

OUR LAND
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Toitū te Whenua,
Toiora te Wai

Final Report

The viability, feasibility, and environmental effects from using New Zealand sourced phosphate

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Executive Summary

1. Phosphate fertiliser is a critical input for sustaining New Zealand agricultural productivity. The Sustainable Phosphate Futures for New Zealand project was established to explore strategies to enhance the efficient use of phosphate resources as well as to review strategies to enhance the security of supply of phosphate for New Zealand agriculture through the use of New Zealand sourced phosphate. This report reviews issues in relation to the use of New Zealand sourced phosphate.
2. Despite the importance of phosphate to the New Zealand economy, there have been very few exploration programmes that have targeted phosphate. It must be assumed that the generally accessible off-shore sources has meant that there has been little incentive to locate a local source with the exception being during World War 2 when the Nauru deposit was not available. There has however been commercial mining of New Zealand deposits with approximately 140,000 tons of phosphate rock mined at Clarendon up to 1924.
3. There are numerous occurrences of phosphate minerals in on-shore sedimentary rocks in New Zealand. L&M Group Limited (L&M) has had an interest in exploring for and potentially developing New Zealand's phosphate resources for a number of years. In 2019 L&M commenced investigations to determine the potential for commercial phosphate production and identified four regions which they regarded as warranting detailed evaluation. Criteria for selection were primarily the potential size and grade of the deposit, and secondarily, the location in relation to transport and infrastructure. These areas are named North Canterbury, South Canterbury, Waitaki and Clarendon.
 - **North Canterbury:** The North Canterbury region extends from about Waipara north to Kaikoura and has the potential to contain in the range of 10 to 20 M tonnes of phosphate resource, and dependant on grade and beneficiation¹ efficiency, the total could be considerably higher.
 - **Waitaki and South Canterbury:** There is insufficient data available to make a resource assessment at this stage, however given the extent of the target formations, there is potential for multi-million tonnes deposits.
 - **Clarendon:** This phosphate deposit is located beneath Fort Hill in Otago, almost midway between Dunedin and Balclutha. The deposit is the largest known in New Zealand and has the most information of all phosphate deposits in New Zealand. L&M has calculated that the drilled areas (1/25th of the deposit) contain a resource of 1.6Mt of phosphate ore with an average grade of 18% P₂O₅. Based on the ore thickness and grades indicated by drilling it is considered that the deposit has the potential to contain significantly more resource than that indicated by the areas drilled to date.
4. **Utilisation:** A range of phosphate fertilisers include Reactive Rock Phosphate (RPR), Partially Acidulated Phosphate Rock (PAPR) as well as a potential feedstock for the production of Single Super Phosphate (SSP) have been identified that could be produced from New Zealand phosphate resources.
5. **Economic analysis:** The economic analysis for the potential use of New Zealand phosphate establishes that the pricing of the different products would be dependent on

¹ Beneficiation is any process that improves (benefits) the economic value of a mineral raw material by removing the less valuable minerals, which results in a higher-grade product.

several factors but would be competitive with products manufactured using imported phosphate rock.

6. **Environmental analysis:** The potential environmental effects associated with the use of New Zealand land based phosphate resources establishes that:
 - There would be relatively minor environmental effects from the quarrying process – there would be a comparatively small mined area (footprint) with a similar impact to current limestone quarries. Potential resource consent conditions relating to quarrying of phosphate have been identified, and it is expected that effects would be similar to those for limestone.
 - The phosphate deposits generally have very low levels of cadmium or uranium present.
 - A comparative analysis of the carbon footprint from imported and New Zealand sourced phosphate for the production of SSP indicate that the GHG emissions from the New Zealand source Phosphate Rock (PR) is 76 T CO₂e per tonne of SSP which is 49% of that of the imported material.
 - A commentary on the use of less soluble P phosphate such as RPR and its ability to reduce the amount of phosphate runoff in agriculture is provided.
 - It is proposed that with the increasing cost of transport and application of fertilisers and a future commitment by the New Zealand Government to bring agricultural emissions into some form of emission taxation regime there is great potential for a New Zealand sourced fertilisers to both reduce the financial cost and the total Green House Gas (GHG) emissions of fertilizer in New Zealand.
7. **Potential farmer use of New Zealand sourced phosphate products.** A survey explored the potential levels of adoption for different phosphate fertiliser products that could be manufactured from New Zealand sourced phosphate was undertaken. It should be noted that the survey had a low response rate however it does provide some insights. It established that though most respondents prefer SSP there were 29% of survey respondents that would use PAPR and 14% who would use high grade RPR. Financial profitability would significantly affect the respondents decision making, while the environmental impact would hold moderate sway. The respondents perceived a limited direct impact of transitioning to New Zealand phosphate on their farms with limited risk being outlined.
8. **Adoption analysis.** An analysis of the potential adoption of New Zealand sourced phosphate fertilisers using the ADOPT model was also undertaken and based on the survey responses. The low response rate to the survey again limit the value of this modelling however they do provide some insights. The survey established that a peak adoption of New Zealand sourced phosphate resources of 25% would occur over an eight-year period. This result was due to the perceived low risk involved in transitioning from current fertiliser products to New Zealand phosphate. The ease of use without requiring new skills or knowledge and its farm-trialling convenience contributed significantly to this swift uptake. However, the adoption plateaued at this relatively low percentage as survey respondents highlighted minimal impacts on profit and moderate effects on the environment as key factors. Three additional scenarios portray the variability of potential environmental and financial impacts of changing to New Zealand phosphate use were assessed using ADOPT and these reflected a subsequent adoption range of 44% to 14%.

9. **Strategic analysis and options.** A strategic analysis relating to the use of New Zealand phosphate identifies a range of economic, environmental and social benefits with comparatively few weaknesses. In summary the use of New Zealand sourced phosphate for fertiliser appears to be viable and feasible while providing potential economic and environmental benefits. The following are suggested as follow-up actions:
- Undertake a more detailed analysis of the environmental and economic impacts associated with the use of New Zealand phosphate resources.
 - Identify the most viable opportunities for the use of New Zealand sourced phosphate and establish fertiliser supply chains to exploit and evaluate these.
 - Include phosphate in the New Zealand list of strategic raw materials and develop an associated supply chain risk management strategy.
 - Increase the level of farmer awareness about the relative environmental and economic benefits associated with the use of alternative (and less soluble) phosphate fertilisers. There has been extensive research that provides a strong evidence base for this including on the use of RPR as a slow-release fertiliser.

1.0. Introduction

1.1. Project background

Phosphate is a critical component of security of New Zealand's food supply and for agricultural production in general. Currently all phosphate is imported. Local production would benefit New Zealand farmers by reducing the dependency upon imports as well as positively contributing towards climate change targets by significant reduction in transportation distance. New Zealand pastoral soils are naturally low in phosphorus and the application of phosphate fertiliser is essential to sustaining pasture and associated crop and animal production. There are however significant risks to the sourcing and use of phosphate in New Zealand including:

- *Environmental effects* — unsustainable phosphorus use has negative effects on freshwater quality, freshwater biodiversity, and human health. Estimated losses of phosphorus from agriculture to surface waters account for about 34% of global fertiliser use. In New Zealand, phosphate pollution of rivers has however been decreasing in recent years (McDowell, R et. al 2019, 2023).
- *Security of phosphate supply* — globally 85% of phosphates produced are used for fertiliser. Five countries hold 85% of known phosphate rock reserves, with 70% found within Morocco and Western Sahara. In 2021 New Zealand imported 689,000 tons representing 3.2% of world imports, the 9th largest global importer. In 2021, 51% of New Zealand imports were from Morocco, 25% from Togo and 9.4% from China. There are however increasing risks to these supply chains including political issues related to supply from Morocco and recent phosphate export restrictions by China. The European Union and Australia include phosphorus as a strategic or a critical raw material where as New Zealand does not have any such list.

There are a range of pressures that are increasing global demand for phosphate including increasing food production and strategies to enhance food and phosphate supply security that place pressure on phosphate supply. The *Sustainable Phosphate Futures for New Zealand* Project was established to address both the security of supply and environmental risks through:

1. The development and evaluation of strategies to enhance the efficient use of phosphate resources and to decrease negative environmental effects from phosphate fertiliser use. The results from this research are detailed in the associated report '*Strategies to improve the efficiency and decrease the negative environmental effects from P fertiliser use*'.
2. This report reviews the viability, feasibility, and environmental impact from using New Zealand sourced phosphate. This report includes an:
 - Overview of New Zealand land based phosphate resources – exploration, mining, quality and quantity of the phosphate resources.
 - An economic analysis for the potential use of New Zealand phosphate.
 - An analysis of the potential environmental effects associated with the use of New Zealand land based phosphate resources.
 - An analysis of the potential levels of adoption for different phosphate fertiliser products that could be manufactured from New Zealand sourced phosphate.

The *Sustainable Phosphate Futures for New Zealand* Project was funded by the National Science Challenge — Our Land and Water through their Rural Professionals Fund.

1.2. Overview – New Zealand phosphate resources

There are numerous occurrences of phosphate minerals in on-shore sedimentary rocks in New Zealand. By far the most common occurrences are located on geological unconformities, particularly in the late Oligocene-early Miocene period (c28 to 20 Million Years Ago). An unconformity is a buried erosional or non-depositional surface separating two rock masses of different ages, indicating that sediment deposition was not continuous. The older layer may have been subject to erosion before deposition of the younger layer, but the term is used to describe any break in the sedimentary geologic record.

There is a zone of unconformity traceable from south of Dunedin to Marlborough on the east coast of the South Island. The phosphatic deposits within this zone are similar in that there is generally a section above the unconformity surface which contains phosphate nodules and phosphatisation of the surrounding matrix in the enriched basal zone (although this is less commonly noted). The phosphate is usually present as nodules and sometimes cement material hosted within greensands or sandy limestones.

Sedimentary Phosphate deposits

Phosphorite, phosphate rock or rock phosphate is a sedimentary rock that contains high amounts of phosphate minerals. The phosphate content (grade) of phosphorite varies greatly, usually up to 20% phosphorus pentoxide (P_2O_5). Marketed phosphate rock is enriched to 30% to 35% P_2O_5 . This occurs through crushing, washing, screening, de-liming, magnetic separation or flotation.

Limestones and mudstones are common phosphate-bearing rocks and phosphate rich sedimentary rocks can range from thin laminae to beds up to several metres thick. These layers generally contain the same textures and structures as fine-grained limestones. The phosphate beds can also include nodules, fossils, and phosphate coated clasts.

