

# **Client Report**

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**Estimation of phosphorus loads from  
dryland and irrigation areas in the  
Hakatamea catchment**

R.W. McDowell

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## Summary

The loss of phosphorus (P) from agricultural land to surface water has the potential to impair water quality. This work examined the likely P losses associated with 1) current irrigation consents, 2) new consents applied for 3) a “community irrigation scheme” and 4) dryland sheep farming in each of the three previous scenarios in the Hakataramea River catchment. Data for total P losses ranged from 0.01 (largely under dryland sheep farming) to 0.09 kg/ha/yr. Among land uses, deer farmed land lost more P than sheep and beef farmed land with an equivalent slope, and dryland sheep farming lost the least amount of P of any land use. Mean losses of P in scenario 1 were 0.21 kg P/ha/yr, which was less than that lost in scenario 2 (0.30 kg P/ha/yr) but greater than for the community scheme (0.15) due to issues of connectivity and insufficient data to predict loads at points on the catchment’s river. These losses are relatively small for catchments dominated by grazed pastures but reflect the proposed widespread use of low intensity sheep and beef farming, spray irrigation and flat topography. However, analysis emphasized the importance of irrigation on increasing the P losses by an order of magnitude above current dryland sheep farming, and hence, also emphasized the need for best management practices to be used where appropriate to decrease the potential for P loss.

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## 1. Introduction

Phosphorus (P) loss from land to surface water has potential to impair water quality via eutrophication. Due to the significant interaction between subsurface flow and P retentive subsoil, P concentrations and loads in groundwater are generally small (e.g., < 0.001 mg P/L and < 0.001 kg P/ha/yr). However, concentrations and loads in overland and shallow subsurface flow are generally 1 to 2 orders of magnitude greater. In a review of P loss, Haygarth and Jarvis (1999) argued that mechanisms of P loss to surface waters could be split into two: background transfers that describe loss when P has had a chance to interact with the soil, and incidental transfers where P applications are followed soon after by an overland or subsurface flow event leading to potentially large P losses (e.g., 30 mg P L<sup>-1</sup>; Preedy et al., 2001). McDowell et al. (2005) have recently developed a model to determine P losses to surface waters. This model has been incorporated into the Overseer nutrient budgets 2<sup>®</sup> model.

## 2. Aims

The purpose of this study was to estimate P losses for four scenarios within the Hakataramea River catchment. The background to these scenarios is described by Zemansky et al. (2006). Briefly, the scenarios considered were:

- scenario 1; P losses from existing irrigated land usage - no change in irrigation,
- scenario 2; P losses from scenario 1 and all new irrigation consents applied for and deemed economically viable,
- scenario 3; P losses from all potentially irrigable land in the Hakataramea catchment. This is defined as the “community scheme”. This scenario includes all land irrigated under scenarios 1 and 2, and
- scenario 4; P losses from the Hakataramea River catchment without any irrigation (dryland sheep only) on land currently with a consent to irrigate in scenario 1 (i), on land under consideration in scenario 2 (ii) and land involved in the “community irrigation scheme” (iii).

## 2.1 Model Description

For a full description of the model and its limitations the reader is directed to McDowell et al. (2005). However, a brief description follows and is conceptualised in Figure 1:

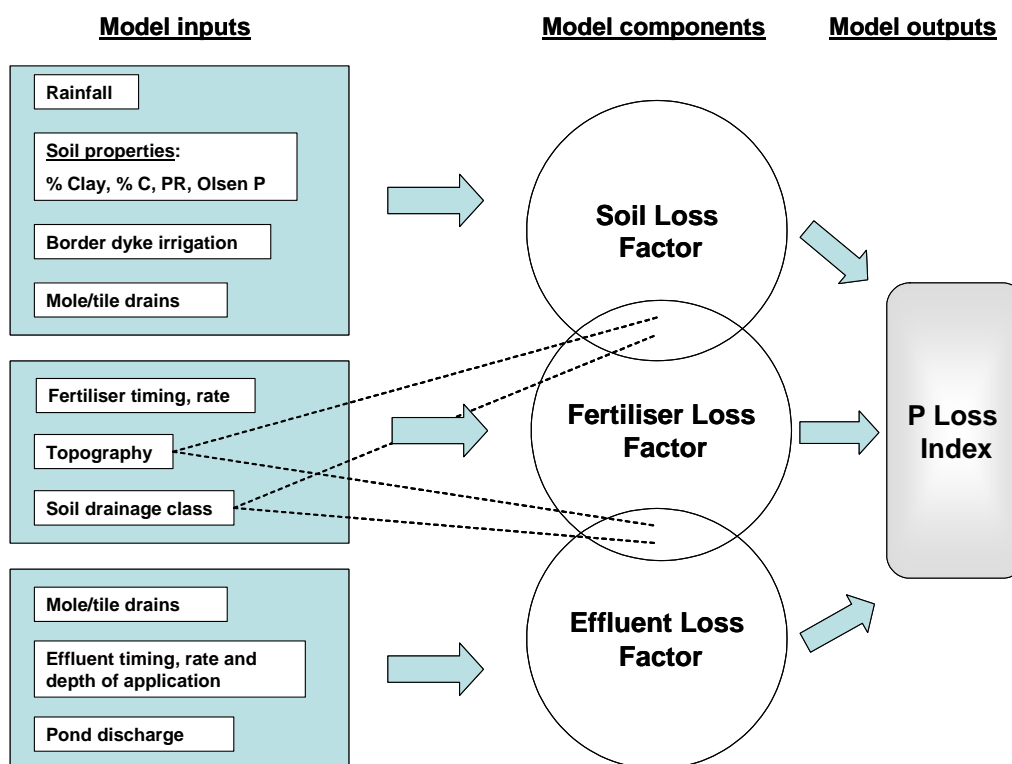


Fig. 1 Conceptual diagram of model structure

### 2.1.1 Background soil P loss risk

Background losses are determined from P losses from the soil, and influenced by transport and management factors likely to influence P loss in the long-term such as tile-drainage and border dyke irrigation.

