Ministry of Business, Innovation & Employment

National Science Challenges

Potential Challenges for Consideration by Peak Panel

Agriculture and the Bioeconomy Including Resource Management

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1 Introduction

The potential challenges in this area cover a wide range of issues related to New Zealand society.

Fifty eight submissions were received from the science sector in this domain. These submissions have been grouped as shown in Table 1.

Table 1: Summary of proposed challenges by grouping

Entry Id	Challenge
Water Management	
105	Making the most of our water
272	More fresh water for New Zealand. We are reaching water-limited conditions, particularly for agriculture. By developing methods of enhancing gain from precipitation and reducing loss through evaporation and groundwater loss to the sea, there is potential
372	Enabling increased economic output from primary production, while concurrently managing New Zealand's freshwater resources within environmental quantity and quality limits.
395	The Water Challenge
420	Using science to inform the development of resilience and sustainable water infra-structure for the 22nd century
437	Maximising the benefits of the water which falls on New Zealand
448	Increasing the productivity of our land whilst improving the quality of our lakes and rivers, and meeting social and recreational needs
459	Healthy and Secure Freshwaters in a Growing Economy. Goal: To manage New Zealand's freshwater resources so that their health and life-supporting capacity is improved and economic benefits from water use are maximised.
486	To improve water quality in lakes and streams and to enable farm production to increase
Increasing Production	
152	Sustainable vegetable growing, producing better yields and quality on less land
157	Significantly grow New Zealand's agricultural production base while preserving the integrity of its environment and its international "clean and green" brand
179	Efficient sustainable use of New Zealand agricultural land
182	Agriculture including dairy that is sustainable competitively and responsibly. Competitive means profitable for the longer term and responsible includes environmental stewardship and high standards in employment and farming practices
241	The commercial growing of onions using non agrichemical solutions to Onion Downy

Entry Id	Challenge
	Mildew Certain agricultural chemicals such as Mancozeb, are the main method of Downy Mildew Control in export onions. Some of the current chemicals may be banned shortly
265	Sustainable agriculture: Ensuring food production for the next 1000 years
344	To maximise value for New Zealand from low value biomass. Use fractionation technologies to produce biomaterials, biofuels and stock feed. Add new exports and reduce imports. Added value opportunities exist to turn 5c/kg into $5/kg
380	Engaging entrepreneurs & the SME sector in 'growing the agrifood economy'
429	Sustainably profitable primary industries
Sustainable Resource Use	
124	Empower NZ to innovate and implement sustainable technologies and practise in as many areas as possible and to develop enough scientific infrastructure that we have the resources to respond quickly and efficiently to biosecurity, health and environmental threats
151	A clean and healthy sea: New Zealand's native land animals and plants are almost entirely gone. Our marine resources are going the same way due to overfishing and by catch, lack of protection, global climate change, and pollution
202	The Coastal Marine Area (CMA) - In a world of extensive exploitation of terrestrial resources, but with increasing demands for primary needs (food, water, energy) there is a vast potential of untapped productive and ecosystem resource in the marine environment
203	Development of realistic and affordable national water and land management resources as a foundation for the increase of primary production development for domestic and export markets
277	To enable New Zealand society to live sustainably
294	(Epi)genetic instructions for organism assembly are highly conserved across all life-forms, but research effort is fragmented. Coordination of (epi)genetic research while allowing end-user customisation of new knowledge would be advantageous
300	New Zealand will improve the management of land and water to increase wealth and environmental integrity
305	Using science, innovative technologies and tools to improve our production from land while maintaining or enhancing our freshwater quality
318	Oceans Management - getting the best from our ocean
324	Rehabilitation and conversion of land and waterways currently deemed as unsafe for productive utilisation due to the presence of Dioxin and other persistent organic poisons. Extension of the current bioremediation project
326	To develop a theoretical basis for understanding the undesirable physiological trade-offs that occur when plants and animals of agricultural importance are subject to genetic selection for production traits
339	New Zealand needs to grow the economic value gained from its land and natural capital and resources while reducing the environmental impact of agriculture and forestry
351	The integration and reconciliation of environmental and economic benefits to support a hybrid approach to prosperity and well-being for New Zealand society

Entry Id	Challenge
362	Increasing agricultural output whilst improving freshwater quality
411	Generating sustainable growth, wealth and resilience from land by managing land and water resources to increase productivity while maintaining environmental integrity
412	New Zealand increases wealth from natural capital while maintaining or improving its environmental integrity
418	Green land, blue water and prosperous people for the next millennium
434	Promote the sustainable use of the New Zealand's marginal agricultural lands and protect the quality, supply and image of New Zealand's high-value products and allow the development of regional industry clusters
435	Urea production from wood waste
454	Land, Water and Coasts - "Achieving integrated management of land, water and coasts, which incorporates the connections between them and leads to productive resource use and sustainable, healthy ecosystems."
398	To have an integrated suite of environmental tools which are used for benefiting all New Zealanders through optimising agricultural productivity whilst being used to enhance biodiversity and optimise water quality
469	Balancing increased agricultural production and environmental concerns
Marine Resource Management	
273	An extreme endurance, multi-tasking, oceans information gathering network. Its primary mission is Fisheries Protection but is also capable of environmental monitoring, survey and scientific research, search and rescue, national and regional defence.
419	Understanding, preserving and benefiting from our Exclusive Economic Zone
426	Wealth and stewardship of our oceans - 95% of the New Zealand estate is under water, making it one of the largest ocean estates in the world
458	Increased Wealth from and Stewardship of our Oceans: Goal: Accelerate development and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides
Higher Value Foods	
206	Robust and defensible food supplies (Organic food studies)
207	Leading the world with the honey bee
239	Population projections state by 2050 there will be 9 billion persons to feed. The aquatic environment will have to produce much more than the present 2% food and biomaterials. Marine studies will have move into 21st century science
302	Increasing the success of New Zealand foods - To leverage New Zealand's national identity, efficient and sustainable primary production base, scientific capabilities and innovative culture to provide consumers with foods that promote mental and physical health a
338	Enable New Zealand to be a powerhouse producer of market-defining, world-beating food and beverage products
354	International competitiveness of agriculture requires export in high value foods.

Entry Id	Challenge
	Manufactured food exports, uniquely sourced from New Zealand, with innovative manufacturing and highly-valued (health) targeting markets is a national science challenge
373	Growing economic value and our economy from New Zealand's land and natural capital/resources
394	The Food & Nutrition Challenge
421	Develop New Zealand's agribusiness sector towards smart* foods for wealth and health benefits
427	Future foods - New Zealand contributes only a small percentage of global food production. Rather than competing solely in undifferentiated commodity markets, New Zealand needs to:
479	Food Prosperity: Wealth from Healthy, Safe and Sustainable Foods
484	Food For Health Evaluation Centre - Development of foods for health is a rapidly growing industry reliant upon marketing and not science. An opportunity exists in New Zealand to create the first international "one stop shop" food for health evaluation centre to assess the health benefits and uniqueness of New Zealand foods, food products and nutraceuticals.
Market Access	
31	Long term assurance of overseas markets for milk and meat. Achieve this through three major themes, (i) food safety, (ii) animal welfare, and (iii) human and animal health
443	Supplying premium agricultural products and technology to the world

2 Water Management

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 2: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
105	Making the most of our water	1. Managing water in the information age 2. Taking stock of our water 3. Joining the dots in water management 4. Understanding our relationship to water
272	More fresh water for New Zealand. We are reaching water-limited conditions, particularly for agriculture. By developing methods of enhancing gain from precipitation and reducing loss through evaporation and groundwater loss to the sea, there is potential	1. Evaluation of the potential for dry-ice cloud seeding to enhance the winter snow pack in the Southern Alps, so increasing the mean discharge of Otago and Canterbury major rivers. 2. Evaluation of snow fences for increased water yield. Creating surface roughness at high altitude has the potential for build-up of snow drifts to yield a greater snow water for summer river flow enhancement 3. Plants for water yield. The goal is to enhance water yield to reservoirs (from alternative planting in water supply catchments) or enhance local groundwater recharge (with alternative shelter belt species) 4. Coastal groundwater recharge with lower-quality water to create groundwater barriers. The goal is to extract more groundwater from coastal aquifers, with recharge of lower quality water along the coast to prevent saline intrusion
372	Enabling increased economic output from primary production, while concurrently managing New Zealand's freshwater resources within environmental quantity and quality limits.	1. Quantification and description of water and nitrate fluxes at the sub-catchment and catchment scales. 2. Incorporating natural attenuation into the 'managing to limits' framework. 3. Developing mitigation options that are based on induced or enhanced de-nitrification in groundwater systems. 4. Developing the decision support tools that are based closely on the biophysical reality and which are trusted by land users, iwi, communities, and regulators.
395	The Water Challenge	1. Increased demand from people, agriculture and industry

Entry Id	Challenge	Themes
		2. Environmental Impact of water supply manipulation 3. Water recycling 4. Skills and research
420	Using science to inform the development of resilience and sustainable water infra-structure for the 22nd century	1. The primary goal is to use science to explore the biophysical, social, cultural, health and economic risk and benefit for alternative uses of waste-water and waste water solids, including water reuse from New Zealand's single largest waste stream 2. The primary goal of this research is to close the gap between producing research outputs and use of the outputs in water and waste decision making and practice, by developing an understanding of the current roles of research and processes for its uptake, and by developing more effective and efficient roles and processes
437	Maximising the benefits of the water which falls on New Zealand	
448	Increasing the productivity of our land whilst improving the quality of our lakes and rivers, and meeting social and recreational needs	Realising the potential of New Zealand's forest
459	Healthy and Secure Freshwaters in a Growing Economy. Goal: To manage New Zealand's freshwater resources so that their health and life-supporting capacity is improved and economic benefits from water use are maximised.	1. Optimal use of water resources Goal: To be optimally allocate both surface and groundwater resources in a manner that integrates multiple-use decision-making and planning, and maintains the health of our waterways 2. To ensure that the ecosystem services of New Zealand's freshwaters are maintained and enhanced to ensure that water resources are of high quality and support economic growth and social values 3. Secure and effective water infrastructure Goal: To ensure that New Zealand has critical water infrastructure that has an improved contribution to economic value, is environmentally optimised, and socially acceptable 4. Empowerment of Māori Goal: To empower Māori participation in the management of New Zealand's freshwater resources, to preserve the mana of waterways, rangatiratanga and kaitiakitanga
486	To improve water quality in lakes and streams and to	

Entry Id	Challenge	Themes
	enable farm production to increase.	

Entry ID	105
Making the most of our water	
Summary	The goal is improving water management processes in New Zealand. Themes include increasing efficiency and precision of water management through information technologies such as sensors, GIS and computer modelling, reviewing and increasing knowledge of New Zealand's water resources including projections of effects of changing climate and water use trends, improving flows of information and technology in water management both within New Zealand and internationally, understanding New Zealand attitudes to water and quantifying benefits of water quality and quantity to New Zealand society, economy and environment
Theme 1 **Managing water in the information age**	
Importance to New Zealand	Information technologies - sensors, GIS and computer modelling - are transforming our potential ability to manage water with efficiency and precision, reducing costs and increasing benefits to the economy and environment. Water users such as farmers have neither the time, money nor the technological background to fully harness the increasing power of information. Commercialisation of emerging technologies can emphasize profit before full, objective evaluation of the technology or the potential for its refinement. Benefits may be hard to verify at the level of individual users. Similarly, water managers such as councils cannot apply state of the art information-led principles where the technology remains inaccessible to users. With increasing financial constraints they too may struggle to keep abreast of technological developments. An objective, big-picture approach is needed at a national level to evaluate water management technologies and the information they provide and to anticipate and initiate further developments.
Research components	Critical information needs in water management must be identified and prioritised. Emerging technologies must be evaluated according to their potential to meet these needs, via theoretical projections and case studies from New Zealand and overseas. New information technologies and synergies must be anticipated, imagined and explored, to generate further research initiatives. The emphasis must be on the potential of technologies to enhance the management of water in practice.
Theme 2 **Taking stock of our water**	
Importance	New Zealand's temperate, moist climate will increasingly be a jewel in the crown

to New Zealand	of the global environment as droughts and floods plague other nations, including some which are major food producers. To maximise the benefits of our position we must fully equip ourselves to make the most of our water. An information revolution in our water management will not only produce but rely upon top quality data.
Research components	A review of the extent and accuracy of our knowledge of New Zealand's water resources must be undertaken. This should extend to projections of changing climate and water use trends. Gaps in our knowledge must be filled according to identified priorities, including the accuracy and applicability of data to emerging technologies and information systems.
Theme 3 **Joining the dots in water management**	
Importance to New Zealand	A proper understanding is needed of the flows of information and technology in water management, and what are the blockages in those flows, both within New Zealand and internationally. Making the most of our water requires not only water management but management of water knowledge.
Research components	The following questions must be addressed: Do the right people have the right information? Is information packaged and accessible in useful formats? How will information be shared in future? Is technology transfer to users effective? Does it realise the potential of the technology for better water management? How does the private sector enable or obstruct best practice in water management? What is the role of government? How well do we access international innovations, and market our own systems and technology for water management overseas?
Theme 4 **Understanding our relationship to water**	
Importance to New Zealand	To get the most from our water we must understand how water is most important to us. This will underpin how we apply new technologies for water management, to provide outcomes that are seen as successful by all New Zealanders.
Research components	Where possible we must quantify the benefits of water quality and quantity to New Zealand society, the economy and the environment. We must also recognise the cultural, spiritual and personal values of water to us, and find ways to incorporate these values in our management of water. We must investigate the significance of water to different regions, lifestyles, traditional livelihoods and new ventures, and different worldviews. We must find ways to promote understanding of how others value water.
Comments	It may help if a National Science Challenge is led by an individual or team, some type of commission or commissioner outside the institutional coalition which undertakes the research, free from the particular interests and pressures within and between those institutions, and solely focused on the Challenge.