Sedimentary phosphorites are predominantly marine sediments formed by upwelling of phosphate-rich waters into relatively shallow marine settings, where biological accumulation further concentrates the phosphate and eventually deposits it on the sea floor.

Current New Zealand phosphate exploration activities

Apart from the permits held by L&M Group Limited (L&M), there are no existing mineral prospecting, exploration or mining permits or applications targeting phosphate onshore in New Zealand. However, some existing permits or applications may include phosphate in the suite of minerals of interest. Chatham Rock Phosphate (NZ) Limited has a minerals mining permit² granted in 2013 for 20 years for an area of 82,122.904 Ha on the Chatham Rise between Banks Peninsula and the Chatham Islands.

² <https://data.nzpam.govt.nz/PermitWebMaps/os/Home/StaticMap?permit=55549>

1.3. L&M Group Limited activity

L&M has had an interest in exploring for and potentially developing New Zealand's phosphate resources for a number of years. As long ago as 1968, L&M (then Lime and Marble) carried out a preliminary evaluation of the potential for phosphate in the Nelson and Marlborough area. Between 2007 and 2011 L&M investigated the potential for exploitation of offshore deposits on the Chatham Rise, Campbell Plateau and on the Hokianga Terrace (north-west of New Zealand). Due to the numerous challenges in development of an offshore resource, this opportunity was not pursued.

In late 2019 L&M commenced investigations to determine the potential for commercial phosphate production in on-shore sedimentary deposits. L&M has carried out a work programme comprising literature reviews, data analysis and field mapping and sampling. Phosphate quality data has been collected from a variety of sources including historic data, private reports made available to L&M, and analyses carried out by L&M.

L&M's initial investigations were very encouraging and it identified four regions which it regarded as warranting detailed evaluation. Criteria for selection were primarily the potential size and grade of the deposit, and secondarily, the location in relation to transport and infrastructure. These regions are North Canterbury, South Canterbury, Waitaki and Clarendon. (

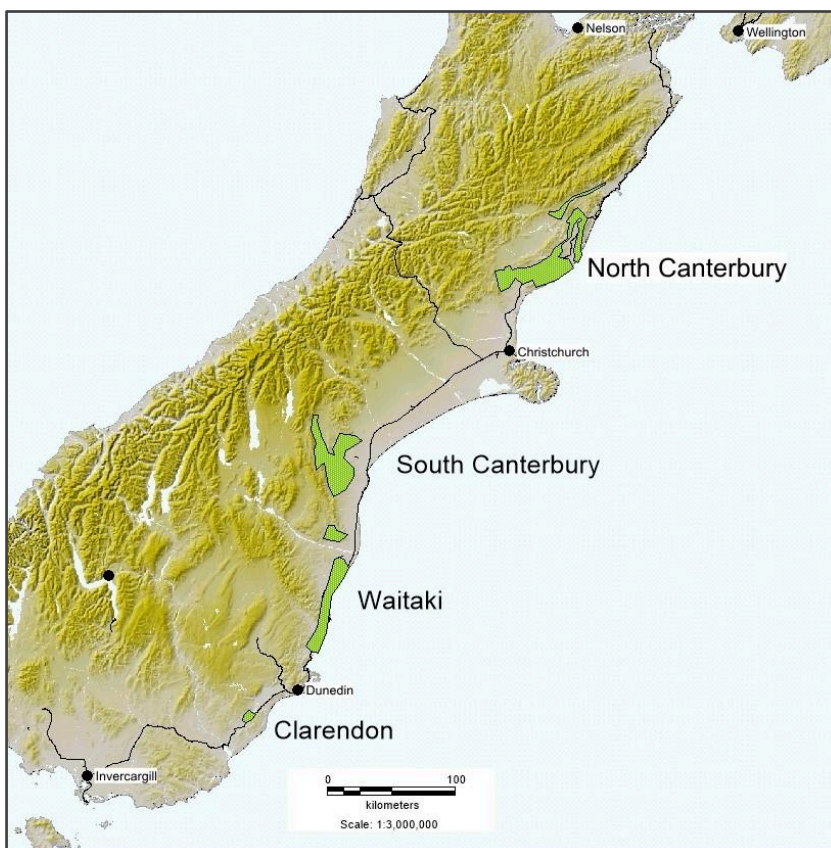


Figure 1). All of the areas are located over deposits of early to mid-Tertiary phosphate-bearing sediments.

Of the areas identified by L&M, Clarendon is the only location where there has been detailed exploration and mining for phosphate. All available data from this mapping, trenching and drilling have been reviewed by L&M. Phosphate was mined at Clarendon early last century, and

again during World War 2 when imported phosphate was unavailable. An estimated 170,000 tonnes was mined in total. The most recent work at Clarendon was carried out by Ravensdown Ltd between 2009 and 2013.



Figure 1. Areas identified as prospective for phosphate; East Coast South Island (light green shading).

2.0. Previous New Zealand phosphate exploration and mining

2.1. Introduction

Despite the importance of phosphate to the New Zealand economy, there have been very few exploration programmes that have targeted phosphate. It must be assumed that the generally accessible off-shore sources has meant that there has been little incentive to locate a local source. The exception was during World War 2 when the Nauru deposit was not available. As discussed below, this led to a large body of work at Clarendon.

2.2. Clarendon

The Clarendon phosphate deposit is located beneath Fort Hill in Otago, almost midway between Dunedin and Balclutha. The deposit is the largest known in New Zealand and has the most information of all phosphate deposits in New Zealand, including more than 300 drillholes, numerous mapping programmes and mining operations in the early to mid-20th Century.

The deposit was first located by R Ewing in about 1900. Following a visit to the phosphate deposits in Florida, he apparently made a search of Canterbury and Otago for a similar phosphate deposit here. He noted the similarity of the Clarendon deposits to the deposits in Florida. Park (1902) provided very detailed descriptions of the geological setting and the nature of the limestone surface and basal phosphate deposits.

Park (1902) noted:

“This discovery will doubtless be followed by other discoveries in different parts of the colony in districts where similar geological conditions exist, the most likely localities being in Southland, North and South Otago, North and South Canterbury, Marlborough, Raglan and North Auckland districts.”

Up to 1924, 140,000 tons of phosphate rock were mined at Clarendon. The occupation of Nauru by the Japanese in 1942 deprived New Zealand of its main source of phosphate rock. Investigations by NZ Geological Survey geologists, H. Wellman and R. MacPherson in 1942 disclosed further potential at Clarendon. Based on MacPherson’s recommendations, (MacPherson 1945), it was decided that further prospecting was warranted. This work was carried out by Mines Department in association with the British Phosphate Commission (BPC). The work was supervised by R.W. Willett of NZ Geological Survey (NZGS). Exploration included 287 drillholes and trenches plus other detailed studies. The drilling was quite limited in extent, covering a very small area of the deposit. The results of the work are reported in Willett (1946). Willett estimated that approximately 150,000 tons of phosphate ore remained in the deposit.

Williams (1965) provided a summary of the deposit with a discussion of the provenance of the phosphate.

Carryer, S (1972) considered that Willett’s resource estimates for Clarendon understated the potential of the deposit. He noted that Willett tested 58.4 acres of a total 1,440 acres, or 1/25th of the deposit. On that basis, Carryer estimated that there could be in the order of 2.25M tonnes of phosphorite at Clarendon.

Field (1986) reported on a visit to Clarendon during the PHOSREP study. This was an Australian sub-project of IGCP Project 156 (Phosphorites). NZGS was approached by Dr Cook, the head of PHOSREP to assist in a field reconnaissance of NZ onshore phosphates.

Douglas, B (1989) carried out an evaluation of the deposit for Spectrum Resources. Spectrum held Exploration Permit 33493 which covered the area north and west of Fort Hill. Douglas considered that the upper phosphatised zone was the only deposit that justified further evaluation. He estimated that there was a possible resource of 5.040 M tonnes at an average grade of 11% P₂O₅.

Ravensdown (2009-2013) carried out some detailed exploration work including completing a number of trenches and drillholes together with detailed analysis of samples.

2.3. Other areas; eastern South Island

There is a wealth of geological data on the Canterbury and Otago areas. The occurrence of phosphate in Canterbury has been recorded for many years e.g. McKay, 1877; Morgan, 1916; Speight & Wild, 1918; Thomson, 1919; Hamilton, 1950; Gage, 1957; Andrews, 1963 and 1968; Browne & Field, 1985; Field et.al, 1989; Morris, 1987; Irvine 2012.

Most reports are of a phosphatic layer at a regional unconformity at the top of the Amuri Limestone or its lateral equivalents. The unconformity has been the subject of an extensive series of studies across the Canterbury Basin. As noted by Morris (1987) this unconformity has often been referred to as the "Marshall Paraconformity" (Carter & Landis 1972, 1982; Findlay 1980; Browne & Field 1985).

Speight and Wild (1917), and Wild and Speight (1918) carried out the only known exploration work in North Canterbury that targeted phosphate. Their first report comprised an evaluation of the Weka Pass Stone and Amuri Limestone in the area between the Waipara River and Kaikoura, particularly focused on the coastal zone. They described a number of sections in the region, identifying four main lithologies. Their observations are summarised below:

- Amuri Limestone; this is described as having an upper section up to 1.8m thick mixed by worm borings that mixed overlying sandstone with the limestone. This zone is often glauconitic and phosphatic.
- Phosphatic Zone; this overlies the Amuri Limestone. Thickness is up to 2m of glauconitic sandstone with phosphatic nodules, particularly concentrated in the basal part of the unit
- Weka Pass Stone; This is not always present but where seen comprises variably glauconitic limestone
- Greensand; Usually present where Weka Pass Stone is absent. Phosphatic, particularly in the basal part of the unit

Their second report (Wild and Speight; 1918) focussed investigations on calcareous rocks in the Canterbury region between Kaikoura and Waihao Forks. The main areas of interest in this study were Kaikoura, Haumuri Bluff, Port Robinson and Gore Bay, Weka Pass, Waipara and Waihao Forks.

They provide analytical data for limestones from a number of sites. The samples of limestones are generally low in P₂O₅, which is expected. Samples of phosphate nodules are much higher grade. Their data shows grades averaging about 20% P₂O₅ in nodules. The authors referred to the glauconitic sandstones found in the Canterbury District. They noted that they are important as they contain P₂O₅ in both the matrix and as phosphatic nodules. They also referred to the fact that this type of layer is worked in England, Belgium and France as a source of phosphate.

