National SCIENCE Challenges

OUR LAND AND WATER

Toitū te Whenua,
Toiora te Wai

Wai Ora, Whenua Ora, Tangata Ora

- Healthy Water, Healthy Land, Healthy People

Strategy for the Our Land and Water National Science Challenge

2018

Contents

Executive Summary

This document presents the revised strategy of Our Land and Water National Science Challenge ('the Challenge' hereafter). It replaces the previous strategy and parts of the Challenge Research and Business Plan to provide a basis for funding to undertake research for the five-year period July 2019 to June 2024.

The future we envisage and how we are going to create it

Our vision looks to a future where catchments contain mosaics of land uses that are more resilient, healthy and prosperous than today. This is a future in which all New Zealanders can be proud of the state of our land and water and share the economic, environmental, social and cultural value derived from them. To reach that future will require ways of thinking and interacting with land and water that are fundamentally different from how they are today. This transition needs to happen quickly, with industry and communities working together for change. We believe that when the incentives and pathways to change are compelling, future New Zealand will contain the right enterprises in the right places to deliver the right outcomes.

To advance this vision, the Challenge draws on two complementary perspectives: a Māori world view which combines cultural and commercial imperatives by acknowledging the intrinsic values of land, the interconnectedness of all living things and the responsibilities we have for environment and community, and a value proposition based on understanding and making use of supply and value chains. We have modified the thematic structure of our research strategy to better reflect these perspectives and to focus on outcomes that advance our objective. The first of our themes examines the **characteristics of our future productive landscapes**, the second looks at the **challenges and drivers** inherent in the multiple pathways to those future states, and the third how we develop the **capacity to transform** at the scale that is required.

Our opportunity to change

The current state of many of the country's soils and freshwater bodies is poor. As a nation, we capture and share only a small fraction of what our high-quality produce is sold for overseas. Solutions to these problems are available, but it will take a generation or more to see real change occur on vital environmental, economic and social issues.

On the positive side, there is an increasing focus on soil and water quality, and the country is on an economic journey 'from volume to value.' However, more needs to be done—and quickly—so that current and future generations can prosper.

Māori innovation, entrepreneurship and ways of managing the land will increasingly underpin the production systems and products of future landscapes. Approaches to land use which arise from mātauranga Māori (Māori knowledge systems) provide pathways to increase value in premium niche markets that can be shared across the primary sector. International consumers are rewarding producers of bespoke products, yet our primary sector has been slow to prioritise these markets. Environmental impacts such as climate change are already modifying our catchments, and we must adjust land uses accordingly to keep producers resilient and market focused.

The role of the Challenge is threefold: 1) to understand the pressures and drivers of change; 2) to provide a vision for the future; and 3) to collaborate and undertake the research and navigate transition pathways for change that meet our statutory objective, namely:
'To enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations.'

The way we work

With this strategy, we reaffirm our commitment to co-innovation. Co-innovation means creating spaces in which researchers and stakeholders work together to generate better, faster, more robust impacts. This commitment is underpinned by efforts to build stronger relationships with Māori partners through a better understanding of te ao Māori perspectives, enabling us to explore new land-use opportunities and models that are based on principles of kaitiakitanga, manaakitanga and whakapapa. We have transparent processes to focus and prioritise our research by engaging the best teams and best thinking to ensure research excellence. We see the Challenge as a hub of research activity, using our convening power to partner with Māori and industry leaders, stimulate ideas, identify alignment, leverage opportunities and function as capability-building brokers.

How to navigate this document

This strategy is in seven parts. It explains the background and purpose of the Challenge, its strategic approach, its main research elements and its ways of working with Māori partners, researchers and stakeholders.

Supporting documents are available on our website at: http://www.ourlandandwater.nz/resources-and-information/future-strategy-documents-2

The strategy starts with a short summary of the Challenge's vision and underlying philosophy. We set out the national-scale issues that drive the need for the Challenge, noting changes that have occurred since the beginning of phase one, including the growing recognition of the connections between anthropogenic climate change and water quality. (**Pages 6-10)**

We then summarise briefly results and outcomes of the Challenge to date**. (Page 11)**

The section entitled 'How we developed our strategy' outlines the collaborative approach we have taken to evaluating our strategy and adjusting it to changing needs and drivers. **(Pages 12-15)** This covers our scans of the Research, Strategic and International landscape, engagement processes and sources of advice and guidance.

The scope of our proposed research, its nine priority areas and the impacts we can expect are described on **pages 15-25**.

Processes and policies for ensuring excellent science, monitoring and prioritising our investment, managing risk and nurturing capability are set out on **pages 25-31**. These pages also set out the way our modus operandi will help us deliver impact, focusing on co-innovation, implementation initiatives, and our relationship with our stakeholders. While mātauranga Māori has a deliberate and strategic profile throughout the document, this section also summarises the role that Vision Mātauranga plays in our approach to meeting our objective.

Changes to governance and management, including resourcing, are described on **page 32**.

In the concluding section, 'New horizons,' we identify and describe potential opportunities for Challenge science, should funding over and above that currently signalled for the 2019-24 period become available. **(Pages 33-35)**

1 The ultimate challenge

The Our Land and Water National Science Challenge has a daunting task: to deliver solutions to the dilemma of preserving the most fundamental treasures of our country—its land, water and associated ecosystems—while producing economic value from those same treasures.

As a challenge, this is the ultimate. Every New Zealander, both alive today and yet to come, has a stake in the outcome. If we get it right, we can imagine a future like this:

> *Two farmers, Marama and Campbell, climb to a favourite lookout on their property. Mountains rise majestic on the horizon. A sparkling stream with healthy stocks of kōkopu and eel flows towards the sea. The surrounding rural landscape is enriched with resilient enterprises and ecosystems—an intertwined mosaic of the traditional and the new.*
>
> *'I'm proud to be a farmer in New Zealand,' says Marama. 'The taonga that Papatūānuku, our Earth Mother, shares with us are not being misused, they're being treasured.'*
>
> *'Āe,' nods Campbell. 'We look after the land and the land looks after us. We have prosperous communities and whānau.'*
>
> *They sit in silence, thankful for what New Zealanders have achieved together as kaitiaki for themselves and their descendants: wai ora, whenua ora, tangata ora—healthy water, healthy land, healthy people.*
>
> *- sourced from the Next Generation Influencers (see section 5.1.1)*

This narrative portrayal of the future captures what success will look like for the Challenge and this is expressed in the following commitment:

The Challenge will be innovative, think beyond boundaries, be clever in the way that we regenerate the land to maximise global value and ensure we are continuously testing and evolving our ecosystem health models for the benefit of Papatūānuku, our whānau and communities.

A central focus of Challenge research is to build clear pathways to ensure the concepts outlined in the above future statement are realised. Achieving our vision of revitalised ecosystems and a landscape of resilient enterprises requires major shifts in decision-making and behaviours, particularly in relation to land-use suitability. Our dictum—'the right enterprises in the right places for the right outcomes'—is an expression of our conviction that New Zealand's land-use ethos must shift from a narrow focus on productive capability to a comprehensive assessment of long-term suitability.

1.1 WORKING WITH MĀORI, OUR TREATY PARTNERS

At the heart of the Challenge is our partnership with Māori. It is focused on achieving outcomes for all. By working in a model of partnership, we will contribute collectively to the transformation of our national landscapes, people and products. This involves bringing deeper, more sophisticated ways of thinking about co-design of the future science we will undertake, and how we will do it. [1].

The Māori world view is an all-embracing, life-enhancing approach to thinking about people, the natural world and the spiritual world. It acknowledges the interrelationship of all living and non-

living things. It is a holistic approach that 'seeks to understand the total system, not just parts of it.' And at its heart is reciprocity: people receiving and benefiting from the land and giving back to it in a harmonious and sustainable balance.

New benchmarks for Challenge collaboration, co-innovation, and implementation will include mātauranga Māori as an integrating system for connecting, organising, understanding and storing knowledge. Mātauranga carries the mana, kōrero and, in some cases, tapu of generations of experiential research commonly referred to as validation. In cases where tapu is involved, mātauranga must be viewed as a taonga and treated accordingly.

The Challenge embraces these perspectives, taking heed of the words of former New Zealander of the Year Dame Anne Salmond: 'Scientists who dismiss the inquiries of thinkers from other cultural traditions (e.g., knowledge systems that do not split people from environment) and proclaim the superiority of natural science over the arts and humanities are unhelpful. Far from protecting the scientific project from bias they are trying to uphold a status quo at a time when new ways of thinking about socio-environmental challenges are urgently needed.' [2].

We believe that combining the two approaches—mātauranga Māori and Western science—will result in a new wave of applied science that is distinctly designed for Aotearoa.

1.2 NATIONAL-SCALE ISSUES THAT COMMAND OUR ATTENTION

New Zealanders have traditionally expected and enjoyed a high environmental quality of life. However, the country's economic growth model, based largely on exploiting natural resources, is starting to approach its environmental limits, especially with regard to water pollution and climate change. This reality provides context and impetus for OLW's future research strategy. Key issues we will address in our strategy are:

- building enduring partnerships with Māori
- maintaining and improving land and water quality
- achieving better environmental outcomes by increasing and sharing value
- identifying transition pathways to make change happen faster

1.2.1 Building enduring partnerships with Māori

The Challenge is committed to partnering with Māori and has a structured approach, co-designed with our Challenge Kāhui, to give effect to this commitment. The Challenge's vision of landscape health and community well-being aligns with a Māori world view of the interdependence of all things in the nurturing embrace of land and water. It therefore seems self-evident that Māori researchers as well as Māori research should be prominent in the Challenge.

Through the development of our Vision Mātauranga strategy, we seek to integrate Māori knowledge systems, practices and value propositions into Challenge science. This commitment extends not just to those already working in the mātauranga Māori space, but to future collaborators, including the funding of Māori secondary-school students on the cusp of science careers who are part of an innovative educational programme (Pūhoro STEM Academy) hosted by one of our partner universities.

Many Māori businesses are already using te ao Māori attributes of connectivity between land, water and people with a focus on short, high-reward value chains. Examples can be found in industries such as sheep and beef, honey, wine, dairy and seafood. The Māori agribusiness sector is exploring

innovative farm and catchment-scale options that are profitable, fit with intergenerational and collective-ownership models, meet environmental and cultural-use aspirations over intergenerational timeframes and align with Māori aspirations.

Providing options that meet the challenge of increasing the economic, environmental, social and cultural value derived from Māori land will provide a strongly sustainable model for land use across New Zealand.

1.2.2 Maintaining and improving New Zealand's land and water quality

Overseas media, markets and scientific reports are becoming increasingly sensitive to the degradation of our land and water quality. Headlines such as 'Polluted Paradise' (Al Jazeera) and '100 per cent pure or 60% polluted' (BBC) are becoming common[1]. Domestic media and scientific reports show similar concerns. While New Zealanders, on average, consider the state and management of our environment to be good or better than other countries [3], scientific reports show that some water and land quality indicators exhibit worsening trends [4, 5].

On the other hand, recent reports also highlight areas of improvement. For instance, from 1994-2013, 54% of monitoring sites in catchments dominated by intensively grazed pasture exhibited median phosphorus concentrations that were not changing or increasing, but closer examination of data between 2004 and 2013 showed an improvement at 57% of sites [4]. This has been attributed to a range of factors from better awareness of issues to having and implementing more options to mitigate losses.

A recent analysis of freshwater policy noted that to achieve small improvements in swimmability would cost the regions $217 million p.a., and in many cases the result would still not meet community expectations [6]. The cost of not doing anything puts at risk revenue from tourists ($12B in 2016), 91% of whom come to New Zealand for its environment [7], and from enterprises who have failed to change and adapt in the face of policy to correct poor water quality. However, **Challenge science indicates that not only can we improve the cost effectiveness of mitigations on existing enterprises by 6-7 times** [8]**, we can do much more by targeting the right land use to the right area, so that losses are minimised and environmental and economic outcomes maximised** [9].