Entry ID	272
More fresh water for New Zealand. We are reaching water-limited conditions, particularly for agriculture. By developing methods of enhancing gain from precipitation and reducing loss through evaporation and groundwater loss to the sea, there is potential	
Summary	The goal is to obtain more fresh water for New Zealand by developing methods of enhancing gain from precipitation and reducing loss of water through evaporation and groundwater loss to the sea.
Theme 1 **Evaluation of the potential for dry-ice cloud seeding to enhance the winter snow pack in the Southern Alps, so increasing the mean discharge of Otago and Canterbury major rivers**	
Importance to New Zealand	Canterbury rivers in particular are under irrigation pressure with the shift to dairying. An increase in summer flow due to enhanced snow melt would be helpful to both dairying developments and also to maintain flows for recreation. In addition, for the Waitaki River, enhanced flows in the headwaters would yield an increase in storage water in lakes Tekapo and Pukaki for winter hydro supplies.
Research components	Preliminary work would evaluate the frequency of winter cloud seeding conditions, in order to make a preliminary estimate of the potential for river flow enhancement. Part of this work would evaluate the cloud seeding operations in Tasmania (for hydro power). Studies from Monash University have indicated enhanced rainfall in the targeted regions. Subsequent on a successful outcome, and experimental trial could be set up, using a target and reference catchment to quantify any precipitation enhancement and evaluate its economic gain.
Theme 2 **Evaluation of snow fences for increased water yield. Creating surface roughness at high altitude has the potential for build-up of snow drifts to yield a greater snow water for summer river flow enhancement**	
Importance to New Zealand	Enhanced snow accumulation by land surface modification is another potential means of enhancing summer river flows for irrigation and recreation.
Research components	Some preliminary work has already been done in Otago on this topic, and this work needs to be followed up in the light of the value of extra water today. Research expertise here would be in the fields of the physics of blown snow and drift accumulation mechanisms. A related research knowledge area is developing computer models of topographically-modified wind flow patterns.
Theme 3 **Plants for water yield. The goal is to enhance water yield to reservoirs (from alternative planting in water supply catchments) or enhance local groundwater recharge (with alternative shelter belt species)**	
Importance to New	Having a simple way to increase water yield by planting alternative vegetation could be a cost-effective means of enhancing water yield from urban water supply

Zealand	catchments. Benefits are hard to quantify but could be considerable if the cost of alternative water supplies are considered. Much of our present shelter belts are radiata pine, which lose the maximum amount of water via interception. An alternative species with less interception could enhance the recharge to groundwater, available for later use in the vicinity via water wells.
Research components	The main research component is the testing of water yield properties of different plant species. There has been some evidence that flax catchments could give rise to higher water yield. Totara may be a shelter belt alternative to pine, if enhanced water yield offsets the slower growth. Catchment test trials would be required to confirm enhanced water yields.
Theme 4 **Coastal groundwater recharge with lower-quality water to create groundwater barriers. The goal is to extract more groundwater from coastal aquifers, with recharge of lower quality water along the coast to prevent saline intrusion**	
Importance to New Zealand	There is presently considerable loss of groundwater in New Zealand as ocean-bottom springs and seeps. However, this is necessary under the natural situation to avoid sea water intrusion from over-exploitation. Following the example of Orange County in California, water of impaired quality such as treated effluent could be injected into the aquifer along the coastline, creating a hydraulic barrier to enable greater extraction of groundwater further inland. At the same time, the impaired water is carried out to sea beneath the sea floor.
Research components	An important component is setting up numerical groundwater models (eg for coastal Canterbury, Bay of Plenty, Hawkes Bay) to ensure that the recharge pumping does not extend inland to any degree. Also essential is microbial expertise to develop techniques to ensure biofilms do not develop in the recharge wells to limit their effectiveness.
Research Gaps and Opportunities	For all the methods indicated, finding the marginal economic value of the water increment is of importance. This has not been done previously over the full range of water enhancement options. Such economic evaluation is essential because it is likely that the current value of incremental water has been enhanced due to competing demands.
Comments	None of the methods proposed here are new, and some have been looked at to some degree previously in New Zealand. However, to my knowledge there has never been a national research programme themed on enhancing the volumetric water supply of the nation.

Entry ID	372
Enabling increased economic output from primary production, while concurrently managing New Zealand's freshwater resources within environmental quantity and quality limits.	
Summary	This proposal is aimed towards enabling increased economic output from primary production, whilst sustainably managing New Zealand's freshwater resources (with a focus on environmental quality). Research will address how water quality can be maintained in the face of ambitious targets to increase land based outputs, with components involving; •Understanding the conditions and indicators that identify presence of groundwater assimilative capacity, •Integrating denitrifying capacity into the GIS data so that land users and regulators know where groundwater systems are vulnerable or where intrinsic natural assimilative capacity is known to exist and can be quantified. • Economic analysis of ecosystem services to assign value to the intrinsic natural capital of the potential denitrifying capacity of groundwater and surface water systems.
Theme 1 **Quantification and description of water and nitrate fluxes at the sub-catchment and catchment scales.**	
Importance to New Zealand	Ambitious targets to increase land-based output are meeting quantity constraints around over-allocated catchments on the east coast and water quality limits generally in our premium agricultural regions and major river catchments. Water storage alone is not sufficient. Water quality is impacted by microbial and nutrient contamination, one of these being nitrates. Currently these catchments are managed via nutrient caps and/or nutrient budget modelling. The government has been purchasing nutrient discharge allowances (NDAs) in the tens of millions of dollars, while new regional council plans are claimed by land users to be reducing or limiting production. By identifying areas of land that have a natural capacity to assimilate nitrates in their groundwater systems, through natural processes such as de-nitrification and dilution/ discharge, some land can be selectively used to increase the intensity of agricultural production. Conversely, those land areas that have low/ no assimilative capacity can be used less intensively. To understand where groundwater assimilative capacity occurs we need better data, and that means at an affordable cost. This theme addresses these issues by developing novel sensors specifically for groundwater and surface water quality needs. The sensors will be tested in the field on carefully chosen catchments. The sensor data feeds will be automatically telemetered and then integrated into groundwater/surface water models. Better data, more locations, higher

	resolution means trusted models and more useful tools. Note: Quantifying the benefits is summarised in the closing Comments section.
Research components	The main research components are: •Understanding the conditions and indicators that identify presence of groundwater assimilative capacity. •The development of novel groundwater sensors for velocity, nitrate and possibly silica into networked data acquisition arrays to improve the resolution of nutrient flows to sub-catchment scale. •Optimise the location of sensors to provide the desired degree of certainty at minimum cost. •Develop and test these sensors in five representative sub-catchments and automate data acquisition. •Advanced groundwater monitoring techniques that will enable vertical profiling of shallow groundwater, which is the most dynamic component of the subsurface system
Theme 2 **Incorporating natural attenuation into the 'managing to limits' framework.**	
Importance to New Zealand	The management cliché that you can't manage what you don't measure is especially true of groundwater, which is complex, varying with mass flow, depth, age, and quality; and it's all hidden from view. Effects may have many contributing factors and take decades to be evident. We need to understand where nitrate fluxes are coming from, spatially and temporally. The N load currently measured at a monitoring site is the cumulative effect of all groundwater flow paths that discharge into a given surface water body. Imposing widespread limits without accounting for these factors is a blunt instrument; potentially limiting further agricultural intensification. Critical sub-catchments could be identified and N leaching reduced through improved management or land use change. The availability of continuous monitoring data from a range of measured sites would allow models to be calibrated in a much more robust way than is currently achievable. The twin goals of economic growth and managing to water quality limits can then be addressed. Lands constrained by water quality constraints can be managed differently with the science, technology and resulting DSS we propose. The risks to water quality can be managed by informing land users which management practices will enable production increases without exceeding environmental limits. At present natural attenuation is excluded from regional plans. Where it exists it needs to be known as we are handicapping ourselves if we treat all root zone losses as nitrates in our receiving waters, when in many places de-nitrification is removing 50% of N in groundwater.
Research components	The main research components are: •Mapping the spatial location and quantum of groundwater hydrological flows in

	combination with nutrient concentrations to determine the spatial variation in nitrate assimilative capacity in given catchments •To integrate denitrifying capacity into the GIS data so that land users and regulators know where groundwater systems are vulnerable or where intrinsic natural assimilative capacity is known to exist and can be quantified. •Land users require decision support services (DSS) and tools that; combine nutrient and mass flow in a time series model. Identify critical sub-catchments, where remedial action is most warranted, and other sub-catchments where intensification is still possible within the nitrate limit imposed. -There is massive data collected from many sources at considerable expense and in some cases it is being acquired but not used for management purposes, only for compliance. -Data should serve management, not be an end in itself. Accordingly we need to develop technology and science that serves stakeholders' needs. •Develop models of catchment-scale water balances and nutrient mass flux so that climate prediction can be integrated, along with near real-time data from water takes to provide a catchment scale management 'dashboard' for users to closely manage both water availability and water quality.
Theme 3 **Developing mitigation options that are based on induced or enhanced de-nitrification in groundwater systems.**	
Importance to New Zealand	An important component of management is to enable land users to adapt management practices which are matched to the natural ecosystems' assimilative capacity. In some catchments we can engineer the creation of de-nitrification and contribute to other community values of freshwater. Constructed wetlands are often proposed but cost and maintenance are issues. For nitrates the mitigation solutions have been prohibitively expensive. We propose to break this barrier. Denitrifying walls have been tested at pilot scale. We propose to test the viability of permeable bioreactors (PBR) at sub-catchment scale. To deploy PBRs one must understand the nutrient mass fluxes – location, concentration, direction, volume. The measurement by novel sensors, and the modelling, based on richer data is the key to testing and up scaling of PBRs. Hence the need to integrate across natural assimilative capacity, nutrient mass flux, and the biochemical disciplines to provide an engineered mitigation solution that is worth investing in because it will enable more land use intensification as nitrates are denitrified before they recharge streams and rivers. There are other mitigation options that function in conjunction with the natural systems, such as methane injection to provide a carbon 'food' for natural bacteria. This has point source applicability and is potentially viable where agriculture can offer biogas as a carbon source. Constructed wetlands have application but have proved to be expensive in New Zealand. By understanding nutrient fluxes better we can decide where these and other such mitigation options are indicated.

Research components	The main research components are: •Mitigation by induced de-nitrification. •The up scaling of potential mitigation in the form of in-situ permeable bioreactors (PBR), taking current pilot scale studies up to sub-catchment scale. This is not the same as a constructed wetland, and is aimed specifically at denitrifying groundwater nitrate mass fluxes. PBRs need the knowledge of the nutrient mass fluxes to be capable of scale benefits to water quality. •The above options can be examined to determine the economics of mitigation versus alternatives such as herd homes, destocking and the like.
Theme 4 **Developing the decision support tools that are based closely on the biophysical reality and which are trusted by land users, iwi, communities, and regulators.**	
Importance to New Zealand	To manage our water more effectively for multiple values requires better combined water mass and nutrient mass flux models based on better data. This is important because land users require trusted real time water management information at a sub-catchment scale. Current models do not have all the data and consequently have a degree of uncertainty. New regional plans rely on nutrient budget models to assess nutrient losses to groundwater, despite these tools are being asked to do more that they were designed for. Farmers are concerned and are asking for real-time measurement. The cost/benefit of a sensor on every paddock is prohibitive, but a deployment of more sensors specifically designed for groundwater and nutrient fluxes has potential to improve the models in terms of trust and utility. User uptake is important, hence the proposal to engage users in the design of this National Challenge. This is a key message from the Land & Water Forum collaborative process. Integrating the novel sensor arrays' data feeds with regional GIS and land users' data into combined hydrological plus nutrient models would allow stakeholders to manage water resources to both improve water reliability and to comply with water quality limits. The human interface needs to generate physical actions which contribute to economic and environmental goals. The ideal situation is a model that is trusted by land users and regulators alike to which all stakeholder groups contribute data. Trust is achieved when all stakeholders believe that the model represents the real world.
Research components	•Economic analysis of ecosystem services to assign value to the intrinsic natural capital of the potential denitrifying capacity of groundwater and surface water systems. This builds to decisions about options such as mitigation technologies. •In collaboration with regulators land users, iwi and agronomists, develop specifications for tools and model that are 'fit-for-purpose' and align with integrated catchment, water reliability, land use economics and kaitiaki needs. •Develop and integrate socio- economic capability into these biophysical models and link them to user defined decision support tools to provide a near real-time 'dashboard' that enables catchments (irrigators, iwi, hydro, regulators) to manage

	catchments to meet the targets set by regional water plans. •We propose that Matauranga Maori is integrated into this challenge, not as an add-on. Concepts such as Mana Atua/Mana Tangata can guide the development of DSS and can influence the outputs of models themselves.
Research Gaps and Opportunities	• To ensure that there are productivity gains to enable regional councils and land users to adopt this improvement in data acquisition. • Integrating this data into combined nutrient mass flux models. • Developing near real-time DSS incorporating GIS, land use, metered water takes, and climate forecast data to create useful DSS with predictive capability. • Ensuring fit for purpose outputs by engaging stakeholders in the design and implementation phases of the project.
Comments	It is widely acknowledged that using our water for economic growth through agriculture can offer substantial economic benefits in the order of billions in exports dollars. The twin constraints to using more water on our limited land are water reliability and environmental water quality. They are often directly linked. Either way, water quality is the ultimate constraint. Irrigable land in some catchments is constrained not by water quantity but water quality. Nitrates in groundwater are the subject of considerable debate in every intensively farmed region. Reducing nitrate losses also makes good farm economics. • Waikato – a long term clean-up plan is underway. • Hawkes Bay – the Ruataniwha scheme has risk around water quality • Manawatu – the One Plan decision has highlighted water quality as a severe constraint to some practices. • Wairarapa – similar concerns. • Hurunui-Waiau – a proposed water storage scheme is already meeting future water quality constraints. • Canterbury Plains – water quality is an issue in all catchments. • Otago – water quality is a constraint in some catchments. • Southland – water quality is already a limiting factor in the Waituna catchment. Irrigable land in Canterbury alone is 350,000 Ha. At $8000/ Ha increased production, that is $2.8 billion pa. Nationally this figure doubles. Water quality issues must be addressed simultaneously with water storage and on-farm management practices. Our National Science Challenge is to provide the science, technology, models, and user decision support tools to enable our catchment communities to understand natural capital, nutrient fluxes, and manage water for sustainable production.