In general, P loss from pastures is dominated by dissolved reactive P (DRP). The model uses the equation derived by McDowell and Condron (2003) to estimate DRP concentration in subsurface and overland flow from soils without recent grazing. This equation uses Olsen bicarbonate extractable P (Olsen et al., 1954) and anion storage capacity or % P retention (PR).

Total P loss incorporates factors that relate to the loss of P in particulate form, largely soil erosion. The structural vulnerability model of Hewitt and Shepherd (1997) estimates

soil resistance to physical degradation and is used, in a modified form, as a surrogate for inherent soil erosion potential. The inputs are anion storage capacity (ASC or P retention), total organic carbon and clay content.

An estimate of total P loss on an event basis was determined from topsoil (0-7.5 cm) Olsen P, the modified structural vulnerability model, and DRP as determined from McDowell and Condron (2003). However, estimating soil P loss on an annual basis (i.e. load) requires inclusion of transport factors such as topography and precipitation as well as unique management factors that alter the flow path and duration of P loss such as irrigation.

### *Estimating transport*

The initiation and transport of P from the landscape requires conditions conducive to either overland or subsurface flow. In many situations the P loss to the stream is dominated by overland flow since soil will adsorb most P from subsurface flow, unless, as with tile drainage, a direct conduit to the stream exists (McDowell et al., 2004). In general, more P is lost from soils with increasing slope, largely as particulate P (Uusitalo et al., 2001). Generally, for flow to occur, a surplus of precipitation must exist.

To estimate the potential for overland flow, two factors, drainage class and a slaking/dispersion index are combined. Drainage class (range 0-1) is based on the USDA curve number method for determining soil hydrologic class and utilises soil texture. Soils with a coarse texture will have less potential for flow (low drainage class) than fine textured soils, not accounting for their position in the landscape.

The slaking/dispersion index takes into account the potential for soil damage to influence soil hydrology. For example, a Pallic soil with a high potential for slaking and dispersion is known to have drainage problems and produce much overland flow and in-turn P loss (McDowell et al., 2003a). Hewitt and Sheperd (1997) present values for the relative slaking and dispersion potential of New Zealand soil orders.

The model estimates default values for both these parameters based on soil texture (drainage class only), soil group (drainage class only), and soil order or soil name.

### *Management influences*

Some management factors profoundly influence the availability of P to flow, the pathway of water flow, and the connectivity between the site of P loss and the stream. Two of these factors are drainage and irrigation. Tile drainage provides a direct conduit for P

from enriched topsoil to be lost to the stream, bypassing most of the soil en route via macropores and enhancing P loss. Irrigation can be border dyke or spray. Due to low rainfall intensities for many spray irrigation systems (e.g., 3 and 18-19 mm/hr for K-line and Rotorainers, respectively) this form of irrigation is included in precipitation values used to calculate potential flow. In contrast, the potential for P loss from border dyke irrigation can be much greater than for tile drainage or spray irrigation, since there is much potential for water flowing over the soil surface where P is concentrated to be lost (Austin et al., 1996). Since this is overland flow (albeit an extreme form), P loss via border dyke irrigation is estimated from the soil's Olsen P concentration and normalised surplus rainfall, which incorporates water added via irrigation.

### **2.1.2 Incidental P loss risk**

Incidental loss of P via fertiliser and manure applications is treated separately, although incidental losses also rely on a similar set of factors (management and transport) mentioned under background losses.

#### *Management factors*

The primary factor in determining P loss via fertiliser and effluent (from farm dairy or feed pads) is the rate of application and transport factors. For effluent application, recent research has indicated that too fast an application may cause bypass flow and direct P loss (Monaghan and Smith, 2004; Houlbrooke et al., 2004). This is incorporated into the model via a weighting for each of three categories (slow, medium, fast). Direct discharge to a waterway from an effluent pond is also accounted for by the model.

#### *Transport factors*

In addition to topography and drainage class, another factor important to the incidental loss of P from fertiliser is the timing of application. Most farmers will try to apply effluent when the soil is not overly wet. However, if applied when wet then the depth of application and presence or absence of mole-tile drains then adjust the risk of P loss accordingly. The time of year of fertiliser and effluent application also influences P loss. Following superphosphate application, the potential for P loss is enhanced for a period up to 60 days (McColl et al., 1975; Sharpley and Syers, 1979). If water flow occurs during this period then an incidental P loss occurs. To account for this, the month of year when P is applied is combined with the probability of overland flow for regions around New Zealand. A month is deemed as high risk if percentage frequency of

months when saturation-excess overland flow (calculated from a water balance model) is > 60%. The risk of incidental P loss from soils with slow release fertilisers such as reactive phosphate rock (RPR) applied is significantly decreased; hence, monthly risk is set to low (McDowell et al., 2003b; Nguyen et al., 2002). For effluent, a sliding scale is used to rank P loss risk according to risk months.

### 3. Model calibration, limitations, assumptions and inputs

Estimates of P loss (background and incidental losses) have been calibrated against data from 23 New Zealand pastoral systems of various scales from plot to catchment (2m to 500 ha). However, estimates of P losses from areas larger than 500 ha have not been tested. Moreover, calibration of P loss from the Hakataramea catchment under the present land use and areas are not available and therefore estimates are subject to some uncertainty. The primary output of the model is total P loss. Dissolved reactive P can also be obtained but will be subject to greater uncertainty without calibration and hence is not presented here.