Morris, J (1987) carried out detailed mapping of the Amuri Limestone and associated sediments in the North Canterbury and Marlborough areas. His work led him to propose the Phosphatic

Conglomerate Bed (PCB) as a separate unit. He defined the PCB as the band of phosphatized nodules which unconformably overlies the Amuri Limestone. The PCB forms the basal layer of the Motunau Group, and the Cookson Volcanics (where deposited). Morris noted that the PCB forms a remarkably uniform veneer over a very extensive area, and is clearly identifiable as far north as Puhī Puhī River north of Kaikoura. He described the PCB as being typically composed of angular, phosphatized sediment clasts, rare shell casts, set in a matrix similar to that of the overlying sediment.

Gage, M, (1957) prepared the geological bulletin “The Geology of the Waitaki Subdivision” which set out details of the geology of the area between the Waitaki River in the north to Kakanui in the south, and inland to a north south line between Kurow and Mt Dasher. Of particular relevance are a number of references to phosphate material within the Tertiary rocks.

During the 1970’s Australian Mining and Oil Investments Ltd carried out a series of studies in the region between Dunedin and Waihao Forks. (Geotechnics Ltd 1971, Jeppe, J 1972, Australian Mining and Oil Investments; 1972, Jeppe, J; 1975). The studies were focussed on locating a deposit similar to Clarendon. The initial high level study showed that there was good prospectivity across the region. They carried out sampling programmes at Waihao Downs and in the Waikouaiti-Palmerston areas. The results are summarised in Section 3.3.

Field (1986) reported on a visit to Clarendon during the PHOSREP study. The field trip included visits to thirteen sites between Kaikoura and Clarendon.

3.0. L&M's studies

3.1. Clarendon

3.1.1. Introduction

As noted above, there is a very extensive geological database for the Clarendon phosphate deposit (see figure 1) and all relevant information has been entered into a GIS and geological modelling package. L&M has plotted all drillholes with reasonable accuracy and has located detailed grade data for almost all sampled holes. The level of detail in this data, together with field mapping and sampling by L&M has led to the development of a new geological model for the Clarendon deposit. This revised model indicates that there is significant further potential in some parts of the deposit.

3.1.2. Geological setting

The Clarendon deposit is situated within the Clarendon Sand Formation of Waitakian (Late Oligocene-Early Miocene) age. It comprises two distinct phosphate — enriched zones, separated by a low grade phosphatic sand zone. Figure 2 below shows some of the target material within the Kapiti Quarry, an area mined in the early years of development.

The lower phosphate zone is at the base of the Clarendon Sand. The Clarendon Sand and lower phosphate zone have developed on an unconformity surface of the underlying Milburn Limestone. This surface is irregular and is generally interpreted as a remnant karst horizon. Where the limestone is absent, the phosphate rests unconformably on a greensand unit. The lower phosphate zone is discontinuous but where present averages about 2m thick. The zone is composed of nodules, banded phosphate layers and phosphate-cemented glauconitic sand. This material averages about 23 to 25% P_2O_5 .

The second zone is the bulk of the Clarendon Sand which overlies the lower phosphate zone. It comprises brown, firm, clay-rich, fine to medium sand which contains 2 to 3% P_2O_5 . Phosphate grade is highest at the top of the unit. The total thickness of the unit is up to about 30m, but it is generally in the range of 5 to 15m.

The upper phosphate zone, the Kapiti Sandstone, is a grey, hard, phosphate-cemented, well rounded fine to medium quartz sandstone. It sits at the top of the Clarendon Sand below the basaltic rocks which cap the phosphatic sequence. The phosphate is primarily in the form of cement binding the sand material. There are no nodules present in this layer. The unit reaches a maximum thickness of 17.7m, averaging 6.4m. Average grade is about 12% P_2O_5 . The phosphate cement is considered to be secondary, derived from phosphate enriched fluids.



Figure 2. Clarendon Deposit. The brown material on the right is Clarendon Sand. The Kapiti Sandstone is directly above the figure in the centre of the photo.

3.1.3. Quality

In total there are more than 1,000 analyses of sediments in the Clarendon deposit. Analysis results are summarised below in Table 1, by lithological unit.

Table 1: Summary of analyses of Clarendon Sand material

Phosphatic Zone		P ₂ O ₅ %	Al ₂ O ₃ %	Fe ₂ O ₃ %	K ₂ O %
Lower Phosphate	Ave	21.45	4.00	6.00	1.47
	Max	36.00	12.58	15.58	4.68
	Min	2.73	0.38	0.84	0.17
Clarendon Sand	Ave	2.88	7.03	9.80	1.78
	Max	16.06	18.64	19.30	2.73
	Min	0.27	0.95	4.47	0.24
Kapiti Sandstone	Ave	11.19	4.97	2.50	1.79
	Max	28.40	8.28	8.30	2.13
	Min	0.30	1.73	0.42	1.23

Beneficiation tests have been carried out on the Kapiti Sandstone and the Clarendon Sands. During the 1940's investigations, Mines Division and others carried out testing of the Kapiti Sandstone and the Clarendon Sands. Both simple crushing and screening and flotation testing were carried out with encouraging results.

Dr Hutton of the NZ Geological Survey (Hutton and Seelye; 1942) found that crushing and screening 12.5% P_2O_5 ore gave a product of 24% P_2O_5 . The Dominion Laboratory carried out several tests with the results summarised in Willett (1946). Crushing and screening tests of Kapiti Sandstone grading 13.6 % P_2O_5 , gave a product with 18% P_2O_5 . Roasting before crushing gave a product with 21.6% P_2O_5 . Willett also reported on work carried out by the Thames School of Mines. In summary, crushing, sieving and flotation treatment gave the following results:

- Kapiti Sandstone 10% P_2O_5 concentrated to 25.5%, 67% recovery.
- Clarendon Sand 2.5% P_2O_5 concentrated to 5.5%, 51% recovery.

Citric Solubility tests have been carried out on both the Kapiti Sandstone and the high-grade phosphate. For all samples tested, more than 30% of the phosphate was citric-soluble.

3.1.4 Resource Potential

The historic drilling data provides sufficient detail to calculate resource estimates for the areas that were drilled. Based on this data, L&M has calculated that the drilled areas (1/25th of the deposit) contain a resource of 1.6Mt of phosphate ore with an average grade of 18% P_2O_5 . This is at less than 5:1 strip ratio (volume of overburden to be mined: tonnage of ore recovered). Based on the ore thickness and grades indicated by drilling we consider that the deposit has the potential to contain significantly more resource than that indicated by the areas drilled to date.

3.2. North Canterbury

3.2.1. Introduction

L&M has carried out a detailed work programme in the North Canterbury region (see figure 1), including extensive mapping and sampling. Most of the mapping and sampling work has been conducted out on private farmland and the cooperation and enthusiasm of the landowners involved has been greatly appreciated.

The focus of the work programme has been to firstly verify the historical accounts of phosphate presence and resample any outcrops that can be located. Detailed analyses have been made to confirm both grade of phosphate and presence or absence of potential contaminants, particularly cadmium and uranium.

3.2.2. Geological setting

The North Canterbury region is located within the northern Canterbury geological basin which extends from the Ashley River in the south to the Hope Fault in the north. Within this zone, the main Paleogene and Neogene sedimentary deposits are subdivided into three groups. The Eyre Group (late Cretaceous to early Oligocene) is the basal group, and comprises sandstones, greensand, mudstone, conglomerates, shell beds and coal at the base. At the top of the Eyre Group is the Amuri Limestone (late Cretaceous to early Oligocene). In Marlborough this limestone is included in the Muzzle Group and is late Cretaceous age. To the south it is included in the Eyre Group and is Oligocene in age. The regional unconformity formed at the top of the Amuri Limestone represents a time gap in the order of 2 to 10 M years (see Gage; 1988 among others).



Sediments of the Motunau Group overlie the regional unconformity in most areas; however, the Cookson Volcanic Group (Oligocene) is present locally in the northwest, lying between the Eyre and Motunau Groups. The Motunau Group is subdivided into four main formations. By far most of the references to phosphate in the Motunau Group are in the Spy Glass (see Figure 3) and Omihi Formations, which are located at the base of the group and are Late Oligocene to Early Miocene in age.

Figure 3. Zone of phosphate nodules at base of Spy Glass Formation, North Canterbury

The main sediments of the North Canterbury area, of relevance to the presence of phosphate are summarised below in Table 2.

Table 2: Main sediments in North Canterbury for phosphate exploration

Group	Formation/Member	Phosphate presence	Age
Motunau	Mt Brown Fm: Whiterock Limestone (Lst) Member	Phosphatic band at base over Isolated Hill Lst	Early to mid-Miocene
	Waikari Fm: Pahau Siltstone	Base contains phos nodules	Early Miocene
	Spy Glass Fm	Almost everywhere	Late Oligocene-early Miocene
	Omihi Fm; Isolated Hill Lst, Weka Pass Stone, Gorries Ck Gsd, Berrydale Gsd	Phos reported in all these members	Late Oligocene
	Cookson Volcanics & Tekoa Fm	Phosphate at the base	Oligocene
	Phosphatic conglomerate bed	Lower part of WPS and Cookson	Oligocene
REGIONAL UNCONFORMITY			
Muzzle / Eyre	Amuri Lst	Phosphatic at top	Late Cretaceous to early Oligocene
Eyre	Ashley Mudstone	Phosphate nodules locally at base & middle.	Eocene to Oligocene

3.2.3. Quality

Analysis work to date has focused on testing for phosphate presence and grade, together with the main contaminants (cadmium and uranium). Testing has been carried out by specialist testing companies, Verum Ltd and SGS Ltd using XRF analysers.

In addition to the element analysis, some limited citric solubility testing was carried out. This testing has been carried out for L&M by independent laboratories.

In total more than 100 analyses of sediments in the North Canterbury region have been carried out. Results for samples for the main target formations and associated sediments are summarised in the following Table 3 and Table 4. Note that these samples are from across the deposits and do not necessarily reflect the potential ore grade.

Table 3: L&M Results of Analysis sorted by the main target geological formations.