While voluntary efforts may have helped to stem a decline or improve water quality in some areas, the National Policy Statement for Freshwater Management now requires that action be taken to achieve the water quality communities desire [10, 11]. Groups organised by farmers, industry, regional governments and NGOs have sprung up nationwide to respond. **The OLW Challenge is in a prime space to supply the right level of science and detail across multiple sectors to provide direction and catalyse change.**

On the issue of climate change, former OECD Environment Director Simon Upton, presenting the OECD Environmental Performance Report 2017 in Wellington, identified agriculture as one of the two key sectors in which New Zealand needed to develop effective national climate policies. The government's climate-change targets for reducing emissions (2020-2050[2]) present a major challenge for the pastoral sector. Moreover, the connections between water quality and climate-change

[1] https://www.aljazeera.com/programmes/peopleandpower/2017/08/polluted-paradise-170831042123144.html; https://www.radionz.co.nz/news/on-the-inside/312339/100-percent-pure-or-60-percent-polluted

[2] https://www.mfe.govt.nz/climate-change/reducing-greenhouse-gas-emissions/new-zealands-greenhouse-gas-emissions-reduction

adaptation are likely to be significant, but have not been well examined. For instance, efforts to offset greenhouse gas emissions, including the planting of a billion trees, will likely alter water flows and quality just as much as efforts to meet our freshwater policy. **The Challenge therefore needs to address both climate change and land and water quality. Otherwise there is a risk that one could be traded off against the other**.

Land-Use Suitability

Land-use suitability marks the sweet spot where the four sustainabilities meet: economic, environmental, social and cultural. The Challenge's contention is that a suitability metric enhances, rather than detracts from, economic growth. Its superiority over the current approach lies in the fact that it brings all relevant values to the conversation—**a conversation that is increasingly a whole-of-society discussion, and not one that involves only the rural sector.**

In thinking about land-use suitability, we build of work done over the last 50 years on land-use capability to describe the various attributes of land, and augment it with its capacity to attenuate contaminants and the effects of these contaminants in waterbodies. We seek to fit the productive activity to the land rather than manipulating land practices to fit a predetermined use. **The goal is to adapt the use to the land, not the land to the use.**

1.2.3 Achieving better environmental outcomes by increasing and sharing value

Although policy can be effective, incentives to change are arguably more so. A large share (>90% in most sectors) of New Zealand's agrifood production is exported, from which we earn approximately $37 billion. But these same products are sold in international markets for an estimated $250 billion [12]. As a country, we are only capturing about a seventh of the value of some of our nation's best produce. In addition, MBIE has declared a target of 'increasing value of exports to 40% of gross domestic product (GDP) by 2025.' **The Challenge's aspiration for the country's future is that no product will leave these shores for a meagre commodity price.**

However, value is more than economic returns, and if we focus only on the bottom line we will continue to internalise the cost of the degradation of environmental, cultural and social metrics. Mike Barton, Taupo Beef, puts the issue succinctly: 'The problem is that we've sold food for the last couple of hundred years without ever accounting for the environmental costs of producing it, so we've convinced consumers that food is really cheap. Now, suddenly, we're turning around and saying that those costs must be paid.'

One of the keys to achieving greater returns for primary producers is understanding global value chains. It is our conviction that when a common vision is held across the value chain, from producer to consumer, everyone benefits.

A value chain starts with the customer who is the final arbiter of value. Customers in high-value markets now expect and demand that the products they are buying are produced to the highest of environmental, cultural and social standards [13]. For instance, markets in Europe will soon require environmental-footprint data as it relates to eutrophication and other water-quality impacts. **Rather than seeing such developments as a constraint on producers and a potential barrier to market access, the Challenge argues that they should be seen as a door-opener to new markets and that the increased value captured from those products be used to reward sustainable land-use practices.**

Producers who collaborate in value chains also need to be assured that their enterprise and the chain itself is recognising and adapting to drivers such as climate change or the trend towards artificially grown meats or plant-based proteins [14]. **The Challenge will assess the magnitude of**

these drivers across sectors so that primary producers avoid lurching from one consumer trend to the next.

Should a driver be significant, flexibility is required to meet market demands or seek out new high-value, low-environmental-footprint opportunities, so that producers are not locked in to a single land use out of fear of losing capital investments. Note, for example, that the conversion of intensive dairy farms to lower nitrogen leaching avocado orchards in the upper North Island has been possible only because of the higher returns of the gourmet fruit [15].

Farming for value and not capital gain is part of the answer, and one that many Māori recognise. Māori-owned land typically has restrictions on its sale, and more land is being returned to iwi through Treaty settlements. In order to truly provide for their shareholders while upholding principles such as kaitiakitanga, Māori land entities are exploring their options. Many are recognised innovators in the agribusiness sector, and partnering with these entities provides the Challenge with exciting opportunities. **With a willingness to take action and at scale, Māori agribusiness and entities are a natural partner for the Challenge that will help us quickly implement Challenge science and transfer the learnings elsewhere.**

1.2.4 Identifying transition pathways to make change happen faster

If New Zealand is to achieve better outcomes for a sustainable future, technology and incentives must be implemented without delay. However, the time taken to reach peak adoption of a new technology in Australasia typically varies from 5-28 years (16 years on average) [16, 17]. Intergenerational change is too slow. We need intragenerational action. Part of the current lag is due to transition pathways being unclear or not compelling enough. In addition, the famed Kiwi individualism means co-operation can be hard to achieve in catchments when collective action is needed.

If we don't have the processes in place and a clear pathway to economic, environmental, social and cultural value, we will miss the opportunities a fast-changing world puts before us. History has shown that our inability to change means that we become uncompetitive and susceptible to shocks, whether political, market-driven or environmental. **One of the Challenge's initiatives is to show how to halve the time to adoption so that transition pathways are incentivised, rather than leaving producers with painful forced change at a later date.**

The change imperative

In all facets of the Challenge's work, we are acutely aware that change is coming, and coming fast. Accelerating rates of climate change are driving a fundamental rethink of global foodways, including the rapid rise of animal-free proteins. Moves toward a global bioeconomy are gaining pace. It is a law of both ecology and economy that change must be met by change, and the risk for New Zealand is that we may mistake our geographical isolation for insulation from global threats, and therefore a feeling that we can 'buy time.' Such thinking would be a mistake.

The message is that the physical and biological environment will no longer be picking up the tab for unsustainable farming practices.

This is the economic and political context in which the Challenge exists. Our vision is large, our motivation is strong, and our strategy is tested. We are ready to take it to the next level of effectiveness, excellence and impact.

2 The story so far…

The Our Land and Water Challenge was launched in January 2016 with four broad purposes: achieving greater value from global markets, fostering innovative and resilient land and water use, building collaborative capacity and integrating the processes of strategy, monitoring and evaluation. The original strategy can be found at: http://www.ourlandandwater.nz/resources-and-information/future-strategy-documents-2.

Results and outcomes of the Challenge to date demonstrate the impact that can be achieved by focusing on science quality and stakeholder needs. Among these outcomes are the following:

- Working with iwi and hapū in Te Tai Tokerau (Northland), we have generated information to underpin a sociocultural indigenous micro-economy model and a multi-iwi land-use change model now being used to inform land-use decisions such as new forest plantings of, including indigenous forest.
- Challenge research informing water resource management policy and guidance in areas such as stock exclusion from waterways and critical source area management.
- Defining the key environmental qualities of New Zealand products has clarified what sustainable production means to our markets and helped refine the Red Meat Story of Beef and Lamb NZ.
- Working with stakeholders, industry bodies, and central and local government, the Challenge developed a land-use suitability classification. The classification categorises land according to its potential for production and profitability, generation of contaminants and the environmental impact of these contaminants.
- Using a collaborative think-piece process Challenge genomics research has illustrated the potential for manipulation of soil-plant-animal microbiome interactions to improve pasture and animal productivity, as well as water quality.
- Challenge research has shown how temperature and nitrogen affect the uptake of phosphorus into stream-bed sediments. Results suggest that as temperatures increase with climate change, limiting movement of phosphorus from land to water would help improve water quality.

Over the life of the Challenge, new drivers and pressures have arisen. Our two-yearly Research Landscape Map that informs us what research is being done and a Strategy Landscape Map that tells us who is identifying and implementing actions that are helping achieve our objective have helped us to focus our research.

We have fostered a way of working that emphasises co-innovation across all programmes, and expect to see a return that results in science that is more robust, trusted, readily adopted and shared. A realisation that the concept of 'best teams' extends beyond science to Māori and industry partners is now evident across the Challenge. For instance, half of the journal publications now published or submitted have stakeholders as co-authors.

A fundamental driver in the Challenge is the importance of Māori playing a more active role in the sustainable management and economic development of land and water. This takes shape in a Vision Mātauranga strategy that is woven into our research programmes.

Across the wider research landscape we have seen the benefits of increased collaboration, and within the Challenge there has been a substantial growth in the number of collaborating partners per research programme.

3 How we developed our strategy

This section outlines the collaborative approach we have taken to evaluating and refocusing our strategy. This process involved:

- re-examining and defining national-scale issues to ensure maximum relevance (section 1)
- comprehensive analysis of the research being done by industry, government, NGOs etc
- advice from experts on maintaining excellence, relevance and a focus on impact
- broad engagement to collaboratively obtain and test our ideas and approaches, summarised in Figure 1.

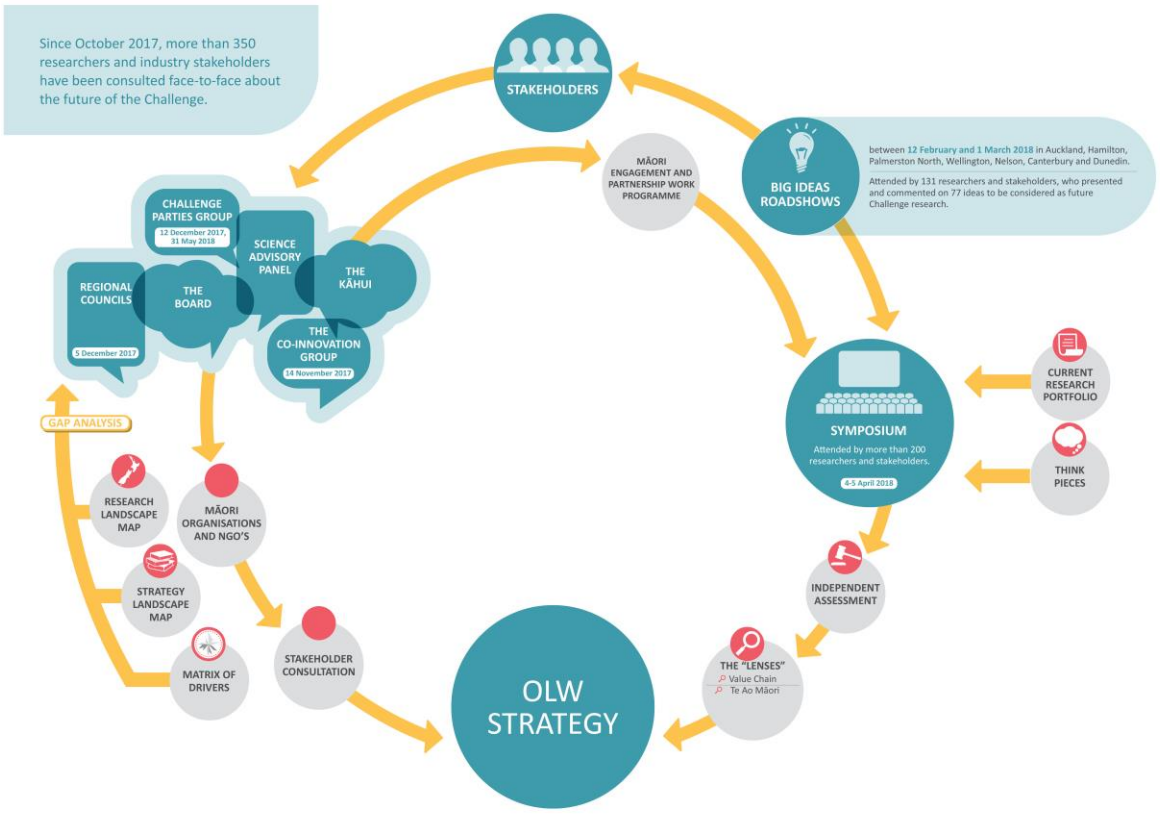


Figure 1. Engagement and consultation approach for the strategy

3.1 MAPPING AND ANALYSIS OF THE RESEARCH AND STRATEGY LANDSCAPES

The **Research Landscape Map** (RLM) identified research and international collaborations being undertaken by scientific partners that is of relevance to the Challenge's mission and could be integrated into our portfolio of activities. The **Strategy Landscape Map** (SLM) identified industry, government, NGO etc. strategies that, if implemented, would help us to achieve the Challenge objective.