During modelling, each farming operation or irrigation scheme was delineated by land use on each soil type. Irrigated areas were analyzed separately from dryland areas. Output is given as a weighted average according to the proportion of landuse on a particular soil type within a farming operation or irrigation area. Data for land use on each soil type was taken from Zemansky et al. (2006). All scenarios were tested at a steady state (i.e. established farm) on an annual basis. For each landuse the following was assumed:

For dryland sheep:

- Soil Olsen P concentration was 8 mg/kg on all soil types, and maintained by inputs of superphosphate of 3 kg P/ha/yr (Jarvis et al., 2002). This supported 1.5 su/ha. No N applied.

For mixed sheep and beef farming on irrigated areas the following was assumed:

- Soil Olsen P concentration was 16 mg/kg on all soil types, and maintained by inputs of superphosphate of 19 kg P/ha/yr. This supported up to 17.7 su/ha (12,140 kg DM/ha; 8.6 breeding ewes/ha, 6.0 finishing lambs and hoggets/ha or 1.7 breeding cows/ha and 1.4 finishing cattle and heifers/ha). Nitrogen use approximately 200 kg N/ha/yr spread evenly in 3 applications during the pasture growth period.

For beef farming on irrigated areas the following was assumed:

- Soil Olsen P concentration was 20 mg/kg on all soil types, and maintained by inputs of superphosphate of 26 kg P/ha. This supported 18 su/ha (1.7 breeding cows/ha + 1.6 finishing cattle and heifers/ha). Nitrogen use was approximately 200 kg N/ha spread evenly in 3 applications during the pasture growth period.

For deer farming on irrigated areas the following was assumed:

- Soil Olsen P concentration was 23 mg/kg on all soil types, and maintained by inputs of superphosphate of 25 kg P/ha/yr. This supported up to 17.7 su/ha (12,140 kg DM/ha; including 5.6 hinds/ha + 4.35 head/ha on finishing portion). Nitrogen use approximated 200 kg N/ha/yr spread evenly in 3 applications during the pasture growth period

Additional assumptions were made for all scenarios:

- The area of arable land is small and contributes little P loss to surface waters. It was assumed that the infiltration rate, slope and position of arable land within the catchment was such that overland flow from arable land was minimised compared to other land uses and not connected to permanent waterways.
- In the absence of exact GIS data, most farms were assumed to have flat topography. The exceptions were properties identified as 13, 16, 19 and 26, which were assumed to have a rolling topography (8-15°).
- An even rainfall of 640 mm (equivalent to the long-term mean) was assumed across all land uses (Zemansky et al., 2006). Irrigation, where simulated in a scenario, was determined by soil type: the Pukaki soil (1) received 459 mm, the MacKenzie stony soil (2) received 522 mm, the MacKenzie very stony soil (3) received 540 mm, and the Edwards soil (4) received 432 mm. Soil chemical parameters (except Olsen P concentration) were taken from the New Zealand national soils database. Since the Edwards soil is not in the database, a similar Typic Laminar Pallic soil, an Otama silt loam was used as a substitute.
- All P was applied as superphosphate and applied to decrease the potential for P loss (i.e. using best management).
- The arrangement of each land use within a zone vis-à-vis the output waterway is random so that no land use will exert undue influence on P loss (e.g., Deer farming abutting a stream).
- It was assumed that 75% of the area available in the “community irrigation scheme” would be irrigated allowing for non-irrigated land such as farm tracks, buildings and roads.
- Since neither the length of waterways within each scenario nor a detailed digital elevation model were known or available, flow routing was not possible. Instead, loads are presented for each property. For scenarios 3 and 4 and dryland sheep farming, which were modelled as covering nearly all the lower catchment’s area,

an attenuation factor was approximated whereby properties closer to the stream yielded their full potential P loss, while those far from the outlet of the Hakataramea River were attenuated. As such, it is preferable that data from each scenario be compared via the potential load of P lost (kg P/ha/y).

#### 4. Results and discussion

Data for the total irrigated and dryland area for each soil type and land use for scenario 1 are given in Table 1 along with companion data for total P losses. Loads for dryland sheep grazing are very small and near the input received via precipitation (Jarvis et al., 2002). Such small loads are outside the range for most grazed catchments in New Zealand (0.3-1.7 kg TP/ha/yr: Wilcock, 1986: Vant, 2001), but not unexpected due to the very low likelihood of overland flow - the main mechanism in most landscapes for P loss to surface waters. However, recent work in the Hawke's Bay has determined TP loss under dryland extensive sheep farming of 0.05 kg/ha/yr (A. Gillingham pers. comm.). This is largely caused by hydrophobic conditions on organic matter-rich soils that promote overland flow in summer when most superphosphate is also applied. Slopes within the Hakataramea are generally flatter than the Hawke's Bay catchment in question and soil organic matter concentrations much less inferring that hydrophobic soil conditions are much less likely and small P losses < 0.01 kg P/ha/yr realistic.

Under scenario 1 (Table 1), of those properties listed, the majority farm sheep and beef. The mean P loss in the upper Hakataramea was estimated to be about 0.15 kg P/ha/yr, increasing to 0.27 kg P/ha/yr at the lower end of the catchment. Overall, the load of P lost was 0.21 kg P/ha/yr. Loads of P loss ranged from 0.04 to 0.87 kg/ha/yr. Loads in properties 13, 16, 19, and 26 were exacerbated by rolling topography. In addition, those properties farming deer tended to be greater than those farming sheep and beef. Overall, variation among properties was minimal due to the dominance of sheep and beef farming and the uniformity of irrigation (i.e. only small volume differences occur between areas of different soils). However, compared to dryland sheep farming, loads from irrigated areas were considerable greater due to increased inputs of superphosphate, greater soil Olsen P concentrations and more stock per ha. The contribution of P via groundwater in this scenario, and indeed in all scenarios, is generally < 5% of the calculated total P loss.