	P ₂ O ₅ %	K ₂ O %	Fe ₂ O ₃ %	Al ₂ O ₃ %	SiO ₂ %	CaO %	MgO%
Amuri Limestone							
Average	0.2	0.4	1.27	1.44	10.95	30.18	0.32
Max	0.73	0.82	1.98	3.03	22.95	37.18	0.71
Min	0.00	0.13	0.77	0.00	3.31	19.97	0.00
Ashley Mudstone							
Average	0.18	1.17	3.17	6.26	29.12	10.14	0.39
Max	0.26	1.78	4.03	8.90	40.13	18.07	0.49
Min	0.11	0.56	2.31	3.63	18.12	2.20	0.28
Berrydale Greensand							
Average	6.27	1.49	6.75	3.19	20.40	9.48	
Max	20.68	2.74	12.67	6.47	55.07	26.62	
Min	0.08	0.59	1.16	0.46	0.91	1.53	
Gorries Ck Greensand							
Average	2.75	1.09	4.89	3.53	22.99	17.59	0.91
Max	24.80	3.12	21.11	11.10	62.42	48.41	2.99
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pahau Siltstone							
Average	3.91	1.69	6.87	2.41	16.59	26.29	1.17
Max	5.91	2.44	7.58	3.76	25.32	33.73	1.93
Min	2.10	1.05	6.53	1.16	9.39	18.15	0.50
Spyglass Fm							
Average	8.02	0.86	4.02	2.45	13.12	31.90	0.83
Max	18.42	1.78	9.36	6.32	29.60	47.19	1.58
Min	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Weka Pass Stone							
Average	1.83	0.86	2.53	2.10	13.17	32.59	0.43
Max	5.13	1.63	5.81	7.11	38.43	43.77	1.13
Min	0.00	0.25	1.28	0.60	5.07	0.89	0.00

Table 4: Historic Analysis Results. (Sourced from Wild and Speight; 1919, Morgan; 1916, Henderson; 1929, Hamilton; 1950)

Formation	P ₂ O ₅ %
Amuri Limestone (n=6)	
Average	0.66
Max	2.05
Min	0.16
Gorries Ck Greensand (n=6)	
Average	24.25
Max	26.74
Min	21.76
Spy Glass Fm (n=8)	
Average	9.75
Max	23.50
Min	0.70
Weka Pass Stone (n=10)	
Average	6.53
Max	22.56
Min	0.48

Cadmium and Uranium

Of the samples tested for Cadmium to date, most are below the level of detection. Three samples from the Spy Glass Formation averaged 9 ppm. Ten samples were tested for uranium. All were below the level of detection.

Citric Solubility Testing

Average citric solubility for samples tested by L&M to date is 29%.

Beneficiation

No beneficiation assessments have yet been carried out for the North Canterbury material.

3.2.4. Results and resource potential

Exploration in the North Canterbury region has not yet reached a point where estimates of resources can be made. However, an assessment of the potential scale of a resource can be made.

For a target of 1M tonnes of P₂O₅, assuming 3m ore thickness and 50% beneficiation yield, this ore would be contained within an area of 26 ha. This assumes a bulk density of 2.5 tonnes per m³ for the phosphate ore.

L&M estimates that the North Canterbury region has the potential to contain in the range of 10 to 20 M tonnes of phosphate resource, and dependant on grade and beneficiation efficiency, the total could be considerably higher.

3.3. Waitaki

3.3.1. Introduction

Following a literature review, L&M has carried out preliminary mapping and sampling programmes within the Waitaki region (see figure 1). This work has focused on locating and sampling outcrops of the Concord Greensand in the south and the Kokoamu and Gee Greensands in the central area. The Gee Greensand and Kokoamu Greensand are exposed in the east and west respectively of the Oamaru district. No work has yet been carried out by L&M in the northern part of the Waitaki region (the Waihao Forks area), however there is some data available for that area as discussed above in 2.3. Other areas; eastern South Island.

Apart from L&M's work in the region, most work relating to phosphate has been carried out by Wild and Speight (1918), Gage (1957) and AMOI (various).

3.3.2. Geological setting

Basement rocks within the Waitaki region are composed of Rakaia Terrane greywackes and schists. Regional subsidence in Late Cretaceous saw the deposition of the Onekakara Group (equivalent to the Eyre Group in North Canterbury). These sediments include (from the base) fluvial sandstone, conglomerate and limited coal measures overlain by marine sandstone, mudstone, greensands, and marl. The Alma Group lies above the Onekakara Group and includes the Ototara Limestone, plus the Waiareka and Deborah Volcanics.

A regional unconformity is present at the top of the Onekakara and Alma Groups separating them from the overlying Kekenodon Group. This group represents a period of reduced sedimentation and was in turn overlain by the Otakou Group of Miocene age. This is largely comprised of marine mudstone and sandstone and is the lateral equivalent of the Motunau Group further north.

The main sediments of the Waitaki region, of relevance to the presence of phosphate are summarised below in Table 5.

Table 5: Main Sediments in Waitaki for phosphate exploration

Group	Formation/Member	Phosphate presence	Age
Otakou	Gee Greensand	Gage, Field	Late Oligocene-early Miocene
Kekenodon	Otekaike Limestone	Speight & Wild, Gage	Late Oligocene-early Miocene
	Concord	Lateral equivalent to Clarendon Sand. AMOI	Oligocene
	Kokoamu Greensand	Speight & Wild, Gage, AMOI	Oligocene
REGIONAL UNCONFORMITY			
Alma	Ototara Limestone	Phosphatic at top (Gage)	Late Eocene to early Oligocene

Gage (1957) reported a thin veneer of phosphate at the surface of the MacDonald Limestone (now Ototara Limestone). Speight and Wild (1918) referred to phosphate in the Kokoamu Greensand unit at Waihao Forks, and Gage (1957) recorded phosphate in the greensand in his area of study. AMOI carried out sampling at Waihao Forks. Although the AMOI reports do not confirm which material they sampled it is most likely that they were sampling the Kokoamu Greensand or a sandy facies of the Otekaike Limestone. The Concord Greensand is the lateral equivalent of the Clarendon Sand and accordingly has been targeted for exploration. AMOI sampled this unit in places in the Waikouiti area. L&M has commenced exploration in the same region, however outcrop is proving hard to find. Otekaike Limestone is widespread in the Waitaki region. Speight and Wild (1918) reported phosphate in the limestone at Waihao Forks, and Gage (1957) reported that this limestone has a bored phosphatised surface in places. Phosphate is recorded in the Kakanui area where the limestone rests on Ototara (McDonald)



this unit, as did Field (1986). L&M has sampled the unit wherever outcrops are located.

Limestone, with a basal layer of phosphatic nodules. Gee Greensand (Figure 4. Gee Greensand at Gees Beach, north of Kakanui. The backpack is sitting on Otekaike and Ototara Limestones) comprises fossiliferous greensand which overlies a bored, corroded Otekaike Limestone. Phosphatic nodules and pebbles of limestone or basalt phosphatised to varying degrees are dispersed through the lower part of the formation in places and occasionally concentrated into a distinct basal conglomerate. Gage (1957) referred to the phosphate in

Figure 4. Gee Greensand at Gees Beach, north of Kakanui. The backpack is sitting on Otekaike and Ototara Limestones

3.3.3. Quality

There are some analyses available for phosphate within the Waitaki area. Of these, only those samples taken by L&M have more than just P₂O₅ analyses. All samples are listed in Table 6 below.

Table 6: Summary of analyses; Waitaki

Author	Formation & P ₂ O ₅ %					
	Ototara Limestone	Kokoamu Greensand	Otekaike Limestone	Concord Greensand	Gee Greensand	
Speight & Wild	3.14	1.34	1.57			
AMOI	Ave	0.7	1.36	1.26	1.44	
	Max	1.51	2.9	2.8	3.6	
	Min	0.23	0.14	0.2	0.23	
L&M	Ave	0.1	0.8	2.2	2.4	3.7
	Max	0.1	0.8	4.1	2.7	16.6
	Min	0	0.8	0.3	1.8	0.03

3.3.4. Resource potential

There is insufficient data available to make a resource assessment at this stage, however given the extent of the target formations, there is potential for multi-million tonne deposits.

3.4. South Canterbury

3.4.1. Introduction

To date, L&M's work in the South Canterbury region (see figure 1). has been restricted to a literature review and a high-level field reconnaissance. There is an extensive geological database for the South Canterbury area, but no work has been carried out that specifically targets phosphate, apart from limited work carried out by Speight and Wild (1918).

3.4.2. Geological setting

The same geological elements are present as for the northern part of the Waitaki region and the southern part of the North Canterbury region. Based on the data available, it is clear that there are prospective zones within this region. Within the South Canterbury region, phosphate has been reported in the following sediments:

- **Otekaike Limestone (Late Oligocene-early Miocene):** The formation is widespread in South Canterbury. Speight and Wild (1918) reported phosphate in the limestone at Waihao Forks to the south, and Tinto (1979) referred to a horizon of phosphatised pebbles overlying a burrowed surface at Tengawai and Otaio.
- **Kokoamu Greensand (Oligocene):** Wild and Speight (1918), Allan (1926), Gair (1959), Tinto (1979), and Dagg, (2010) all refer to the presence of phosphate in the Kokoamu Greensand in the Waihao area, and further north at the Otaio and Tengawai Rivers.
- **Waihao Greensand (Eocene):** Phosphate is recorded in this formation by Wild and Speight (1918) and Allan (1926). Field and Browne (1986), state that the formation is recorded at McCullochs Bridge, Kakahu Rvr, Boundary Stm, Otaio Otaio River and

Staveland. They note that the Otaio Limonitic Greensand Member is locally phosphatic. Piekarski (2020) described the phosphatic horizon in this member.

3.4.3. Quality

L&M has not yet carried out any sampling in South Canterbury and there are no analyses available for phosphate within the South Canterbury area.

3.4.4. Resource potential

There is insufficient data available to make a resource assessment at this stage, however given the extent of the target formations, there is potential for multi-million tonne deposits.

4.0. Economic analysis

4.1. Production costs

Quarrying of phosphate in New Zealand is expected to be at a similar cost level to other opencast quarrying, for example limestone, and for opencast coal or gold mining. These costs are site-specific and vary dependant on the amount and nature of overburden that is required to be moved, the nature of the ore, and other site characteristics.

The other variable that will have the greatest impact on costs is the amount of beneficiation carried out on the ore. At the simplest level, this comprises crushing and screening. More complex systems incorporate crushing and screening followed by washing and flotation to upgrade the ore.