The RLM had three aims: to assess alignment and relevance to the Challenge mission, to indicate research gaps and to provide metrics on co-innovation.

A formal survey identified 226 programmes ($97M pa) that were contributing to the Challenge objective. Ninety-five programmes were assessed as having 'moderate' to 'very high likely' relevance to the Challenge mission. We chose to formally align 39 of those in 2017, chosen on their likelihood

of helping us deliver impact. Formal alignment allows us to select the most relevant and best programmes from Challenge parties to fill gaps in the portfolio of Challenge research activities. We have conducted two RLMs. Compared to the first RLM, the number of 'high likely' or better investments was boosted by an increase in moderate- to high-impact Strategic Science Investment Fund (SSIF) programmes under the control of CRIs, but balanced by an increase in low- to very low-impact programmes funded by MBIE (Figure 2). Overall, government funding contributing to the Challenge objective has decreased, but industry is funding more research, especially in precision agriculture and meeting water-quality limits.

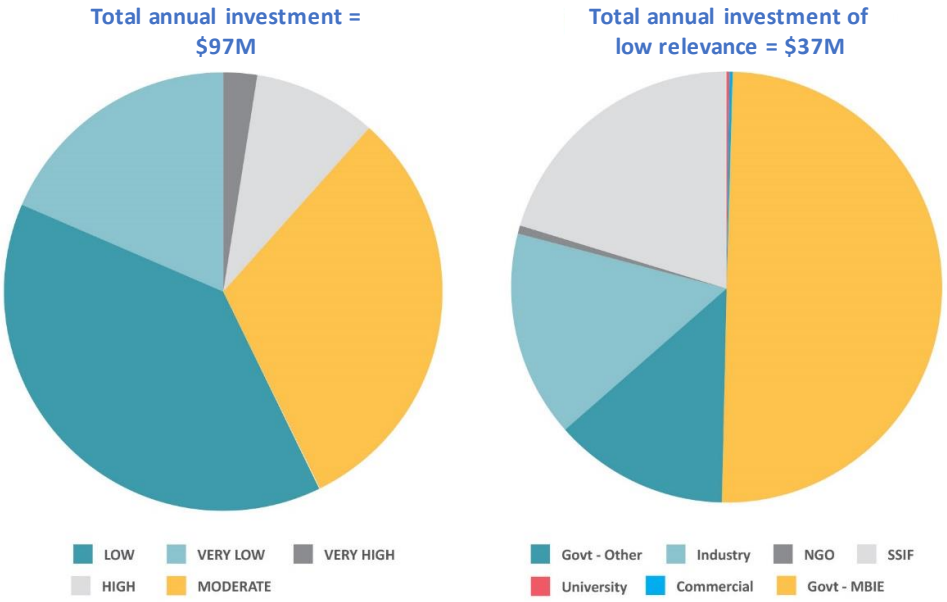


Figure 2. The **magnitude** and **proportion** of investment assessed as very low to very high relevance to the Challenge objective (left) and the **source** of funding for investments with low or very low relevance to the Challenge objective (right).

We used the RLM to assess shifts in the research landscape and gaps against the 2017 strategy. Following the revision of the strategy to contain nine strategic areas, some gaps remained. These have informed priority research areas to be investigated via a think-piece process post-June 2019 before being considered further.

The RLM also gave us metrics on **co-innovation**, a new way of doing science that the Challenge is using to increase impact. ***Co-innovation involves embedding stakeholders in the co-design of science questions, the co-development of research (e.g. working in the same location) and the co-production of outputs.*** The shared results of this process lead to co-innovation. Compared to the first edition of the RLM, there was a significant improvement in co-innovation metrics and a significant increase in the recognition of the importance of collaboration, building capacity and putting knowledge into action.

We also used the RLM to show where **international linkages** were being used. However, building off work conducted in the first tranche of funding we have targeted international collaboration where greater expertise exists overseas, where the interests of New Zealand are best served by partnering with international organisations, and where New Zealand scientists have the best capability to lead an area. Targeted examples of existing collaboration include with:

- Deltares (The Netherlands 0.25 FTE co-funding) on the ability of models to talk to one another (i.e. interoperability)

- an EU-funded programme ($1M EUR co-funding) on the implications of the EU meeting the UN Sustainable Development Goals for New Zealand trade and market access
- our leadership of the UN Environment Programme's Acidification and Eutrophication Task Force responsible for developing global guidance and consensus on indicators for eutrophication

We will continue to maintain a strategic approach to international collaborations. For example, we are cultivating three additional co-funded collaborations with the EU due to their strength in precision agriculture and value chains, microbiomes and low-carbon bioeconomies.

The **Strategy Landscape Map** used published data and selected interviews from 53 stakeholder organisations to indicate the alignment of stakeholder strategies to the Challenge strategy and gauge the likelihood of those organisations to be active in ways that might benefit the Challenge mission.

The greatest level of alignment was apparent in central government, CRIs and regional councils, but with subtle differences. For example, CRIs, primary producers and processing industries had a strong emphasis on adding value to their sector(s) that recognised the need to sustainably manage land and water, while regional councils focused on engaging with the public more broadly. Māori development organisations and not-for-profits considered themselves to be only loosely aligned to our 2016 strategy, instead emphasising the interdependence of people and land and an intergenerational approach, and community engagement, respectively. ***This finding reinforces a need to place greater emphasis on te ao Māori and community engagement in the implementation of Challenge science.***

A subset of the 53 organisations were interviewed to determine their likely future activities in strategic Challenge research areas. Areas most likely to receive stakeholder attention were creating value from the New Zealand brand, the development and application of land-use tools to create social capital, and community awareness and participation.

3.2 ADVICE—HOW AND WHERE WE SEEK IT

We use the **Co-Innovation Group (CIG)** and **Science Advisory Panel (SAP)**, to provide advice on the relevance of Challenge research (CIG), science excellence (SAP), and national- (and international-) scale issues (including the Environment and Conservation and Primary Sector Roadmaps) that may affect the likely impact of the research (CIG and SAP). We also rely on our Kāhui for strategic advice and direction on engaging with Māori partners and the Māori science and thought-leadership communities.

Reports from both groups have emphasised the need to implement Challenge science at a much faster rate, albeit with different levels of risk. For example, the CIG called for a greater implementation of near-to-market science, while the SAP asked for a balance of near-to-market and blue-skies science that remained agile in order to manage national and international drivers and threats.

Both groups recognised the role of co-innovation in accelerating implementation and impact; however, the SAP also highlighted the need for the Challenge to monitor the progress of co-innovation as a testable hypothesis. The advice of the SAP for the Challenge to play a leadership or primary supporting role in exploring the roadmaps is summarised in Table 1.

Table 1. Role of the Challenge in delivering to the Environment and Conservation and Primary Sector Science Roadmaps

LEADERSHIP ROLE	PRIMARY SUPPORT ROLE
ENVIRONMENT AND CONSERVATION	
Understanding links between land and freshwater to improve decision-making	Climate-change adaptation in land sector
Understanding how contaminants affect ecosystems and human health	Interactions between GHG emission mitigation and water quality
How to build social and cultural capital to manage the environment more effectively	
PRIMARY SECTOR	
Adding value e.g. traceability and provenance, desired values and attributes, culturally distinct products, co-creation etc.	Kaupapa Māori approaches to climate change and co-development of innovative solutions, integrating Māori values, products and systems in value chains
Integrating people and values by undertaking socially integrated science with the community using collaborative processes	Protecting and sustaining natural resources, defining limits for sustainability and enhancement of land and water resources

Our scanning of the research and strategy landscapes and advice received from the CIG and SAP suggest a need to adjust our 2016 research themes to provide a greater focus on government policy (e.g. freshwater management and climate change), implementation and outcomes. This conclusion was affirmed by the **2018 symposium**, where participants called for a greater focus on imagining the future (better planning), understanding risk (evidence and confidence to act), agility to innovate (strategy and monitoring that foster thinking without undue pressure) and implementation (partnerships with Māori and non-Māori for impact).

Modification of the thematic structure will also improve integration and increase the base of research disciplines and other knowledge sources (including economics, biophysical sciences, social sciences and the reservoirs of knowledge that sit with communities and stakeholders).

4 What we are going to do

4.1 RIGHT ENTERPRISE, RIGHT PLACE, RIGHT OUTCOME

We envisage a future in which catchments contain mosaics of land uses that are more resilient, healthy and prosperous than they are today; a future where all New Zealanders can be proud of the state of our land and water and share economic, environmental, social and cultural value from them.

This future cannot be quantified by one metric alone, such as economic or environmental. Multiple viewpoints are inevitable, and there will be multiple pathways to transition to the future from the current state. To keep pace with a rapidly changing world, these transitions must occur at a rate much faster than at present but with as little societal pain as possible.

Therefore, our hypothesis is this:

When the incentives and pathways are compelling, the future contains the right enterprises, in the right place to deliver the right outcomes.

The null hypothesis is that the economic, environmental, social and cultural cost of the current conditions outweighs the benefits.

Consider the picture below (**Figure 3**) and imagine a catchment.