It must be mentioned that in scenarios 1 and 2 no consideration has been given to the various combinations of landuse and soil type outside of the properties listed as this data was not available. However, if it is assumed that the vast majority of this was

dryland sheep farming, which loses very little P per ha, then loads from irrigated areas may have been attenuated before reaching the Hakataramea River.

In scenario 2 (Table 2) all new applications for irrigation consents were modelled. Here, P losses in the upper part of the catchment were estimated to be 0.28 kg P ha/yr, while that lost to the lower part of the catchment would be 0.42 kg P/ha/yr. Overall these new consents would lose about 0.3 kg P ha/yr. Again since flow routing could not be done the actual losses may vary greatly from these loads. The mean load of P lost from the new consents was 0.38 kg P/ha/yr almost double that lost in scenario 1, while the range was from 0.05 to 0.83 kg P/ha/yr.

In scenario 3, the community scheme was estimated to contribute about 0.16 and 0.11 kg P/ha/yr into the upper and lower parts of the Hakataramea River, respectively. Overall, the loss was about 0.15 kg P/ha/yr. The losses were less than in scenarios 1 and 2 on a “per ha” basis (but greater overall i.e. kg P lost: see Table 6) due to the modelling of sheep and beef farming in the irrigated areas and the absence of deer farming and steep land.

In scenario 4, three estimates were determined i) that all existing land with irrigation consent is reverted to dryland sheep farming ii) that all new applications for irrigation consents being considered are under dryland sheep farming and iii) that dryland sheep farming is the landuse of the “community scheme”. The data are in Tables 4, 5, and 3, respectively. Losses on an area specific basis are all at or < 0.1 kg P/ha/yr, even from properties with rolling topography.

A comparison of each scenario is given in Table 6 on area basis. Likely mean P concentrations in streamflow for the dryland sheep scenarios and, as a comparison, for the community irrigation scheme are also given. Concentrations of P in streamflow are only estimates, but relate well to the 10-y median total P concentration of 0.011 mg P/L for samples taken near to the MBHR gauging station.

While irrigation is clearly the dominant factor in determining P losses in this analysis, data would be improved by the inclusion of topographical and climatic information to better discern the likelihood of P losses within each farming system. This analysis also does not consider irrigation of arable land to be a serious influence on P losses due to the small area under arable land use relative to pastoral land uses, and high infiltration rates (> 200 mm/hr) in most cultivated soils that render overland flow on flat land unlikely. However, it is recognised that grazing of winter crops can decrease infiltration rates due to pugging and increase the likelihood of overland flow and P loss. (McDowell et al., 2003c,d). This is exacerbated if practiced near the stream or on a

slope. To mitigate the potential for P loss a number of management practices can be used. Some are listed below:

- Decreasing soil Olsen P concentrations to agronomic or economic optima by having a negative P balance.
- Establishing riparian or buffer strips in near stream areas to prevent P loss by overland flow. No grazing should be allowed in these areas, but hay or silage should be cut to harvest nutrients.
- Fencing off streams and waterways.
- Minimising treading damage on wet soils by using feedpads or on-off grazing strategies.
- Avoiding application of fertiliser-P in near stream areas or areas likely to be connected to a stream either by a culvert or natural topography (e.g., an erosion gully, drainage depressions).
- Decreasing P lost in overland flow, and in most soils decreasing overall P loss (even though subsurface losses are increased) by installing drainage in wet areas.
- Channelling flow from bridges and laneways away from the stream.
- For dairy farms: installing an effluent storage system so effluent can be applied in areas unconnected to the stream at times of the year when P loss is less likely (e.g., late spring and summer for most soils, except cracking soils).

Table 1: Current Irrigation and Dryland Phosphorus Losses By Soil Group - Scenario 1