Entry ID	395
The Water Challenge	
Summary	Meeting the growing demand for water for personal, agricultural and industrial use and improving water efficiency and recycling. At the same time encouraging water quality, lower energy use, improved waste recycling, carbon footprint reduction and minimising environmental impact of water supply manipulation. It is also important develop measures to secure talented chemical engineers in the water sector in order to maintain progress in all parts of the water economy
Theme 1 **Increased demand from people, agriculture and industry**	
Importance to New Zealand	Water demand is not confined to any one sector. However, provision of adequate supplies to the world's population for drinking, cooking, sanitation and personal hygiene must be the top priority. Current trends suggest that the demand for drinking water may double by 2025 and this has enormous implications for humanity. At the same time, agricultural and industrial water demand is increasing, particularly in the rapidly industrialising nations. Climate change impacts, including severe storms, drought and rising sea levels bring additional threats to security of supply. Water treatment technologies can be energy intensive and the energy footprint in water is substantial. The challenge is a complex one, demanding a difficult mix of political intervention, new technology, improved water conservation and distribution, technical and engineering skills and better public education. A chemical engineering approach, based on systems thinking is required.
Research components	Improving process 'water efficiency': in a difficult financial climate, viable process economics is a key concern across the chemistry using industries. IChemE reasserts that this goal should not be pursued at the expense of the other components of the triple bottom line and environmental and social concerns, including process safety, cannot be ignored. Improved use and re-use of water, which sees widespread use as a coolant, solvent and adsorbent in industrial processes, will have a positive impact on profitability whilst at the same time easing the pressure on supplies and reducing the energy required for water processing and distribution. A renewed focus on efficiency and demand optimisation is needed in both the developed and emerging economies. The concept of virtual (or embedded) water in food products and consumer durables must be afforded greater prominence. IChemE will continue to encourage support for innovative R&D in products and processes that improve water efficiency and reuse, alongside appropriate regulation that will deliver a better balance between the needs for water quality, lower energy use, improved waste recycling and carbon footprint reduction.
Theme 2 **Environmental Impact of water supply manipulation**	
Importance	Across the globe, over 250 river basins are shared by two or more countries,

to New Zealand	mostly without adequate legal or institutional arrangements. Extensive river diversion in some countries has resulted in restricted water supplies in neighbouring nations. Damming for irrigation and the consequent water run-off is increasing salinity levels and algal bloom. Securing adequate water supplies is a priority for all nations but the geopolitical consequences can be severe; however, many water treatment technologies are energy intensive and this works against the drive for a low carbon economy. Chemical engineers must support efforts to minimise environmental impacts and mitigate the adverse effects of watercourse diversion.
Research components	Irrigation and management systems Governments world-wide must be urged to take a stronger line in water management, using regulation where appropriate, to conserve water supply and rehabilitate badly disrupted ecosystems. The factors influencing the availability and cost of water need to be better understood, enabling more sustainable strategic decision making. This does not always require heavy capital investment in new infrastructure and technology, rather the management and control of distribution systems can be improved by the application of process audit, systems thinking and better process control to ensure optimal efficiency in both water and energy use.
Theme 3 **Water recycling**	
Importance to New Zealand	Recycled, reused or reclaimed water is water that is used more than once before it passes back into the natural water cycle. Water recycling sees the reuse of treated wastewater for irrigation, industrial processes, toilet flushing and ground water recharge. A step change in water recycling is required but meeting national targets is proving difficult, even in countries where relieving water stress is a political priority. For example, Australia is unlikely to meet its 30% water recycling target by 2015. The situation is improving in Singapore where a 7,000km drainage network, which directs rainwater into 15 reservoirs and four plants that recycle water from sewerage using membrane technology can now meet 30% of the total water requirement with recycled water, dubbed ‘NEWater’. Petroleum refiners, including Exxon Mobil and SRC at the Jurong Island complex are adding to the demand for recycled water. Industrial process wastewater streams often contain recoverable metals, nutrients and calorific value. Recovery is becoming economically viable as wastewater treatment costs increase. Chemical and process engineers can deploy their fundamental understanding of unit operations to improve water reuse across a wide range of industrial and domestic processes.
Research components	Water treatment technology: Bacteria, protozoa and viruses are common in untreated water supplies along with chemicals from pesticides, urban runoff, industrial discharges and inadequately treated wastewater. Public concern over the environmental impact of residual active ingredients from pharma and personal care products has increased. The removal of such contaminants, whilst commonplace in the developed economies, is energy intensive with high operation and maintenance requirements and tends to be geared primarily towards the

	protection of the environment, rather than human health. Large volumes of sludge are also generated. Newer technologies including membrane bioreactors, which can deal with stringent purity limits, are now attracting much interest. IChemE supports the development of a hierarchy of sustainable water treatment technologies and encourages further R&D with a strong international perspective and a focus on energy optimisation, carbon neutral/carbon negative processes and passive treatment technologies.
Theme 4 **Skills and research**	
Importance to New Zealand	Skilled chemical and process engineers are needed to secure and maintain progress in all parts of the water economy. IChemE Salary Survey data consistently reveals that the salaries paid to chemical engineers in the water sector lag behind those in the oil and gas, petrochemicals and pharma sectors. This trend may be starving the water industry of top quality talent. Competent professional chemical engineers are in high demand and specific measures may be needed to secure the talent pipeline in the water sector. Regulatory frameworks often skew the research agenda towards wastewater treatment rather than step change innovation in water conservation, supply and reuse.
Research components	Wastewater valorisation Reduction; reuse and recycling options must take priority in any water waste strategy. Metals and other valuable materials can be recovered from process waste streams. Sewage streams are rich in nutrients and potential feedstocks for algal bioreactors, which can capture CO_2 and produce biofuels. However, the applicability of novel technologies is highly dependent on the quality and consistency of the waste stream and cost effectiveness. Chemical engineers must engage with emerging thinking on wastewater management and contribute to strategies that explore ways of optimizing the use and/or reuse of waste streams. Effective risk assessment is paramount, as is the need for early public engagement.
Research Gaps and Opportunities	More than a billion people have inadequate access to safe water, with less than 10% of the global population receiving a treated supply. Urbanisation and increased demand from agriculture and industry is making matters worse. Desertification, salination and pollution are increasing as a result of many complex and interrelated factors including over-extraction and large scale diversion projects. The roadmap calls upon governments and policy makers to develop sustainable regional water management strategies based on a better understanding of the factors influencing cost and availability. Technological advances are needed to secure to sustainable water supplies. Research priorities should include water purification, treatment, and sewage sludge disposal. Chemical engineers can help industry to design and implement processes that reduce water use; however, appropriate regulation is needed to support sustainable water supply and wastewater disposal. Efforts must be made to minimise demand and improve the treatment of sewage sludge Universal water metering is a desirable goal but this must be supported by appropriate pricing mechanisms and public education to encourage more sustainable water use.

Comments	see http://www.icheme.org/media_centre/technical_strategy.aspx

Entry ID	**420**
Using science to inform the development of resilience and sustainable water infra-structure for the 22nd century	
Summary	The goal is more efficient water management in New Zealand. Themes include using science to explore the biophysical, social, cultural, health and economic risk and benefit for alternative uses of waste-water and waste water solids, closing the gap between water management research and its applications in decision making
Theme 2 **The primary goal is to use science to explore the biophysical, social, cultural, health and economic risk and benefit for alternative uses of waste-water and waste water solids, including water reuse from New Zealand's single largest waste stream**	
Importance to New Zealand	Critical infrastructure such as waste-water and drinking-water is a prerequisite for a modern society to function. Providing these services is expensive in terms of both natural and economic capital. 9% of water allocated in New Zealand is used for drinking-water supplies resulting in 1.5 billion litres per day of domestic waste-water being discharged into the environment. Its provision accounts for 37% of local government energy consumption, costs $600 million a year to run and the infrastructure has a replacement value of $23 billion. With the anticipated growth and redistribution of the New Zealand population, as well as improved environmental and health standards and expectations, these costs will increase unless new solutions, which are both technically feasible and socially acceptable, are developed and implemented. The technical approach to drinking and waste water management reflects a very successful 19th century approach to public health. There is a recognition that the water systems and management has to change. However, there are multiple barriers to evolving water management for the 21 and 22nd centuries which require New Zealand-relevant scientific solutions. The Canterbury earthquake sequence demonstrated the vulnerability of our water reticulation systems to a natural disaster. In some areas industrial and residential development is being constrained by provision and management of the "Three Waters" (waste-, storm- and drinking-water). Where infrastructure cannot extend to provide access to reticulated water services, activities rely on on-site systems. Much of our tourism is served principally by on-site systems and carries the greatest risk and frequency of exposure to biological hazards arising from waste-water.
Research components	Though research into public health and water management has occurred the current level of knowledge is not sufficient to address the future challenges. Research is needed into the: biophysical, social, cultural, health and economic risks and benefits for alternative uses of waste-water and waste water solids. It will require skills in public health, engineering, sociology, behavioural economics,

	participatory action research, sociology and integrative modelling
Theme 3 **The primary goal of this research is to close the gap between producing research outputs and use of the outputs in water and waste decision making and practice, by developing an understanding of the current roles of research and processes for its uptake, and by developing more effective and efficient roles and processes**	
Importance to New Zealand	There is growing awareness in all aspects of water management that research is not delivering to its potential. This is not a phenomenon unique to water management; similar conclusions have been drawn from the fields of management, agriculture, ICT and planning to mention a few. The situation is frustrating for researchers, research users and research funders. Though claims have been made on what the problems might be and how to solve these, on closer inspection the evidence base to support the claims is weak, often anecdotal, based on personal reflections and the findings are not generalizable. Research should be capable of providing critical information for describing the current state of water management in New Zealand and for describing options of possible future states. Once decisions have been made about the most desirable future state, research has a role in providing information to support implementation decisions, and to monitor progress and evaluation of impacts. A breakthrough in the efficacy of provision and use of critical information obtained through research for water management decisions would transform the New Zealand water sector, the wider economy and the broader service sector.
Research components	Closing the gap will require researchers and research users to work together, combining multiple disciplines with theory and practice. It will require hypothesis generation, data collection, theory generation and testing using knowledge from: • policy and decision making • traditional biophysical, social science and engineering • service science and complexity including the coupling of natural and human systems.
Research Gaps and Opportunities	Researchers in the field of water management are tackling the problem of research uptake; however, this is not being done in a systematic way and is not the primary focus of their research. The problem is often addressed as an extension to the main biophysical research, treated as a knowledge transfer problem. When research is used to inform practice, it is usually based on extrapolating the findings of studies beyond what would be regarded by the researcher as reasonable and ignoring the context or methodological limitations of the original studies. Though much work has recently taken place in Europe into the gap between producing research outputs and use of the outputs, the small scale of New Zealand provides a perfect decision making and science systems environment to develop and test a number of theories. There are opportunities to produce agile solutions which benefit New Zealand rather than adopting the Leviathan models being developed elsewhere. Management of drinking and waste waters involves the sacred and the profane,

	human values and our relationship to nature, policy, governance and technical issues. Research has been successful in viewing drinking and waste water management as a technical engineering challenge. Significant research, most recently in the field of modelling, has been carried out on this aspect of drinking and waste water management. Whilst valuable and in many cases highly successful, it has tended to focus on optimising the performance of current systems. This approach has been less successful in developing integrated solutions, in part due to the absence of robust biophysical data to inform the models around the alternative approaches to waste management, but also because these approaches have been unable to include the human dimension of water and waste management in anything but a superficial manner. Unlike many other waste streams, there are good prospects for alternative, beneficial end-use options for waste water and waste water solids due to the high levels of nutrients that they contain. Though water wastes also contain a complex cocktail of contaminants, some of which e.g. pharmaceutical and body care products, are unique to this waste stream. As in other countries, current risk assessment procedures in New Zealand are reductionist, and focus on the fate and effects of individual chemicals not taking into account the additive effects of multiple hazards. An integrated research approach to waste management presents an opportunity for developing knowledge and solutions around alternative use of waste-water, reducing the demand for water in New Zealand's unique social, cultural and physical environment.

Entry ID	**437**
Maximising the benefits of the water which falls on New Zealand	
Summary	This challenge proposes a research programme into maximising water retention to make more water available for hydro-generation, irrigation and ecology, e.g. through the introduction of a Canadian beaver population into New Zealand waterways to create dams in upstream catchment areas.

Entry ID	**448**
Increasing the productivity of our land whilst improving the quality of our lakes and rivers, and meeting social and recreational needs	
Summary	The goal of this challenge is to increase the productivity of land while improving water quality and meeting social needs, with a focus on New Zealand's forest landscape. Specific research components include exploiting forests' potential to protect land and waterways, harvesting materials in native forests for new products, using biomass in New Zealand forests to solve issues like energy supply

	and effects of climate change.
Theme 1 **Realising the potential of New Zealand's forest**	
Importance to New Zealand	The goal is making our forest landscape work better for New Zealand, contributing to our economy and quality of life whilst simultaneously ensuring sustainability and minimal impact on the resource. New Zealand is a very forested land. Most of this land (both native and exotic species) is in conservation estate, but could be "sustainably exploited" to a greater degree. MPI forecasts for plantation forests indicate that a large area of forest planted in the mid-1990s will mature in 8-10 years, increasing wood supply from 26 million m^3/yr to approx 36 million m^3/yr for a period of 10 years. This raises several questions: • What will we do with this extra wood? • Why would investors engage when the additional supply is time-limited? • How can we sustain supply at this higher level? Around 12 million m^3/yr of New Zealand's wood supply is currently exported as unprocessed logs export markets. Investment in cost-efficient, small, distributed processing technologies could allow a shift toward export of higher value product. Many of New Zealand's new plantation forests are in remote regions that lack infrastructure and processing facilities. Cost-efficient distributed pre-processing could avoid the unnecessary haulage of 'waste' to processing sites, further increasing the value of our resource. The majority of New Zealand's forest activity involves radiate pine. Given the impact of Psa on the kiwi-fruit industry, work should be done now to explore the viability of alternative species in the event of a catastrophic event affecting radiate pine. Significant tracts of marginal land could be planted with higher revenue-generating non-pine species whilst simultaneously rejuvenating the land.
Research components	What new businesses or enterprises could/should be created off the back of our forested landscapes? Can we make more use of the bounty of raw materials found in trees to provide alternatives to non-sustainable industrial materials, medicines or even food production? Are there materials in native forests that might be harvested as new products? What technologies could be developed to more efficiently process increased wood production with minimal environmental impact and at lower cost? Is there a potential role for trees in land remediation beyond nitrogen fixation and phosphorus removal?

