring), and 5 m wide by 21 m long (105 m^2 in area).

Figure B-4: Potential site for wood-chip filter on Pirie Farm. Subsurface drain flow to be diverted via weir into filter and then returned to drain at exit. High flow bypass via drain to be maintained.

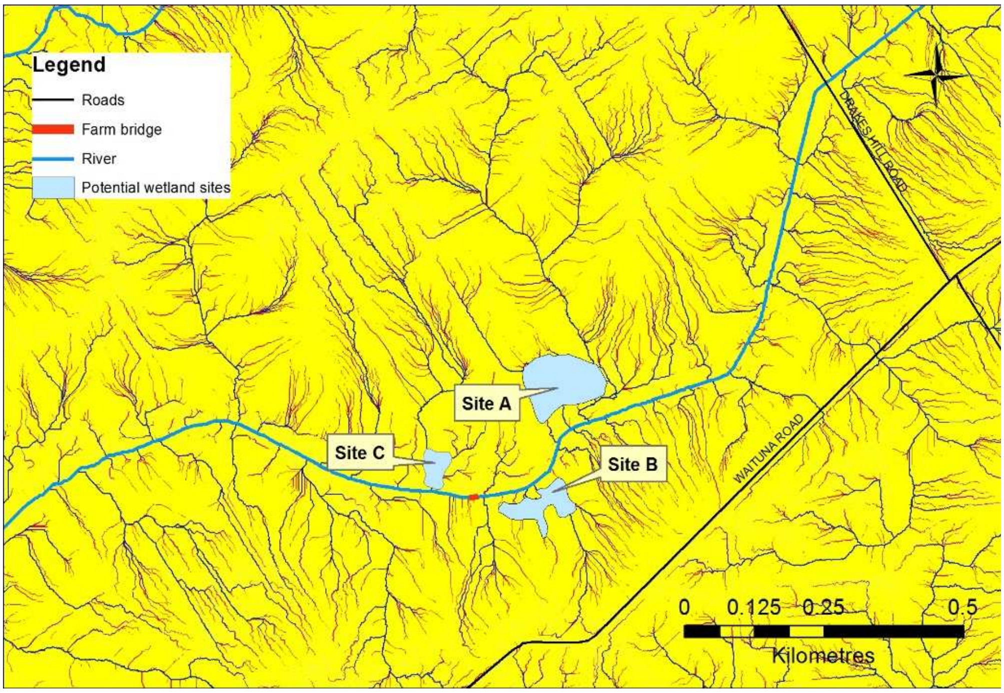

Figure B-5: Pirie farm potential contributing catchments for site A-C. The detailed drainage network (obtained from LiDAR data) illustrates the approximate areas that drain into the wetland sites.

Figure B-6: View towards Pirie C site. Subsurface drain emerges at left end of hedge. In foreground poorly drained remnant *Sphagnum* peat bog. Proposed to site woodchip filter between drain and peat bog area.

Appendix C Preliminary site engineering assessments

From report of John Scandrett; 7 May 2014

Background

Further to the report prepared April 2014 entitled Waituna Catchment Wetland Sites for further assessment (REV1) a number of selected sites were visited with a view to looking at the practical feasibility of developing these into wetland sites.

When the sites are further short listed more engineering data and plans can be prepared.

This report details the sites in the order as they were inspected.

Site 22B – Peter Clinton's Property

This site is a broad gully upstream of the Rimu Seaward Downs Road. It is characterised by seepages either side of the valley plus a small area of undeveloped reverting organic soil in the valley floor.

The outlet for the valley is a concrete culvert pipe under the road which from a drainage point of view would ideally have been in deeper. At this point a 300mm diameter PVC pipe is carrying water from the valley floor drainage system to the culvert pipe. The lack of depth is probably compromising the drainage in the lower valley area. The high water table as a consequence precludes any further intensive drainage.

I used a spear to check the profile below the surface level and found varying depths of topsoil, some of which was very organic, overlying saturated silt, sand and gravel. There is 3.1m fall over the last 2 paddocks in the valley.

A phone call to Peter Clinton confirmed that Peter was happy if up to 0.4ha was turned into a wetland but not 2-3ha. One of the issues would be having the right balance of catchment to wetland area.

To create a wetland would effectively involve quite a lot of excavation of wet soil which would bring practical difficulties as well. I think this site can be discounted as a suitable wetlands site in the interim.

