Osbornes Drain - Mitigation Measures Assessment

Prepared for

Te Rūnanga o Ngāi Tahu

c/- Boffa Miskell

Prepared by

Lowe Environmental Impact

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Te Rūnanga o Ngāi Tahu

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1 EXECUTIVE SUMMARY

Osbornes Drain collects runoffs and drainage water from a 1,620 hectare catchment before discharging into Te Waihora / Lake Ellesmere. Water quality sampling at various locations indicates some contamination exists, mostly from phosphorus and, to a lesser extent, nitrogen. The review of available information reveals that phosphorus is mostly present under its dissolved reactive form (DRP) and that the bulk of the nitrogen is predominantly organic.

A 2013 Pattle Delamore Partners Ltd (PDP) report on the quality of the sediments in Osbornes Drain indicates that total nitrogen (TN) and total recoverable phosphorus (TRP) show their highest concentrations in the surface layer of the sediments (0 - 0.2 m) which can act as a pool source for the DRP and which is a direct result of surface run-off rather than leaching/drainage into groundwater and surfacing as springs.

Based on this, Lowe Environmental Impact Ltd (LEI) has selected several mitigation measures aimed at reducing the discharge of phosphorus and nitrogen into Osbornes drain and has ranked them based on various factors such as the overall efficiency, the ease of implementation and the financial viability ("Bang for Buck"); the common factor between those mitigation measures being that they tend to address the "root cause" instead of reducing contamination levels of the water once in the drain.

The possible mitigation measures outlined in this report include a number of measures that range in efficiency from unknown to 80% P removal and a financial gain ranging from $0 to greater than $550 per kg of P conserved (that does not enter the drain).

Staging of mitigation measures implementation is also proposed to give priority to the low cost measures that help achieve the greatest reduction in sediment discharged into Osbornes drain, as well as the opportunity to monitor the effects of the different stages of the implementation of the proposed mitigation measures.

2 INTRODUCTION

2.1 Introduction

This work was commissioned to provide Te Rūnanga o Ngāi Tahu (Ngāi Tahu), and a working party of the Department of Conservation, Environment Canterbury and SDC, with independent advice on SDC's proposal to obtain a new consent to discharge land drainage and stormwater from Osbornes Drain into Te Waihora / Lake Ellesmere.

The overall objectives of this work were to provide a more specific (and scientifically robust) basis for:

a) The development of acceptable water quality standards for the discharge from Osbornes Drain into Te Waihora; and

b) Understanding the effectiveness of the water quality improvements suggested in the 2013 Pattle Delamore Partners Ltd (PDP) report (or any alternative measures) for achieving acceptable water quality standards for the discharge from Osbornes Drain and, thereby, ecological and cultural benefits for the downstream wetlands and lake.

To achieve, this the following three parcels of expert technical (scientific) advice were undertaken:

a) Mitigation Measures Assessment - Lowe Environmental Impact (LEI); addressing the agricultural/soil aspects of the existing land use practices, in order to provide recommendations of viable on-farm mitigation measures and give Te Rūnanga o Ngāi Tahu a better understanding regarding the effectiveness of the proposed (or alternative) measures for reducing nutrient and sediment losses into ground and/or surface waters;

b) Hydrology and Water Quality Assessment - GHD; addressing groundwater and surface water quality, in particular evaluating the potential effectiveness of in-drain mitigation measures and the on-farm mitigation strategies recommended by LEI;

c) Ecology Assessment - Boffa Miskell Limited; addressing the ecological condition of Osbornes Drain, the downstream wetland area and the immediate margins of Te Waihora; the likely effects of the discharges from Osbornes Drain on the values of these areas; and recommendations regarding the potential ecological impact of mitigation measures.

2.2 Scope

The scope of this report is to provide technical expertise on agricultural and soil aspects of the existing land use practices and to provide recommendations of viable on-farm and possibly off-farm mitigation measures.

This report also aims at giving Ngāi Tahu a better understanding regarding the effectiveness of the proposed measures for reducing nutrient and sediment losses into ground and/or directly to surface waters.

2.3 Background

The Osborne drainage scheme is a network of about 9 km of drains operating over 1,620 ha of farmland, draining into Te Waihora in the vicinity of Greenpark Huts (Hudsons Road). Water quality sampling at various locations indicates some contamination exists and is most likely due to the land use activity (high nitrogen and phosphorus concentrations; low dissolved oxygen; elevated turbidity as well as elevated nutrients in the sediments).

The Selwyn District Council (SDC) is in the process of redrafting a consent application for the discharge of land drainage water from the Osbornes drainage scheme into Te Waihora. The draft application proposes a number of improvement / mitigation measures to improve the quality of the Osbornes Drain discharge along with a monitoring program to track actual water quality improvements.