#	Prop_ID	Irrigated Area (ha) By Soil Group								Dryland Area (ha) by soil type				Total Irr. (ha)	Land Use	Irrigated P losses (kg)				Dryland P Losses (kg)				Mean P loss/ha /property
		1				2				3						4								
		1	2	3	4	1	2	3	4	1	2	3	4			1	2	3	4	1	2	3	4	
1	1	0	97	20	23	0	80	17	19	255	140	Deer	0.0	42.0	15.9	20.6	0.0	2.1	0.7	1.1	0.32			
2	3	0	6	44	0	0	3	16	0	69	50	S&B	0.0	1.4	16.2	0.0	0.0	0.0	0.3	0.0	0.26			
3	4	0	50	0	0	0	26	0	0	76	50	Deer	0.0	21.7	0.0	0.0	0.0	0.7	0.0	0.0	0.29			
4	5	15	105	0	0	12	89	0	0	221	120	S&B	0.7	24.8	0.0	0.0	0.0	0.8	0.0	0.0	0.12			
	6A	0	0	95	121	0	0	24	30	270	216	S&B	0.0	0.0	34.8	42.8	0.0	0.0	0.4	0.7	0.29			
	6B	112	23	0	45	28	6	0	11	225	180	S&B	5.1	5.4	0.0	15.8	0.1	0.1	0.0	0.3	0.12			
	6C	29	4	0	0	7	1	0	0	42	34	S&B	1.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06			
8	7A	6	0	49	0	2	0	14	0	70	54	S&B	0.2	0.0	18.0	0.0	0.0	0.0	0.2	0.0	0.26			
9	7B	0	83	0	0	0	23	0	0	106	83	S&B	0.0	19.6	0.0	0.0	0.0	0.2	0.0	0.0	0.19			
10	7C	133	7	27	0	37	2	8	0	215	168	S&B	6.0	1.7	10.1	0.0	0.1	0.0	0.1	0.0	0.08			
11	8A	0	0	96	0	0	0	4	0	100	96	S&B	0.0	0.0	35.3	0.0	0.0	0.0	0.1	0.0	0.35			
12	8B	0	24	0	0	0	1	0	0	25	24	S&B	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.23			
13	9	45	3	0	0	105	8	0	0	161	48	S&B	2.0	0.7	0.0	0.0	0.3	0.1	0.0	0.0	0.02			
14	10	0	40	0	0	0	83	0	0	123	40	S&B	0.0	9.4	0.0	0.0	0.0	0.7	0.0	0.0	0.08			
15	11A	0	0	0	0	0	3	0	0	3	0	Deer	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.03			
16	11B	0	59	76	0	0	5	5	0	147	136	Deer	0.0	25.7	60.7	0.0	0.0	0.1	0.2	0.0	0.59			
17	12	0	60	0	0	0	50	0	0	110	60	S&B	0.0	14.2	0.0	0.0	0.0	0.4	0.0	0.0	0.13			
18	13	64	6	9	0	11	1	2	0	94	80	Deer	32.3	9.2	17.0	0.0	0.1	0.1	0.2	0.0	0.63			
19	16A	0	18	0	0	0	0	0	0	20	18	S&B	0.0	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.71			
20	16B	0	32	0	0	0	0	0	0	35	32	S&B	0.0	25.2	0.0	0.0	0.0	0.0	0.0	0.0	0.72			
21	17	31	21	14	128	0	0	0	0	240	195	S&B	1.4	5.0	5.3	45.3	0.0	0.0	0.0	0.0	0.34			
		0	0	0	0	8	5	4	30			Arable	0.0	0.0	0.0	0.0	4.0	2.5	2.0	15.0				
22	18	151	0	0	0	3	0	0	0	154	151	S&B	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04			
23	19A	0	9	6	0	0	0	0	0	15	15	S&B	0.0	7.1	6.0	0.0	0.0	0.0	0.0	0.0	0.87			
24	19B	9	174	0	0	0	0	0	0	184	184	S&B	1.4	137.1	0.0	0.0	0.0	0.0	0.0	0.0	0.75			
25	20A	75	6	7	0	0	0	0	0	109	88	S&B	3.4	1.4	2.6	0.0	0.0	0.0	0.0	0.0	0.16			
		0	0	0	0	17	2	2	0			Arable	0.0	0.0	0.0	0.0	8.5	1.0	1.0	0.0				
26	20B	3	0	28	1	1	0	6	0	39	32	S&B	0.1	0.0	10.3	0.4	0.0	0.0	0.1	0.0	0.28			
27	21	0	43	1	0	0	28	0	0	73	44	S&B	0.0	10.1	0.4	0.0	0.0	0.2	0.0	0.0	0.15			
28	22	0	0	6	0	0	0	0	0	6	6	S&B	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.37			
29	23	97	33	0	0	2	1	0	0	133	130	S&B	4.4	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.09			
30	25	0	3	9	0	0	6	13	0	30	12	S&B	0.0	0.7	3.3	0.0	0.0	0.1	0.2	0.0	0.14			
31	26	9	19	30	0	6	13	20	0	97	58	S&B	1.4	14.9	30.1	0.0	0.1	0.4	0.9	0.0	0.49			
32	27	0	0	13	0	0	0	0	0	13	13	S&B	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.37			
Total		781	926	531	318	239	436	135	90	3,460	2,557	Total (to Wright's Crossing)	13	118	130	79	0	4	2	2				
												Total (MHBR to Wright's Crossing)	53	288	143	46	13	6	5	15				
												Combined	67	406	273	125	13	10	7	17				

**Table 2: New Consent Phosphorus Loss By Soil Group - Scenario 2**

#	Prop_ID	Irrigated Area (ha) By Soil Group				Total_A	Total GrIrr_A	Assumption Used in Modeling	Use	Irrigated P losses (kg)				Mean P loss/ha /property	
		1	2	3	4					Irrigated by soil type					
										1	2	3	4		
1	2A	35	0	0	0	82	35	20% Beef, 80% Sheep	Beef	1.6	0.0	0.0	0.0	1.6	0.05
2	2B	0	18	0	0	43	18	20% Beef, 80% Sheep	Beef	0.0	4.2	0.0	0.0	4.2	0.24
3	2C	0	19	0	0	46	19	20% Beef, 80% Sheep	Beef	0.0	4.5	0.0	0.0	4.5	0.24
4	2D	0	4	3	121	300	128	20% Beef, 80% Sheep	Beef	0.0	0.9	1.1	42.7	44.8	0.35
5	3	7	78	35	0	373	120	20% Beef, 80% Sheep	Beef	0.3	18.4	12.9	0.0	31.6	0.26
6	4	13	127	0	0	147	140	100% Deer	Deer	2.0	55.0	0.0	0.0	57.0	0.41
7	7	92	22	6	0	290	120	100% Deer	Deer	13.9	9.5	4.8	0.0	28.2	0.24
8	11A	0	1	15	0	15	15	100% Deer	Deer	0.0	0.4	11.9	0.0	12.4	0.83
9	11B	0	0	77	0	77	77	100% Deer	Deer	0.0	0.0	61.3	0.0	61.3	0.80
10	11C	16	11	174	0	201	201	20% Beef, 20% Deer, 60% sheep	Beef	0.1	0.5	12.8	0.0	13.5	0.07
									Deer	0.5	1.0	27.7	0.0	29.1	
									Sheep	0.4	1.6	38.4	0.0	40.4	
11	13A	0	2	0	0	2	2	100% Deer	Deer	0.0	0.9	0.0	0.0	0.9	0.43
12	13B	0	3	0	0	3	3	100% Deer	Deer	0.0	1.3	0.0	0.0	1.3	0.43
13	14	17	4	25	0	56	46	100% Deer	Deer	2.6	1.7	19.9	0.0	24.2	0.53
14	15	0	6	34	0	46	40	100% Deer	Deer	0.0	2.6	27.1	0.0	29.7	0.74
15	24A	2	17	11	0	99	30	20% Beef, 80% Sheep	Beef	0.1	4.0	4.0	0.0	8.1	0.27
16	24B	0	11	1	0	37	12	20% Beef, 80% Sheep	Beef	0.0	2.6	0.4	0.0	3.0	0.25
Total		182	323	381	121	1,817	1,006		Total (to Wright's Crossing)	19	97	171	43	329.5	
									Total (MHBR to Wright's Crossing)	3	12	51	0	66.3	
									Combined	22	109	222	43	395.8	