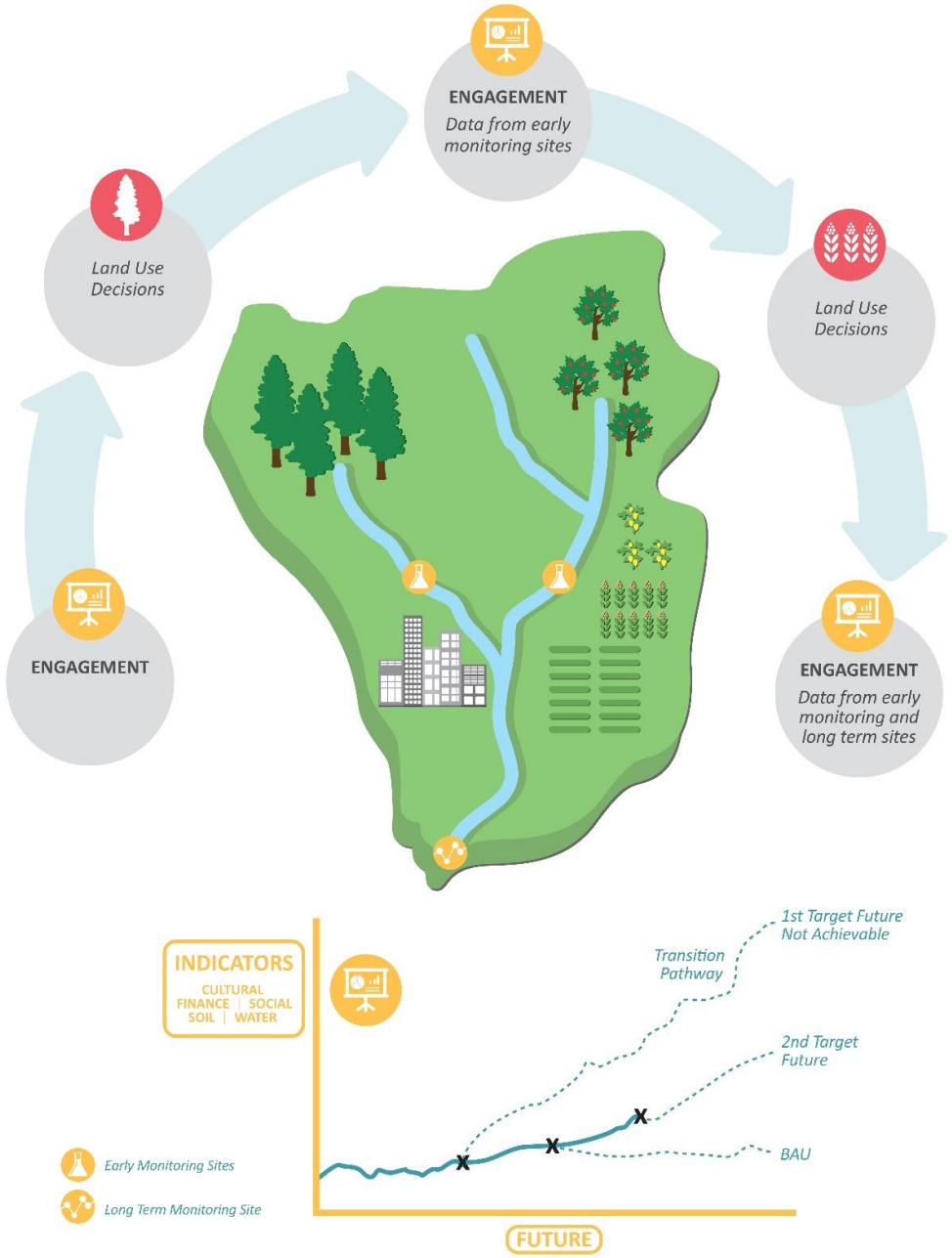


Figure 3. The link between futures and transition pathways.

Its status is measured by a variety of indicators. Individuals and the community set themselves objectives as to what their properties and catchment would look like in the future; that too is measured. Future land use and land-use practices may look completely different from what they are

now. However, the selected future or futures have a transition pathway that is better than the current trajectory under business as usual (BAU). At a point along the first transition pathway, progress reporting from early warning sites close to changes in land use or practices suggest that long-term changes may not occur, or that the result for the individual is unsustainable. A new land use or land-use practice and transition pathway are chosen and compensated for by the catchment collective. Elements of this process are happening around New Zealand now, but individuals lack both the tools to see what is possible in the future and how to transition there equitably, leading to poor decisions and poor outcomes for individuals, catchments and NZ.

4.1.1 Seeing outcomes, making impacts

We will know we have realised this vision of the future when the following outcomes (in standard type) and impacts (***in bold italics***) have been achieved:

Outcome: The land and water in our productive environment is in a state that realises our values as New Zealanders and meets the expectations of those abroad. ***Decisions on individual land-use change and management practices are able to be made with confidence, leading to measurable and substantial improvements in catchment land and water quality.***

Outcome: We use our land and water to produce products with high value to consumers that we capture and share with producers. ***Compared to now, at least 20% more economic value is shared with producers who manage their land in a way that ranks highly (top 20%) when assessed against environmental, social and cultural indicators.***

Outcome: We all see ourselves as having a guardianship role, proud of the way we have achieved the land and water outcomes we desired. ***We are using intergenerational business and land-use models that are underpinned by principles of kaitiakitanga.***

We measure our progress towards these outcomes with a clear plan to extend the legacy of Challenge research and impact beyond its scheduled end in 2024.

4.2 RESEARCH PRIORITIES FOR THE NEXT FIVE YEARS

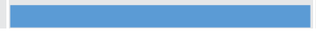
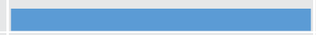
The following section describes the priority research we will conduct in nine strategic areas (Table 2) of the Challenge. These research and strategic areas align with our vision that the future contains mosaics of land uses with the right enterprise in the right place for the right outcomes when the incentives and the transition pathways are clear. Processes to prioritise research are outlined in section 5 'How the Challenge will deliver research outcomes'. Note also that programmes funded during tranche 1 will be reviewed before being considered for further investment. Their existing objectives and impact have been considered during the prioritisation process for tranche 2. Some have already been listed amongst programmes for tranche 2, but this should not be seen as a signal that they will continue their existing form.

Thematic areas are deliberately designed to contain a mixture of disciplines to deliver outcomes and impacts, but can only be achieved through the integration across themes. Many of the proposed activities, although assigned to a particular strategic area, are relevant to a number of areas and themes. For example, understanding the barriers and advantages to achieving a lower carbon economy applies across strategic areas 1, 2 and 3. Mechanisms to support integration are found in the section focusing on outcomes.

4.3 SCOPE OF OUR RESEARCH IN A NUTSHELL

Table 2. Alignment of current and new research activities (either developed or still under development) aligned to strategic and thematic areas. The blue and orange bars represent indicative percentage investment (0-100% scale) in each strategic area by the Challenge and currently aligned research programmes, respectively. Although in some areas the proportion of Challenge investment is relatively small, it represents a targeted approach in key research gaps.

1. Theme	2. Strategic area (indicative % investment of tranche 2 research funds)	3. tranche 1 investment in strategic areas ($M invested)[1]	4. Activities signalled by the board to be initiated in the second half of 2019 (by strategic area)	5. Activities prioritised for further development after July 2019 by think-piece or other investment process[2]	6. Aligned research activities from the 2017 Research Landscape Map ($M pa invested)[3]	7. Priority stakeholders[4]
FUTURE LANDSCAPES **Aim: In the future landscapes contain mosaics of land use that are more resilient healthy and prosperous than today. To realise this we need to work in strategic areas 1-3**	**1.** Be able to see what diversity is possible and match land use to what it is suitable for (22%). *Outcome: We will have determined if a diverse mosaic of land uses can deliver better economic, environmental, social and cultural results than the current mix of land uses.*	- Land-Use Suitability (2.75) - Physiographic Environments of New Zealand (0.1) - Benign Denitrification and Measuring Denitrification (0.4)	- Creating resilient, diversified landscapes - Assessing the utility and value of land-use suitability, nationally - Visualising landscapes through augmented and virtual reality - The diversification of land use that meets social and cultural expectations	- Creating a biosphere data commons for NZ where data are held across multiple institutions with common objectives and interests (with New Zealand's Biological Heritage)	Understanding catchment systems and attenuation (10)	BL, DoC, DairyNZ, FAR, FOA, FOMA, Fonterra, LINZ, MfE, MPI, RCs, Rural Banks, TTP, TALT, Valuers
	2. Understand and model the management of land and water quality (17%). *Outcome: Individuals and communities have the understanding and tools they need to achieve good land and water quality.*	- Interoperable models (0.9) - Sources and Flows (3.15) - Faecal Source Tracking (0.25) - Cascade of Soil Erosion (0.4)	- Leveraging open, low-cost, cloud-based, accessible and high-quality data, at farm to national-scale - National scale interoperable modelling linked to meaningful indicators	- The implications of climate change for water quality contaminant delivery (with Deep South) - Valuing land and freshwater biological heritage in diversified landscapes (with New Zealand's Biological Heritage) - Protecting and enhancing the estuarine environment in sustainable land-use futures (with Sustainable Seas) - Tracking the source and timing of water- and soil-quality impacts in productive landscapes	Methods to set water quality limits and strategies to mitigate contaminant discharge (17) Measuring and predicting soil erosion (7) Maintain and improve aquatic biodiversity (4)	DoC, DairyNZ, IRANZ, MfE, NGOs, RCs, StatsNZ
	3. Provide the novel production systems that use healthy land and water to generate high-value products (20%). *Outcome: New Zealand farmers produce a diversity of food and non-food products that they, their community and consumers value.*	- Next Generation Systems (2) - Soil-Plant-Animal Microbiomes (1.8)	- Novel and niche production systems - The critical traits of successful production systems - The role of soil-plant-animal microbiomes in developing functional foods (with High Value Nutrition) - Quantifying and scaling up biological processes - High-value, low-impact options for steep, especially Māori-owned, drystock country	- New production systems utilising new molecular technologies - New productive systems and technology (including precision technologies and autonomous primary enterprises—with Science for Technological Innovation and MPI)	Plant—animal production systems (10) Farm systems (6) Precision agriculture (15) Water allocation and irrigation efficiency (7)	BL, DairyNZ, FAR, FOA, Fonterra, MPI, Ngai Tahu, Nuffield & Kellogg Leaders, TTP
INCENTIVES FOR CHANGE **Aim: New Zealand's primary producers are well-rewarded for producing high-value products in sustainable ways. To realise this we need to work in strategic areas 4-6**	**4.** Capture and share with the producers more of the value consumers associate with our products (8%). *Outcome: New Zealand is producing high-value products across all sectors that capture and share more value from consumers to producers.*	- Integrated value chains (1.7)	- Tracking credible and integrated transition pathways (e.g. how individuals can contribute to achieving the UN Sustainable Development Goals) - The use of ngā āhuatanga Māori into brands that reflect Māori values and tikanga	- Transitioning to an optimal value chain by changing culture and business models - Using ecosystem services to clarify the environmental, social, cultural cost and benefits of primary production	Increase the value of the NZ brand (6) Equitably distribute value from consumer to producer (3)	ANZCO, DairyNZ, FOA, FOMA, Fonterra, MIA, MPI, NZMerino, NZWine, Taupor Beef, Treasury, Wakatu, Zespri
	5. Increase and share value based on mechanisms that reward sustainable land use and high-value products (11%). *Outcome: Agribusiness plays a key role in improving New Zealand's social, cultural and environmental footprint.*	- Credence attributes (0.35) - Eutrophication product footprinting (0.22) - Indicators working group (0.2)	- Mechanisms to generate cash flow from non-monetary values. - Alternative investment models to increase the participation of Māori communities in high-value market chains	- Quantifying the environmental, economic, social and cultural benefits of regenerative agriculture - Ensuring that the environmental attributes of production systems are flexible and translatable enough to maintain market access	Incentivise and reward sustainable land-use practices (1)	BL, DairyNZ, Fonterra, FOA, HortNZ, MPI, Synlait, Zespri
	6. Enable communities to identify and adopt sustainable land use practices (3%).	- National register of actions to remediate poor water quality (0.2)	- Pan-sector farmer, industry and government networks and citizen science to catalyse change	- Identifying the level of social and economic investment required to make transformational change	Sector-specific services offered by levy bodies (unquantified)	BL, Fonterra, NZ Landcare Trust, MfE, MPI, RCs