3 SITE DESCRIPTION

3.1 Osbornes Drain

The Osbornes Drainage Scheme, with a total of 9 km of drains, was designed in 1967 - 1968 to drain an area of low lying flat land across a catchment area of approximately 1,620 hectares. Osbornes Drain (and numerous side collector drains entering the main drain) is the collecting arm of this drainage scheme area, with a pumped discharge via a Pump House from the south eastern corner of the scheme area (see **Figure 3.1.1**). The pumps discharge the water from Osbornes Drain to Te Waihora, via a constructed channel through an area of wetland administered by the Department of Conservation (DOC)/Ngāi Tahu on the eastern side of the lake between Greenpark Sands and Kaituna Lagoon.

3.2 Surrounding Land Use

Surrounding landuse in the catchment is currently primarily farming, with irrigated dairy farms, dry stock farms, and some smaller lifestyle blocks. A large composting operation is also situated to the northwest of Osbornes Drain where materials are used for soil conditioning (PDP, 2013) – see **Figure 3.1.2**.

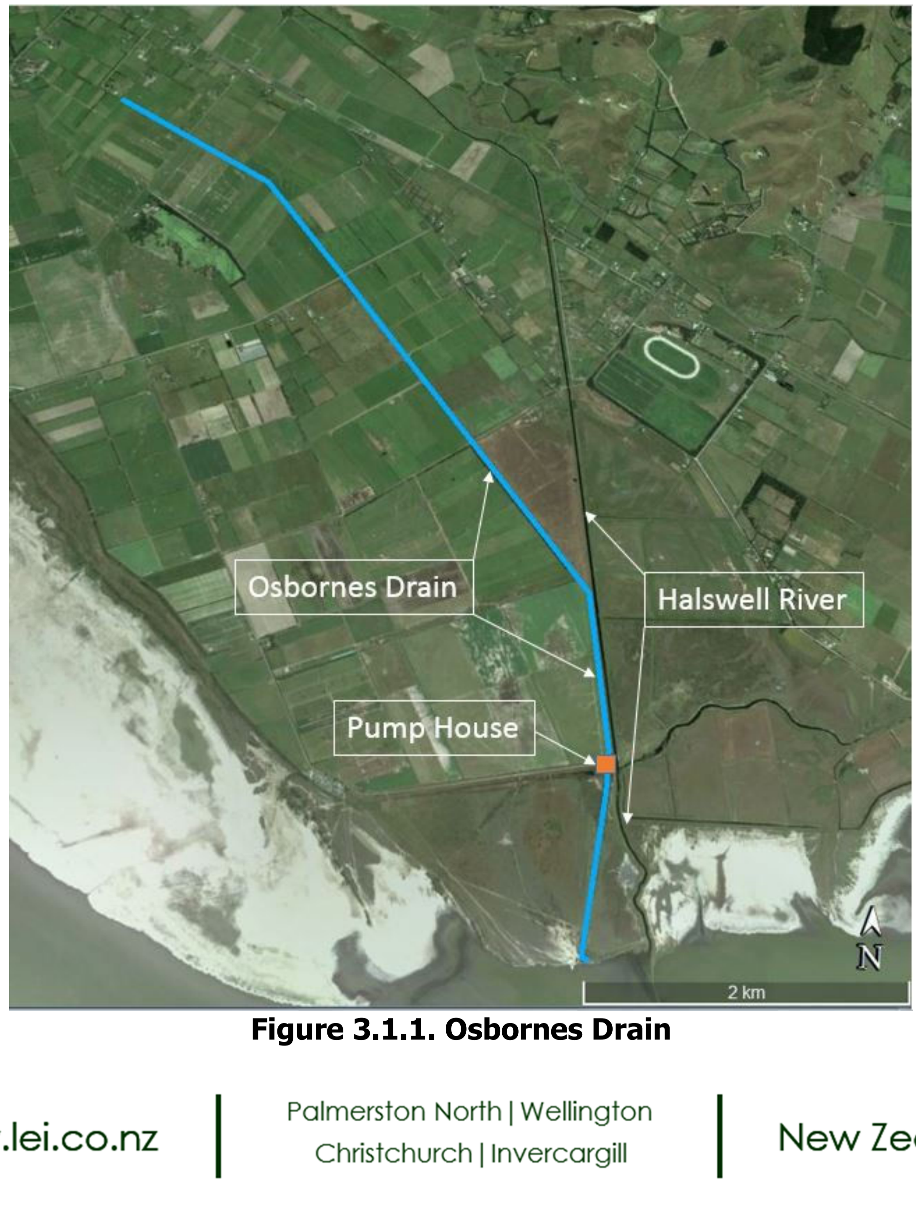

Figure 3.1.1. Osbornes Drain

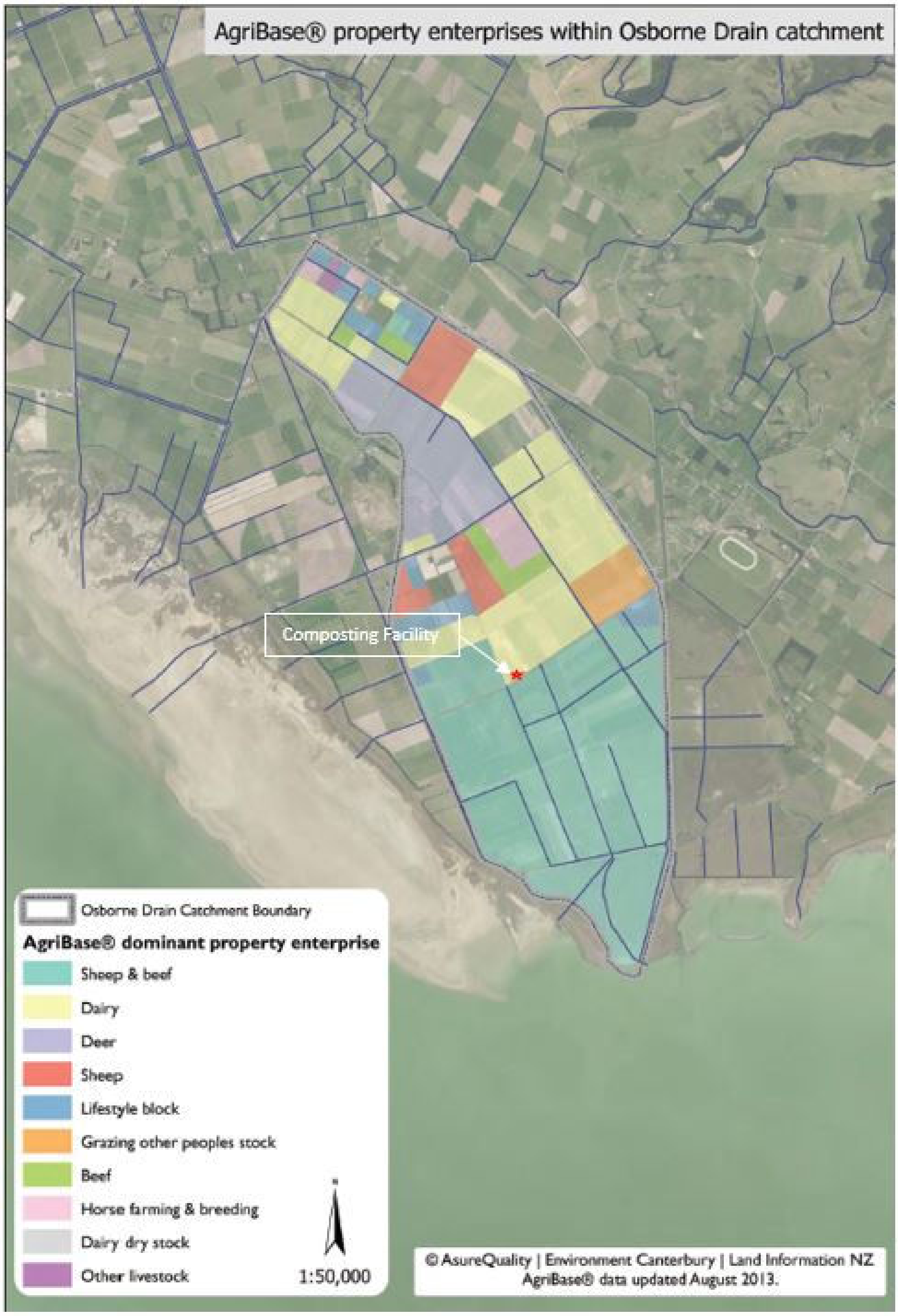

Figure 3.1.2 – Osbornes Drain Land Use (PDP, 2013)

3.3 Te Waihora

Te Waihora, also known by the name Te Kete Ika a Rākaihautā, the fish basket of Rākaihauā, is a tribal taonga for Ngāi Tahu.

Te Waihora is Canterbury's largest and New Zealand's fifth largest coastal lake. It is a shallow 20,000 hectare brackish water lake that has important fringing wetland systems (supporting significant bird populations) and an internationally important wildlife area. Furthermore, the lake represents a major mahinga kai and important source of mana to Ngāi Tahu.

What was once an outstanding clean resource, the lake is now in a much degraded condition. Degradation is primarily as a result of cumulative anthropogenic activities and land use change (Taylor 1996; Hughey and Taylor 2009).

4 REVIEW OF INFORMATION

The first stage of this assessment included the review and comment on different sources of information regarding Osbornes Drain, with particular emphasis on the effectiveness of recommended mitigation measures. The documents reviewed include the following:

Pattle Delamore Partners Ltd (PDP):

- Osbornes Drain - Water Quality Improvements (2013);
- Sediment Quality of Sub-surface Sediments within the Upper Reaches of Osbornes Drain (2015).

Environmental Canterbury (ECan):

- Osborne's Drain: Assessment of water quality and sediment monitoring (2011-2012 - DRAFT).

Selwyn District Council (SDC):

- Pump house operation data and monitoring data spreadsheets.

The findings from this review are presented below under various headings.