Table 3: Community Scheme Phosphorus Loss - Scenarios 3 and 4iii															
Prop_ID	Irrigated Area (ha) Outside Community Scheme					Losses (kg P/yr) - Irrigated					Losses (kg P/yr) - Dryland Sheep				
	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
<b>COMMUNITY SCHEME 1:</b>															
<b>Current Outside</b>															
1	0	97	20	23	140	0.00	14.94	9.18	8.30	32.42	0.00	0.78	0.40	0.76	1.94
3	0	6	44	0	50	0.00	0.92	20.20	0.00	21.12	0.00	0.05	0.88	0.00	0.93
6B	13	0	0	0	13	0.49	0.00	0.00	0.00	0.49	0.03	0.00	0.00	0.00	0.03
9	3	2	0	0	5	0.11	0.31	0.00	0.00	0.42	0.01	0.02	0.00	0.00	0.02
11A	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11B	0	8	0	0	8	0.00	1.23	0.00	0.00	1.23	0.00	0.06	0.00	0.00	0.06
<b>Total</b>	<b>16</b>	<b>113</b>	<b>64</b>	<b>23</b>	<b>216</b>	<b>1</b>	<b>17</b>	<b>29</b>	<b>8</b>	<b>56</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>3</b>
<b>New Outside</b>															
2A	35	0	0	0	35	1.31	0.00	0.00	0.00	1.31	0.07	0.00	0.00	0.00	0.07
2B	0	18	0	0	18	0.00	2.77	0.00	0.00	2.77	0.00	0.14	0.00	0.00	0.14
2C	0	19	0	0	19	0.00	2.93	0.00	0.00	2.93	0.00	0.15	0.00	0.00	0.15
2D	0	4	3	121	128	0.00	0.62	1.38	43.68	45.67	0.00	0.03	0.06	3.99	4.09
3	7	78	35	0	120	0.26	12.01	16.07	0.00	28.34	0.01	0.62	0.70	0.00	1.34
7	10	1	0	0	11	0.37	0.15	0.00	0.00	0.53	0.02	0.01	0.00	0.00	0.03
<b>Total</b>	<b>52</b>	<b>120</b>	<b>38</b>	<b>121</b>	<b>331</b>	<b>1.94</b>	<b>18.48</b>	<b>17.44</b>	<b>43.68</b>	<b>81.55</b>	<b>0.10</b>	<b>0.96</b>	<b>0.76</b>	<b>3.99</b>	<b>5.82</b>
<b>Community Scheme</b>															
	3,572	3,485	2,183	1,979	11,219	100	403	751	536	1790	7	28	44	65	144
<b>COMMUNITY SCHEME 2:</b>															
<b>Current Outside</b>															
13	60	6	9	0	75	2.24	0.92	4.13	0.00	7.30	0.12	0.05	0.18	0.00	0.35
16A	0	20	0	0	20	0.00	3.08	0.00	0.00	3.08	0.00	0.16	0.00	0.00	0.16
16B	0	32	0	0	32	0.00	4.93	0.00	0.00	4.93	0.00	0.26	0.00	0.00	0.26
19A	0	2	0	0	2	0.00	0.31	0.00	0.00	0.31	0.00	0.02	0.00	0.00	0.02
19B	0	68	0	0	68	0.00	10.47	0.00	0.00	10.47	0.00	0.54	0.00	0.00	0.54
23	11	0	0	0	11	0.41	0.00	0.00	0.00	0.41	0.02	0.00	0.00	0.00	0.02
25	0	3	9	0	12	0.00	0.46	4.13	0.00	4.59	0.00	0.02	0.18	0.00	0.20
26	9	19	30	0	58	0.34	2.93	13.77	0.00	17.03	0.02	0.15	0.60	0.00	0.77
<b>Total</b>	<b>80</b>	<b>150</b>	<b>48</b>	<b>0</b>	<b>278</b>	<b>3</b>	<b>23</b>	<b>22</b>	<b>0</b>	<b>48</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>2</b>
<b>New Outside</b>															
13A	0	2	0	0	2	0.00	0.31	0.00	0.00	0.31	0.00	0.02	0.00	0.00	0.02
13B	0	3	0	0	3	0.00	0.46	0.00	0.00	0.46	0.00	0.02	0.00	0.00	0.02
14	17	4	25	0	46	0.64	0.62	11.48	0.00	12.73	0.03	0.03	0.50	0.00	0.57
15	0	6	34	0	40	0.00	0.92	15.61	0.00	16.53	0.00	0.05	0.68	0.00	0.73
24A	0	17	6	0	23	0.00	2.62	2.75	0.00	5.37	0.00	0.14	0.12	0.00	0.26
24B	0	11	1	0	12	0.00	1.69	0.46	0.00	2.15	0.00	0.09	0.02	0.00	0.11
<b>Total</b>	<b>17</b>	<b>43</b>	<b>66</b>	<b>0</b>	<b>126</b>	<b>1</b>	<b>7</b>	<b>30</b>	<b>0</b>	<b>38</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>2</b>
<b>Community Scheme</b>															
	3,010	903	450	551	4,914	84	104	155	149	493	6	7	9	18	40
<b>Overseer nutrient budgets 2 assumptions</b>						<b>TOTALS:</b>									
<b>Use</b>	<b>P Losses (kg P/ha/yr)</b>					Community Scheme 1				1,927				153	
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>		Community Scheme 2				579				44	
Beef	0.039	0.162	0.491	0.393		Combined				2,506				197	
Sheep	0.037	0.152	0.451	0.353		Community Scheme 1 kg P/ha/yr				0.164				0.013	
Assume 20% Beef and 80% Sheep						Community Scheme 2 kg P/ha/yr				0.109				0.008	
Dryland Sheep	0.002	0.008	0.02	0.033		Combined kg P/ha/yr				0.147				0.012	