At this stage it is not possible to define production costs given the variables outlined above. International examples of operating costs for phosphate projects are provided below in

Presence of contaminants

Phosphate fertilisers generally contain cadmium (Cd) as an impurity with phosphate being the primary source of cadmium to agricultural soils. Historically, P fertiliser manufactured in New Zealand used P rocks sourced from Nauru, Christmas Island, and North Carolina, which had Cd contents often exceeding 400 mg Cd kg⁻¹ P. The fertiliser industry has however had a voluntary limit for cadmium levels in phosphate fertilisers of 280 mg cadmium/kg of phosphorus in place since 1997. Since 2003, Ballance Agri-Nutrients Ltd and Ravensdown Ltd have carried out weekly analysis for total Cd concentrations in each of their main phosphate fertiliser products dispatched from their main manufacturing sites. Average Cd concentrations for each manufacturing site are then calculated, weighted by the production of each sampled fertiliser product. Monitoring indicates that the average monthly Cd concentration in P fertilisers was 184 mg Cd kg⁻¹ P, with 95% of the samples with Cd concentrations less than 246 mg Cd kg⁻¹ P. The cadmium levels for New Zealand rock phosphate referenced in this report have levels of generally below detection or, where recorded, below the 280 mg level.

4.3. Economic comparison of New Zealand phosphate compared with imported phosphate.

4.2. Potential utilisation

Potential uses for the on-shore NZ phosphate deposits are:

Reactive rock phosphate (RPR) / Sulphur blends

Taking advantage of the citric solubility demonstrated by analyses, there is potential to use NZ-based material for RPR production. For RPR production, a higher P level is preferred. The Fertmark Code of Practice declares that RPR should contain not less than 10% total P, and at least 30% must be soluble in 2% citric acid.

Although not meeting the Fertmark specifications, a product with less than 10% P (e.g. 6% P) may be suitable for some applications.

Whichever level of P was used in the RPR, it is anticipated that sulphur would be required to be added at between 4% and 10%.

Partially acidulated phosphate rock (PAPR)

For farmers that need some quick release P, blends of RPR and soluble phosphorus can be

produced. Production of partially acidulated phosphate rock, with the addition of sulphur is a viable use for NZ's phosphate rock. Based on testing to date, ore from Clarendon can be delivered at 9% P or higher, and subject to further testing, material from North Canterbury and Waitaki is likely to be able to be upgraded to the same level.

Feedstock for conventional superphosphate production

Current imported phosphate generally contains in excess of 30% P₂O₅. Upgrading of the higher-grade Clarendon ore to this level is potentially feasible, as is the potential to provide a lower grade (e.g. 25 to 30% P₂O₅) with a very low cadmium content which may be used to dilute Cd in imported material.

Infrastructure requirements for development of most of these options would be minimal, generally comprising a crushing & screening plant plus mixing equipment. Production of material with P₂O₅ levels above 30% may require more sophisticated plant incorporating flotation. Further testing is required to determine the most cost effective beneficiation options.

Pricing of the different products would be dependent on several factors but would be expected to be competitive with products manufactured using imported phosphate rock.

Table 7 sets out the basic parameters of each of the potential products together with possible source areas for feedstock based on our current understanding of the deposits.

Table 7: Potential phosphate products from New Zealand phosphate

Product	P ₂ O ₅ Feed Grade	P% in product	Additives required	Most Probable NZ Sources
RPR low grade	10% +	4–6%	Sulphur	All areas
RPR high grade	20% +	10–12%	Sulphur	All areas
PAPR	18–25%	10%	Sulphur	All areas
Superphosphate feed stock	30–35%	13–16%		Clarendon

Presence of contaminants

Phosphate fertilisers generally contain cadmium (Cd) as an impurity with phosphate being the primary source of cadmium to agricultural soils. Historically, P fertiliser manufactured in New Zealand used P rocks sourced from Nauru, Christmas Island, and North Carolina, which had Cd contents often exceeding 400 mg Cd kg⁻¹ P. The fertiliser industry has however had a voluntary limit for cadmium levels in phosphate fertilisers of 280 mg cadmium/kg of phosphorus in place since 1997. Since 2003, Ballance Agri-Nutrients Ltd and Ravensdown Ltd have carried out weekly analysis for total Cd concentrations in each of their main phosphate fertiliser products dispatched from their main manufacturing sites. Average Cd concentrations for each manufacturing site are then calculated, weighted by the production of each sampled fertiliser product. Monitoring indicates that the average monthly Cd concentration in P fertilisers was 184 mg Cd kg⁻¹ P, with 95% of the samples with Cd concentrations less than 246 mg Cd kg⁻¹ P. The cadmium levels for New Zealand rock phosphate referenced in this report have levels of generally below detection or, where recorded, below the 280 mg level.

4.3. Economic comparison of New Zealand phosphate compared with imported phosphate

An analysis of the costs associated with accessing the resource (mining, processing) was undertaken by The AgriBusiness Group — to provide a basis for comparison with imported P. It is important to note that the detail that is possible in this analysis should be considered as being at the pre-feasibility level and that it has been made on limited available data.

An analysis of the cost at the Phosphate Rock (PR) level in order to make the comparison with the imported PR material. All of the additional processing to turn the PR into the range of possible fertilisers will have to be carried out regardless of where the source material is derived from.

Three publicly available costs of the mining of and the beneficiation costs of sourcing PR were analysed. The core elements of each are shown in

Table 8.

Table 8: Costs of the mining of and the beneficiation costs of sourcing PR (\$NZ / tonne)

	Cabinda, Angola	Farim, Guinea-Bissau	Ardmore, Australia	Average
Ore Reserve (Mt)	4.72	102.50	10.10	
Quality (% P₂O₅)	30.10	36.50	30.20	32.20
Annual Prod (tpa)	187,500		800,000	
Strip ratio	3.20 (t/t)	10.10 (m ³ /t)	.60	
Mining cost	6.97	61.25	16.35	28.19
Mining-related Ore costs	15.27	0.00	2.79	6.02
Beneficiation costs (variable)	30.81	12.95	13.58	19.11
Beneficiation costs (fixed)	10.38	0.00	0.00	3.46
G&A expenses	34.28	9.46	7.42	17.05
Total mining costs	92.56	86.15	40.14	72.95

Definition of terms used in table 8

- Annual production (tpa) = tonnes per annum
- Strip ratio - in surface mining, stripping ratio or strip ratio refers to the amount of waste (or overburden) that must be removed to release a given ore quantity.
- Beneficiation - is any process that improves (benefits) the economic value of a mineral raw material by removing the less valuable minerals, which results in a higher grade product.
- G&A = general and administrative expenses - costs associated with running a business that aren't related to products or sales

Findings from the various reports detailing the mining costs is that the biggest variants in terms of mining costs are:

- The strip ratio which determines the amount of overburden that has to be removed before access to the ore material is achieved.
- The amount of grinding of the source material which is required to make the PR pliable enough to be used in the subsequent processing.
- The amount of removal of carbonate material from the sample.
- The amount of removal of non-phosphate material from the sample to get the percentage of P₂O₅ up to over 30%.
- The location of the operation in relation to the further processing facility and therefore the transport costs.

The AgriBusiness Group suggests that while operating costs will obviously vary, with strip ratio and detailed geochemistry of individual deposits, adopting the average values in Table 8 are satisfactory for this level of costing comparison. The major variances that saw in using the data from the three costings is the cost of mining a greater tonnage of lower grade ore to produce the same tonnage of marketable product, and the increased cost of beneficiation of these additional tonnes of ore to achieve the equivalent level of P₂O₅ in the PR. The range of possible costs of PR across the range of potential percentages of P₂O₅ are shown in

Table 9.

Table 9: Calculation of the possible impact of the percentage of P₂O₅ on the total cost of PR.

P ₂ O ₅ %	Variance from Moroccan 24% P ₂ O ₅	Variable Beneficiation cost. \$/t	Variable Mining cost. \$/t	Total cost of PR. \$/t
5	4.8	92	164	276
10	2.4	46	82	148
15	1.6	31	55	106
20	1.2	23	41	84
24	1.0	19	34	74
30	0.8	15	27	63

Using this method of calculation of the possible impact of the percentage of P₂O₅ on the total cost of PR it is proposed that anything with a percentage of P₂O₅ of 5% and upwards would theoretically be able to at least equal the quoted cost of PR landed in New Zealand of \$240/t³.

³ NZIER (2014): Further information request from EPA (16 June 2014) – Response to Requests 28 to 33.

It is noted that the figure used in the NZIER report was created in 2014 and it is expected that both the cost of the PR material and the cost of transporting it will have changed since that date.

In conclusion that given the range of costs that have been referenced, which could be best described as a pre-feasibility assessment, The AgriBusiness Group is confident that PR sourced from within the known resources in New Zealand can be quarried and provided at a comparative cost to the imported material. If it were possible to source P from the New Zealand deposits, there would be a positive economic benefit for both the local and the New Zealand economies.

5.0. Environmental Effects

5.1. Overview

This section includes the following:

- An outline of the potential style and scale of a phosphate quarrying operation.
- An assessment of the potential environmental effects likely to arise from phosphate quarrying and processing at sites between Balclutha and Kaikoura, and where possible, practicable mitigation measures that might be used to reduce these potential effects.
- An outline of possible consenting requirements for the sites. The area of interest is encompassed by six Territorial Authorities and two Regional Councils. No in-depth study of consenting requirements is warranted at this stage.
- An analysis of the environmental effects associated with the use of New Zealand sourced P — including an analysis of the carbon footprint and the use of less soluble P resources.

5.2. Quarry operations

Quarrying of phosphate will involve the following processes:

Site preparation

Prior to carrying out any earthmoving, access roads are constructed, preliminary water management systems installed, and site infrastructure established (site office, workshop, storage, power and water supplies).

Vegetation removal

Any trees or scrub areas are removed and salvageable timber harvested. Other material is stockpiled or mulched.

Topsoil and subsoil stripping

Topsoil and subsoil are stripped separately from underlying material and are initially stockpiled in preparation for re-spreading. This work is generally carried out by small scale truck excavator and trucks, however motor scrapers may be used if the topography is suitable. As soon as practicable, soil is respreads directly on land that has been mined and relevelled. The topsoil and subsoil stockpiles may be utilised as temporary noise and landscaping bunds.