4.1 Contaminants

The available data, including the Boffa Miskell Ecology Report, indicates that Osbornes Drain experiences poor water quality which, in turn, is discharged into Te Waihora. Nonetheless, due to its relatively low flow, the contribution of mass content to the lake is of a small scale.

The main sources of contaminants are from land use activities and from sediments within the drain.

Two sets of results have been reviewed from the above sources. The first set of results are from the period 2011 - 2012, and the second set is from 2014 - 2015, over a 12 months period but with a two month gap between November 2014 and February 2015.

The contaminants of concern are (in order of concern): Dissolved Reactive Phosphorus (DRP), Total Phosphorus (TP), Total Nitrogen (TN), reduced dissolved oxygen (DO) concentration, turbidity and Total Suspended Solids (TSS). A deeper review of those parameters reveals that phosphorus is most present in its dissolved reactive form and that a significant component of the nitrogen is organic.

4.2 Source of Contamination

It is important to determine not only the type of contaminants but also their origin and through which path they end up in the drain: *are they run-off based or groundwater based?* An assessment of the water quality and sediment analysis results has been carried out by GHD (2015) and the report outlines that, although the information available is limited, it is likely that the organic–N matter in the drain is unable to be fully converted to inorganic forms via microbial action due to low DO concentrations, keeping loss of nitrogen via denitrification from happening. Still, when coupled with anoxic conditions, any oxidised nitrogen could also be reduced to N_2 gas. The same report indicates that phosphorus is likely to enter the drain attached to soil particles or within effluent that is within surface runoff water. It also outlines that, under anoxic conditions, microbial activity converts the sediment bound P into its soluble form (i.e. dissolved reactive phosphorus) which is readily available for plant uptake and, at the right proportions with DIN, can lead to algal blooms.

The comparison of the results for the different parameters confirms that much of the contamination is still in organic form and therefore more likely to be a direct result of surface run-off rather than leaching into groundwater and surfacing as springs. This is supported by a 2015 PDP (2015) report on the quality of the sediments in Osbornes Drain which indicated that Total Nitrogen (TN) and Total Recoverable Phosphorus (TRP), which are the two elements of most concern, show their highest concentrations in the surface layer of the sediments (0 - 0.2 m) which can act as a pool source for the DRP. It also indicated that the higher phosphorus concentrations in Osborne Drain likely reflect background soil concentrations and land-use activities and that the sediment in Osborne Drain potentially provides a readily available source of phosphorus and subsequently Lake Ellesmere/Te Waihora when under certain conditions.

The GHD assessment of the available data (2015 report) indicates that the top layer of the sediments (i.e. 0 – 0.2 m) contained the highest concentration of nutrients, total organic carbon, and organic matter. Therefore, the removal of sediment from the drain has likely removed a high proportion of the organic matter from the drain and associated nutrients.

4.3 Suggested Mitigation Measures (PDP, 2013)

The list of suggested improvements is shown below. Some of these improvements have already been partially implemented (confirmed during the site visit):

- Remove accumulated sediment from the lagoon upstream of the pump station;
- Remove all accumulated sediment for the entire length of Osbornes Drain (partially implemented, from the stone weir above the pump house to Gammacks Road);
- Base flow augmentation (Local bores);
- A recirculation pump;
- Aerator, e.g. typical waste water treatment plant kit;
- Construction of weir(s) directly upstream of the pump house; and
- Farm plans designed to achieve water quality standards for drainage water using the current planning instruments in the short to medium term and achieve contact recreation standard over the next 15 - 20 years.

4.4 Site Visit

A joint site visit/walk was undertaken on the 20th April 2015 (LEI, GHD and Boffa Miskell), in order to understand the layout of the drain, the topography, low lying land, the soil types, the farming types, the types of drains, the drain buffers and the types of planting. The site visit only included the part of the catchment that is located along Osbornes Drain itself and did not include detailed observation of the secondary drains discharging into it. However, the secondary drains were noted where they joined Osbornes Drain and where they could be seen from the road. The following observations were made:

- The width of the drain is constant for the major part of it and the flow seems to be fluctuating within the year;
- The secondary drains are all shallow and do not appear to have been constructed to intercept groundwater. The baseflow component of Osbornes Drain was very low so it also may not intercept groundwater to any large degree – this is confirmed by the GHD Report (2015);
- There does not appear to be any contribution to the drain from the Halswell Canal;

- There are several secondary/contributing drains discharging into Osbornes Drain. Some of these secondary drains are not maintained or dredged;
- Several parts of the drain have recently been dredged and the removed sediment has been deposited on the banks. The sediments removed from the drain have not been stabilised with vegetation, which raises the concern of sediment being flushed back into the drain in a large storm event in some locations;
- The sediments are of sandy type;
- The distance between the drain and the paddocks/fields over a large portion of the drain is unlikely to be sufficient to ensure proper riparian effect against sediment runoff;
- There are no apparent subsurface or mole drains;
- The stopbank located between the drain and the Halswell Canal appears to be grazed;
- Some paddocks adjacent to the drain had recently been cultivated and there were newly constructed secondary drains from these cultivated areas direct to the drain; and
- Animal parking/resting areas in some paddocks were in undesirable areas, such as low spots or adjacent to shallow drains with direct runoff to the drain.