Table 4: Dryland Sheep Current Phosphorus Loss - Scenario 4i																		
#	Area Currently Irrigated (ha)								Water Use	Losses (kg P/ha/yr)				Losses (kg P/yr)				
	Prop_ID	Irr_A By Soil Group				Total_A	Irr_A	1		2	3	4	1	2	3	4	Total	
		1	2	3	4													
1	1	0	97	20	23	255	140	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.78	0.40	0.76	1.94	
2	3	0	6	44	0	69	50	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.05	0.88	0.00	0.93	
3	4	0	50	0	0	76	50	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.40	0.00	0.00	0.40	
4	5	15	105	0	0	221	120	Dryland Sheep	0.002	0.008	0.020	0.033	0.03	0.84	0.00	0.00	0.87	
5	6A	0	0	95	121	270	216	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.00	1.89	4.00	5.89	
6	6B	112	23	0	45	225	180	Dryland Sheep	0.002	0.008	0.020	0.033	0.22	0.18	0.00	1.48	1.89	
7	6C	29	4	0	0	42	34	Dryland Sheep	0.002	0.008	0.020	0.033	0.06	0.03	0.00	0.00	0.09	
8	7A	6	0	49	0	70	54	Dryland Sheep	0.002	0.008	0.020	0.033	0.01	0.00	0.98	0.00	0.99	
9	7B	0	83	0	0	106	83	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.66	0.00	0.00	0.66	
10	7C	133	7	27	0	215	168	Dryland Sheep	0.002	0.008	0.020	0.033	0.27	0.06	0.55	0.00	0.87	
11	8A	0	0	96	0	100	96	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.00	1.92	0.00	1.92	
12	8B	0	24	0	0	25	24	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.19	0.00	0.00	0.19	
13	9	45	3	0	0	161	48	Dryland Sheep	0.002	0.008	0.020	0.033	0.09	0.02	0.00	0.00	0.11	
14	10	0	40	0	0	123	40	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.32	0.00	0.00	0.32	
15	11A	0	0	0	0	3	0	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.00	0.00	0.00	0.00	
16	11B	0	59	76	0	147	136	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.47	1.53	0.00	2.00	
17	12	0	60	0	0	110	60	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.48	0.00	0.00	0.48	
18	13	64	6	9	0	94	80	Dryland Sheep	0.007	0.025	0.049	0.074	0.45	0.16	0.46	0.00	1.06	
19	16A	0	18	0	0	20	18	Dryland Sheep	0.007	0.025	0.049	0.074	0.00	0.45	0.00	0.00	0.45	
20	16B	0	32	0	0	35	32	Dryland Sheep	0.007	0.025	0.049	0.074	0.00	0.80	0.00	0.00	0.80	
21	17	31	21	14	128	240	195	Dryland Sheep	0.002	0.008	0.020	0.033	0.06	0.17	0.29	4.23	4.75	
22	18	151	0	0	0	154	151	Dryland Sheep	0.002	0.008	0.020	0.033	0.30	0.00	0.00	0.00	0.30	
23	19A	0	9	6	0	15	15	Dryland Sheep	0.007	0.025	0.049	0.074	0.00	0.23	0.29	0.00	0.52	
24	19B	9	174	0	0	184	184	Dryland Sheep	0.007	0.025	0.049	0.074	0.07	4.36	0.00	0.00	4.42	
25	20A	75	6	7	0	109	88	Dryland Sheep	0.002	0.008	0.020	0.033	0.15	0.05	0.14	0.00	0.34	
26	20B	3	0	28	1	39	32	Dryland Sheep	0.002	0.008	0.020	0.033	0.01	0.00	0.56	0.03	0.60	
27	21	0	43	1	0	73	44	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.34	0.02	0.00	0.36	
28	22	0	0	6	0	6	6	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.00	0.12	0.00	0.12	
29	23	97	33	0	0	133	130	Dryland Sheep	0.002	0.008	0.020	0.033	0.19	0.26	0.00	0.00	0.46	
30	25	0	3	9	0	30	12	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.02	0.18	0.00	0.20	
31	26	9	19	30	0	97	58	Dryland Sheep	0.007	0.025	0.049	0.074	0.06	0.48	1.47	0.00	2.01	
32	27	0	0	13	0	13	13	Dryland Sheep	0.002	0.008	0.020	0.033	0.00	0.00	0.26	0.00	0.26	
Total		781	926	531	318	3,460	2,557	Total (North of Wright's Crossing)					0.68	4.01	8.14	6.24	19.07	
							Total (MHBR to Wright's Crossing)					1.29	7.80	3.79	4.27	17.14		
							Combined					1.97	11.81	11.93	10.50	36.21		