Site 13 West – The Warnock Property

Site 13 comprises of a deeply incised open drain down to a gravel base with coal in the ditch bed at the first corner upstream of the road. The valley floor is very narrow in the area with quite a lot of fall on it. There is a 0.5m drop in the ditch floor where the coal is. Any wetland would mainly be created through excavation and a sound dam structure would be needed across the ditch.

There was a significant amount of water coming down the drain so a good overflow structure would be required. Given that it is a reasonably steep sided gully, a dam would not affect side drainage too much. Inspection of the ditch bank indicated a substantial number of seepages into the drain particularly on the north side.

This site appears to have good access and is close to a road and would provide firm ground to work on.

Site 13 East - Brian & Rosie Matthews Property

This is on the east side of the road. We spoke to Mrs Matthews who was not interested in being part of any project. Secondly the existing duck pond is important to the Matthews and they would not want it comprised by any wetland development. A further practical consideration is that the drains around the site are very deep and would require significant damming to build the water level up to flood the site. It's likely a significant amount of excavation will be required as well. I believe this site can be discounted from any further development.

Pirie C-N Filter Site

A site inspection revealed a well-defined catchment and gully system on the north side of the valley flowing south to the stream. The gully narrows at the west end of a shelter belt which is at the margin of the rolling higher terrace ground and the flatter flood plain area. The drain in the gully is apparently quite deep, approximately 1.8m although that seems very deep. I would be surprised if it is as deep as that.

There is a reasonable amount of fall down the gully and flood plain so it should be feasible to dig back up the gully and then re-lay a pipe on a flatter grade to bring the outfall closer to surface level to supply a rectangle shaped pond 5m x 21m. There are seepages along the edge of the terrace and there is a significant network of tiles in the area. However there is no reason why a lined pit couldn't be created at this site.

Pirie B

This side is on the south side of the creek and the third hollow to the east of the farm lane. There is very good fall down the gully which consists of two branches which merged to form a wide gully floor, approximately 18m wide. There is a very hard pan under the topsoil, I believe it is probably sand. The depth to the pan is minimal, 200mm to 500mm depending where you probe.

It would be possible to establish a pit for N filtration and removal across the gully and I expect that the sand would be stable for the side of the pit. Ground water may want to seep in and may have to be drained when the pit was first established. It would depend on the soil conditions at the time.

Site 4 on Rex Botting's Property

This is a flat site adjacent to a duck pond. The site is actually the floor of a gully and the 6" tile that used to flow down the gully has been diverted into the duck pond. Rex didn't seem unhappy about the tile being diverted back to a wetland. I think it would be feasible to have the top banks of the wetland area raised above the existing ground level so that the overflow from the wetland went back into the pond if necessary.

I used the level to check the fall and as suspected the site was flat for a length of at least 40m. For the next 15m heading up the gully there was only 90mm fall. The water level in the pond is only 130mm lower than the ground level at the wetland site. There was gravel along the sides of the wetland area so I imagine that there would be seepage coming in. There is possibly limited room to increase the width of the wetland area without a lot of excavation. Overall not a difficult site to develop and it would be reasonably easy to dig out 450mm of material.

Site 21 Drakes Hill Road

This is a main gully and a continuation of the drain that runs through the Peter Clinton property. A substantial open channel has been excavated down to sand. There is also a significant amount of sand in the subsoil. This is a significant water way in terms of size and would need a very good overflow for flood conditions. The sand base in the open drain has eroded badly in places and the depth of water is up to 3/4m in scour holes within the open drain.

To create a wetland I think it would be best achieved by damming with some excavation and it's probably best to start above the confluence of a gully coming in from the west. I observed a tank on the ditch bank and am wondering whether a water supply intake is taken from the gully coming in from the west. Further levels would be needed because it's hard to tell from the LiDAR survey exactly how much fall is down the ditch bank but I suspect two dams would be needed. The margins of the gully are quite steep so damning wouldn't affect too much the outfall from any side drains. These could be dug up and relayed at the end to ensure adequate outfall. The culvert under Drakes Hill Road is in the order of one metre in diameter.

Site 28

We met Winy Van Rossum and her sharemilkers onsite. We looked at Site 28 which is at the lower end of the gully where it meets the flood plain. The flood plain has only been developed into in the last 2-3 years and is still very wet. It would be possible to create a wetland from a combination of excavation and bunding.