	How might GE be used to improve the genetic viability of other species in the event that a catastrophic event wiped out radiata pine in NZ? How can we effectively inform the public about the use and benefits of GE? How can the enormous biomass stored in NZ forests be used usefully and sustainably to solve looming issues for NZ, like energy supply, effects of climate change, regional development? What opportunities would be afforded to New Zealand from the rejuvenation of species such as rimu and beech? What contribution might native forests make with respect to water quality? Is there potential to identify more added value products from native fauna? • Exploit their ability to protect land and waterways • Strengthen indigenous forests for product, social and cultural values • Realise the benefits from exploiting ecosystem services • Mitigate risk through exploration of alternative species
Comments	We understand that some approaches might identify themes regarding Resource Management and Governance; Resource Efficiency; Realising Wealth from Resources; etc and understand the value of this horizontal approach across the challenge. However, we believe it is also necessary to consider the scope of the challenge vertically, in relation to specific resources. We propose that the final version of this challenge description should address both horizontal and vertical concerns in a holistic manner. This thematic description aims to outline opportunities in respect of our forest landscape. We would expect that similar consideration be given (by other organisations) to science excellence in the areas of agricultural and water resources, and that these details should supplement the horizontal approach that advocated to avoid duplication of effort across the challenge.

Entry ID	**459**
Healthy and Secure Freshwaters in a Growing Economy. Goal: To manage New Zealand's freshwater resources so that their health and life-supporting capacity is improved and economic benefits from water use are maximised	
Summary	The goal is optimal management of New Zealand's water resources. Themes include understanding and optimising use of water resources by developing forecasting methods for water quantity and quality, developing techniques to enhance the health of freshwater ecosystems and corresponding economic, environmental, cultural and social benefits, developing water infrastructure that is more secure, effective, integrated and cost-effective, empowering Māori participation in the management of New Zealand's freshwater resource, preserving rangatiratanga, kaitiakitanga and mana of waterways

Theme 1 **Optimal use of water resources** **Goal: To be optimally allocate both surface and groundwater resources in a manner that integrates multiple-use decision-making and planning, and maintains the health of our waterways**	
Importance to New Zealand	New Zealand's freshwater resources support a wide range of users, including sectors that are key contributors to our economy. These include the primary production sector (e.g., irrigation, livestock water), energy sector (e.g., hydro-power generation, geothermal production), industrial processes, communities (e.g., for drinking water and biodiversity), recreation (e.g., fishing), tourism (e.g., iconic lakes and rivers and water-centric landscapes), and resource users (e.g., gravel extraction). They are critically important to Māori (e.g., taonga species, mahinga kai resources, spiritual values) and are intimately connected to New Zealand's national identity (e.g., clean, green image) and sense of place. Freshwaters can be a significant hazard when rivers flood, but nevertheless underpin the entirety of society and the economy. This theme embodies understanding of water quantity, how it is distributed in time and space, how water resources will change as a result of environmental change, and demographic and economic pressures. It focuses on how to maximise the quantity of water available for multiple uses while maintaining ecosystem health of natural freshwater systems.
Research components	Research components required to optimise use of water resources include: • Developing methods and models for forecasting changes in water quantity due to direct human activities at catchment scales. • Predicting natural changes and variability in the hydrological cycle to quantify groundwater and surface water resources. This is essential for maximising levels of water allocation for multiple uses (e.g., irrigation, energy generation etc). • Determining the relationship between water quantity and the levels of key contaminants (e.g., nutrients, sediment, pathogens) in surface water and groundwater that are applicable to given water bodies and catchments. This is necessary for the development of water allocation strategies that limit or reduce contaminant levels. • Determining and mitigating the impacts of hydro and geothermal energy generation while maximising energy production.
Theme 2 **To ensure that the ecosystem services of New Zealand's freshwaters are maintained and enhanced to ensure that water resources are of high quality and support economic growth and social values**	
Importance to New Zealand	Despite this importance healthy ecosystems, many of New Zealand's waters are threatened, are degrading in quality, and are already, or are becoming, not fit-for-purpose (Land and Water Forum's 1st Report September 2010). There is a significant cost to the nation in lost economic opportunity, degraded social and cultural outcomes, and loss of biodiversity. Recognition of these problems is reflected in the increasing effort placed on the establishment of mechanisms for

	investigating our management processes, for garnering community ideas and perceptions, and for developing policy and regulation. It is also reflected in the growing efforts to restore the chemical, physical and biological integrity of degraded water bodies in New Zealand (e.g., Lake Taupo, Waikato River, Te Waihora). Strong and healthy ecosystems yield substantial economic, environmental, cultural and social benefits that include enhanced biodiversity, enhanced health and well-being of iwi, increase in recreational value, increased resource recovery, and maintenance of a competitive market advantage (clean green image). This theme will contribute to meeting New Zealand's commitments to international biodiversity initiatives. In addition, freshwater ecosystems support species that are iconic to Māori and to the wider New Zealand population (e.g., eels, whitebait) that are an indicator of wider health of the environment. A critical component is the need to track progress, including the need to measure trends, monitor systems, report environmental state, and analyse the ecosystem consequences of actions associated with water use and allocation.
Research components	Development of management tools and techniques for maintaining, enhancing and, where necessary, restoring, the health of freshwater ecosystems will include science to: • Measurement and monitoring networks to determine the health of our water bodies to aid reporting, management and restoration. • Determine the activity levels that will support limit setting to decrease cumulative impacts on freshwater ecosystems. This includes allocation limits for sustaining freshwater ecosystems. • Develop new models to predict the effects of global change, especially climate, on freshwater ecosystems. This will also require linking such models with those associated with water use impacts on ecosystems. • Develop methods for the control or eradication of freshwater invasive species (e.g., weeds, pest fish, didymo). • Provide new techniques for information, biodiversity and biosecurity management, including ecosystem restoration. This research supports iwi and community aspirations to restore degraded waterways.
Theme 3 **Secure and effective water infrastructure** **Goal: To ensure that New Zealand has critical water infrastructure that has an improved contribution to economic value, is environmentally optimised, and socially acceptable**	
Importance to New Zealand	New Zealand needs infrastructure for water use that is capable of producing, storing and delivering safe and high-quality water fit for the desired purpose, while providing transport and effective use-specific treatment of wastewater and storm water. Freshwater is extracted, diverted or stored to support economic activities, prevent damage (e.g., urban storm water infrastructure, flood mitigation) and provide water to communities. It is discharged back, directly or indirectly, once used. The infrastructure associated with extraction, diversion, storage and discharge must

	be secure, robust and cost-effective and meet the purpose for which it was designed. There is also an increasing demand for "green" infrastructure, which includes concepts of water and energy conservation and resource recovery. At present New Zealand's infrastructure is commonly based on old, often inadequate, technologies, with a shift in practice required to improve the resilience of communities and protect our "clean green" image (e.g., PCE, 2000, 2001). This theme strongly contributes to the National Infrastructure Plan (2011), which indicates that New Zealand needs a more integrated and cost-effective approach to treat water catchments, supply, wastewater and storm water to ensure the growth and wellbeing of communities.
Research components	Research that can contribute to the entire scope of infrastructure processes includes: • Innovative infrastructure design, best management practices for infrastructure systems. • Optimised and effective water and wastewater treatment processes. • Hydraulic engineering; planning and engineering toolboxes. • Life-cycle analysis. • Integration of infrastructure into wider catchment management and land-use practices (sustainable agriculture). • Flood and hazard management. • Energy generation. Research will need to inform innovative technologies for water systems that combine multiple outcomes (e.g., pollution prevention, resource recovery, water re-use, co-benefit generation), with significant economic advantages (e.g., low capital and operational costs).
Theme 4 **Empowerment of Māori** **Goal: To empower Māori participation in the management of New Zealand's freshwater resources, to preserve the mana of waterways, rangatiratanga and kaitiakitanga**	
Importance to New Zealand	This theme recognises the necessity of providing for iwi rights and interests in freshwater, including rights to access water for customary and commercial use. Water is integral to Māori cultural identity in many ways including where there is a significant interest in traditional food and resources, and the places where those resources are obtained. In addition, for water management systems and processes to be effective and stable, iwi rights and interests need to be resolved (Land and Water Forum Reports 1-3).
Research components	Research on management techniques that incorporate matauranga Māori into the use of water resources will include: • Development of cultural health indices for freshwater and their incorporation into freshwater management practices. • Protection, enhancement and restoration of mahinga kai resources within national freshwater lakes, rivers and estuaries. • Quantification of water resources to aid development of Māori assets. • Planning tools and process that recognise Māori values in freshwater.

Research Gaps and Opportunities	Opportunities: • New Zealand's highly variable climate and physiography provide considerable challenges to predictions of water resources that will be needed for water management , land use management, infrastructure, water related hazards and economic development. • Collaborative processes for solving freshwater issues are increasing. These will require a combination of social, economic political and biophysical sciences in a way not yet fully contemplated. New Zealanders could be international leaders in this area. • Cultural recognition of freshwaters and development underpinned by the Treaty of Waitangi will cross disciplinary divides and allow for further development of the Māori economy. • Land-use impacts on surface and groundwater combined with our international brand will force the need for innovative mitigations, farming practices, novel infrastructures and, in urban environments, water treatment. These innovations will enhance economic and social outcomes related to water. • Development of predictive models of water resources underpinned by improved data collection and dissemination will improve forecasting and more efficient economic use of the land with increasing certainty. Gaps: • Integrated studies of the whole hydrological cycle (climate, surface and groundwater distributed across the landscape in rivers, lakes, aquifers and wetlands) are urgently needed to allow holistic water resource planning and policy implementation. • Ecosystem services that freshwaters provide (including maintenance of many estuarine and coastal systems as well as groundwater ecosystems) are not well understood, but their identification and quantification will provide better conservation, recreation and enhancement of the nation's freshwaters. • Limit setting as directed in the National Policy Statement for Freshwater Management requires more information on limiting factors, thresholds for change and economic, social and biophysical science integration to ensure this national policy is implemented effectively. • The science of ecosystem and biodiversity restoration needs to develop in concert with social and economic drivers to improve New Zealand's waters for tourism, the conservation estate, cultural values and our international brand for economic development, including exports. • A particular challenge will be the need to introduce robust science to the collaborative processes that we see as underpinning the future of water resource management in New Zealand.
Comments	In order to meet this Challenge for New Zealand, four interlinked outcomes are needed—(i) water use needs to be optimised (both quality and quantity) (ii), freshwater ecosystems (surface and groundwater) need to be in a healthy state with demonstrable life supporting capacity; (iii) water infrastructure needs to be secure and effective, and (iv) Māori need to be empowered in their responsibilities (taonga species, kaitiakitanga etc.). Since April 2011 the Government has made significant moves that underscore the

	national importance of freshwater: • Gazetted the National Policy Statement for Freshwater Management. • Established the Irrigation Acceleration Fund. • Established the Fresh Start for Freshwater Clean Up Fund - funding at several sites has begun. • Received the 2nd and 3rd Reports of the Land and Water Forum. • Initiated a process for establishing a framework for national objectives for water quality. • Established a Water Directorate of officials centred at the Ministry for the Environment. It is worth considering that 87% of New Zealanders live in cities and these have the lowest freshwater quality of any part of New Zealand and that land-use intensification, while a significant contributor to water quantity and quality issues in New Zealand, is by no means the only one. It is also notable that freshwaters directly affect coastal and estuarine ecosystems and developments (aquaculture) and the links to the wealth of our oceans are direct in many places. New Zealand has the science infrastructure and skills to advance the goal and themes of this National Science Challenge. Infrastructure includes high performing analytical laboratories, stable isotope facilities, field equipment including access to new remote sensing technologies, experienced field dive teams located throughout New Zealand, high performance computing and databases (GNS Science, NIWA, universities). Development of this National Science Challenge has been undertaken collaboratively by NIWA, GNS Science and Landcare.

Entry ID	**486**
To improve water quality in lakes and streams and to enable farm production to increase	
Summary	The goal is to improve water quality in lakes and streams while optimising farm productivity. Themes include Measurement of nutrient outflows from farms to improve the accuracy and reduce the cost of measuring or modelling outflow of nutrient from farms into underground or surface waters. Modelling of water quality to improve the accuracy of measuring and modelling water quality in lakes and rivers. Incorporate new technologies in catchment modelling to integrate GIS, LIDAR, remote sensing and other tools so as to create whole-catchment models that better optimise farm productivity and water quality. Farming systems to reduce nutrient outflows and increase production to develop, test and improve farming systems (including farm infrastructure) that reduce nutrient outflows while sustaining or increasing production. Better biological or chemical modifiers (soil conditioners etc.) to improve and develop biological or chemical means of reducing outflow of nutrients from farms, by modifying pasture, feeds, animals (or their biota), or soils. Treatment of streams and lakes to develop and improve methods of improving water quality through in-lake and in-

	stream measures.