Table 5: Dryland Sheep New Phosphorus Loss - Scenario 4ii																	
#	New Irrigated (ha)							Water Use	Losses (kg P/ha/yr)				Losses (kg P/yr)				
	Prop_ID	Irr_A By Soil Group				Total_A	Irr_A		1	2	3	4	1	2	3	4	Total
		1	2	3	4												
1	2A	35	0	0	0	82	35	Dryland Sheep	0.002	0.008	0.02	0.033	0.07	0.00	0.00	0.00	0.07
2	2B	0	18	0	0	43	18	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.14	0.00	0.00	0.14
3	2C	0	19	0	0	46	19	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.15	0.00	0.00	0.15
4	2D	0	4	3	121	300	128	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.03	0.06	3.99	4.09
5	3	7	78	35	0	373	120	Dryland Sheep	0.002	0.008	0.02	0.033	0.01	0.62	0.70	0.00	1.34
6	4	13	127	0	0	147	140	Dryland Sheep	0.002	0.008	0.02	0.033	0.03	1.02	0.00	0.00	1.04
7	7	92	22	6	0	290	120	Dryland Sheep	0.002	0.008	0.02	0.033	0.18	0.18	0.12	0.00	0.48
8	11A	0	1	15	0	15	15	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.01	0.30	0.00	0.31
9	11B	0	0	77	0	77	77	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.00	1.54	0.00	1.54
10	11C	16	11	174	0	201	201	Dryland Sheep	0.002	0.008	0.02	0.033	0.03	0.09	3.48	0.00	3.60
11	13A	0	2	0	0	2	2	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.02	0.00	0.00	0.02
12	13B	0	3	0	0	3	3	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.02	0.00	0.00	0.02
13	14	17	4	25	0	56	46	Dryland Sheep	0.002	0.008	0.02	0.033	0.03	0.03	0.50	0.00	0.57
14	15	0	6	34	0	46	40	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.05	0.68	0.00	0.73
15	24A	2	17	11	0	99	30	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.14	0.22	0.00	0.36
16	24B	0	11	1	0	37	12	Dryland Sheep	0.002	0.008	0.02	0.033	0.00	0.09	0.02	0.00	0.11
Total		182	323	381	121	1,817	1,006	Total (North of Wright's Crossing)					0.33	2.24	6.20	3.99	12.76
							Total (MHBR to Wright's Crossing)					0.04	0.34	1.42	0.00	1.80	
							Combined					0.36	2.58	7.62	3.99	14.56	

**Table 6: Comparison of Scenario Model Results<sup>1</sup>**

Scenario-Use	P Loss (kg/ha/yr); kg lost in brackets			P Concentration (mg/L) <sup>4</sup>		
	Upper	Lower	Combined	Upper	Lower	Combined
<b>Model Estimates<sup>2</sup>:</b>						
Current Irrigated Areas						
Irrigated Various Uses (Scenario 1)	0.152 {348}	0.269 {568}	0.213 {917}			
Dryland Sheep (Scenario 4)	0.009 {19}	0.013 {17}	0.010 {36}	0.004	0.006	0.005
New Irrigation Applications (Scenario 2)						
Irrigated Various Uses (Scenario 2)	0.281 {678}	0.419 {634}	0.300 {1311}			
Dryland Sheep (Scenario 4)	0.008 {13}	0.007 {2}	0.008 {15}	0.004	0.003	0.004
Community Scheme (Scenario 3)						
Irrigated Beef and Sheep (Scenario 3)	0.164 {1927}	0.109 {579}	0.147 {2506}	0.030	0.021	0.027
Dryland Sheep (Scenario 4)	0.013 {153}	0.008 {44}	0.012 {197}	0.006	0.005	0.006
<b>Comparison of Estimates<sup>3</sup>:</b>						
Current Irrigation (Factor)	16.9	20.7	21.3			
New Irrigation (Factor)	35.1	59.9	37.5			
Community Scheme (Factor)	12.6	13.6	12.3			

<sup>1</sup>"Upper" indicates farm areas north of Wright's Crossing while "Lower" indicates farm areas south of Wright's Crossing to the MHBR. "Combined" is the sum of both.

<sup>2</sup>Summary of results from Tables 1, 2, 3, 4 and 5 on a kg P/ha/yr basis.

<sup>3</sup>Comparison of irrigated to dryland alternatives for same farm areas presented as factors (e.g., current irrigation results in an increase in potential phosphorus loss by a factor of 16.9 for the upper Hakataramea River catchment).

<sup>4</sup>Estimated concentrations for scenarios 1 and 2 are not given since no stream routing data was available. Community scheme considered to be linked by irrigation network to Hakataramea River.

## 5. Conclusions

The estimated load of P loss to surface waters among the properties in each scenario ranged from 0.01 to 0.87 kg/ha/yr. The mean load under dryland sheep farming was about 0.01 kg P/ha/yr, increasing to 0.87 kg P/ha/yr if irrigated on rolling land. Although the range of P lost in the first scenario was just as great as that in the second scenario, the increased land irrigated in the second scenario meant that on average more P was lost in scenario 2. Due to the exclusion of deer farming and the use of flat land for irrigation, the mean load of P lost in scenario 3 was less than either scenario 1 or 2, although the overall loss (kg) of P would be much greater. Due to poor data availability (e.g., location of land use and detailed topographic information), estimates are only a guideline of real loads. However, the analysis did emphasize the importance of irrigation on influencing P losses, and the relatively minor influence of dryland sheep farming, (0.01 kg P/ha/yr) in scenario 4. The estimated loads are small for New Zealand pastoral systems, but reflect the flat topography, and the use of spray irrigation. However, loads and concentrations in streamflow under irrigation are likely to be much greater than from dryland sheep farming and additional best management practices should be adopted where appropriate to mitigate the potential for P loss.

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