Overburden stripping

Overburden (rock material overlying the phosphate ore) and interburden (material between beds of phosphate ore) are generally removed using excavator and truck fleets. Initial overburden material will be stockpiled outside the quarry pit, however as quarrying proceeds, direct backfilling will generally be possible. None of the areas investigated to date contain rock that would need to be drilled and blasted prior to excavation.

Phosphate extraction

Phosphate ore would be excavated using an excavator and truck fleet. The material would be carted to a processing area where initial crushing is carried out using a portable crushing plant. The product from the crushing plant would be carted off site for storage and further beneficiation as required. It is anticipated that the quarry would operate a maximum of 354 days per year, (11 Public Holidays not worked), up to 12 hours per day.

Mining schedule and area of disturbance

No assessment of phosphate production at any one site can be made at this stage. However, taking the resource assessment set out in 3.2.4. Results and resource potential as a guide, if total annual production of 100,000 tonnes was achieved, and assuming a total ore thickness of 3.0m, this would result in the disturbance of in the order of three to five hectares per year, taking account of land required for the mine pit and ancillary works.

Expected personnel levels

A typical quarry and processing plants would require approximately 20 full time equivalent staff. These would be a mix of contractors and company personnel. Specialist input would also be required from environmental consultants and engineers.

5.3. Potential environmental effects from phosphate quarrying and processing

5.3.1. Introduction

Prior to commencement of quarrying operations at any site, an assessment of environmental effects (AEE) would be carried out. This assessment would be undertaken by specialists in the relevant scientific fields. The level of detail of such studies is guided by the size and scope of the proposed operation. The AEE would address the construction and operation of the proposed quarry, transport, processing and load out facilities and include the following:

- Effects on the community including any socio-economic and cultural issues
- Effects on the locality including noise, landscape and visual amenity
- Effects on ecosystems including plants or animals and the physical disturbance of habitats in the vicinity
- Effects on natural and physical resources having aesthetic, recreational, scientific, historical, spiritual or cultural, or other special values
- Any discharge of contaminants into the environment (air, land and water) and options for the treatment and disposal of contaminants
- Any effects on natural processes in the air, land or coastal environment
- Any risk to the community or the environment through natural hazards created by the proposal
- A plan for the rehabilitation of the area

Specific environmental effects are discussed below.

5.3.2 Terrestrial Ecology

The construction and operation of a quarry and processing plant would result in the retirement of the land from other activities (e.g farming) for the life of the operation. The majority of any vegetation on the site would need to be removed. To mitigate the effects resulting from any loss of habitat and vegetation on the plant site, buffer areas can be established around the site perimeter. Potential mitigation and offsetting methods such as those described below may be appropriate.

- Transfer of populations of some species to alternative suitable habitats. This may not be practical for all species.
- Protection may be able to be provided to other populations that are presently threatened by predation or other threats.
- Residual effects of operations on affected populations of rare plant and animal species would need to be mitigated.

5.3.3. Surface water, ground water and aquatic ecology

The removal of overburden and phosphate extraction have the potential to affect surface waterways. The use of progressive infilling and land restoration will minimise the disturbed area. There may be opportunities for ponds/wetlands to be created during restoration of disturbed areas. Waterways can also be reinstated as a part of the restoration programme.

Land disturbance has the potential to increase the concentration of fine sediments in nearby waterways. High concentrations of fine sediments can adversely affect invertebrates and fish by reducing food sources and by clogging of respiratory structures. Suspended sediments can affect areas at some distances from the source. In order to avoid and minimise the effects of sediment discharges on surface waterways, appropriate buffers or setbacks, settling ponds, land-based disposal of sediment laden water, or flocculants can be used.

Dependent upon site specific geology and topography, the dewatering of the proposed quarry has the potential to impact the level of the water table and flows in nearby surface water bodies. Reduced surface flow can affect the availability and/or suitability of habitat in these waterways, and may interfere with other users of the water (e.g. farm stock water supplies).

Treatment of any water discharges would be a priority and given the options available, it is expected that any adverse effects would be mitigated or minimised. The quality of the waters being discharged from the phosphate quarries can be expected to be as good as, or better, than the existing water quality.

As part of the detailed design of a quarry, an Erosion and Sediment Control Plan would be developed. The aim of this plan would be to minimise the discharge of sediments and contaminants resulting from proposed construction and to outline the runoff treatment systems that would be utilised.

5.3.4. Air Quality

The activities that will take place at a quarry site during construction and operations, which may generate air discharges, are:

- Earthworks and extraction
- Vehicle movements on roads
- Loading, carting and unloading of ore
- Crushing and screening of ore
- Unconsolidated surfaces such as areas stripped for quarrying, stockpiles, yards, roads and areas in the process of rehabilitation

Deposited dust has the potential to cause amenity effects due to soiling of surfaces such as excessive dust deposits on and in houses, cars and laundry that is hung outside. Dust can also affect plants and roof and stock water supplies, though mainly at higher loadings. Whether or not these effects become a problem depends on the circumstances of the particular proposal.

As a class of materials, deposited particulates have minimal physical health impacts as the particles have only limited penetration into the respiratory tract. Excessive dust deposition has the potential to adversely affect areas of ecological value and the more sensitive flora and fauna that live in them.

When dust particles are released into the air they tend to fall back to ground at a rate proportional to their size (volume). Dust particles generated by activities such as construction and quarrying fall into the larger size fractions, with an aerodynamic diameter of 10µm or greater.

The critical wind speed for dust pick-up from surfaces is 5m/s (18 km/h). At wind speeds above 10m/s (36 km/h), dust pick-up increases substantially. Wind speeds on the east coast of the South Island are frequently higher than 20 km/hr and gusts can exceed 100 km/hr. Consequently, winds exceeding 5m/s are expected to occur quite frequently. The most sensitive receptors will be the properties downwind of the propose activities. Sites within approximately 1 km of a quarry should be considered to be potentially affected by dust emissions in worst case conditions.

The use of appropriate mitigation measures can significantly reduce the potential for dust to cause adverse effects beyond the boundary of the site. Industry standard methods that are available for controlling dust that are relevant to quarrying include:

- Minimising exposed areas and re-vegetating or stabilising exposed areas as soon as practical
- Using water as a dust suppressant to keep un-vegetated and un-stabilised surfaces and roads damp
- Using water to suppress dust from surfaces of stockpiles, transfer points and during loading and unloading activities
- Limiting vehicles speeds on access roads and around the site
- Minimising drop heights through the use of telescopic or luffing heads on stackers and loaders
- Minimising vehicle movements through efficient layout design
- Maintaining surfaces of road and yard areas to minimise the build-up of fine materials that can be entrained in the wind
- Full or partial enclosure of conveyors and transfer points where practical
- Limiting the height of stockpiles
- Sheltering potential dust sources from the wind through enclosure or providing shelter

The design of a processing plant would include emission control equipment and management systems that meet industry standards. Providing these measures are used where appropriate, and an adequate buffer distance is provided between the plant and the closest nearby sensitive receptors, adverse effects resulting from discharges to air should be adequately avoided, remedied or mitigated.

5.3.5. Landscape and visual effects of the operation

Quarrying is a reasonably common land use on the east coast of the South Island, with a number of limestone quarries being located in areas with potential to host phosphate resources. Quarrying is therefore an accepted activity to rural communities.

The potential landscape and visual effects of a quarry and processing plant include noise, dust and increased vehicle movement reducing the amenity of the immediate area. The main effects would be the advent of industrial structures in a pastoral landscape, creating a distinct contrast in land use, movement patterns, form, texture and colour. These issues could be largely mitigated by:

- Creating a buffer on the site boundary by using exotic and native vegetation
- Mitigation of dust and noise, and minimisation of vehicle movement
- A full restoration plan to be undertaken which would include re-grading contours, planting and maintaining public access.

5.3.6. Noise, vibration, light and traffic

The establishment and operation of the quarry and processing plant may adversely impact on any nearby sensitive receptors such as residential properties, businesses and community facilities.

Noise and vibration may be caused by heavy transport vehicles and quarrying and processing equipment. These factors will need to be taken into account when designing the layout of the quarry and processing plant and when specifying mechanical equipment.

5.3.7. Summary

The following environmental aspects are relevant to a phosphate quarry and processing development:

- **Ecology:** the value and sensitivity of flora and fauna of the site and the adjacent land
- **Noise and vibration:** noise and vibration caused by construction vehicles, quarrying vehicles, processing plant and load-out facility
- **Air quality:** generation of dust and engine emissions
- **Hydrology, hydrogeology and water quality:** flooding and drainage, groundwater levels and flows, water take, contamination of surface water, coastal water and groundwater
- **Soils and subsidence:** ground contamination, erosion from land disturbance
- **Access:** increased traffic on local and state highway roads from quarry traffic
- **Amenity:** recreational values or enjoyment of the surrounding land
- **Landscape and views:** quarrying and the processing and load-out facilities will change the look and feel of the immediate area
- **Society:** people living and working in close proximity to the sites may be sensitive to some activities
- **Cultural values:** effects on areas important for food gathering, or on sites of cultural significance
- **Hazardous materials and waste management:** use of hazardous substances, generation of hazardous waste, and the management of substances and waste to avoid pollution or contamination.

5.4. Consent applications

The area of interest is encompassed by six Territorial Authorities and two Regional Councils. No in-depth study of consenting requirements is warranted at this stage, however the likely consent requirements are summarised in the following table.

Table 10: Summary of likely resource consents for the proposed quarrying and processing activities.

Activity	Regional Water Plans	Regional Air Plans	District Council Plans
Emissions to air		●	
Water takes, divert and discharge surface water and groundwater	●		
Bulk earthworks and removal of indigenous flora and fauna	●		●
Discharge to land or water	●		
Noise			●
Road access and realignments			●
Contaminated land	●		●

An Assessment of Environmental Effects (AEE) would be required to accompany the resource consent applications.

5.5. Analysis of the environmental effects associated with the use of NZ-sourced phosphate

The AgriBusiness Group undertook an analysis of the two major environmental effects associated with the use of NZ-sourced P, the effect of the carbon footprint of the PR and the effect of the use of less soluble P resources.

5.5.1. Carbon footprint — greenhouse gas

In his report Ledgard, S (2019), set out to provide updated information on the energy use and greenhouse gas (GHG) emissions of a range of fertilisers commonly used in New Zealand using Life Cycle Assessment (LCA) methodology. In that report he calculated the GHG emissions for single super phosphate (SSP) from all stages of production. The results are shown in Table 11.