1. Theme	2. Strategic area (indicative % investment of tranche 2 research funds)	3. tranche 1 investment in strategic areas ($M invested)[1]	4. Activities signalled by the board to be initiated in the second half of 2019 (by strategic area)	5. Activities prioritised for further development after July 2019 by think-piece or other investment process[2]	6. Aligned research activities from the 2017 Research Landscape Map ($M pa invested)[3]	7. Priority stakeholders[4]
	Outcome: Sustainable practices are the norm in primary production			- Identifying the characteristics of and practices that good scientists and leading rural entrepreneurs need, and use, to catalyse sustainable land-use practices and change land use - The relative effectiveness of positive incentives and regulation in driving behaviour change		
CAPACITY FOR TRANSITION **Aim**: **We understand what it will take, and have the tools to help us, transition to resilient healthy and prosperous futures. To realise this we need to work in strategic areas 7-9**	**7.** Increase our social capital so that we can have well informed debate about alternative futures (5%). *Outcome: An increased number of urban and rural people understand how land and water issues can be addressed.*	- The Collaboration Lab (1.5)	- Investigate the characteristics of a social licence to operate amongst different rural and urban groups, including appropriate ways to generate and share information	- Measuring the differences between collaborative and adversarial processes, in terms of enduring, trusted and robust outcomes	Create social capital to understand and address land and water issues (1) Develop tools to make better, faster and more enduring community decisions (6) 	FF, FOMA, MfE, MPI, NGOs, RCs, Science Media Centre
	8. Act as kaitiaki, being responsible for our actions within enterprises, in a catchment and beyond (6%). *Outcome: There is more evidence of kaitiakitanga leading to improved outcomes.*	- Mauri whenua ora (2) - Communicating kaitiakitanga (0.25) - Whenua, life, values (0.25)	- Understanding, designing or refining the processes catchments will use to incentivise change and accountability at the enterprise and catchment level (e.g. to meet discharge limits)	- Understanding the strengths and benefits that arise when people are better connected to land, water and their primary products		FF, FOMA, Ngati Rangi, NGOs, RCs, TAWI
	9. Manage pressures and remove the barriers to a transition (8%). *Outcome: New Zealand primary enterprises are able to manage pressures collectively and better than their international competitors.*	- Biennial scan of national and international drivers for change (0.2)	- Understanding the barriers to, and advantages of achieving a lower-carbon bioeconomy than our international competitors	- System effects on primary production with agriculture joining the emission trading scheme - The risk of ignoring international drivers for the competitiveness of New Zealand primary producers - Paradigm shifts in food and fibre preferences and their implications for land use (e.g. what is the future of pasture-based farming in NZ in the face of plant-based proteins and alternative foods?)	Climate and climate change effects (4) 	BL, Fonterra, HortNZ; MfE, MIA, MPI, RCs

[1] All current programmes will be reviewed before being considered for further investment to bolster planned activities in tranche 2. Their presence in the next column does not signal a continuation of the programme in its existing form.

[2] Processes to prioritise research are outlined in the section 'How the Challenge will deliver research outcomes.'

[3] Comes from a mix of funding sources (MBIE, Other government sources, CRI - Strategic Science Investment Funds and Industry), but exclusive of Challenge investment. Note that additional alignment will occur during negotiation, prior to July 2019.

[4] Processes to prioritise stakeholder contributions are outlined in the section 'How we will deliver Impact.' Abbreviations refer to the primary stakeholders in each strategic area. Abbreviations: BL = Beef and Lamb; DoC = Department of Conservation; FAR = Foundation for Arable Research; FF = Federated farmers; FOMA = Federation of Māori Authorities; FOA = Forest owners association; HOrtNZ = Horticulture NZ; IRANZ = Independent research association of New Zealand; LINZ = Land Information NZ; MfE = Ministry for the Environment; MIA = Meat Industry Assocaition; MPI = Ministry for Primary Industries; NGOs = Non-governmental organisations including Fish and Game, Forest and Bird, Greenpeace, etc.; RCs = Regional Councils; StatsNZ = Statistics New Zealand; TALT = Te Arawa Lakes Trust; TAWI = Te Atihaunui Whanganui Incorporation; TTP = Te Tumu Paeroa.

4.3.1 Māori-led research

Our Kāhui has facilitated a plan to ensure the next phase of the Challenge continuously improves and implements best practices and processes with our Māori partnerships across its programmes and projects. The plan will change the way Vision Mātauranga is given effect across the Challenge to support Māori innovation, entrepreneurship, and leadership.

In the next phase we will take a Challenge-wide co-design approach to address critical research engagement, methodological, capacity and implementation issues as identified by 12 Māori organisations and other Māori entities throughout New Zealand. These partners have signalled their intent to collaborate and implement Challenge science and were chosen for their geographic spread, strong hapū/whānau identity at a national level and their influence and ability to make change happen in a culturally nuanced way.

The issues identified through the engagement process lend themselves to research topics that align to the Challenges nine strategic areas. The topics include but are not limited to: the diversification of land use that meets social and cultural expectations **(strategic area 1)**; high-value, low-impact options for steep drystock and forestry country **(strategic area 3)**; and the development of branding that reflects Māori values and tikanga **(strategic area 4)**; alternative investment models to increase the participation of Māori communities in high-value markets and chains **(strategic area 5)**.

Outcome: Māori-centred research leads the way in understanding how we can best share and improve land and water.

4.3.2 Future landscapes

Strategic area 1. Match land use to land suitability and demonstrate the benefits

Problem: Large parts of New Zealand are dominated by single land uses that have resulted in sub-optimal environmental outcomes. Diverse landscapes and catchments are more resilient than those dominated by a single land use. When land uses are matched to land suitability, outcomes are better. However, primary producers have difficulty envisaging rural land and water futures within a Land-Use Suitability framework. They need to have confidence that positive results for the environment are due to their actions and not some other factor.

Proposed research: The Land-Use Suitability framework currently provides metrics and tools to describe and assess what a land parcel can economically produce, what the loss of contaminants will be, and what effect those contaminants will have in receiving water bodies. The framework will be expanded to include other effects of land use (e.g. habitat modification) and social and cultural metrics. Once all these effects and metrics are in place, co-innovation with stakeholders (see strategic areas 5 and 6) will show the value proposition for mosaics of land uses within a catchment. The Challenge will produce new and updated tools to help individuals and communities envisage future patterns of land-use and work with interested groups to explore and understand the benefits of a diversified landscape. The Challenge cannot generate the required information alone which is why the Challenge has put in place agreements to obtain this information through alignment and partnering with the right organisations.

Outcome: We will have determined if a diverse mosaic of land uses can deliver better economic, environmental, social and cultural results than the current mix of land uses.

Strategic area 2. Understand and model the management of land and water quality

Problem: Achieving a functioning mosaic requires understanding of how management and land and water quality interact and how targeted management can achieve our shared values. This requires a

deeper understanding than we currently have of the sources and flows of contaminants from mountains to sea, the effect of perturbations like climate change on contaminant processing, and our ability to model these interactions using open-source interoperable models feeding off low- (or no-) cost, readily available and high-quality data.

Proposed research: Our existing interoperable modelling programme is co-funded by stakeholders to provide a platform where the best models can 'talk' to each another for a range of purposes, at different scales. This programme will use the best available data and be augmented by open, cloud-based data systems that can provide much faster, cheaper analyses and visualisation experiences, and outputs that are meaningful for the measurement of national scale change (e.g. land use) or regulatory limits. We will work with regional and central government (and via our alignment exercise) to fill data gaps and facilitate the stewardship of these models.

We will deliver additional impact by interfacing with other science challenges such as Deep South, over the impact of climate change on contaminant delivery (see also the 'Scenario Planning' section, page 30), Sustainable Seas over the delivery and mitigation of contaminants to estuaries, and the co-benefits for biodiversity in landscapes managed for improved water quality (a cross-cutting topic with the NZ Biological Heritage).

Outcome: Individuals and communities have the understanding and tools they need to achieve agreed land and water quality outcomes.

Strategic area 3. Provide novel production systems that use healthy land and water to generate high-value products

Problem: Future landscapes will involve new land uses or practices, some of which don't yet exist. Their emergence and uptake relies on a combination of science that demonstrates the (economic, environmental, social and cultural) viability of novel systems and rural entrepreneurs willing to take a chance on them. Without both elements working in tandem, nothing will change.

Proposed research: By analysing what is now considered 'alternative,' but also called 'novel,' 'niche' or 'biological' by others, we will derive the critical traits that constitute desirable on-farm attributes. We will work with leading rural entrepreneurs to identify and implement these across the landscape according to land-use suitability. This will result in a diversity of food and non-food production options that may span many domains. Research into soil-plant-animal-human microbiomes is an example. Research into microbiomes aims to identify, capture or manipulate processes in the soil to minimise the leaching of nutrients while providing nutrients to nutrient-efficient plants, which in turn provide the micronutrients and energy that animals can metabolise into foods that are nutritious and promote a healthy human gut. We will also explore the efficiency in resource use and production possible by the precision management of landscapes via the application of a wide diversity of technologies (e.g. artificial intelligence, sensing systems).

Outcome: New Zealand farmers produce a diversity of food and non-food products that they, their community and consumers value.

What will change?

By world standards, the state of our land and water is good in many areas but poor in some. Deterioration is reflected in surveys of public perceptions [3] where water is seen as the most important environmental issue.

A recent report [6] indicated that under current land use, the implementation of the Clean Water Package launched by MfE in February 2017 [11] would cost New Zealand $217 million annually and

result in an improvement in swimmability of 6.9%. Challenge science suggests that this low level of improvement is due to the current policy targeting only large streams, thus missing contaminant inputs to a multitude of smaller upstream tributaries [18].

However, the Challenge has shown that when measures to improve water quality are targeted to the specific areas that account for most loss, the cost effectiveness of intervention increases 6-7 times [8]. Other efficiency gains can also be made. For example, between 1990 and 2010 sheep and beef farms increased the volume of saleable products by 47% while decreasing nitrate leaching and greenhouse-gas emissions by 21 and 40% respectively [19]. ***Challenge research has shown that water quality objectives can be met, but that land use must change to reflect suitability for production without negative environmental (or socio-economic) consequences*** [9].

4.3.3 Incentives for change

Strategic area 4. Capture and share with the producers more of the value consumers associate with our products

Problem: New Zealand currently captures only one seventh of the value of our primary products in overseas markets.

Proposed research: More value must be captured and shared with producers to incentivise sustainable land uses and land-use practices, make transition pathways more compelling and reward good environmental, social and cultural attributes. The Challenge will demonstrate how collaborative value chains enable those involved to create, capture, prove and share value equitably based on good environmental, social and cultural attributes. This will be done using cases studies, chosen carefully so that their learnings can be used by other businesses. We will integrate across these attributes iteratively, at each stage back-casting from a future ideal to show the benefits and trade-offs and to determine if a new transition pathway is required.

Additional areas will be investigated, including who to target and facilitate a change in business models towards collaboration and quantifying the true value of food, with environmental, social and cultural costs accounted for.

Outcome: New Zealand is producing high-value products across all sectors that capture and share more value from consumers to producers.

Strategic area 5. Increase and share value based on mechanisms that reward sustainable land use and high-value products

Problem: Current schemes to incentivise and reward sustainable land-use practices commonly focus on one method (e.g. organic production) that may perform well in some attributes but not in others. Moreover, any investments (e.g. environmental mitigations) typically raise the value of land and tend to lock it into existing land uses.

Proposed research: The Challenge will show how New Zealand agribusinesses can generate cash-flow from non-monetary values. There will be a focus on Māori agribusinesses, which have shown an intent to reward across a wide set of values, with the aim of using these as exemplars that other businesses can learn from. Research will address market incentives (e.g. tax credits, payments for ecosystem services), regulation (e.g. the role of an Emissions Trading Scheme), and voluntary (e.g. risk protection programmes) schemes that reward environmental, social and cultural attributes [20, 21] which are meaningful to consumers.