Winy seemed quite keen on us looking at site 30A which has a much bigger catchment. In that case I think the water would be best diverted out of the open drain and to a bunded area which is still very wet to the east of the drain on the floor plain. It would be possible to have a larger wetland area by doing this and not affecting the better developed ground on the west side of the open drain. There is plenty of fall to develop the diversion.

Sites 31-33 on Anray

We were directed by farm staff down a dairy lane to the paddocks where Sites 31-33 have been identified. This is on the south side of the creek from Winy Van Rossum's. Site 33 comprises a steep narrow gully which was dry, therefore well drained which opens out onto a large alluvial fan. There was gravel and sand at 800mm depth. The fan appeared to be well drained in contrast to the north side of the creek.

A combination of bunding and excavation could create a wetland here. This would be an easy site to work given how dry and firm the ground was. Sealing the subsoil would be essential to create the wetland given the way the ground was behaving.

Site 32

Was the middle gully which discharges closer to the waterway than Site 33? It is a broader gully although is still quite well defined at the fence line. The gully appears to be flatter and there would be less room for a wetland area between the gully outlet and the creek.

Site 31

Was also at the outlet of a steep sided gully. Again the flats were well drained and this would be an easy site to develop for that reason although again sealing would be essential to maintain the wetland. It may be that the gravels on this side of the creek are more free-draining or alternately there may be less seepage out of the terrace across the flat. There was a notable difference in the soil moisture between the north side i.e., Van Rossum's and the south side i.e., Anray. The soils on the south side seem less organic and would appear to have developed under a drier regime.

Appendix D Site engineering evaluations and costings

From Report of John Scandrett June 2014

Engineering evaluations and costings were focussed on a subset of sites determined to be the most appropriate as constructed wetland trial sites. Based on economic feasibility as demonstration trial sites (allowing for additional monitoring and reporting costs), these were mainly smaller catchments. One particularly suitable larger wetland site (#21) was also investigated to extend the range of construction cost estimates. All cost estimates assume good weather and soil conditions for construction and make no allowance for possible ingress of ground-water during construction. This will generally reduce the period suitable for construction for most prospective wetland sites to late summer and early autumn months.

Site 21

Catchment area 129ha.
Wetland area required 3ha.

Wetland site features
Fall along drain bank = 1m per 225m.
Length of wetland site 600m.
Width of wetland on East bank from drain to foot of slope, 17m to ~40m.
Total wetland width would vary from 30 to 60m, approx.
Subsoil very sandy, topsoil quite organic.

Work required to create Wetland(s)
Two dams, one above Drakes Hill Road fence and one at 300m above Drakes Hill Road fence to create an upper and lower wetland within the area available.
Dams 1.0m high above natural ground level with spill way at 0.6m above natural ground level.
Lower dam length approximately 50m.
Upper Dam length approximately 60m.
Topsoil stripped and subsoil removed to create a level platform for the wetland.
Side drains would need to have outlets lifted to new outfall height

Lower Dam & Wetland Construction
Excavation of Wetland area.
From -0.2m depth at South end to 0.73 plus 0.4m = 1.13m depth at North end.
Average depth of cut along ditch bank line 0.46m.
Depth of cut increases towards margin of flood plain, but is very variable.
Assume range is from 0.25m to 0.8m.

Cross section of cut required at lower dam site assume ~0m^2, as some fill may be required.
Cross section of cut North end. Cut from 1.13m to 1.5m, width ~40m.
40m x 1.3m = 52m^2.
Volume of cut (52m^2 + 0m^2) ÷2 =26m^2 x 300m length = 7,800m^3 material to shift.

Least cost option is to move surplus material up onto ridge or into drain. Drain would need to be filled in last.
Upper wetland would need to be built first.
Need to strip topsoil and cover subsoil at appropriate depth.
Typically the work rate will be 100m^3/hr to 140m^3/hr for stripping upper topsoil and removing from site, stockpiling remaining topsoil, removing subsoil to depth and replace topsoil.
Ground is soft so may require low ground pressure machines to cart spoil.
Assume 90 hours at $500/hr for 3 machines **$45,000** (approximately equal to $5.80/m^3) may range up to $8.00m^3 depending on conditions encountered.

<u>Dams</u>
A full depth dam will be required across the waterway and a lower dam across the floodplain.

In waterway
Drive rails or poles for head and tail wall, line with H5 treated tantalised timber and line with polypropylene on inside of headwall.
Install minimum 375mm diameter pipe in bed with up stand.