4.5 Summary of Findings from the Review

Contaminants

Based on the results that have been provided for review, the two contaminants of concern are nitrogen and phosphorus and, more precisely, organic nitrogen and dissolved reactive phosphorus. Other exceedances (for example dissolved oxygen, as discussed in GHD, 2015) measured into the drain are either direct consequences of the release of these elements into the water (eutrophication) or are inherent to the natural conditions of a drain where the flow is highly fluctuating within the year with long periods of stagnancy followed by flushes during rain events.

Source of Contaminants

Given the form under which nitrogen and phosphorus are most present in the drain, it is apparent that the source of the N and P is not groundwater but rather caused by runoff of N and P enriched material from the surrounding land parcels (or the banks) and/or direct deposit into the drain (e.g. by stock defecating in the drain), with part of it being carried away by the current, and/or dissolved into the water, and part of it trapped into the sediments. The sediments play a major role in the gradual but constant release of P and also contribute to the anoxic conditions of the drain.

Suggested Mitigation Measures

Although most of the mitigation measures suggested by PDP (2013) are valid and have potential positive impacts on the water quality of the drain, only the Farm Plans really address the "Root Cause", which is the main source of the contaminants. The proposed (and partially implemented) dredging addresses what is most likely the core of the contamination (the sediments) but does not keep it from occurring again. In order to maximise the long term benefitss of the mitigation measures, it is essential to have the concept "bought in" by the occupants of the catchment.

5 POSSIBLE MITIGATION MEASURES

5.1 Global Concept

Better mitigation starts with a better understanding of what contaminants need to be addressed and where contaminants are coming from. Applying a monitoring pattern and choosing sampling locations based only on their easy accessibility doesn't tell much more than the presence or absence of contaminants. A more systematic sampling could be helpful at identifying the sources and determining the "Critical Source Areas" (CSA), such as up and downstream of major secondary drains. Those CSAs will constitute the targets of the Tier 1 mitigation measures as these areas are most likely contributing the bulk of the contaminants discharged into Osbornes Drain.

The most cost effective mitigation will consist of a mix of source reduction mitigation measures aimed at keeping contaminants from entering the drain via riparian measures, field (paddock) management measures and the development of adapted infrastructure.

"*The effect of livestock exclusion cannot be separated from the impacts of other attenuation tools in New Zealand catchment scale studies (Wilcock et al. 2007; Williamson et al. 1996). For example, livestock exclusion is just one of several mitigation tools being implemented in the Dairy Focus catchments (see Wilcock et al. 2007), and therefore cannot be isolated from other water quality improvements in these catchments.*" (NIWA, 2007-Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems).

However, it is anticipated that reducing sediment from being entrained in runoff (erosion), as well as putting in measures to reduce sediment in the runoff (sediment control), will result in the most cost effective mitigation. This is likely to require farm soil disturbance (cultivating/ploughing, etc.) to be treated in the same manner as construction earthworks and require an Erosion and Sediment Control Plan, with appropriate mitigation measures.

The determination of the CSAs will be done by thorough field inspections and by detailed assessment of the farm activities. Based on the results, it is more than likely that not all farms will have to support the same level of the mitigation measures as not all types of farm will be impacting the drain the same way and at the same level.

Mitigation measures will address both "diffuse" and "point source" contamination.

Diffuse Inputs:
Diffuse Inputs include losses from the use of fertilisers/effluents on the paddocks reaching the drain via sheet runoff, subsurface flows and/or via feeding from groundwater and direct deposit of faeces and urine by livestock grazing the Drain embankments.

Point Source Inputs:
These include runoff containing sediment from paddocks into subdrains.

Assuming the main contaminant source is from surface water rather than groundwater (as discussed by GHD 2015), then the ***main focus*** of the mitigation measures will be:

Phosphorus Forms: Particulate or Dissolved
Although it is unclear about the proportion of phosphorus originating from sediments (GHD 2015 notes the main mechanism may be sediment-bound P being released in the water column under low dissolved oxygen (DO) conditions), this assessment starts from the basic premise that the

best way to address the Dissolved Reactive Phosphorus (DRP) issue is to aim at reducing sediment inputs. However, some of the most cost effective proposed mitigation measures are addressing both, DRP and particulate P.

Nitrogen Forms: DIN or Organic
This assessment starts from the understanding that the majority of nitrogen inputs to Osbornes Drain will be in organic form. Therefore, measures aimed at keeping livestock and runoff away from the drain are the first steps of the mitigation process to be implemented.