Outcome: Agribusiness schemes plays a key role in improving New Zealand's social, cultural and environmental footprint.

Strategic area 6. Enable communities to identify and adopt sustainable land use practices

Problem: Despite action to improve water quality by many individuals, communities and primary producers, the pace of change is not keeping up with the environmental pressures. What is needed is a clear demonstration that proposed transition pathways benefit all.

Proposed research: Working with international collaborators, we will collate, assess and review the efforts of individuals and groups who have acted over the last 20 years to improve water quality (e.g. Sustainable Farming Fund, Landcare Trust, Regional Council groups etc.). We will identify what actions worked, where and why, to provide the confidence to invest for those who are wanting to act. We will create a national map that will be implemented within an existing platform (being scoped with Land Air Water Aotearoa www.lawa.org.nz) so that actions can be linked to outcomes via the nearest water quality indicator site.

Outcome: The production of sustainability-produced products is greater and more widely spread.

What will change?

Primary-industry leaders aim to get a 20% premium for New Zealand products relative to international commodity prices, across the primary sector [22], but achieving this will require consumers to see the value in our products, and for that value to be shared with producers. Value chains which are successfully doing this not only have a quality product but also have environmental and other credence attributes as a core component of their brand, and reward producers appropriately (e.g. the Zespri brand, which manages a third of internationally traded kiwifruit yet accounts for two-thirds of value ([23] p 19). Adopting a te ao Māori perspective adds a further point of difference to New Zealand's position and identity in overseas markets. While some Māori enterprises are successful, there is considerable scope for improvement. Some estimates put the cultural component of added value as $8 billion over a 10-year period [24, 25].

4.3.4 Capacity for transition

Strategic area 7. Increase our social capital so that we can have well informed debate about alternative futures

Problem: While New Zealanders as a whole value primary production, many consider that the environmental impacts of some primary production systems are unacceptable. From an urban perspective in particular, this means that those farming systems have lost their social licence to operate. Regaining that licence requires raising the level of understanding of land and water issues, so that our communities can have informed debate about the need to change and the ways in which it can happen.

Proposed research: We will partner with other experienced organisations to build on our understanding of the prerequisites for the social licence to operate, including the types of strategies that will be needed to improve understanding and promote a wider sense of ownership of both the problems and their solutions. We will establish a series of engagement events with communities of interest where people can discuss the kinds of issues the Challenge is confronting.

Outcome: An increased number of urban and rural people understand how land and water issues can be addressed and trust the evidence for improved environmental performance as a consequence of changing practices and land uses.

Strategic area 8. Foster kaitiakitanga, generating accountability in catchments and beyond

Problem: The concept of kaitiakitanga is an essential attribute for a sustainable future. However, little progress has been made in generating a sense of collective responsibility and accountability for action on a scale necessary to effect more than local improvements. We are still dogged by an

inability to motivate change and provide assurance about, for example, implementing water-quality limits.

Proposed research: Work will draw upon the concept and practice of kaitiakitanga to investigate how to generate amongst landowners a sense of collective responsibility and accountability for action. Where this involves the wider community, it will also help to build and sustain social capital (see 7 above). We will identify institutional barriers and enablers of kaitiakitanga and begin to build evidence of the extent to which this is associated with improved environmental outcomes.

Outcome: There is growing evidence of kaitiakitanga in action, leading to improved environmental outcomes.

Strategic area 9. Manage pressures and remove barriers to transition

Problem: Successful transition to catchments that contain a resilient mosaic of sustainable land uses require the removal of barriers to change, for enterprises to manage and adapt quickly to pressures such as climate change or the imposition of tariffs, and for these to be acted upon collectively. Failure to remove barriers impedes progress, and allows our international competitors to overtake us (e.g. in creating value from a low-carbon bioeconomy). A sector-by-sector view may also distort what is required for success. If we do not manage pressures effectively, we become vulnerable to detrimental production and productivity impacts such as widespread crop failure or loss of market access.

Proposed research: Work will address the long-term planning needed to avoid infrastructural barriers that lock in capital-intensive land uses (e.g. oversized milk driers that cannot accommodate customised uses). We will also examine the trade-offs among land uses associated with transitioning to a lower-carbon bioeconomy, such as effects of land use on water quality and the ability to adjust to international trends such as a large-scale market shifts away from pasture-based farming products in favour of plant-based proteins and other alternative foods.

Outcome: New Zealand's primary enterprises are able to manage pressures collectively and better than their international competitors.

What will change?

The average return on research investment has been estimated to be a factor of between 10 and 32 [26]. The impact of research can be magnified still further if it is integrated across disciplines [27] and is designed and undertaken in partnership with stakeholders. However, the time to peak adoption is, on average, 16 years [16], and the lag between investment and return is estimated to be 24 years [28]. Research on specific issues (e.g. dairy heifer growth rates) has shown that uptake can be increased and the time to see a return decreased through co-innovation [29].

Not only can changing the way we do science accelerate transformation, but there is also much to be learned about what is needed to enable change on a large scale. The outcomes of research into our capacity for transition will include stronger community networks characterised by trust and reciprocity, an increased sense of collective accountability and the commitment of effort for the common good.

4.4 ALIGNMENT BY CHALLENGE PARTIES

Alignment among research providers can be a powerful tool to fill gaps and accelerate research in strategic areas. Every two years the Challenge undertakes a rigorous formal alignment process to maximise resources and adapt to different investment timings. The process involves discussions with Challenge parties on research areas that would significantly advance the impact of the Challenge,

consideration by Challenge parties of what programmes they manage and fund that could contribute to these areas, and agreement between the Challenge and Challenge parties based on the principle of reciprocity or mutual benefit. Evidence of strong alignment in tranche 1 includes the documentation of modified milestones/deliverables in existing contracts.

Challenge parties have committed to align research in the 2018-19 year, recognising that their portfolio will likely change. An indication of likely alignment is given in Table 2 from the 2017 Research Landscape Map.

5 How the Challenge will deliver research outcomes

5.1 ENSURING EXCELLENCE

We ensure science excellence through:

Processes that ensure we are monitoring, aligning, prioritising, and reshaping our research portfolio to maintain and invest in high-impact science;

Policies that provide clear guidance on how we undertake our research, maintain transparency and develop capability; and

Structures that encourage and promote to ensure science excellence is being measured and achieved.

Our processes for monitoring, prioritising and revising our research and investment

We monitor our research performance quarterly, review our portfolio annually and review our strategy biannually.

Quarterly monitoring of projects and programmes collects data on delivery to contracted milestones and deliverables, but also stakeholder interactions, risks and science highlights. These data are analysed by the science leadership team and used to manage risk around delivery, foster collaboration and co-innovation, and to encourage the programme or project to adapt if, through their findings, more fruitful lines of inquiry arise.

Programmes (large investments) and projects (smaller investments) are formally reviewed annually. Performance is measured against contracted milestones and deliverables, how the team have undertaken their research and the impact their research could or is having. If, during the review, performance is considered to be low, the team will be asked to work with a member of the science leadership team to change their research (a 'plan B'). The money remains with the contracted organisation, allowing them the security and certainty to think more broadly, but additional funds will not be paid until a suitable plan B is accepted by the science leadership team. This process, plus the continual refreshing of our science strategy, allows the Challenge to be agile enough to modify research plans quickly.

Our research strategy is revised biannually (Figure 4). This allows us to take into account of the changing pressures on land and water, the much larger amount of research in land and water (outside of the challenge), but allows sufficient time for strategic areas to be tested. The science leadership team formulates the strategy for sign-off by the board. The last revision was conducted in 2017 and reviewed by MBIE, receiving a score of 4 out of 5. Our strategy is informed by:

- The science advisory panel (SAP); who advise on science excellence and national- (and international) scale issues;
- An assessment of international mega-trends and drivers relevant to New Zealand;
- The co-innovation group who comment on the relevance of the research (CIG);
- The challenge parties who provide stakeholder intelligence and align research to the challenge;
- The Research Landscape Map that provides an assessment of what research is being done, how it is being done and what relevance it has towards the Challenge objective; and
- The Strategy Landscape Map which provides a commentary on what the science, industry, NGO, and government sectors plan to do to enact their research.

Additional research priorities may be acted upon through regular interactions between the directorate and Challenge parties, and structured monthly discussions amongst the science leadership team and stakeholder theme leaders. We have also agreed a number of initiatives to improve the impact of aligned research and the benefits arising from the relationship between the Challenge and Challenge parties (Table 3).

Table 3. The aim, activities, mechanisms and measures of success for the Challenge parties.

What	Why	How	What success looks like
A pan-system consensus to **building key research capability** in land and water science, particularly transdisciplinary science, Māori capability and emerging researchers	To build on the collective power of the group to build science capability nationally. Increase the uptake and impact of science contributing to the Challenge mission by both Parties and Stakeholders	• Identification of key capability gaps • Pūhoro STEM academy for young Māori • Collaborative teaching of Land and Water courses among Universities, ideally linked to CRIs • Create opportunities for young land and water researchers to interact, collaborate and learn • Active collaboration with Māori research groups to target and pipeline existing Māori research talent	Larger pool of young land and water scientists, especially Māori, who have the knowledge, networks, transdisciplinary and collaborative skills to contribute to the Challenge objective
Advising on new and emerging **issues/priorities of national interest** to which the Challenge can provide agile leadership in articulating the research response	To quickly highlight, review and create a value proposition on issues to advance collaborative research efforts with OLW and other funding pools/stakeholders (e.g. Policy, MBIE, SSIF)	• Action via quarterly meetings of the Challenge Parties Group summarising challenge key findings • identifying where 'think-pieces' etc. needed to address emerging research and information needs • CPG communicate out to their networks	Coordinated, agile and effective response to national priorities by Challenge Parties anticipating future needs and taking action in advance
Achieving greater **impact from science** by scaling up and out, and delivering 'whole solutions'	Accelerate the transfer of good results, data and practices to new regions or nationally and new sectors, and ensuring the science system collaborates to deliver the whole solution.	• Continued meaningful alignment with the Challenge, and between challenge parties to avoid duplication of research • Funding provided to facilitate discussions with agreed target 'customers' • Think-piece on how to identify, articulate and find mechanisms	Challenge AND aligned science is used nationally.

		to scale up and out Challenge best practice, results and data	
Supporting **increased innovation through influencing behaviour change**	Need to increase the quantum and speed of innovation in NZ, by increasing access to innovation and reducing the risk of uptake to stakeholders.	• Challenge brings together a wider breadth of stakeholders (including committed Māori entities identified through prior engagement) than individual organisations that builds trust amongst stakeholders that the science community is taking priority needs collaboratively • Increasing the opportunities for cross-pollination of ideas amongst researchers and stakeholders. • Sponsored R&D events • Reciprocal secondments between research providers and regulatory/industry sectors • International exchanges and sabbaticals • Bite-sized summaries of key Challenge findings are articulated	Evidence of stakeholders adopting/trialling new practices and greater collaboration across sectors.
Science excellence	Recognising science excellence as co-production and trans-disciplinary and consistently apply co-innovation to increase impact	• Leveraging the Challenge's international advisory panel to benchmark science excellence and metrics to demonstrate successful impact	More transdisciplinary and stakeholder involvement in publications from Challenge parties resulting in uptake as signalled by End user surveys
Greater **public understanding** of land and water challenges and solutions, and visibility of OLW and challenge partners	Trusted honest brokers needed to provide sound commentary and vision to encourage effective collective action to meet challenge mission	• Strong collaboration between communications teams of OLW and Challenge Parties • Effective systems within OLW of soliciting commentary and public responses from Challenge Parties	Informed public debate and greater unity of purpose across urban and rural communities, government, industry and NGOs results in accelerated progress towards Challenge objective

From the strategy the science leadership team uses a number of mechanisms to invest in a research portfolio that focuses on high-impact research with a range of risk profiles. The investment processes include:

- Targeted requests for proposals (RfPs) for well-defined research questions that result in larger research programmes that have a range of low- and high-risk research elements
- Working groups that focus on incremental, low-risk but high-impact research components that are identified for development within crowded research areas
- Seed funding for a research area recognised as critical for the Challenge, but requiring significant stakeholder commitment via co-investment to succeed

- Open contestable funding of projects to capture high-impact research questions and solutions unforeseen by the Challenge
- A think-piece process created by the Our Land and Water Challenge but now also used by other Challenges that commissions researchers and stakeholders to co-produce an output (e.g. white paper or high-quality journal review article) and refine the research questions in a workshop open to scientists and stakeholders before considering it for investment.