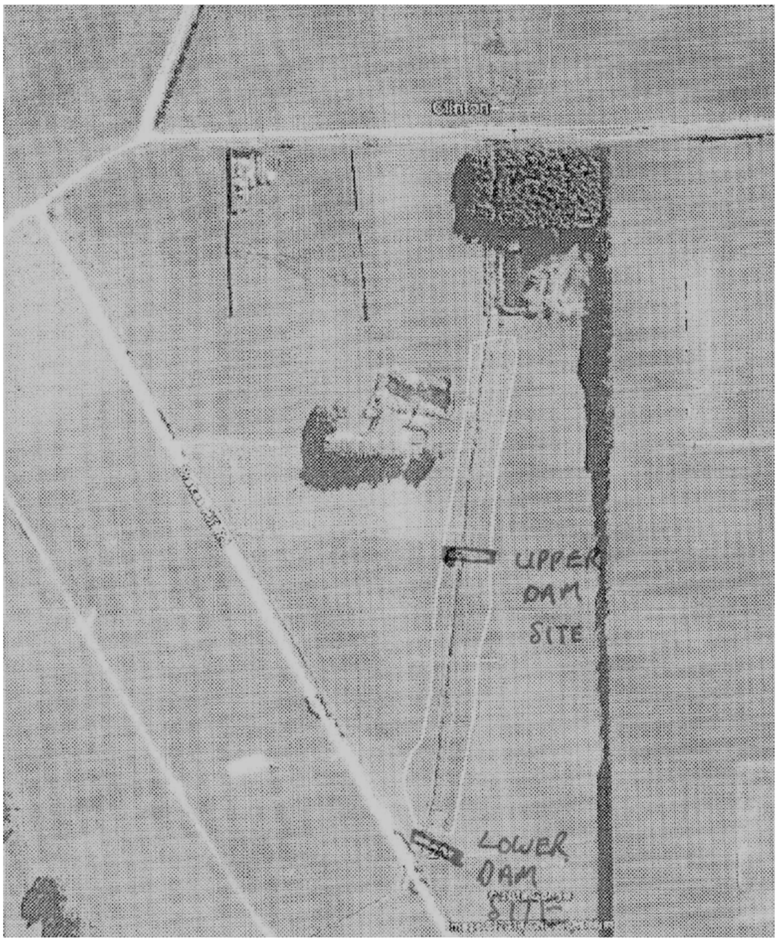

Figure D-1: Conceptual plan for wetland construction at site 21. Location of two proposed dams and general extent of wetland shown.

Site 21 On-site Costs

Posts, delivered	$1,600	
Timber, delivered	$1,100	
Liner	$200	
Digger time & Labour	$1,500	
PVC pipe and up stand – allowance	$2,500	
Concrete		
5m wide spillway x 15m length x 0.2m		
= 15m^3 x $400/m^3 placed	$6,000	
Steel – allowance	$500	
Labour	$500	
Subtotal		**$13,900**
In Flood Plain		
Harvest and compact suitable fill, and shape for concrete spillway	$3,000	
Sundry		
Uplift & relocate fences – allowance	$2,000	
Uplift and relay tile drains with PVC – allowance	$1,000	
Earthworks	$45,000	
		$64,900
Contingency 20%		$12,980
TOTAL		**$77,880**

For 2 dams assume double the cost, $77,800 x 2 = **$155,760**

"Off-site" costs – Design, Administration, Supervision

Design

To provide sufficient detail in a specification to invite contractors to provide a price. Assumes the contractors selected are competent and will understand the job requirements and desired outcome. Also assumes adequate supervision will be provided as the job progresses to provide design guidance.

Design – allowance	$3,000 - $5,000
Consent application	$5,000 - $8,000
Invite prices	$2,000 - $3,000
Supervision	$5,000 - $10,000
Range in prices	**$15,000 - $26,000**

Site 31

Catchment area 12.4ha.
Wetland area required 0.32ha.

Wetland Site Features
Defined gully with 1:25 fall prior to flattening out onto the flood plain.
Soil variable, from stony to 600mm depth of organic topsoil mixed with sand and silt overlying gravel.
Profile near main drain dominated by excavated spoil.
A tile drain along the foot of the terrace running parallel with the main drain would need to be diverted.