Mitigation measures will be split into "On-Farm Mitigation" and "In-Stream Mitigation"

5.2 On-Farm Mitigation Measures

5.2.1 Riparian Measures

Livestock Exclusion

Target: Dissolved and Particulate P and Organic Nitrogen

Keeping livestock from having access to Osbornes Drain, and the associated farm drains, as well as the banks will:

- Avoid direct deposit of faeces and urine into the drain, and avoid deposits on the banks, which are susceptible to be flushed in by runoff;
- Reduce pugging and potential erosion;
- Improve the diversity and abundance of riparian vegetation as well as wildlife habitat near the stream by not allowing direct grazing.

Constraints: Time; fencing costs; loss of productive land; potential for constraining farm access where multiple farm drains need to be fenced

Notes:

- Livestock exclusion from streams also induces better herd health and livestock safety. *"Restricting livestock access to streams and providing an alternative water source will prevent livestock from depositing harmful manure-borne organisms in the stream, and will limit the livestock's contact with these organisms. Harmful waterborne organisms can reduce livestock productivity…Excluding cattle from streams may also decrease leg injuries associated with traversing muddy and/or steep banks"* (Zeckoski, Benham and Lunsford - 2012).
- McDowell (2008) reported a decrease of 90% in TP concentrations after a head water stream had been fenced off from red deer.
- It is critical that all streams, whatever their size and/or their ephemeral nature, are fenced as they may account for a large part of catchment runoff (McDowell, 2012).

Grass Strips/Buffers Zones

Target: Particulate P

Grass/buffer strips, when the width is adequately setup according to the slope, act as a filter and, by slowing down runoff velocity, allow for the deposition of sediment and associated P on land before entering the waterway. While not really addressing the source of the particles being discharged into a drain or stream, grass strips and buffer zones address the transport process to the stream.

The installation (or maintaining) of riparian vegetation along drains and water bodies and increasing/ensuring sufficient distance between drain and fence line will:

- Intercept surface runoff during rainfall, lower velocity and therefore limit the sediment discharge;
- Stabilise stream banks and reduce erosion.

Constraints: Time; fencing costs; loss of farming area; loss of farm access

Note:
Grass strips mitigation efficiency can quickly decrease due to the quick saturation of the strip unless they are associated with fencing and livestock exclusion. (McDowell, 2012).

The size of the grass strip or buffer zone can vary from 3 metres to 20 metres according to the geology, the soil type and the slope of the banks. "*In Victoria (Australia) the normal width of streamside vegetation is 5 - 10 m, but the maximum benefits are achieved at widths of 20 - 30 m (Department of Conservation and Environment 1990)*"

Ensure Riparian Zone Integrity

Target: Particulate P

Avoiding any deposit of material on the riparian zone (i.e. dredging material - sediments) will ensure the proper development of the vegetation of the riparian zone and, consequently, its effects on the drain protection. The deposit of sediment removed from the drain adjacent to the drain and on the relatively steep embankment creates a sediment "slab" which keeps the grass strip from acting as an effective filter and also provides material susceptible to be eroded by runoff and therefore constitutes a pool of potentially re-contaminating material at close distance from the drain.

Constraints: Cost of transporting and disposal costs if disposed at another location outside the farm. Shifting the deposited sediment further from the drain and off the drain side of the embankment would be beneficial and not too costly.

Avoid Subsurface Drains *Target: DRP and DIN*

Subsurface drains do not appear to be used in this catchment. Existing drains appear shallow to intercept and drain runoff from low areas. However, if in future subsurface drains are installed, then there should be some good practice guides to ensure subsurface drains are constructed with 400 – 600 mm of soil above the drainage chip to filter/adsorb leachate on its way to the drainage chip and pipe and associated with infrastructural measures like constructed wetlands (see section 5.4.2).

5.2.2 Paddock Management

Parking/shading/feeding areas

Target: Dissolved and Particulate P, Organic Nitrogen

Water feeding points (troughs) and resting areas are known as being locations of a paddock where pugging occurs and where N and P are returned to the soil via dung and urine from the livestock. The purpose of this mitigation measure is to ensure that livestock are kept away from the drain or any sensitive areas and to create and position water feeding points, as well as shading and parking areas, away from any potential runoff path, such as low areas, ephemeral swales. It is important to make sure that the mitigation measures address all aspects at the same time (water feeding, shading, parking) and not separately as, for instance, a parking area at a non-shaded location will not keep livestock from spending equal amount of time under the shade, hence the risk of runoff when these shaded areas are located along drains.

Constraint: Time; relocation of drinking troughs; installation of shelters; tree planting

Implement Low/Zero Tillage Practices

Target: Particulate P

Low/zero tillage is an agricultural technique which increases the amount of water that infiltrates into the soil, increases organic matter retention and cycling of nutrients in the soil and reduces soil erosion. Consequently, low/zero tillage practices significantly reduce the potential for runoff. These practices also reduces the potential for erosion by not having large areas of disturbed and unprotected soil.

Although zero tillage may not be practical for all farming activities, it should be encouraged and the ability to cultivate ground as part of a crop rotation should be restricted in sensitive areas – adjacent to the drain, or areas that have secondary drains or shallow swales. Intensive rotational/strip grazing of green feed crops should be actively discouraged in this catchment and particularly in sensitive areas.