Once investments have been made, the programmes or smaller investments such as contestable projects, working groups and think pieces are overseen by members of the science leadership team. All investments are subject to quarterly reporting and an annual performance review.

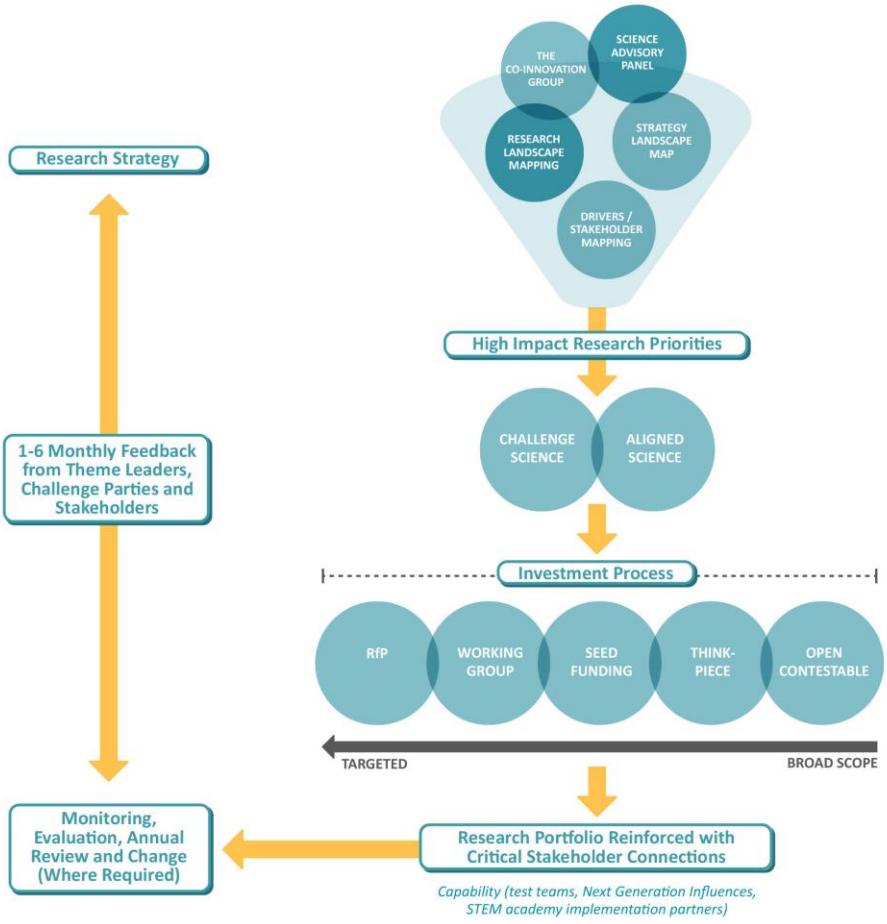


Figure 4. Processes used to prioritise, invest in and monitor research.

5.1.1 Policies to ensure science excellence, minimise risk and maintain and develop capability

Our policies are designed to ensure we are transparent and impartial in our decisions and deliver impact by producing high-quality science and demonstrating or developing the best mix of capability.

Transparency is maintained within our investment mechanisms. Proposals are reviewed by a panel of independent scientists, to judge science excellence, and stakeholders, to assess relevance (particularly to Māori), and, collectively, co-innovation and impact. The same criteria are used to assess proposals by the science leadership team. The chair of the panel and chief scientist discuss and make recommendations to the director and Challenge Board for investment.

The risk that science may not be of high quality or co-innovated is minimised by clear polices as part of the investment and review procedures. Policies include, but are not limited to:

- Researchers are expected to publish their results in appropriate high-quality peer-reviewed journals and disseminate the benefits of their results to the Challenge and New Zealand;
- The Challenge guideline is that a high-quality journal output, preferably co-authored with stakeholders, should be produced for every $200,000 of investment;
- The publication of at least 75% of Challenge research papers should be in the top 25% of internationally recognised journals (SCOPUS Scimago);
- Evidence of co-design, development, production and innovation must be demonstrated (e.g. the awareness and use of a review or white paper is enhanced when stakeholders are co-authors); and
- Research outputs should be open-source, with publications and data (where possible) to be made open-access.

We require proposals and existing programmes to have the right team. A proposal may require a team with a track record (or high likelihood) of delivery, and a history of good collaboration and demonstrated impact. However, proposals and programmes must also identify a member who has excellent translation and synthesis skills to enhance implementation. Finally, proposals must have a plan to develop capability. The Challenge is also developing capability by supporting, and in some cases funding, people at different stages in their careers. Key initiatives include:

1. The **Pūhoro STEM Academy**, developed by Massey University, supports cohorts of Māori pupils through school and university to create future Māori researchers. The programme has achieved results that exceed the national averages and currently has more than 450 students across three regions.
2. **Co-innovation graduates**, proposed by Lincoln University, is an initiative which aims to get undergraduate and postgraduate students and Challenge Research teams working together to train the next generation of scientists in how to do high-quality research that has impact.
3. The **Next Generation Influencers** programme exposes early-career leaders working in diverse areas to the Challenge in terms of both its research and its ways of working, with a view to creating champions of Challenge concepts beyond the life of the Challenge.

5.2 HOW WE WILL WORK TO DELIVER IMPACT

This section focuses on how the challenge will deliver impact. Delivery will be achieved by:

- Designing a research portfolio to deliver transformational science
- Co-innovation to ensure that science is relevant to stakeholders and therefore used faster
- Implementation pathways that are enhanced by the right teams through stakeholder interactions
- Targeting stakeholders who have the willingness and resources or power to act
- Emphasising Vision Mātauranga as central to achieving our objective

5.2.1 The importance of transformation and additionality

Achieving the challenge objective will require fundamental shifts in attitudes and behaviours on a national scale. The science required to underpin these changes needs to be transformational in scope and additional in its achievements. This means high impact research that will deliver step changes and new ways of generating and sharing knowledge. **Figure 5** shows the way we target our research to focus challenge science at the innovative end of the research spectrum.

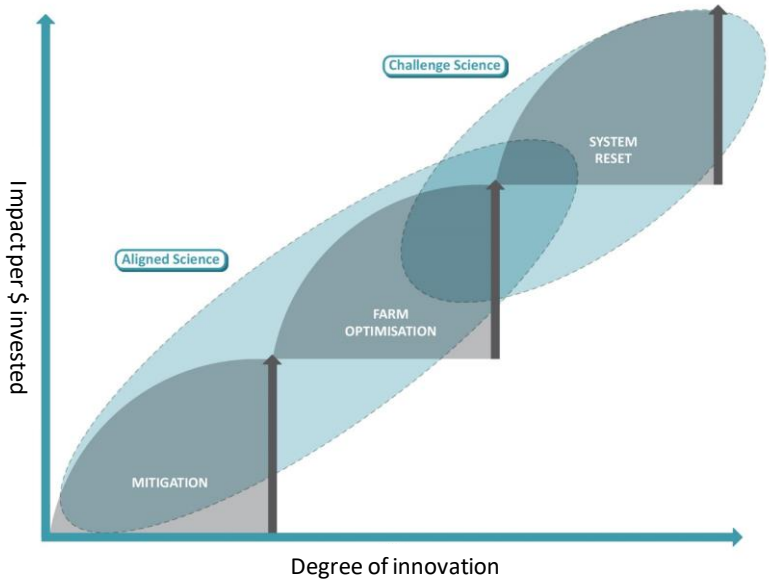


Figure 5. Prioritisation of Challenge science (top right oval) to incorporate and leverage Challenge and aligned science for additional impact. For example, to achieve community outcomes for catchment water quality might require more than mitigation and optimisation. This could mean research that considers the catchment as a 'blank canvas' and investigates a systems reset.

5.2.2 The benefits of co-innovation

Drawing on evidence from sustainable-development literature [30, 31], the Challenge has developed the hypothesis that co-innovation will ensure that science impact is greater and delivered faster than in its absence. Co-innovation comprises:

- Co-design such as the development of research questions with stakeholders
- Co-development where scientists and stakeholders work together for example in the same location
- Co-production such as the co-authorship of outputs by scientists and stakeholders
- Co-innovation where stakeholders are able to enact the wider implementation of the science and measure its efficacy as impact, revising the research through co-design if necessary.

We test our hypothesis and the effect of co-innovation on impact through the Research Landscape Map. We are already seeing results. For example, a co-designed publication questioned the efficacy of a national fencing policy, leading to the affirmation of better regional policy [18]. ***Our Science Advisory Panel noted that such widespread use of co-innovation by the Challenge is rare internationally, and should be monitored to determine if it can advance science practice and impact elsewhere.***

We will support the development of co-innovation by providing a seminar, and mentoring from those researchers proficient in this research method. This will also be a role for our co-design group.

5.2.3 Improving implementation

We have found that co-design is often not enough to improve implementation. Unfamiliarity with the concept, resistance to a new way of working, tight time frames or lack of connections can all

affect uptake. We will resource a Challenge-wide **co-design group** to interact with Challenge researchers several times during 2018/19 to offer advice on improving impact.

Having a '**best team**' approach is an important part of Challenge research. To ensure that the benefits of co-innovation are fully realised, we will include **implementation partners** in our research teams and make sure that they are given the resources and information they need to participate meaningfully with scientists. We will also require research teams to include people who are experienced in working with Māori partners and stakeholders, including having competency in te reo Māori, to ensure te ao Māori perspectives are understood and appropriately reflected

5.2.4 Targeting stakeholders

Our regular stakeholder mapping exercise identifies stakeholders who are willing and in the best position to create impact by implementing Challenge science. This includes strong representation of Māori stakeholders. Targeting delivers impact faster. However, we will also seek buy-in from those stakeholders who have little willingness, but potentially high influence on the achievement of our outcomes. Similarly, we will work with those who are willing to help but have little influence, to see if the Challenge can provide them with support.

To make targeting manageable, we will identify up to five key individuals (for each theme) as part of the annual review process with whom we would like to develop a relationship and link these to our implementation partners.

To speed up action on the ground, we have initiated an open-access national register of groups who are actively improving, or have taken measures in the past to improve, land and water quality (Strategic research area 6). This register aims to show what activities are going on or have gone on; what measures worked, or did not work, and why; and to transfer learnings to other regions. Part of this exercise is to map groups' willingness to change and level of resourcing in an effort to integrate groups with Challenge research. The working hypothesis is that mapping and targeting these groups will allow us to increase implementation and impact of Challenge science.