Work required to create a Wetland
A ring bank would be required of approximately 270m length.
The site has two hollows running through it which would need filled. The site also need levelled, material removed in cut could be used to create the bank.
To seal the floor the subsoil will need compacted.
The upper topsoil needs stripped and discarded.
The next layer of topsoil needs stripped and stock piled for spreading out on the levelled subsoil.

Upper topsoil volume,	4,000m^2 x 0.75m = 300m^3
Topsoil to stock pile,	4,000m^2 x 0.200m = 800m^3
Subsoil to shift,	4,000m x 0.6(ave) = 2,400m^3
Ring bank volume,	270m x 3.6m x 1.0m = 972m^3

Site 31 On-site Costs

Topsoil removal and replacement	$8,000	
Subsoil cut and fill	$9,600	
Ring bank	$7,200	
Relay drains	$2,500	
Subtotal		**$27,300**
Contingency 20%		$5,460
TOTAL		**$32,760**

"Off-site" costs – Design, Administration, Supervision

Design fees and documentation	$2,500 - $3,500
Supervision	$2,000 - $3,000
Range in prices	**$4,500 - $6,500**

Site 32

Catchment Area 22.9 ha
Wetland area – assume approximately 0.4ha

Wetland Site Features
A well-defined gullies discharges onto a flood plain.
The flood plain is bordered by a raised peat mound on the downstream side.
There is seepage water flowing from the foot of the terrace adjacent to and on the downstream side where the gully enters the flood plain.
The soils are very mixed throughout the proposed wetland area including artificial mixing of straight sand in some of the peaty areas.

Work required to create a Wetland
A cut to fill exercise very similar to site 31.
May be more difficult to seal the wetland floor due to the nature of the soil.
May be more difficult to build a ring bank along three sides without bringing in better material from off the ridges.

Strip Soil
4,500m^2 x 75mm = 338m^3 topsoil to discard.
4,500m^2 x 250mm = 1,125m^3 topsoil to remove and replace after subsoil compacted.

Level Subsoil and Compact
4,500m^2/2 x 0.7m = 1,575m^3 top soil to shift.

Build Ring Bank
Approximately 250m long x 3.6m wide x 1.0m deep = 900m^3.

Site 32 On-site Costs		
Topsoil removal and replacement	$12,000	
Subsoil cut and fill	$12,000	
Ring bank	$9,000	
Relay drain and outfall	$1,000	
Subtotal		**$34,000**
Contingency 20%		$6,800
TOTAL		**$40,800**

"Off-site" costs – Design, Administration, Supervision	
Design fees and documentation	$3,000 - $4,000
Supervision	$3,000 - $4,000
Range in price	**$6,000 - $8,000**