Constraints: none

Timing

Target: Particulate P and Organic Nitrogen

Assuming diffuse losses would represent a significant contributor, this measure consists of programming fertiliser applications and other amendments outside forecast rain periods.
"The potential losses from fertilisers and/or manure is greatest soon after application and declines exponentially with time as fertilisers' P is sorbed to the soil and manures/slurry infiltrates into the soil or crusts-over preventing the interaction of the manure with runoff and invertebrates action buries P into the soil." (McDowell, 2012)

Constraints: re-organisation of application/irrigation schedules based on weather forecasts; modification of the Farm Management Plan

5.2.3 Infrastructural Measures

Bunding/Sediment Traps

Target: Particulate P

Bunding, or the building of sediment traps across the low areas of the paddocks located along Osbornes Drain and/or any contributing secondary drains will pond sediment laden runoff allowing sediment to be settled out and reduce it from reaching the drains. The ponded water eventually infiltrates leaving the sediment on the surface to be incorporated into the topsoil. This measure may seem at odds to the original intention of the drainage system (to quickly remove ponded water from the paddocks), however, research in the Bay of Plenty has shown that by allowing temporary ponding in ephemeral areas has reduced sediment and Particulate P from entering surface waters.

Sediment traps are useful for the retention of coarse-size sediment. However, the removal rate is lower for fine particles. Therefore, this type of mitigation is to be implemented in conjunction with other mitigation measures.

Constraints: Time; earthworks and bypass piping costs; temporary loss of production in ponded areas

On-farm Constructed Wetlands

Target: Dissolved and Particulate P, and DIN

CSAs located within the catchment and away from Osbornes Drains but still contributing to the contaminants to the drain via secondary contributing drains during rain events can be equipped with collection and treatment infrastructure aiming at the interception and the treatment of runoff (and shallow groundwater, if appropriate). One of the most interesting aspects of constructed wetlands is that, not only do they allow the reduction of readily available N and P (including plant uptake and inclusion of P-sorptive material) and can act as a buffer for peak flows, but they also can act as sediment traps which, given the type of issues encountered within Osbornes Drain, has an appreciable and positive impact on the turbidity and the content of Total Suspended Solids (TSS). Subsurface drains draining wet patches lower the risk of runoff during rainy events and allow a controlled conveyance of the water to the constructed wetlands. However, studies have shown that P losses can be enhanced by tile drainage. Therefore, it's important to associate tile draining with the wetland sequestering capabilities.

Constraints: Time; earthwork and planting costs; loss of farm area; fencing costs; maintenance costs

5.2.4 Farmer Education

Information Sessions

Target: Support from farmers and others within the catchment

Having farmers and other stakeholders within the catchment buy-in the concept and/or strategy to mitigate the water quality in Osbornes Drain is a key factor. It is important to explain the impact of the farms on the drain and, eventually, on Te Waihora, and the scale effects within the catchment. It is also important to make the results of the different assessments accessible to the public and clearly outline how these results compare against the regional plans. These information sessions will be used to present the "Mitigation Toolbox", and how it applies to the different type of farms/others of the catchment.

Constraints: none

5.2.5 Sediment and Nutrient Management Plans

Target: Farm management; Best management practices

The main objective is to address the release of contaminants as early as possible during their journey from the farm to the drain, therefore addressing the root cause of the contamination rather than fixing the consequences. Considering that the activity within the catchment is mostly farming, the requirements for management plans as outlined by the proposed Land & Water Regional Plan provide the basis for a more "Osborne Drain focused" management tool.

While Farm Environmental Management Plans address the impact of the farm activities on the Environment in general, they are not specific to the Osbornes Drain context. As the Osbornes Drain catchment is directly connected to and contributing to the enrichment of Te Waihora, it would be key to address the impacts of the farming activities through a more specific plan. A Sediment and Nutrient Management Plan (SNMP) is recommended as a subsection of the Farm Environmental Management Plan (FEMP) and would cover sediment, N and P management related good practices. The plan would outline the different CSAs within the farm and individually and specifically address the different farming activities.

In addition, with the inclusion of the SNMP, the Farm Environment Management Plan would outline all the benefits achievable - at the farm level - from "upgraded" practices compared to current ones.

A sample SNMP is included in **Appendix A.** This is for a theoretical farm.

Constraints: Contractors/consultancy costs; change in culture/mind set

5.3 In-Stream Mitigation Measures

5.3.1 Maintain the Wetland Characteristics of the Drain

Target: Dissolved and Particulate P, and DIN

Including instream wetland vegetation will assist in removing nutrients such as inorganic nitrogen and dissolved phosphorus as well as trapping sediments and particulate phosphorus. If done appropriately this could also enhance the ecological values in the drain (Boffa Miskell, 2015).