3 Increasing Production

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 3: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
152	Sustainable vegetable growing, producing better yields and quality on less land	1. Smart management strategies and tools so vegetable crops achieve >90% of potential yield, sustainably, with less or equal leakage of nutrients to surrounding land or water
157	Significantly grow New Zealand's agricultural production base while preserving the integrity of its environment and its international "clean and green" brand	1. Develop the world's best tools and information systems for managing nutrient discharges from agricultural enterprises 2. Manage the risks to New Zealand's agricultural sector of soil contaminants associated with agri-nutrient use 3. Establish a globally recognised nutrient management quality assurance system
179	Efficient sustainable use of New Zealand agricultural land	1. To improve the efficiency and sustainability of New Zealand farming systems
182	Agriculture including dairy that is sustainable competitively and responsibly. Competitive means profitable for the longer term and responsible includes environmental stewardship and high standards in employment and farming practices	1. Increase on-farm profit through greater productivity 2. Preserve the natural heritage of New Zealand through proactive environmental stewardship and wise use of natural resources 3. Develop highly skilled people throughout the industry 4. Enhance the assurance levels of New Zealand's biosecurity, food security and standards of animal health, welfare and well-being
265	Sustainable agriculture: Ensuring food production for the next 1000 years	1. Improving land and water sustainability on-farm 2. Growing more from less 3. Future proofing New Zealand agriculture
344	To maximise value for New Zealand from low value biomass. Use fractionation technologies to produce biomaterials, biofuels and stockfeed. Add new exports and reduce imports. Added value opportunities exist to turn 5c/kg into $5/kg.	1. Identify, develop and optimise key technologies for optimal fractionation technologies linked to specific biomass sources that ensure highest value natural compounds are produced 2. Evaluate and prioritise biomass fractionation products using scale, yield, quality and marketability as key criteria 3. Explore value add opportunities to substitute green and locally sourced compounds for imported fossil fuel-derived and possibly more harmful compounds

Entry Id	Challenge	Themes
		4. Explore the opportunities to develop and establish dedicated crops for biomaterials production
380	Engaging entrepreneurs & the SME sector in 'growing the agrifood economy'	1. Connecting SMEs to the science providers 2. Understanding the national innovation infrastructure in New Zealand 3. Unlocking Māori economic potential
429	Sustainably profitable primary industries	1. globalising the primary industries business model: value chain integration and taking farming to the world] 2. increasing productivity in primary production systems 3. future proofing our primary industries 4. sustainable use of natural resources

Entry ID	152
Sustainable vegetable growing, producing better yields and quality on less land	
Summary	This challenge proposes a research programme into smart management strategies and tools to produce more and better vegetable crop yield on less land while reducing nutrient leakage into ground and surface waters
Theme 1 **Smart management strategies and tools so vegetable crops achieve >90% of potential yield, sustainably, with less or equal leakage of nutrients to surrounding land or water**	
Importance to New Zealand	Intensification of land use to meet export demands can affect the quality of the land and lead to nutrient leakage into ground and surface waters. New smart management strategies and tools would produce more and better yields on less land while reducing such leakage to natural background levels. This would benefit: (a) Export earnings, as we can defend New Zealand's green credentials in overseas markets for our produce; (b) The environment and hence tourism and our quality of life; (c) The profitability of horticulture - less land, managed better, affords economies and a degree of control that we lack now; (d) New Zealand's ability to respond rapidly to changes in marketplace requirements for food quality and environmental accreditation.
Research components	1. Understanding the background natural rates of nutrient leakage into waterways; 2. Developing crop varieties that produce better yields using less fertiliser and water; 3. Developing fertilizer formulations and application techniques that increase the efficiency of plant uptake; 4. Designing land and crop management schemes to minimise the amount of

	tillage required and the amount of down-time between crops; 5. Design and testing of crop rotation schemes to ensure a profitable succession of compatible crops that minimise the need for external inputs of nutrients; 6. Design and testing of machinery needed for the new land management methods; 7. Validation of schemes, including monitoring of offsite nutrient losses, establishment of potential yields, and assessing changes in enterprise profitability and changes in natural capital of the affected landscapes; 8. Economic and behavioural studies to ensure that progress made in (1) - (7) is adopted rapidly and effectively by growers while being understood and accepted by exporters and their markets as well as the general community.
Research Gaps and Opportunities	1. Understanding the best ways to develop radically new land management systems with the industry involved from start to finish (so that adoption is very rapid); 2. Understanding the dynamics of nutrient uptake, storage and use within crops so that yield and quality remain as close to potential as possible; 3. Defining the optimal conditions for early establishment of crops so that the genetic potential of the seed is attained;
Comments	A very large stretch component of this would be getting a way for engineers, and soil and plant scientists, to work directly in with industry leaders, marketers and engineers so that all are empowered to focus most effectively. The logistics would be crucial and would perhaps be best controlled by a virtual company created to drive the research and pioneer its applications.

Entry ID	**157**
Significantly grow New Zealand's agricultural production base while preserving the integrity of its environment and its international "clean and green" brand	
Summary	The goal of this proposal is to significantly grow New Zealand's agricultural production base while preserving the integrity of its environment and its international "clean and green" brand. Themes include: 1. Develop the world's best tools and information systems for managing nutrient discharges from agricultural enterprises - increase the power and accuracy of OVERSEER across the diversity and complexity of farming systems in New Zealand and link it to a suite of other agricultural models (eg, economic models, etc.), map the properties of New Zealand agricultural soils in a nationally consistent and comprehensive manner, establish and protect through covenant nationally significant sites for long term research trials 2. Manage the risks to New Zealand's agricultural sector of soil contaminants

	associated with agri-nutrient use - collection, collation and mapping of detailed information on Cd and F levels in New Zealand soils etc.
Theme 1 **Develop the world's best tools and information systems for managing nutrient discharges from agricultural enterprises**	
Importance to New Zealand	The response in most other countries when their agricultural sectors face similar environmental challenges as New Zealand is to reduce agricultural inputs such as fertiliser, feed supplements and stocking rates and thereby reduce production and economic return. New Zealand needs to find a better answer to this problem if it is to grow food and beverage exports to $58billion by 2025 within environmental limits. Rather than continue down the path of more and tougher regulations on farmers based around input controls like other countries have, it needs to manage nutrient outputs, ie, the level of nutrients "leaking" from farm systems and impacting the environment. This involves developing new and innovative tools for measuring and managing nutrient discharges which are underpinned by world class information systems.
Research components	A key component to developing an output based approach to growing agriculture within environmental limits is the development of modelling tools to estimate diffuse nutrient discharges from farming enterprises. Fortunately New Zealand already has the basis of an innovative nutrient management modelling tool – OVERSEER. This tool has been created through a partnership involving the fertiliser industry, MPI and AgResearch and it gives New Zealand a potentially significant economic advantage over other countries. What is needed now is to increase the power and accuracy of this tool across the diversity and complexity of farming systems in New Zealand and link it to a suite of other agricultural models (eg, economic models, catchment models) and information systems (eg, soil and climate databases). A second key component is to map the properties of New Zealand agricultural soils in a nationally consistent and comprehensive manner and at a resolution that will improve the accuracy of OVERSEER estimates. This is critical because nitrogen discharges are highly sensitive to soil type and properties. Landcare's existing S-map initiative provides the basis for this endeavour, but achievement of national coverage will require a concerted and co-ordinated national effort and the development and implementation of new soil mapping technologies. A third key component is the establishment and protection through covenant of nationally significant sites for long term research trials aimed at increasing agricultural production sustainably.
Theme 2 **Manage the risks to New Zealand's agricultural sector of soil contaminants associated with agri-nutrient use**	
Importance to New Zealand	There are some elements which occur naturally in the raw materials used in the manufacture of phosphate fertiliser, a mainstay of New Zealand agricultural productivity, which are not able to be partly or wholly removed from the finished product. These include cadmium, which poses a potential health risks if it enters the food chain in more than minimal amounts; and fluorine, which poses a long-

	term animal health challenge to New Zealand's grazing ruminants. The management of the accumulation of these elements in New Zealand soils is crucial to protecting human and animal health, continued market access of New Zealand farmed products, the premium enjoyed by New Zealand food products in some markets, the value of agricultural land, and the flexibility of our land use (eg, the ability to convert farm land into residential land without costly mitigation measures). Furthermore it will allow the continued long-term use of cost effective superphosphate fertiliser in New Zealand. This research theme is also vital for the effective delivery of the objectives of the Cadmium Management Group which is sponsored by MPI and MfE and involved a range of agricultural stakeholders.
Research components	Key research components include: • Collection, collation and mapping of detailed information on Cd and F levels in New Zealand soils • Collection of plant uptake data for Cd for a range of New Zealand vegetables and arable crops and F uptake data in livestock • Develop risk-based soil guideline values for Cd and F for the protection of soil productivity and value • Assess toxicity of Cd and F to soil organisms, including microbes, under New Zealand agricultural conditions • Develop Cd and F models for modelling the long-term accumulation of these elements in New Zealand soils under various conditions in a range of farming systems • Develop a range of cost effective mitigation technologies for managing soil Cd and F in areas where guideline values have been exceeded
Theme 3 **Establish a globally recognised nutrient management quality assurance system**	
Importance to New Zealand	Access of New Zealand farmed products into many high-value international markets is increasingly associated with the need to provide proof of low environmental impacts from the production of New Zealand's key agricultural products (eg, milk, meat, wool, kiwifruit). Most of these markets are developing eco-labelling of products or requiring suppliers to have an environmental reduction plan in place. This is occurring at both the national level and at the supermarket chain level. Proof of sustainable nutrient management practices is now being sought by some retailers and is a growing compliance issue. So far there has been very little development of nutrient management assurance programmes in New Zealand and what has been done is uncoordinated with the immediate potential for many different models and standards to be developed across many sectors resulting in inefficiencies and market confusion. Furthermore, there are no robust on farm monitoring and verification processes in place in New Zealand for nutrient use.
Research components	A key research component will be the development of nutrient management assurance standards though a collaboration involving industry groups, standard setting bodies, CRIs and universities. Specifically this will involve: • A consultation process covering processors, sector groups, farmers and marketing organisations to agree on the technical approach, data requirements, and agree on audit and data management approaches • Developing the basis of a life cycle assessment indicator reflecting potential impacts of nitrogen and phosphorus discharges from agricultural enterprises to waterways • Working with Standards New Zealand to develop a draft set of recognised standards for nutrient

	management assurance • Working with international standard setting groups and accreditation bodies to ensure acceptance and harmonisation of the New Zealand standards with international standards
Research Gaps and Opportunities	A key research gap is the development of innovative devices for the cost-effective direct measurement of diffuse discharges of nitrogen from agricultural enterprises. Direct measurement of nitrogen discharges is not presently economically feasible, costing hundreds of thousands of dollars per farm to establish the required lysimeter systems. Modelling of nitrogen discharges using OVERSEER can be done at marginal cost and is thus the method of choice at present. However, the accuracy of OVERSEER needs to be improved through obtaining many more direct measurements of nitrogen discharges across many different farming systems in order to better calibrate and validate the model. The development of such measurement devices will require collaboration between physicists, biologists, and agronomists and incorporate miniaturisation technologies. Another research gap is the development of devices that will allow farmers to access quickly information about their farms, such as soil properties and nutrient use, and that will provide advice on nutrient mitigation measures as they go about their business (eg, hand held devices supported by the cloud and broadband information services). New Zealand is fortunate to have two long-term agricultural research sites - Winchmore and Ballantrae - which have been in existence for 60 and 39 years, respectively. However, these sites need to be modernised and imbued with a new research vision so that they can contribute significantly to pertinent research on increasing agricultural production sustainably including irrigation scheduling, and water and nutrient use efficiency.
Comments	The success of this science challenge will contribute significantly to New Zealand being able to lift agricultural production significantly, meet its economic goals, protect its environment and avoid the imposition of the type of onerous input based regulatory controls that beset agriculture in most countries and have led to declining production, lack of innovation and an uncompetitive industry requiring subsidies to survive. The ultimate vision for this challenge is that New Zealand becomes an undisputed global agricultural powerhouse taking full advantage of its natural attributes to produce premium agricultural products with some of the lowest environmental footprints in the world.

Entry ID	**179**
Efficient sustainable use of New Zealand agricultural land	
Summary	This challenge proposes a research programme into improving the efficiency and sustainability of New Zealand farming systems through understanding regional soil, water and climatic conditions and assessing and implementing new technologies (e.g. germplasm and biotech solutions). No research themes provided.