Table 11: GHG emissions for single super phosphate per tonne as calculated by Ledgard 2019.

Stage of Production	GHG (T CO ₂ e)	Percentage (%)
Shipping	100	64
Mining and Beneficiation	39	25
Mixing and Distribution	17	11
Total	156	100

Table 11 shows that 64% of the GHG's emitted from SSP comes from the shipping of the raw material from overseas while mining and beneficiation makes up 25% and mixing and distribution makes up 11%.

If the same values used by Ledgard are converted to calculate the GHG emissions from New Zealand sourced PR used to produce a 7% SSP the results are as is shown in Table 12.

Table 12: GHG emissions for single super phosphate (7%) per tonne sourced in New Zealand.

Stage of Production	GHG (T CO ₂ e)	Percentage (%)
Shipping	2	2
Mining and Beneficiation	56	74
Mixing and Distribution	18	24
Total	76	100

The total amount of GHG emissions from the New Zealand source PR is 76 T CO₂e per tonne of SSP which is 49% of that of the imported material. Mining and beneficiation is the largest source of GHG emissions at 74% while mixing and distribution are 24% and shipping is only 2%.

5.5.2. Use of less soluble P

The use of less soluble P in a form which is not water soluble has long been advocated in New Zealand agriculture but has not been widely adopted for a range of reasons including the fact that the P in RPR only becomes available slowly over time and the relative cost of transport and application of the material compared with the soluble product.

Reactive Phosphate Rock (RPR) is defined in the Fertmark Code of Practice as being not less than 10% P and having a citric solubility of at least 30%. Once land reaches its optimum Olsen P level it is possible to apply RPR every two or three years to maintain the optimum Olsen P levels. The more acidic the soil, the quicker the P becomes available and there is a liming effect if the RPR is mixed with Calcium (Ca). Sulphur (S) can also be applied with RPR in an elemental form which becomes available to the plant over time. Preliminary testing shows that the New Zealand sourced material has both the percentage P₂O₅ and the citric solubility that is required to produce RPR.

The testing also indicates that the material would be suitable to manufacture a partially acidulated phosphate rock (PAPR), with the addition of S, which has a proportion of readily available P and a proportion of RPR which becomes plant available over time.

With the increasing cost of transport and application of fertilisers and a future commitment by the New Zealand Government to bring agricultural emissions into some form of emission taxation regime there is great potential for a New Zealand sourced fertilisers to both reduce the financial cost and the total GHG emissions of fertilizer in New Zealand.

The use of non-water soluble forms of P will also have the ability to reduce the amount of P runoff in agriculture.

6.0. Analysis of the potential use of New Zealand phosphate fertiliser

An evaluation of the potential demand from New Zealand farmers for phosphate fertiliser products sourced from New Zealand was undertaken as part of this project using a survey as well as the ADOPT (Adoption and Diffusion Prediction Tool) developed by the Australian Government's Commonwealth Scientific and Industrial Research Organisation (CSIRO).

6.1. Survey

A farmer and stakeholder survey was undertaken using the Survey Monkey survey tool to inform the ADOPT analysis on New Zealand phosphate products. The survey obtained feedback from participants about their views on potential New Zealand phosphate products and variables that would impact their adoption of the products. The survey was distributed by Our Land and Water and by The AgriBusiness Group and had 13 completed responses between the 26th of October and the 16th of November. The response number is very low for the survey however the responses do hold some value in informing the positioning of farmers in changing from current phosphate products to New Zealand Phosphate products. Due to the low response rate a broad overview of the results is included however details around the findings have been left out due to the limited value they provide.

Results Overview

In the survey, the majority of respondents were farmers, with seven identifying as farmers/growers, while rural professionals and rural service providers constituted smaller proportions. The survey assessed opinions on four New Zealand phosphate products (RPR low grade, RPR high grade, PAPR, and Superphosphate). Respondents ranked these products based on desirability, with Superphosphate ranked the highest, followed by RPR high grade, PAPR, and RPR low grade. Respondents expressed a willingness to use Superphosphate in the future, while limited interest was observed for the other products, possibly due to limited awareness. Additionally, respondents indicated a generally consistent willingness to pay between \$350 and \$450 per tonne for the different products, with RPR low grade being the only exception.

Adoption Questioning

The respondents were also asked about to respond to questions that asked them about both the variables that would impact their decision making and their opinion on how the change to NZ phosphate products would impact their profitability, risk levels and environmental outcomes.

The survey participants were queried on the factors influencing their decision making when it comes to adopting a new innovation. They highlighted that financial profitability would significantly affect their decision making, while the environmental impact would only hold moderate sway. Managing risk emerged as a crucial consideration in implementing any alterations on their farms.

The survey respondents were also asked to rank from 0 to 5 on the impact they believed a change to New Zealand phosphate would have on their profitability, the environment, risk and convenience. 1 being minimal impact and 5 being significant impact. The following figure demonstrates the average responses.

Table 13: Adoption Related Answers

Anticipated Impacts	Ranking
Impact on Profitability	2
Impact on Environment	3
Associated Risk	2
Impact on Convenience	2

Table 13 outlines that the respondents perceived a limited direct impact of transitioning to New Zealand phosphate on their farms with limited risk being outlined. Table 13 shows the survey respondents anticipated minimal influence on farm profitability but moderate environmental effects resulting from the switch. Notably, majority of farmers typically base their fertilizer decisions on the cost per unit of P and 100% of respondents expressed willingness to switch to New Zealand phosphate if given the chance.

6.2. Adopt analysis

ADOPT represents a web-based solution designed to assess and forecast the probable adoption and dissemination of specific agricultural innovations within targeted populations. Managed by the CSIRO, it was created with support from the Cooperative Research Centre for Future Farm Industries, alongside contributions from GRDC, ACIAR, CSIRO, University of Western Australia, DAFWA, and Victorian DEPI..

The framework of ADOPT revolves around four primary categories influencing adoption:

- Innovation characteristics
- Target population attributes
- Relative advantage offered by the innovation
- Understanding the relative advantage of the innovation

Users engage with both qualitative and quantitative inquiries related to twenty-two variables that impact adoption. This interactive process not only aids in evaluating these variables but also enhances understanding of their interrelationships and their impact on adoption and diffusion.

ADOPT stands as a widely respected tool for forecasting farmer acceptance of new agricultural practices. ADOPT generates a comprehensive report detailing various results, including the time required to reach near-peak adoption levels, the percentage of farmer uptake at that peak level, yearly adoption rates, and an exhaustive sensitivity analysis covering key sensitive questions.

Using the results from the survey to inform the answers inputted into the ADOPT software it was possible to generate potential adoption outputs for the use of New Zealand phosphate fertiliser. Drawing from the detailed survey results (Adoption Questioning), which served as a reference for understanding the influences on farmers and their perceptions regarding the innovation's potential impact on them, an adoption output, as depicted in **Error! Reference source not found.** was formed.

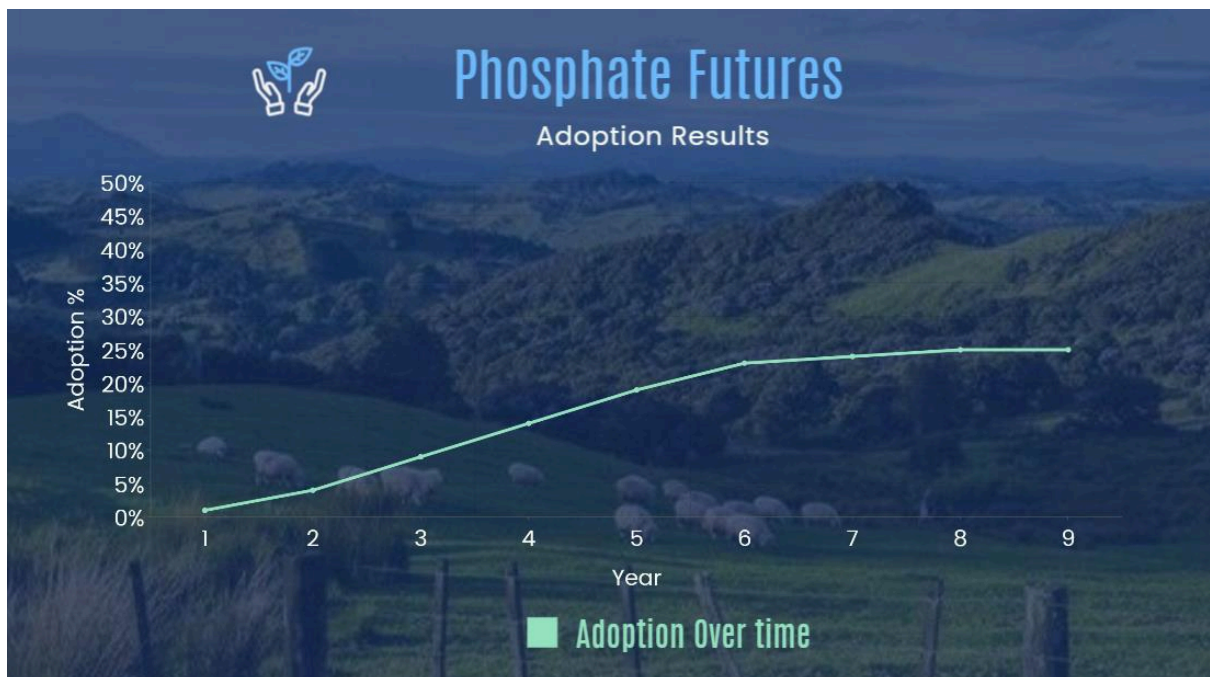


Figure 5. Adoption of New Zealand Phosphate Products over time.

Error! Reference source not found. shows that over an eight-year period, the adoption of New Zealand phosphate products steadily increased, reaching a peak of 25% adoption. This result was due to the perceived low risk involved in transitioning from current fertiliser products to New Zealand phosphate. The ease of use without requiring new skills or knowledge and its farm-trialling convenience contributed significantly to this swift uptake. However, the adoption plateaued at this relatively low percentage as survey respondents highlighted minimal positive impacts on profit and moderate positive effects on the environment as key factors.

The predominant influence on peak adoption was the significant weight placed on financial benefit as a driving force.