Constraints: None

5.3.2 In-stream Sediment Traps

Target: Particulate P

In association with the other in-stream measures (**section 5.3.1**), installing weirs at regular distances within the drain to create ponding would regulate the flows and allow the sedimentation of coarse and finer elements including particulate P. It will provide succinct areas for sediment removal rather than the entire length of the drain.

Constraints: Time; earthworks and weir construction; maintenance costs.

5.4 Mitigation Matrix

The choice of mitigation measures will depend on the location within the catchment, as well as the type of activities undertaken within those farms, and will aim at addressing the "root cause"; that being contaminants entering the drain.

Table 5.4.1 below outlines the possible mitigation measures, a ranking of their expected efficacy against Nitrogen and Phosphorus removal, the ease of implementation and their order of cost.

Table 5.4.1 - Mitigation Matrix

Mitigation Measures	Overall Effectiveness[1]	Ease of Implementation[2]	N Reduction	P Reduction	Cost ($/kg P conserved)[3]
Livestock exclusion	3	3	Y	10 – 30%[3]	5 - 65
Grass strips/Buffers zones	2	3	20 - 40%[4]	20 - 40%[4]	30 - >250
Ensure riparian zone integrity	3	3	N	Y	(*)
Parking / shading / feeding areas	2	3	Y	Y	(*)
Implement Low/zero tillage practices and grazed crops	2	2	N	30 – 50%[3]	40 - 250
Timing	1	2	Y	Y	3 - 250
Bunding/Sediment Trap	3	3	20 - 60%[4]	40 - 80%[4]	>550
Constructed wetlands	3	1	20 - 60%[4]	40 - 80%[4]	150 - 500
Farmer education	3	5	Y	Y	(*)
FEMPs	3	4	Y	Y	(*)
Low solubility P fertiliser	2	4	NA	0 - 20%[3]	0 - 30
In-stream Wetland	3	5	Y	Y	(*)
In-stream Sediment Trap	2	4	N	Y	(*)

[1] 1=poor efficacy; 5=high efficacy
[2] 1=difficult; 5=easy
[3] McDowell and Nash, 2012
[4] Christchurch City Council, 2003
(*) Can't be estimated

Note: Putting costs against mitigation measures aimed at nitrogen reduction alone is difficult in this case as N is not considered to be coming through from leaching below the soil profile but essentially considered to be coming from overland runoff along with P and is therefore likely to be reduced through the same processes.

6 RECOMMENDATIONS AND CONCLUSIONS

The possible mitigation measures outlined in Section 5 include a number of measures that range in efficiency from unknown to 80% P removal. Table 5.4.1 shows that the cost per kg P of conserved (that does not enter the drain) ranges from $0 to greater than $550.

The implementation of the proposed mitigation measures can be staged in a way that will address the CSAs as highest priority and by implementing the mitigation measures having the best overall technical and economical effectiveness at first. Some of the mitigation measures are obvious in certain cases (i.e. avoiding the direct access for the livestock to the drain) and represent the "low hanging fruits" that need to be harvested first. In the same way, the education of the farmers on the different environmental issues encountered within the Osbornes Drain catchment represents not only an important initial step but also constitutes a warranty in getting farmers' buy-in and will ensure their sustainability (continued existence).

Developing and maintaining the wetland characteristics of the Osbornes Drain as well as the implementation of several in-drain mitigations will likely improve the quality of the water discharge via the pump house into Te Waihora and potentially improve ecological values (Boffa Miskell 2015).

By staging, it is also possible to monitor the measure's effectiveness, i.e. implement and monitor before undertaking further measures.

The recommendations at the farm level are therefore to start with the measures that are low cost and give the greatest reduction in sediment, P and N. The ranking is therefore:

(1) Educate farmers on benefits of reducing sediment erosion and runoff and putting together a FEMP with SNMP subsection and implementing this. This will identify critical areas within the farm that need to be protected or special care taken, such as keeping watering and stock camping areas away from drains and low spots. It may require some critical areas to be retired from farming;
(2) Timing of fertiliser application and using low soluble P;
(3) Fencing of drains with appropriate buffer;
(4) Setting back dredging's from drain maintenance from the drain and vegetating these dredging's;
(5) Planting the fenced off buffer areas;
(6) Implementing zero or low tillage practices and removing strip grazing of winter greenfeed crops. These will come into the S&NMP for critical areas within the farm;
(7) Consider future drain management options to reduce drain clearance works and associated impacts;
(8) Sediment bunds on ephemeral areas, particularly if a paddock has been cultivated; and
(9) Wetlands on the end of drains prior to exiting the property and entering Osbornes Drain and/or specific works within Osbornes Drain.

It is recommended that the first 7 steps are initially undertaken as these are low cost. Measures' 8 and 9 would only be implemented if an area needed to be cultivated that could have runoff associated with it and therefore the extra protection was warranted.

Monitoring prior to and then after implementation of the initial steps should continue for at least two years prior to implementing the more costly measures. Subdrains could be used to monitor the effectiveness of some of the on-farm practice changes but this would also require collection of baseline data.

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