Theme 1 To improve the efficiency and sustainability of New Zealand farming systems	
Importance to New Zealand	Geography provides New Zealand with a good temperate climate for agriculture. As a consequence it is New Zealand's primary industry. We should take advantage of this unique opportunity and use it as efficiently and wisely as possible
Research components	Understanding regional soil, water and climatic conditions Develop and Implement tools to measure current sustainability and efficiency, undertake a national survey Applied on Farm research to assess new technologies (including uptake of new germplasm and biotech solutions) Develop a professional body to raise farming standards across the board Support independent decision making tools and communication channels for farmers (e.g. refine Dairy New Zealand and Sheep and beef etc) Incentivise implementation of new technologies Develop better value capture chain especially of seed and sheep and beef production (e.g. support technologies and industries)
Research Gaps and Opportunities	Refocus the CRIs to undertake more focussed research (having come from a CRI I am aware of the waste and mistargeted research) and undertake basic pre-competitive research in key areas plus provision of independent advice innovation and uptake for the industry. Post competitive research by CRIs cause a conflict of interest. Incentivise applied research on farms to demonstrate advantages of new technologies. Re-evaluate the risk benefit equation of certain biosecurity and MPI practices on agriculture Research gap in whole-system analysis of farming practices right through to efficiency of the products use by the consumer (eg compare and evaluate niche products vs. standard including wastage %, for example organic products vs. conventional, standard milk vs. calcitrim etc

Entry ID	**182**
Agriculture including dairy that is sustainable competitively and responsibly. Competitive means profitable for the longer term and responsible includes environmental stewardship and high standards in employment and farming practices	
Summary	The goal is to promote profitability, sustainability and environmental responsibility in the New Zealand dairy industry. Themes include investing in productivity R&D to enable dairy farms to produce more from less land and increase profits, developing technologies and systems to enable dairy farms to use resources wisely and demonstrate environmental stewardship, increasing knowledge in areas essential to education and training in the dairy industry to develop highly skilled people industry-wide, increasing standards of animal welfare and protection against disease and pest incursion on dairy farms to protect New Zealand dairy industry's position in global markets

Theme 1 **Increase on-farm profit through greater productivity**	
Importance to New Zealand	Agriculture has contributed over 50% of the total merchandise exports since the early 1990's with dairy being the single largest export earning industry with 19-23% of export receipts from 2000 -2007 . Whilst the value of dairy exports was $5.9 billion in 2006/07, The 'New Zealandier' estimated that the total economic contribution of the industry to New Zealand was NZD$23.5 billion in that financial year. To continue to underpin the economy of New Zealand, the sector must significantly improve current practices to remain internationally competitive whilst reducing its impact on the environment - Profitable dairy farming is essential to the viability of the industry and its resilience, especially its ability to respond to challenges - Profitable dairy farming is also essential to exploring new options and investing in the future - Greater productivity means producing more from less, which drives New Zealand's competitive advantage versus other means of increasing profit -New Zealand must invest in productivity research and development to maintain and enhance its competitive advantage - Research and development pushes the boundaries beyond what can be normally achieved in the commercial farming context - It is important to create viable options for the future
Research components	Forage and alternative feed production, Forage value score development, animal breeding, phenotypes and genetics, farm systems research, precision agriculture, alternative options for production management, information management including modelling (e.g. animal and forage production, farm systems) - Development of industry levels systems in areas such as breeding worth, forage value, and knowledge for minimum standards in areas such as farm management, equipment supply, food safety, animal welfare and professional accreditation of industry and related personnel -It is important to create viable options for the future - what options are possible and viable for future dairying whilst addressing on-going profitability and the environmental footprint and potential capability and skill issues
Theme 2 **Preserve the natural heritage of New Zealand through proactive environmental stewardship and wise use of natural resources**	
Importance to New Zealand	New Zealand has a rich natural heritage and biodiversity that is highly valued - Dairy farmers what to leave their farms in better shape as a legacy to future generations -Dairy farmers want to be respected in their work and take pride in their contribution to New Zealand - A number of environmental issues face New Zealand (e.g. climate change, water quality) and solutions to these should be based on robust research and address/ optimise the four values in the RMA - economic, environment, culture and social
Research components	Development of solutions to enable wise use of resources and environmental stewardship including - systems management and modelling including economics and farm and catchment modelling - alternative systems for future dairy farming - precision agriculture - alternative and efficient resource use options e.g. sources

	of nitrogen, alternative feeds and forages and - innovative solutions to current and future issues related to dairy farming
Theme 3 **Develop highly skilled people throughout the industry**	
Importance to New Zealand	The Primary Industry including the dairy industry depends on the capability of people both on farm and in supporting roles (e.g. farm advisers and suppliers, policy makers in national and local government)
Research components	Consolidating and extending the body of knowledge through research in areas for example of farm management and systems, animal health and welfare, appropriate environmental practices, farm and catchment systems modelling including economics etc. This knowledge will form the basis of education, extension and training to develop skills and capability required across the sectors (both industry and support)
Theme 4 **Enhance the assurance levels of New Zealand's biosecurity, food security and standards of animal health, welfare and well-being**	
Importance to New Zealand	The New Zealand dairy industry must maintain high standards of food safety and supply chain security to retain ready access to global markets, and its position as a preferred supplier of dairy products - New Zealand dairy farms must be protected against threats from disease and pest incursions which could threaten their productivity or create major disruptions - Dairy farmers understand that looking after their animals is in their interests from the perspective of animal productivity and risk management - Public confidence in dairy farmers treating animals well is important to the positive perceptions of the industry and acceptance of New Zealand dairy products in markets - Animal management is an important part of the "farm system" when addressing other areas such as profitability and environmental footprint
Research components	Research into pre, border and post border issues is important in areas of plant and animal health and pest risk management. Key animal health issues require on-going research as well as management of animal welfare and well-being. It is important that the resulting knowledge is grounded within farm systems management and biosecurity management
Research Gaps and Opportunities	Over the last five years there has been a move to "farm systems management" including moving researchers to think more about how their outputs will work within a system so that practical and pragmatic advice can be given to farmers. Systems-thinking is now being expanded to catchment management, and possibly regional and national. New Zealand needs to find solutions across the economic, environmental, cultural and social values in terms of land and resource use and not just define the problems. Research including appropriate systems research and modelling needs to help management by providing technically based solutions and options. Partnership between researchers and relevant industries and government agencies (local and national) are essential if solutions are to be not only readily found but implemented

Entry ID	241
Making the most of our water	**The commercial growing of onions using non agrichemical solutions to Onion Downy Mildew Certain agricultural chemicals such as Mancozeb, are the main method of Downy Mildew Control in export onions. Some of the current chemicals may be banned shortly**
Summary	The goal is to identify nutritional and biological solutions to controlling onion Downy Mildew without the use of agricultural chemicals.
Theme 1 **Solutions to Controlling Downy Mildew without the use of agricultural chemicals**	
Importance to New Zealand	New Zealand has high disease pressure for Downy Mildew in Onions. However one of our main export markets is the EU. Some of the main agricultural chemicals used in New Zealand for Onion Downy Mildew may be banned under the EU Farm review Policy. New Zealand exports approx 150,000 tons of onions. The onion industry relies heavily on the Polynesian community for hand harvesting. A decrease in exports of onions impacts on the casual employment of Polynesian workers particularly from South Auckland.
Research components	The project will provide nutritional and biological solutions to controlling onion Downy Mildew without the use of agricultural chemicals. Pilot studies have determined a method and a spray programme to achieve this in the Franklin region. It is necessary to repeat the trial using statistical analysis of data to provide results which can be published.
Research Gaps and Opportunities	There are observational results from two years of successful cultivation of onions of exportable onion varieties on a small commercial scale. To gain sufficient credibility for the methods for commercial growers to successfully adopt the technology it is necessary to have scientific data, with statistical analysis. The opportunity for New Zealand is to add a niche market product for world markets for biologically grown onions.
Comments	World markets could demand full traceability for the use of agricultural chemicals in future and nil tolerance to residue of some of the most commonly used agricultural chemicals eg Mancozeb, when these products may be banned in Europe in the near future.

Entry ID	265
Sustainable agriculture: Ensuring food production for the next 1000 years	
Summary	The goal is to promote sustainable and productive agriculture. Themes include increasing agricultural production while maintaining quality and quantity of water and soil resources long-term, developing ways to produce more from less land, e.g. genetic selection of plants and animals, novel pest control systems, planning for a sustainable future for New Zealand agriculture by understanding the effects of a changing climate and ensuring farmers implement up to date sustainable technologies

Theme 1 Improving land and water sustainability on-farm	
Importance to New Zealand	New Zealand is an agricultural exporting nation, reliant on its farming community for the wealth of the nation. The push for intensification of agriculture will be at a time when there are multiple drivers making this more difficult, including land quality is decreasing due to overuse and poor management, and water issues due to increasing demand for irrigation. In this developing scenario, New Zealand must produce food for itself and for the world, to survive economically and socially. The New Zealand government's economic growth agenda calls for export earnings from the land to increase by 40% by 2025. No other country will investigate how to make New Zealand soils sustainable or manage our water resources. The challenge is to increase production while also maintaining the quality and quantity of our soil and water resources for future generations. This is the biggest national challenge because it focusses on the economic future of New Zealand's biggest industries, our major export earner, and the health and welfare of all New Zealanders.
Research components	Water is one of the major limiting inputs for agriculture. Although New Zealand has an abundance of water, it is not always where it is needed, when it is needed. The quality of our waterways is also under threat. Research is required that ensures the sustainability of farming practises, such as managing irrigation systems and ensuring clean water through reduction of leaching of soils. Sustainable farming is also based on maintaining healthy soil. Research which underpins farming methods that maintain microbial communities and other soil components necessary for plant growth is required across the many soil and climate zones of New Zealand. Managing issues like nitrogen and phosphate levels in soil without reducing the sustainability of system are crucial to future farming.
Theme 2 **Growing more from less**	
Importance to New Zealand	Food production is facing an uncertain future, threatened by many issues but facing rising world-wide demand. We will have to grow more, from less land. Communities and regulators are demanding less chemical inputs in growing food; and other factors such as non-tariff trade barriers based on residues on food will become increasingly used to restrict food trade. Currently, food exports are valued at over $15 billion, accounting for around 16% of GDP. The size of returns for any improvement in productivity is, therefore, massive, as even small percentage increases lead to very large amounts. Conversely, not developing truly sustainability agriculture will threaten the entire industry. The status quo will not be maintained without changes in farming practise, as demonstrated by the current issues with water contamination from nitrogen fertilisers in our rivers. Therefore, returns must also consider potential decreases if we do nothing.
Research components	Healthy plants: New Zealand's agricultural exports are largely based on growing plants and trees. Selection of the appropriate plant cultivar, reducing pest, weed

	and disease issues, developing crop rotations and determining stocking levels that maintain agricultural productivity and sustainability are required. Developing novel sustainable pest management systems, for example, that do not cause residue issues or ecosystem disruptions would greatly improve our sustainability credentials. Animal performance: As the country derives much of its export earnings from cattle or sheep, research which improves animal performance is required. Animal health, genetic selection for more appropriate high producing animals and improving animal welfare are research targets.
Theme 3 **Future proofing New Zealand agriculture**	
Importance to New Zealand	Food exports are vitally important to the New Zealand economy, contributing 16% of GDP. If the country's farmers do not farm sustainably, this contribution to the economy is at risk due to the very high proportion of our production that is exported. In addition, farming employs over 114,000 people, which is 11% of the total workforce. However, it is not enough to simply look at sustainability in today's agriculture. Tomorrow's farmers must also be technological able to adapt novel practises in a changing world. Climate change, technological advances and changing food requirements around the world will all continue to impact. Sustainability of New Zealand will require planning for the future. It is highly likely that in the future, food that is produced in a certified sustainable manner will attract a premium from wealthy countries which may not be able to produce enough of their own food. With the onset of climate change the number of countries that will require increased food imports is likely to increase.
Research components	Climate change impacts: Current scenarios around the effect of the changing climate on New Zealand suggest that while the impacts will not reduce the ability to produce of the land, regions will be change what can be grown there. In addition, more unpredictability of weather events is likely. Therefore, research is required on the likely impact on sustainable farming for each region and produce type. Adoption of technology and knowledge: To ensure sustainable New Zealand agricultural systems knowledge and technology generated from research and business must be adopted by agriculturists. This often neglected area requires research on how farmers learn of new techniques, and what incentives the agricultural community to change practises.
Research Gaps and Opportunities	As described under the themes: Research is required that ensures the sustainability of farming practises, especially managing irrigation systems and ensuring clean water through reduction of leaching of soils. Research which underpins farming methods that maintain microbial communities and other soil components necessary for plant growth is required across the many soil and climate zones of New Zealand. Managing issues like nitrogen and phosphate levels in soil without reducing the sustainability of system are crucial to future farming. Selection of the appropriate plant cultivar, reducing pest, weed and disease issues, developing crop rotations and determining stocking levels that maintain agricultural productivity and sustainability are required. Developing novel sustainable pest management systems, for example, that do not

	cause residue issues or ecosystem disruptions would greatly improve our sustainability credentials. Research which improves animal performance is required. Animal health, genetic selection for more appropriate high producing animals and improving animal welfare are research targets. Research is required on the likely impact on sustainable farming for each region and produce type. Research on how farmers learn of new techniques and what incentives the agricultural community to change practises.
Comments	The New Zealand government's economic growth agenda calls for export earnings from the land to increase by 40% by 2025. This is New Zealand's largest export earning sector, and has a direct effect on the next largest, tourism. It is difficult to see any science challenge bigger for the economic and social wellbeing of New Zealand than sustainable agriculture. Key organisations which would be involved in the research under this challenge are Lincoln University (including the Bioprotection Research Centre), Landcare Research, AgResearch, Plant & Food, NIWA, Massey University. This science challenge aligns strongly with the Landcare Research National Science Challenge: "Increasing land productivity within environmental limits".

Entry ID	**344**
To maximise value for New Zealand from low value biomass. Use fractionation technologies to produce biomaterials, biofuels and stockfeed. Add new exports and reduce imports. Added value opportunities exist to turn 5c/kg into $5/kg	
Summary	The goal of this proposal is to maximise the value of New Zealand biomass by producing biomaterials biofuels and stockfeed and. The proposed research programme includes the following themes: 1. Identify, develop and optimise key technologies for optimal fractionation technologies linked to specific biomass sources that ensure highest value natural compounds are produced - catalogue and compare biomass fractionation technologies, evaluate target biomass opportunities etc. 2. Evaluate and prioritise biomass fractionation products using scale, yield, quality and marketability as key criteria - isolate and identify biomass compounds, explore and quantify the scale of relevant biomass, the yield of each compound able to be derived from a commercial scale operation etc. 3. Explore value add opportunities to substitute green and locally sourced compounds for imported fossil fuel-derived and possibly more harmful compounds - research and development of market ready products etc. 4. Explore the opportunities to develop and establish dedicated crops for biomaterials production - Assess available sources in broad terms such as grasses, softwoods and hardwood trees.