To explore various adoption outcomes further, three potential scenarios were assessed using ADOPT:

- **Adoption 1:** New Zealand phosphate adoption yields minor impacts on farmers' profitability and the environment.
- **Adoption 2:** As indicated in the survey, adoption leads to minor impacts on farmers' profitability but moderate effects on the environment.
- **Adoption 3:** New Zealand phosphate adoption results in moderate impacts on farmers' profitability and the environment.

These scenarios maintain consistent variables such as risk and trialability while solely examining the possible ranges of profitability and environmental impacts on potential outcomes for farmers utilising New Zealand phosphate.

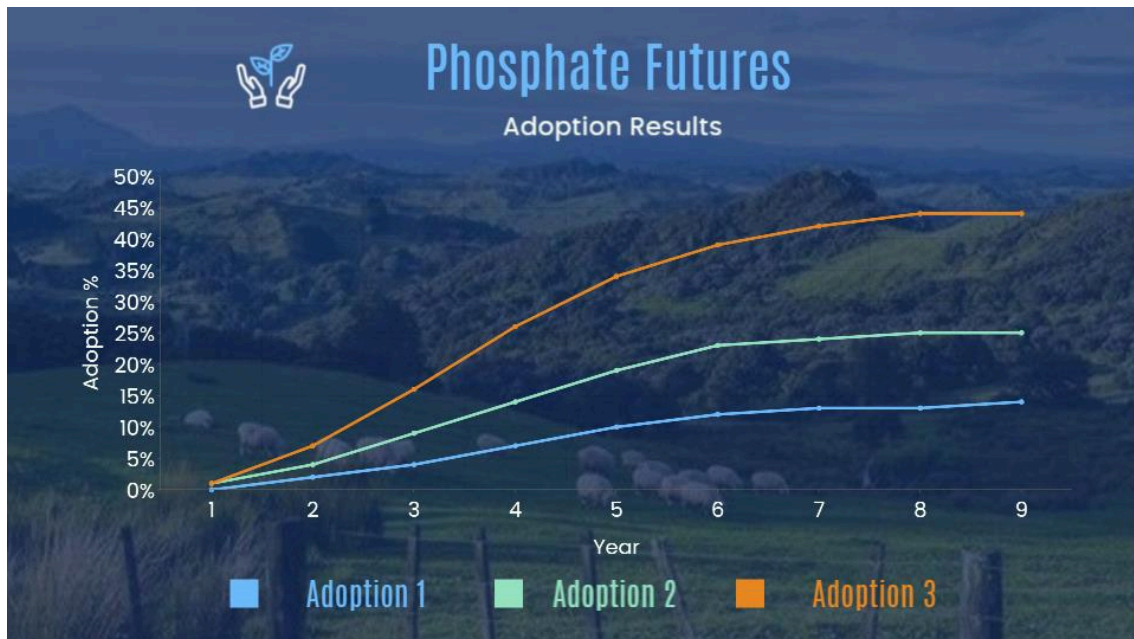


Figure 6. Adoption of New Zealand Phosphate — Potential outcomes of three scenarios.

Error! Reference source not found. shows how outcomes of the three scenarios reveal distinct patterns. In Adoption 3, where there's a moderate positive impact on farmer profitability, there's a surge in the adoption of New Zealand phosphate. This scenario demonstrates substantial growth, peaking at 44% adoption in the eighth year. Contrarily, Adoption 1 indicates that if the positive environmental effects of transitioning to New Zealand phosphate products were minor, the adoption rate would remain minimal. This scenario portrays a slow and steady increase in adoption, reaching a peak of 14%. The lack of significant drivers compelling farmers to switch from their current practices contributes to this restrained adoption rate. Adoption scenarios 1, 2 and 3 portray the variability of potential environmental and financial impacts of changing to New Zealand phosphate use.

7.0. Conclusions

7.1 Summary

The Sustainable Phosphate Futures for New Zealand project was established to review strategies to enhance the efficient use of phosphate resources as well as to review strategies to enhance the security of supply of phosphate for New Zealand agriculture through the use of New Zealand sourced phosphate. This report reviews issues in relation to the use of New Zealand sourced phosphate and its findings include:

- There are extensive phosphate deposits in the East Coast of the South Island and that some of these are of a quality to be used for a range of phosphate fertilisers. These fertilisers include RPR, PAPR as well as a potential feedstock for the production of SSP. Testing to date indicates that phosphate deposits generally have very low levels of cadmium or uranium present.
- The economic analysis for the potential use of New Zealand phosphate establishes that the pricing of the different products would be dependent on several factors but would be competitive with products manufactured using imported phosphate rock.
- An analysis of the potential environmental effects associated with the use of New Zealand land based phosphate resources establishes that there would be a relatively minor environmental effects from the extraction process. While potential resource consent requirements for quarrying have been identified, these have not been reviewed in detail. It is expected that development of a phosphate extraction operation would be similar to those for limestone rock.
- A comparative analysis of the carbon footprint from imported and New Zealand sourced phosphate for the production of SSP indicate that the GHG emissions from the New Zealand source PR is 76 T CO₂e per tonne of SSP which is 49% of that of the imported material.
- A commentary on the use of less soluble P phosphate such as RPR and its ability to reduce the amount of P runoff in agriculture is provided.
- It is proposed that with the increasing cost of transport and application of fertilisers and a future commitment by the New Zealand Government to bring agricultural emissions into some form of emission taxation regime there is great potential for New Zealand sourced fertilisers to both reduce the financial cost and the total GHG emissions of fertilizer in New Zealand.
- A survey exploring the potential levels of adoption for different phosphate fertiliser products that could be manufactured from New Zealand sourced phosphate was undertaken and established that though most prefer SSP there are 29% of survey respondents that would use PAPR and 14% who would use high grade RPR. Financial profitability would significantly affect the respondents decision making, while the environmental impact would hold moderate sway. The respondents perceived a limited direct impact of transitioning to New Zealand phosphate on their farms with limited risk being outlined
- An analysis of the potential adoption of New Zealand sourced phosphate fertilisers using the ADOPT model established that peak adoption of 25% would occur over an eight-year period. This result was due to the perceived low risk involved in transitioning from current fertiliser products to New Zealand phosphate. The ease of use without requiring new skills or knowledge and its farm-trialling convenience

contributed significantly to this swift uptake. However, the adoption plateaued at this relatively low percentage as survey respondents highlighted minimal impacts on profit and moderate effects on the environment as key factors.

- Three additional scenarios portray the variability of potential environmental and financial impacts of changing to New Zealand phosphate use were assessed using ADOPT and these reflected a subsequent adoption range of 44% to 14%.

The additional following strategic analysis for the use of New Zealand sourced phosphate has been prepared:

7.2 Strategic Analysis

7.2.1 Strengths

Economic impact

- **Cost competitive:** the cost of phosphate fertiliser products made from New Zealand phosphate can be quarried and provided at a comparative cost to the imported material.
- **Product versatility:** the range in quality of New Zealand phosphate makes it suitable for the production of a variety of phosphate fertilisers including as a feedstock for the manufacture of superphosphate, the production of PAPR as well as RPR.
- **Potential resource scale:** current studies indicate that there is excellent potential for large scale phosphate deposits in the areas identified by L&M. The resource potential is in the multi million tonne range.
- **Supply chain security:** the domestic sourcing of phosphate would significantly decrease potential risks from disruption to international phosphate supply chains. The strategic importance of maintaining phosphate supplies is reflected in the [European Union listing it as a strategic critical raw material](#)⁴ and Australia listing it in its strategic mineral list. The 2019 *Minerals and Petroleum Resource Strategy for Aotearoa New Zealand: 2019–2029*⁵ lists a future action for developing a critical minerals list for New Zealand. It is very strongly recommended that phosphate is included on this list.
- **Price fluctuations:** currently international phosphate prices are volatile with significant price swings. A domestic supply could be insulated from such volatility.

Environmental impact

- **Lower carbon footprint -** Phosphate fertilisers from New Zealand sourced phosphate can decrease the phosphate fertiliser carbon footprint by 49% in comparison to imported phosphate. This provides an opportunity for the reduction of the total carbon footprint for those farmers using New Zealand phosphate fertiliser products.
- **The promotion of less soluble phosphate fertilisers such as RPR will decrease water pollution risks.**
- **The phosphate resources are discussed in this report are largely located on land used for agriculture with development and subsequent rehabilitation resulting in**

⁴ https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

⁵ <https://www.mbie.govt.nz/dmsdocument/7148-responsibly-delivering-value-a-minerals-and-petroleum-strategy-for-aotearoa-new-zealand-2019-2029>

minimal adverse environmental effects. Based on current knowledge of the deposits, only a relatively small area (3 to 5 Ha) of mining would be required to supply 100,000 tonnes per year.

- Exploitation of land based resources avoids many of the issues associated with development of sub-sea deposit.

Social impact

- The establishment of phosphate quarrying activities in New Zealand will provide jobs and economic development in East Coast South Island rural communities.
- Political and social issues relating to the use of 'blood phosphate' from the contested Western Sahara would be effectively addressed.

7.2.2 Weaknesses

Farmers have traditionally used and prefer SSP and have a lack of awareness or experience in using other types of phosphate fertilisers.

7.2.3 Opportunities

NZ phosphate resources would become more important as a buffer against any increases in price for imported phosphate or any restriction on the availability of imports.

SSP was first manufactured in New Zealand in Dunedin in 1882, there are possible opportunities for newer and improved types of phosphate fertiliser that address economic and environmental expectations that could be defined through targeted R&D.

7.2.4 Threats

Inertia: a lack of recognition of the potential risks and impact from disrupted supplies of phosphate to New Zealand could result in a significant shock to both agriculture production and the New Zealand economy if the international supply of phosphate is disrupted.

7.3 Next steps

In summary, the use of New Zealand sourced phosphate for fertiliser appears to be viable and feasible while providing potential economic and environmental benefits. The following are suggested as follow-up actions:

- Undertake a more detailed analysis of the environmental and economic effects associated with the use of New Zealand phosphate resources.
- Identify the most viable opportunities for the use of New Zealand sourced phosphate and establish fertiliser supply chains to exploit and evaluate these.
- Include phosphate in the New Zealand list of strategic raw materials and develop an associated supply chain risk management strategy.
- Increase the level of farmer awareness about the relative environmental and economic benefits associated with the use of alternative (and less soluble) phosphate fertilisers. There has been extensive research (McDowell, R et.al; 2019, 2023) that provides a strong evidence base for this including on the use of RPR as a slow-release fertiliser.

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