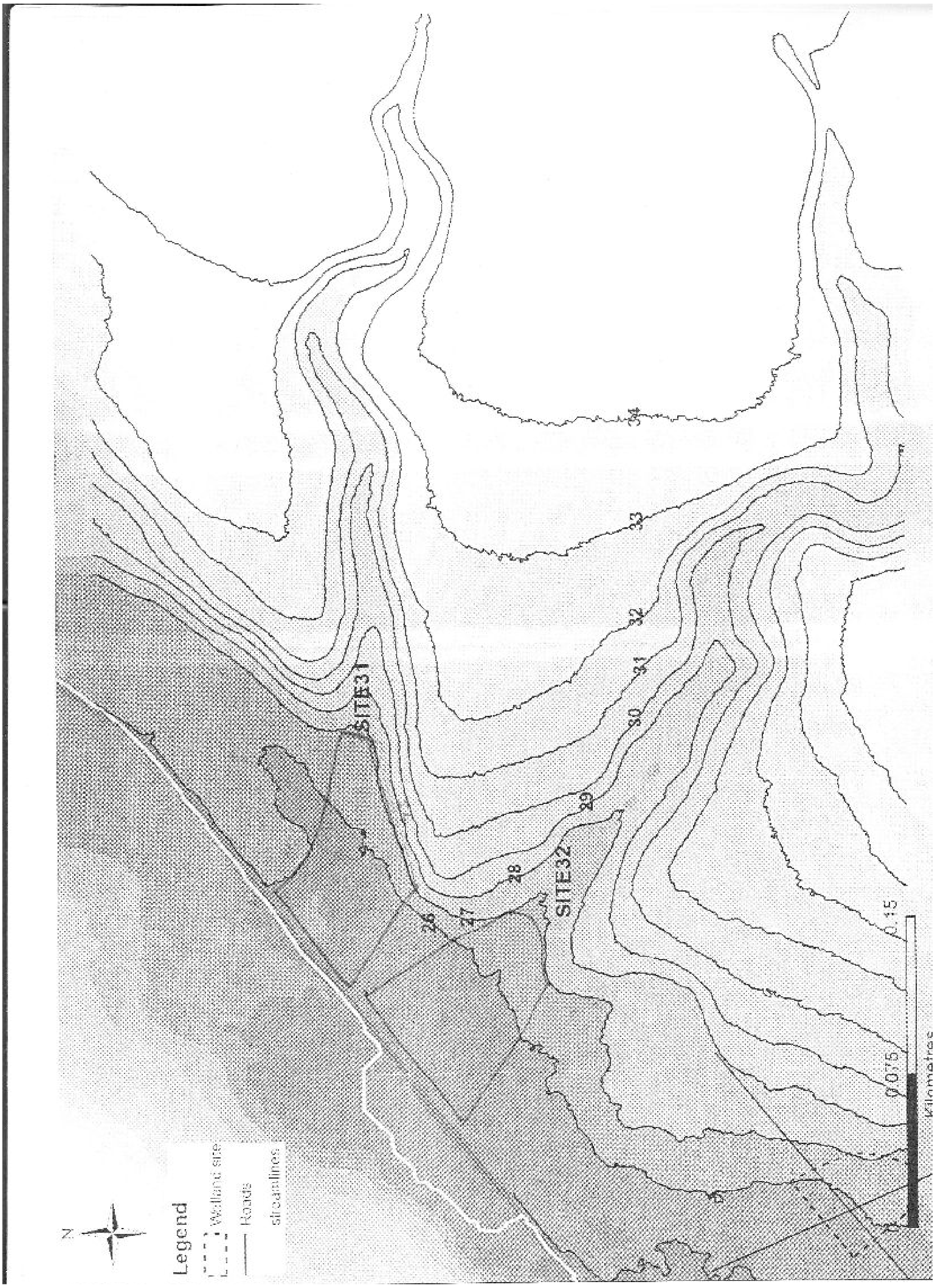

Figure D-2: Conceptual plan for wetland construction at site 31 and 32.

Site 33 - Anray Sites

Catchment area 6.7ha.
Wetland area required 0.19ha.

Wetland Site Features
Well defined gully discharges out onto the flood plain.
Gravel and sand at 0.8m depth.
Gully appears well drained with no sign of seepages.

Work required to create Wetland
A cut to fill exercise with ring bank for 2 sides and end. May need key trench in upper section.
Heavily compacted subsoil may seal floor, otherwise artificial sealing material would be needed.

Strip Topsoil
~2,500m^2 x 75mm = 188m^3 to discard.
2,500m^2 x 250mm = 625m^3 to remove and replace after subsoil compacted.

Level Subsoil and Compact
2,500m^2/2 x approximately 0.6m depth = 1,500m^3 to shift.
1,500m^3 ÷ 100m^3/hr = 15 hours.

Replace Topsoil
625m^3 x 100m^3/hr = 7 hours.

Build Ring Back
Approximately 124m long x 3.6m wide x 0.8m deep = 360m^3.
360m^3 over 2,500m^2 = 144mm depth to be cut from wetland site to form bank.

Site 33 On-site Costs

Topsoil removal and replacement	$6,000	
Subsoil, cut and fill	$6,000	
Ring bank	$500	
Subtotal		**$16,100**
Contingency		$3,220
TOTAL		**$19,320**

"Off-site" costs – Design, Administration, Supervision

Design fees and documentation	$2,000 - $3,000
Supervision	$2,000 – $3,000
Range in prices	**$4,000 - $6,000**