Theme 1 Identify, develop and optimise key technologies for optimal fractionation technologies linked to specific biomass sources that ensure highest value natural compounds are produced	
Importance to New Zealand	New Zealand grows plant biomass very effectively and efficiently. Therefore, various streams of lignocellulosic biomass exist including forest waste, wheat straw, and horticultural waste. These contain compounds that have potential for other uses. The variety of biomass types (grasses, softwood, hardwood) implies the need for a variety of technologies to add extra value and minimise the volume of waste produced. (Applying a one stop shop fractionation approach will not provide optimal yield in quality nor production.) Rather, specific existing technologies may be applied or adapted to specific biomass sources to yield value. (New fractionation technologies may emerge yet this will be a windfall rather than a specific goal.) Several of these situations have the potential to deploy substantial new businesses in the rural sector ranging in turnover from $10 million to $70 million with high ROI and IRR.
Research components	1. Catalogue and compare biomass fractionation technologies including Organosolv, soda, Kraft (along with less well-known approaches). The emphasis would be on technologies which preserve as many valuable biomass components as possible, rather than on destructive methods such as pyrolysis. 2. Evaluate target biomass opportunities especially those that involve added costs or even problems to a sector. These could include Radiata waste at hauler skid sites, wheat and barley straw that is not used for stockfeed, and waste streams from horticulture. Each of these situations presents an opportunity to reduce waste while creating value. 3. Combine a biomass source with the optimal fractionation technology 4.Build and utilise small scale extraction equipment for proof of concept studies 5.Prioritise and progress those with highest potential to pre-commercial scale technology development. 6.Scion and IRL are able to provide key skills and resources to facilitate proof of concept and pre-commercial scale technology development
Theme 2 **Evaluate and prioritise biomass fractionation products using scale, yield, quality and marketability as key criteria**	
Importance to New Zealand	Rather than focus on producing a single or blended product from biomass the challenge is to identify and isolate multiple valuable compounds from within a given lignocellulosic biomass source. Since the typical biomass source may have dozens or hundreds of components, the importance of this challenge is to prioritise key products. For instance, lignin is the second most common natural compound behind cellulose. (Lignin is produced within plant cell walls and provides the architecture to hold plant cells together in wood, leaves and bark). Therefore, the first part of this challenge is to identify opportunities to derive the best quality lignin rather than destroying lignin during the fractionation of biomass. Within the plant kingdom various forms of lignin have been identified. Each may offer New Zealand the opportunity to create and deploy new high value products. For instance, lignin derived from hardwoods using Organosolv

	technology may well substitute for phenols in the polyurethane sector. Other lignins have other points of utilisation and therefore other value. Cellulose as a feedstock has a very wide range of potential uses. As cellulose fibre it may be used as an animal feed or for paper pulp or textile fibres. After conversion to glucose it can be fermented to ethanol or butanol for biofuels, and to a wide variety of biomaterials. Hemicellulose sugars can also be used for a wide variety of food or fermentation applications. The importance to New Zealand is manifold, including reduction in imports and new value add export opportunities.
Research components	1. From proof of concept (Theme 1) isolate and identify biomass compounds a. This should include stringent biochemical analysis using skills and resources at Scion, IRL and AgResearch b. Focus research on key components of lignocellulosic biomass including: i. Cellulose ii. Lignin iii. Hemicellulose, 2. Explore and quantify the scale of relevant biomass, the yield of each compound able to be derived from a commercial scale operation 3. Test and evaluate compounds to determine suitability as substitutes for known products.
Theme 3 **Explore value add opportunities to substitute green and locally sourced compounds for imported fossil fuel-derived and possibly more harmful compounds**	
Importance to New Zealand	Adding value to products from biomass challenges the preconception that New Zealand should target commodity markets. Instead, there may also be significant opportunities for biomaterials where smaller scale resources, are transformed to niche products of high utility and value. Commercialisation requires assessment of market opportunities and trends in markets, aligned to an understanding of skills and resources to fulfil markets. Given a commitment to Themes 1 and 2, New Zealand will be best placed to evaluate new opportunities in biomaterials. This theme integrates the challenge with the market place. That does not imply a total and comprehensive understanding of the market for biomaterials, yet it does imply that New Zealand must clarify key opportunities linked closely to the scale and quality of core compounds available from New Zealand biomass resources. Failure to integrate markets and biomaterials resources means that the biomaterials challenge could target false opportunities. Integration with markets will underpin the opportunity to focus on and target opportunities with significant potential. Transforming New Zealand's own biomaterial compounds to fully manufactured green products will drive business interest and investment in biomass sources. Before that occurs science must pave the way with investment into utilisation of source compounds.
Research components	1. Based on potential resources of high value natural compounds derived from biomass, research and development of market ready products should be undertaken. 2. Product samples from proof of concept stage will be supplied to alternative science expertise and commercial partner entities for trial and evaluation

	3. This stage will require significant insight to achieve targeted R&D on markets that best fit New Zealand's core compounds and skills. Nevertheless, the closer to the market the better for New Zealand in general. 4. An example is the use of lignin as a substitute to manufacture 'green' polyurethane
Theme 4 **Explore the opportunities to develop and establish dedicated crops for biomaterials production**	
Importance to New Zealand	This challenge is premised upon deriving biomaterials from biomass. There is little question that New Zealand provides great rainfall, wonderful skills and a variety of climatic conditions for growing crops. Yet if the premise that different sources of biomass provide alternative product streams for biomaterials then it would be short-sighted to suggest that current crops cover all biomass 'classes'. There may be alternative biomass that will improve the biomaterials sector. Given that biomass is the source of biomaterials being considered, and that biomass takes time to be assessed and trialled this theme should not be left until the biomaterials sector is active. 'Dedicated biomass crops' is an approach that lends itself to sustainable land use. This applies particularly to sensitive catchments such as Taupo and Rotorua where more traditional forms of land use such as pastoral farming form part of the problem. A solution that adds value to the New Zealand economy is surely good for our environment, our communities and our land owners.
Research components	Assess available sources in broad terms such as grasses, softwoods and hardwood trees. Quantify the likely sources from within those streams Identify gaps in each of the broad biomass streams Collate other R&D that has occurred within the 'gaps' Determine the relevance and fit of biomass streams with other themes.
Research Gaps and Opportunities	In the past there have been many successful businesses developed by isolating a single valuable product from a biological source material. However, our vision is of a biorefinery approach where multiple valuable materials can be derived from a single lignocellulosic feedstock. The research gap we have identified is in selecting the best fractionation technique to apply to a given feedstock type, and to optimise it for the production of several valuable biomaterials in high yield and high quality. New Zealand has only recently started to coordinate the research and development of biomaterials. For that reason alone this is a new and exciting sector for research and development. As an infant sector there is ample opportunity to achieve significant gains if New Zealand 'gets it right'.
Comments	This challenge has been prepared as an integrated and inter-related set of science goals. Conceptually, there must be stringent feedback between: 1. Theme 1 and theme 2 to ensure that resources are spent on biomass fractionation of specific resources that produce preferred compounds for products from fractionation businesses. 2. Theme 2 and theme 3 to ensure that streams of compounds with appropriate

	quality are truly available for value add business opportunity. 3. Opportunities may exist to develop dedicated crops of biomass for this challenge. This challenge has focussed on existing biomass opportunities yet dedicated crops may open further opportunities to develop the scale and quality of biomass based biomaterials and biofuels in New Zealand. Interaction between the primary sector, science community, business and markets is vital to success from the biomaterials from biomass challenge. Any prioritisation and dominant position taken by the primary sector or science community risks a production or resource driven program rather than clear emphasis on delivering to markets. For some time the Liquid Biofuels Interest Group, a sub-group of the Bioenergy Association of New Zealand has recognised that success is more likely if biomaterials AND biofuel are produced from the same biomass. Adding revenue streams through biomaterials is vital to cost effective 2nd generation biofuels. Hence this group has redefined itself as "Biomaterials and Biofuels". This challenge has the capacity to reduce New Zealand's dependence on imports of oil, improve our carbon footprint and make a difference to land and water quality. The challenge is unlikely to compete with food, and may actually complement food production.

Entry ID	**380**
Engaging entrepreneurs & the SME sector in 'growing the agrifood economy'	
Summary	The goal of this proposal is to improve New Zealand's economic performance by linking SME entrepreneurs to the agrifood economy. The proposal's proposed research programme includes the following themes: 1.Connecting SMEs to the science providers 2.Understanding the national innovation infrastructure in New Zealand 3. Unlocking Māori economic potential
Theme 1 **Connecting SMEs to the science providers**	
Importance to New Zealand	Existing research indicates that the individuals who operate New Zealand's small and medium-sized enterprises (SMEs are defined here as firms with fewer than 100 employees) are highly entrepreneurial. At the same time the enterprises they run are characterised by low levels of innovation and R&D. The consequence of this firm-level behaviour is that the SME sector as a whole (which includes 99% of the 469,118 enterprises as at February 2012 that make up the entire New Zealand economy) sector is failing to contribute to the economic growth it is capable of. This is a critical factor for New Zealand: Until all firms are connected to the science providers as a way of supplementing any internal R&D they are undertaking, the New Zealand economy will continue to under-perform.
Research	Although previous research has been conducted on the innovation process in

components	SMEs in other developed nations, there has been little previous research in New Zealand. Statistics New Zealand reports innovation and R&D levels via its Business Operations Survey, but this excludes firms employing less than 6 staff and, therefore, 89% of the businesses in New Zealand. This component of the project will employ a mixed-method approach to investigate the causes of low levels of innovation and R&D in firms employing fewer than 6 staff. The focus will be on those firms operating in the agrifood business sector – defined here as encompassing primary production, food processing and the servicing activities that relate to these areas of operation.
Theme 2 **Understanding the national innovation infrastructure in New Zealand**	
Importance to New Zealand	By international standards New Zealand SMEs are poor innovators. This is surprising given New Zealand's high levels of entrepreneurship and high 'social proximity'. Both of these factors are generally associated with high innovation levels as they make it possible for networks to evolve on the basis of shared trust – and for the firms that are members to collaborate with each other. Higher levels of collaboration could be of critical importance in New Zealand – where almost 70% of the whole business population (469,118 enterprises as at February 2012) is operated by individual with no employees. It is unclear whether (or how) these self-employed individuals participate in the 'national innovation infrastructure' – a term that refers to a range of organisations that support New Zealand's commercial sector. – those Gaining a better understanding of the barriers to engagement will be the first step in improving the design of the system in a way that overcomes any barriers to participation.
Research components	The project uses a qualitative social network approach to capture the dynamics of small firm networks in New Zealand, and to build a picture of these networks from the perspective of the firm (with one firm being selected as the 'primary networker') and the network. Data collected will be supplemented by data from key informants, as the researchers seek to develop a rich picture of the entire infrastructure and to identify how this can be improved in ways that will contribute to the overall project goal. The focus will be on those firms operating in the agrifood business sector – defined here as encompassing primary production, food processing and the servicing activities that relate to these areas of operation.
Theme 3 **Unlocking Māori economic potential**	
Importance to New Zealand	The New Zealand government's commitment to the settlement of historic grievances has created considerable challenges and opportunities for Iwi and other Māori organisations. BERL estimates that the asset base of the Māori economy is currently $36.9 billion, and will add a potential $12.1 billion to New Zealand's GDP by 2060. The individuals involved in the organisations managing these assets now need new skills in order to maximise their capacity to manage their assets in ways that are productive and sustainable. While current research indicates that Māori are highly entrepreneurial, as yet the knowledge institutions

	(universities and science providers) have failed to understand how best to unlock this potential or to develop appropriate delivery mechanisms for Māori organisations and to the entrepreneurs that run them. The consequence is that the Māori economy is largely disconnected from the national innovation infrastructure and from the science institutions that are at its heart. This situation needs to be reversed in order to ensure Māori enterprises fully participate in the innovation effort facing New Zealand as a whole.
Research components	The central element of the project is a research programme on Māori entrepreneurship which will focus on leaders in a wide variety of fields including for-profit business, not-for-profit, community and iwi. The inclusion of not-for-profit and community enterprise is deliberate as it is likely that these sectors may provide the most fruitful findings. This qualitative research will be used to identify the key characteristics of Māori entrepreneurship and develop a framework for Māori leaders to contribute to, and transform, Māori business performance – with a focus on those firms operating in the agrifood business sector.