5.2.5 Putting Vision Mātauranga into action

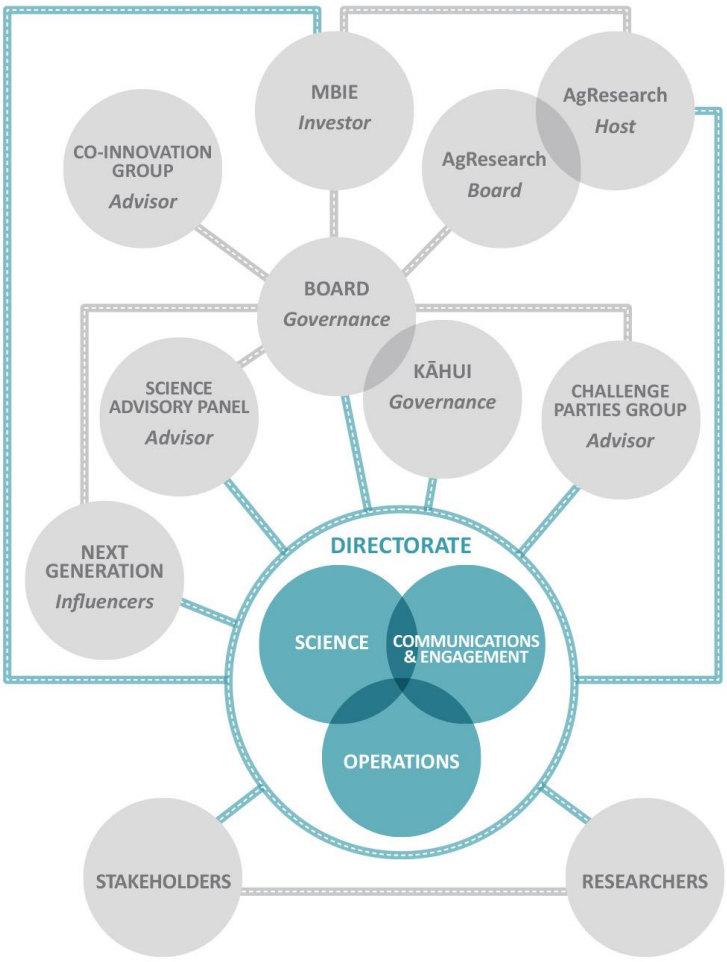
Tranche 1 of funding saw the Challenge increase its capacity and capability in Vision Mātauranga considerably. Building off this to implement our Vision Mātauranga objectives we will:

- work with the Kāhui to ensure there is visibility and opportunity for engagement on co-design and co-innovation across key Challenge decision areas
- develop new requirements or indicators that relate to Vision Mātauranga and implement effective mechanisms for Kāhui oversight of subsequent performance
- increase Māori research capacity and capability through Pūhoro STEM Academy and a variety of other mechanisms such as internships and scholarships, including those offered by Ngā Pae o te Māramatanga relationships
- recognise that the availability of resources will be a critical factor in developing key relationships with Māori entities and will assess their support needs accordingly

6 Investing in our future

6.1 GOVERNANCE AND MANAGEMENT

The Challenge has established a sound governance and management structure that supports collaborative ways of working at all levels. This includes a network of external advisory groups including a Co-innovation Group, Science Advisory Panel and Challenge Parties Group. These groups include high-level industry stakeholders, independent national and international science advisors and parties to the collaboration agreement. The Next Generation Influencers programme, a Challenge initiative, comprises early career leaders working in diverse areas that affect land and water. The Board and directorate are developing a relationship with this group, which includes listening to their perspectives on strategic matters for the Challenge.



As noted in the January 2017 MBIE review '…the Challenge is fortunate in the strong Board and Board Chair. They are taking good external advice and this will be further strengthened by the appointment of the co-innovation group. The management team is also highly effective and relationships between them and board chair appear confident, open and supportive.'

Building on this endorsement, the Challenge will further develop its operational policies/processes, and refine its structure over the next 12 months to ensure that they remain relevant to the shift in direction of the Challenge research strategy and appropriate to support the magnitude and nature of the task.

Figure 6. Operating structure.

6.2 Allocation of investment

The Challenge Board will increase by one member to provide consistency during a rotation process which provides for the replacement of two members per year. This will result in a full rotation of the board over the period of tranche two funding. The Kāhui has welcomed two new members within the last 12 months and appointed a new chair. The chair's participation in all board meetings reinforces the Kāhui's pivotal role in the Challenge.

The Board retains full oversight of the financial performance of the Challenge via regular reporting and approves the budget, including research expenditure. AgResearch, as host, holds the funds on behalf of the Challenge and provides the framework within which the Challenge finances operate, including policies and practices, software and limited accounting support. The Challenge has worked resolutely over the last 18 months to improve transparency in the handling and reporting of Challenge funds by the host. The Challenge will continue to work closely with the host but will need to increase resourcing for financial management, budgeting, forecasting and expenditure, and will explore the option of undertaking these functions inside the directorate.

The Science Leadership Team will continue to be responsible for overseeing the quality and impact of science undertaken by the Challenge. Substantial additional resources will be allocated to this team to better support and assess strategic science investment, integration, impact and uptake, along with improved implementation of our monitoring and evaluation plan. We regard monitoring and evaluation as a learning opportunity as much as an accountability mechanism.

A key component of improving resourcing for science leadership is greater support for Vision Mātauranga leadership. This will better enable strategic leadership and help ensure that te ao Maori underpins all aspects of the Challenge, including the delivery of our mātauranga Maori responsibilities and the full realisation of its opportunities.

Table 4. Indicative Budget shows the distribution of funds across the Challenge in tranche 2.

	FY19/20	FY20/21	FY21/22	FY22/23	FY23/24	Total
Governance	*125,790*	*129,564*	*133,451*	*137,454*	*141,578*	*667,836*
Kāhui	*51,000*	*52,530*	*54,106*	*55,729*	*57,401*	*270,766*
Science Advisory Panel	*56,000*	*57,680*	*59,410*	*61,193*	*63,028*	*297,312*
Science Leadership	*1,697,500*	*1,748,425*	*1,800,878*	*1,854,904*	*1,910,551*	*9,012,258*
Science Collaboration /Co-innovation	*129,900*	*132,819*	*135,826*	*138,922*	*142,112*	*679,579*
Evaluation of Science Excellence	*81,000*	*77,380*	*68,801*	*70,265*	*71,773*	*369,220*
Research Prioritisation	*50,000*	*4,000*	*13,000*	*52,000*	*101,000*	*220,000*
Operations	*595,250*	*613,108*	*631,501*	*650,446*	*669,959*	*3,160,263*
Communications and Engagement	*255,435*	*260,398*	*265,510*	*270,775*	*276,199*	*1,328,317*
Host Charges (AgResearch)	*353,000*	*353,000*	*353,000*	*353,000*	*353,000*	*1,765,000*
General Expenditure	3,394,875	3,428,903	3,515,482	3,644,689	3,786,601	17,770,551
Capability	400,000	400,000	400,000	400,000	400,000	2,000,000
Contracted Research	7,429,417	8,915,301	10,401,184	10,896,479	11,887,068	49,529,449
Total Expenditure	**11,224,292**	**12,744,204**	**14,316,667**	**14,941,168**	**16,073,669**	**69,300,000**

7 New horizons: directions for further research investment

Beyond the gaps and new research areas discussed in section 4, there are a number of topics of high relevance—and high potential impact—to the Challenge mission that we have targeted for future research. These are briefly described below. Pursuing this research would require additional investment, but we consider that the legacy outcomes for land and water use would be considerable.

Future Landscapes: Enhancing food production in the peri-urban environment

There are more than 175,000 lifestyle blocks in New Zealand. They occupy around 873,000 ha, mostly located close to major conurbations (Andrew and Dymond 2013). This is around double the national land area currently in cropping and horticulture. Many of these properties are on high-producing soils. While this land use is frequently framed as a problem in the context of loss of primary productivity, little attention has been paid to the opportunities such holdings might offer for the generation of high-value niche agricultural products. Little is known of the current productive return on this land, or of the potential value that might be generated through unlocking its productive potential. Research is needed to test the proposition that such opportunities might arise not just because of the versatility of available soils, but also because of the close social networks lifestyle communities provide, the potential for developing collective enterprises, and the risk profiles of landowners for whom agriculture is a secondary source of income.

Outcome: New Zealand receives enhanced value from primary production on small holdings

Future Landscapes: Does losing versatile soils to urbanisation matter?

Despite New Zealand's economy being highly dependent on agricultural production, expansion of lifestyle blocks (defined as land where the principal use is non-economic) and urban areas on to high-class land continues apace. Nearly 6000 lifestyle blocks are added annually, and in the Auckland area alone 10,500 ha of high-quality soils were lost to urbanisation between 1996 and 2010. More than 10% of New Zealand's urban and peri-urban areas occupy land classified as 'high class.' The impact of these large-scale changes has been a matter of speculation and debate for many years, but particularly since regulatory controls on the loss of land with high value for food production were lifted in 1991. Research is needed to determine the degree to which these land-use changes actually impact on both national primary productivity and the overall value of the land, taking environmental (including ecosystem services), cultural and social factors into account, and whether mechanisms, including value-chain orientation and design to enhance value capture for primary producers will impact on the incentive structures for converting from primary production, along with any flow-on consequences.

Outcome: When peri-urban land goes to its highest value use, New Zealanders can be confident that any changes are in the nation's long-term interest

Incentives for Change: Is water and soil science adequate in a rapidly changing policy making environment?

One end point of our research is to inform decision makers, including communities, in a way that leads to interventions that effectively target the problems we are confronting and avoid unintended consequences or undesirable outcomes. It is likely that many of the mechanisms to deliver the transformational change required of the Challenge will include tools that underpin national and

regional policy methods and rules. There are likely to be significant shifts in the next few years. Such tools are frequently subject to challenge on the basis that the underpinning science is inadequate, that tools are being used in ways they were not designed for, or that they are capable of being manipulated to circumvent the policy intent. The now widespread use of OVERSEER© in regional plans to prescribe nutrient-discharge limits is a frequently cited example of these issues. We need to examine carefully the utility of models and decision-support systems that support Challenge-relevant policy interventions, identify barriers to their use and what is needed to overcome them, and undertake the science necessary to ensure robustness and acceptability.

Outcome: Land users, regulators and the community have confidence in the science underpinning policy tools that impact significantly on land-use choices and practice

Capacity for Transition: Water quality and quantity consequences of climate-change policy

The public, central government and the primary production sectors have all recognised that the issues of climate change and freshwater quality require action. Although action is occurring on both fronts, the interaction between climate-change adaptation, our need to develop lower-carbon land uses and freshwater quality has received little attention. For example, aspects of climate-change policy that influence land-use change, such as planting of large numbers of trees to sequester carbon or bringing agriculture into the Emissions Trading Scheme, could have as much influence on freshwater quality by initiating land-use change as the National Policy Statement for Freshwater Management.

Although the funding landscape for climate-change research is complex, the roles of the various funding and research entities, including the Deep South NSC, are well defined (NZAGRC, 2016). Key gaps include the implications of climate change on freshwater quality and the attributes of systems that would be profitable and resilient under the lower-carbon land uses necessary to succeed in a changed climate and meet New Zealand's international GHG commitments. The Our Land and Water Challenge could work alongside other funding organisations to fill these gaps, and has already agreed with other research providers to co-ordinate research to increase impact. In particular, the Our Land and Water and Deep South NSCs have agreed to co-fund research where this advances each Challenge's mission. OLW has already signalled its intention to work with Deep South on the implications of climate change for contaminant delivery in productive landscapes, but a number of other critical research areas lie outside of the likely tranche 2 funding envelope. These focus on the integration of research into adaptations needed for improved water quality and GHG emissions from farm to regional scale, targeting of management interventions and the social, cultural and economic dimensions of implementation of measures.

Outcome: New Zealand farming systems operate profitably under GHG emission constraints, while realising co-benefits for carbon footprint, water quality and biodiversity impacts

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