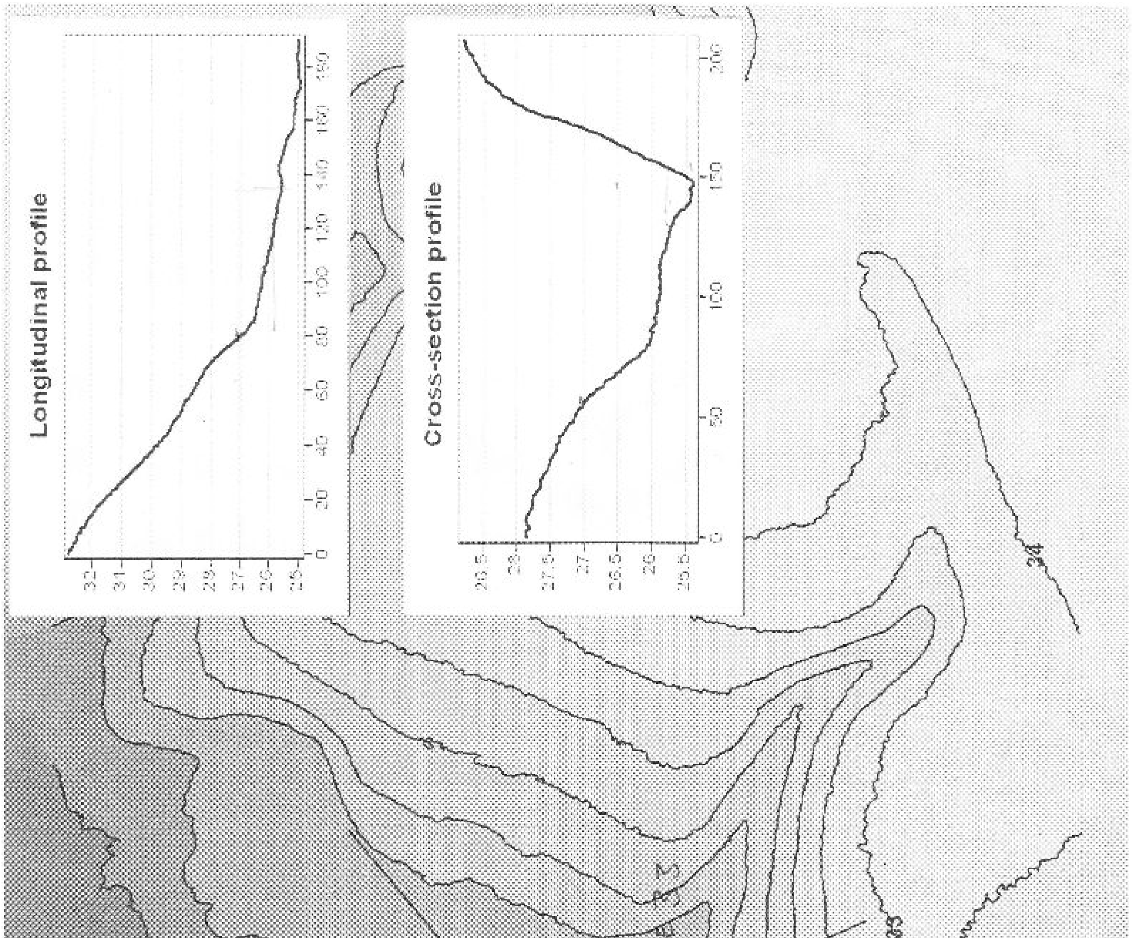

Figure D-3: Landscape contours for wetland area 33.

Pirie C-N Filter Site

Site Features
A site inspection revealed a well-defined catchment and gully system on the north side of the valley flowing south to the stream. The gully narrows at the west end of a shelter belt which is at the margin of the rolling higher terrace ground and the flatter flood plain area. The drain in the gully is apparently quite deep, approximately 1.8m although that seems very deep. I would be surprised if it is as deep as that.

There is a reasonable amount of fall down the gully and flood plain so it should be feasible to dig back up the gully and then re-lay a pipe on a flatter grade to bring the outfall closer to surface level to supply a rectangle shaped pond 5m x 21m. There are seepages along the edge of the terrace and there is a significant network of tiles in the area. However there is no reason why a lined pit couldn't be created at this site.

To Create the Filter
The incoming drain will need to be dug up and re-laid in sealed pipe at a flatter gradient to bring the inflow to the reactor up to 0.3m below ground level.

A polypropylene liner would be made to measurements taken after the filter site was excavated. It would be anchored in an anchoring trench around the perimeter of the filter.

Pirie C - On-site Costs		
Excavate and relay drain in PVC	$1,100	
Excavate and reconnect other drains in the area affected by works, allowance	$500	
Excavate filter, material left stock piled on site, landscaping done to divert surface water as required	$500	
liner, approximately 260m^2	$3,510	
Inlet and outlet weir box structures	$600	
Subtotal		**$6,210**
Contingency 20%		$1,122
TOTAL		**$7,332**