Entry ID	**429**
Sustainably Profitable Primary Industries	
Summary	The goal of this proposal is to increase the value of New Zealand's primary sector products via a research programme with the following themes: (1) globalising the primary industry model (2) increasing productivity in primary production systems (3) future proofing our primary industry (4) sustainable use of natural resources
Theme 1 **Globalising The Primary Industries Business Model: Value Chain Integration And Taking Farming To The World**	
Importance to New Zealand	Research is required to improve the reliability of product flows through what are often very long value chains that link New Zealand producers to their ultimate consumers, often passing through multiple agents along the way. It is important in extracting the maximum value from New Zealand primary industries and in providing security of food supply. International research stresses that to optimize management of New Zealand's biological value chains, collaboration, organisational culture and leadership, structure and strategy, trust and respect, long term planning and effective communication are critical success factors. These critical factors are very much the province of university-based business schools both within New Zealand and internationally. They are also factors addressed successfully by corporations that lead the world in the quality and outcomes achieved from professional value chain management. New Zealand will increasingly struggle with capacity issues in domestic

	agricultural production. The opportunity exists to think not in terms of what can we produce within New Zealand, but what can we produce globally, managed from New Zealand. The role of science is to determine the transferability of New Zealand systems to other regions (i.e., accounting for different environments, soils, genetics and disease pressures) and in developing the sensors and IT infrastructure/software so that conditions in offshore production bases can be monitored and responded to from New Zealand in real-time.
Theme 2 **Increasing productivity in primary production systems**	
Importance to New Zealand	Understanding the fundamental biological processes in plant and animal-based systems is critical to making informed decisions on how to manipulate and manage these for greater profitability and reduced environmental impact. Significant progress has been made over recent decades using traditional plant breeding; however, there remains significant untapped potential to increase productivity and fitness-for-purpose by applying new (non-GE) science approaches. Genetic, genomic, proteomic and physiological techniques have rapidly advanced, and can now permit more bespoke targeting of desired traits (such as inducible or repressible flowering or regeneration; specific pathogen resistance). There is particular scope to apply these new approaches to species at the heart of New Zealand's production systems such as ryegrass and clover, in order to achieve step-wise gains in productivity. There is also scope for generating greater coordination between plant and animal-based researchers to better align supply (e.g. plant nutrition or growth timing) with demand (animal nutrition or human consumption needs). There is also scope to fill critical capability gaps in the areas of plant biochemistry and physiology and soil<>plant microbiology (e.g., microflora / soil rhizobia <> plant interactions), and in invertebrate genetics, physiology and ecology and genetics (e.g., in improving pollination capacity and in pest control). Significant animal health and productivity gains are also possible through the application of new techniques developed out of human studies (e.g., in genetics, reproduction, pharmacy, anatomy and immunology). This could lead to new disease diagnostics, animal remedies and delivery systems that would heighten productivity and reduce on-farm animal health costs.
Theme 3 **Future proofing our primary industries**	
Importance to New Zealand	Developing a biosecurity system that can respond to the ever increasing pressures associated with free trade and globalisation is imperative. This requires the development of state-of-the-art detection, diagnostics and management responses. The utilisation of modern technology (e.g., portable diagnostics) to detect will greatly heighten management (containment or eradication) responses. Related to this is the ability to build more resilience into livestock, plants and pollinators to make them less susceptible to disease incursions. Modern genetics

	and genomics can greatly improve traditional breeding approaches to select for heightened genetic diversity, whilst also targeting specific traits. The ability to reduce New Zealand's greenhouse gas emissions is likely to play an increasing part on both on-farm profitability (e.g., if GHG/C-equivalent taxes or emissions trading schemes are implemented). It may also become a 'licence to operate' issue in some premium markets. Developing tools that help farms measure and manage emissions is likely to be an increasing need.
Theme 4 **Sustainable use of natural resources**	
Importance to New Zealand	Minimising and managing the impact the agriculture has on the natural environment will increasingly become a 'licence to operate' issue for the sector nationally and internationally. Failure to mitigate off-site impacts will also have knock on consequences in other economic spheres such as tourism. It is critical that robust scientific approaches are applied at the appropriate level (e.g., farm vs. catchment level). Again, the role of new techniques to measure and monitor physical and biotic changes in ecosystems will play an important role in creating a full picture of what these impacts are and why they are occurring. This understanding is a necessary precursor to taking steps to prevent or mitigate them. Of particular importance in this regard is the impact that intensive dairying is having on freshwater systems. The ability to model, measure and monitor multiple stressors on freshwater ecosystems will be important to generating 'real world' insights and designing meaningful interventions. This theme is also likely to require understanding the human factors important in influencing behaviour change.
Comments	This Challenge covers a wide area with extensive capability across CRIs & Universities. The University of Otago works collaboratively with many providers in this area and sees its role as both providing critical support to core work programmes and leading specific/niche Research Components. The continued profitability of New Zealand's primary industry is critical for New Zealand's overall economic success. There is a compelling need to maintain and extend the science-led innovation that has made New Zealand a world leader in many of the primary sectors. However, there is also an increased recognition that continued growth through intensification is unsustainable. Smarter approaches are therefore required that can 'make more from less'. By being more market led and understanding and integrating with global value chains more value can be captured per kg of protein exported or per hectare of land used. The quantity and quality of production can also be increased through exploiting new scientific tools that enable a greater understanding and manipulation of the biological systems being farmed (be it plants, trees, animals or fish/shellfish). There is also a pressing parallel need to future-proof the primary industries from biosecurity threats, and reduce the impact that it has globally (greenhouse gas emissions) and regionally/nationally (impact on water and soil quality).

	To achieve this Challenge requires both building on the extensive experience developed within the traditional primary industry-based research providers such as AgResearch, Scion, Plant & Food, Massey and Lincoln, and linking with new thinking, technology and expertise from other quarters. A particular exciting opportunity is the targeting of innovation at the agritech and farming-related service sector (e.g., stock feeds; fertiliser manufacturers; seed companies). Delivering innovation to companies in this sector not only lifts the productivity of their primary industry client base, but also makes them more internationally competitive.

4 Sustainable Resource Use

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 2: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
124	Empower NZ to innovate and implement sustainable technologies and practise in as many areas as possible and to develop enough scientific infrastructure so that we have the resources to respond quickly and efficiently to biosecurity, health and environmental threats.	1. Developing sustainable technologies/behaviours and implementing them into all parts of daily life and business practises as well as adopting sustainable technologies and practise developed elsewhere. 2. Having the scientific infrastructure in place that enables us to have the resources and expertise to respond quickly and efficiently to biological, health, geological and environmental threats. 3. Supporting scientific personnel - enabling us to retain a pool of capable researchers in NZ and to tap their expertise efficiently. 4. Improve general science education/awareness to allow us all to work together to understand new sustainable technologies, biological threats etc. better.
151	A clean and healthy sea: New Zealand's native land animals and plants are almost entirely gone. Our marine resources are going the same way due to overfishing and by catch, lack of protection, global climate change, and pollution.	1. Improve water quality entering the sea from the land 2. Protecting important and representative ecosystems along all of New Zealand's coasts 3. Evidence-based decision-making regarding resource extraction from the sea 4. Examining ways to reduce the effects of global changes to the sea
202	The Coastal Marine Area (CMA) - In a world of extensive exploitation of terrestrial resources, but with increasing demands for primary needs (food, water, energy) there is a vast potential of untapped productive and ecosystem resource in the marine environment.	1. Understanding and managing anthropogenic impacts on water quality in the CMA 2. Improve national planning for the CMA recognising New Zealand's need for productivity as well as protection 3. Predicting and planning for impacts on CMA productivity from global environmental changes
203	Development of realistic and	1. Develop regional plans that provide realistic and profitable systems for increased primary

Entry Id	Challenge	Themes
	affordable national water and land management resources as a foundation for the increase of primary production development for domestic and export markets.	production for domestic and export markets 2. A focus on the issues around the reduction in profitability through increased compliance costs for primary producers standpoint 3. Management of risks associated with the intense farming practises
277	To enable New Zealand society to live sustainably.	1. To reverse the loss of New Zealand's biodiversity 2. To understand the limits to the consumption of non-renewable resources and how these will affect New Zealand in coming decades 3. An identification of the likely impacts of climate change 4. Understand societal resistance to change
300	New Zealand will improve the management of land and water to increase wealth and environmental integrity	1. Develop best-practice management approaches, tools and technologies to enable optimal use of land and water resources at catchment- and farm-scales. 2. Advance New Zealand's economy and enhance environmental integrity by using science to identify, realise and protect the unique advantage provided by our land and water resources. 3. Deliver an appropriate evidence base, participatory processes and uptake methods to facilitate more effective land and water resource governance and decision-making at catchment-, regional- and national scales. 4. Establish credible information at appropriate scales to characterise the state, trend, impacts and opportunities for land, water and associated ecosystem services.
305	Using science, innovative technologies and tools to improve our production from land while maintaining or enhancing our freshwater quality.	1. Development of best practice land management to reduce leaching of contaminants and reduce impacts on receiving waters to within limits for environmental sustainability 2. Robust understanding and assessment of the assimilative capacity of New Zealand's freshwater systems so that they can be utilised and managed to achieve a better outcome of productive land within environmental limits 3. Develop an integrated model to include the farming system (including economics), transport and attenuation processes through the soil, unsaturated zone, and groundwater, groundwater-surface water interface, in-stream

Entry Id	Challenge	Themes
		processes and estuarine environments 4. To gain a shared ownership of the issues concerning land productivity while achieving environmental limits by a broad spectrum of society so that a range of innovative solutions can be assessed in a grounded manner to give the desired outcomes
318	Oceans Management - getting the best from our ocean	1. Bringing Together Data on Ocean Ecosystems and Human Activities/ Impacts 2. Setting objectives for oceans management 3. Legal and economic system of oceans management
324	Rehabilitation and conversion of land and waterways currently deemed as unsafe for productive utilisation due to the presence of Dioxin and other persistent organic poisons. Extension of the current bioremediation project	1. Understanding the impact of persistent organic poisons on the productivity of land, soil and waterways 2. Maintenance of the Health of the population and understanding the evidence of harm from persistent organic poisons 3. Managing the future risk to Papatuanuku and whenua
339	New Zealand needs to grow the economic value gained from its land and natural capital and resources while reducing the environmental impact of agriculture and forestry.	1. The goal is to increase productivity from agricultural land in a way that is socially and environmentally sustainable and acceptable to New Zealanders, and to the markets/consumers on which our exports rely 2. The goal is to increase the real value we derive from the food, beverage and fibre we export. In doing so we will be adding value and also getting a bigger slice of the value that is created 3. The goal is to develop better models of rivers and lakes to ensure the impacts of draw-offs enable recovery
326	To develop a theoretical basis for understanding the undesirable physiological trade – offs that occur when plants and animals of agricultural importance are subject to genetic selection for production traits. This requires a combination of Evolution th	1. To understand the process of portioning energy in organisms and the links to gene expression 2. Determine the mechanism of Developmental Programming and the link to the trade off between traits. Investigate how this link is mediated 3. Apply the results of themes 1 and 2 to develop a breeding strategy for organisms which are productive and resilient

Entry Id	Challenge	Themes
351	The integration and reconciliation of environmental and economic benefits to support a hybrid approach to prosperity and well-being for New Zealand society	1. What have we got – Measuring the state, trends, and limits of our natural resources 2. How do we value it – Understanding and prioritising values around natural resources within an inclusive society 3. What can we do about it – Integration by creative and innovative win-win solutions to wicked problems 4.How do we evaluate progress – Providing a feedback loop for learning how to deliver integration
362	Increasing agricultural output whilst improving freshwater quality	1. Understand interactions between agricultural activity and freshwater quality 2. Understand soils and soil processes in New Zealand 3. Improve nutrient use efficiency in plant-based production systems 4. Improve downstream processing of agricultural outputs and decrease post-harvest losses
411	Generating sustainable growth, wealth and resilience from land by managing land and water resources to increase productivity while maintaining environmental integrity	1. Establish and maintain credible information at appropriate scales to characterise the state, trend, threats and opportunities of land, water and associated ecosystem services in relation to land use, land-use change and climate change 2. Provide a robust scientific framework for explaining variability and limitations to productivity, developing innovative solutions for improved management and resource use efficiency and new opportunities for increasing productivity within environmental limits 3. Collaboration for sustainable land use and integrated resource use: threats & opportunities 4. Contribute to growing wealth by developing coordinated national, regional and industry strategies and policy to incentivise land uses and implement the adoption of practices to maximise the environmental, social, cultural and economic benefits from the landscape
412	New Zealand increases wealth from natural capital while maintaining or improving its environmental integrity.	1. Develop best-practice management approaches, tools and technologies to enable optimal use of land and water resources at catchment and farm scales. 2. Advance New Zealand's economy and enhance environmental integrity by using science to identify, realise and protect the unique advantage provided by our land and water resources 3. Deliver an appropriate evidence base, participatory processes and uptake methods to

Entry Id	Challenge	Themes
		facilitate more effective land and water resource governance and decision making at catchment, regional and national scales 4. Establish credible information at appropriate scales to characterise the state, trend, impacts and opportunities for land, water and associated ecosystem services. This theme underpins all other themes by providing baseline state-and-trend data
418	Green land, blue water and prosperous people for the next millennium	1. Enable the integrated management of land, freshwater and coastal resources through partnerships between resource managers, iwi, catchment communities (including e.g. private, commercial, and lobby or/and special interest groups) and scientists building on the collaborative approach taken by the Land and Water Forum 2. Identify and evaluate potential approaches for increasing primary sector returns in order to determine what actions should be taken to realise the desired gains 3. Ensure that all stakeholders have access to the environmental data they need to be actively involved in decision making 4. Determine which tools and approaches for ecosystem health monitoring New Zealand should use and deploy them
434	Promote the sustainable use of the New Zealand's marginal agricultural lands and protect the quality, supply and image of New Zealand's high-value products and allow the development of regional industry clusters.	1. Authenticity of product involving sample collections by industry 2. Leptospermum plantations, improving New Zealand environmental image 3. Sustainable bee management and product quality 4. Development of economically sustainable opportunities in regions -Developing self-supporting economic clusters of opportunities around endemic plant species
435	Urea production from wood waste	
454	Land, Water and Coasts - "Achieving integrated management of land, water and coasts, which incorporates the connections between them and leads to productive resource use and sustainable, healthy ecosystems."	

Entry Id	Challenge	Themes
398	To have an integrated suite of environmental tools which are used for benefiting all New Zealanders through optimising agricultural productivity whilst being used to enhance biodiversity and optimise water quality	1. To have an integrated suite of environmental tools which are used for benefiting all New Zealanders through optimising agricultural productivity whilst being used to enhance biodiversity and optimise water quality
469	Balancing increased agricultural production and environmental concerns	

Entry ID	124
Empower NZ to innovate and implement sustainable technologies and practise in as many areas as possible and to develop enough scientific infrastructure that we have the resources to respond quickly and efficiently to biosecurity, health and environmental threats.	
Summary	This research proposes to develop sustainable technologies and behaviours which are integrated into everyday public-usage through the development of an advanced scientific infrastructure. Research will firstly identify areas where the biggest improvements can be made (e.g. improving farming technologies to benefit waterway health), and will then need to develop appropriate technologies/ co-opt other technologies that are suited for use in the NZ environment.
Theme 1 **Developing sustainable technologies/behaviours and implementing them into all parts of daily life and business practises as well as adopting sustainable technologies and practise developed elsewhere**	
Importance to New Zealand	New Zealand needs to continually improve its efficiency and sustainable practise. Our environment (e.g. waterways, air pollution, energy use, greenhouse emissions, amount in landfills) will benefit. Our health should benefit. And we would waste less money and resources. The more efficiently we can do things and the less mess we make when we do the better for everyone. At the moment this is not something we do consistently or well. I see the benefits of this being huge. Also in order to develop and implement sustainable technologies we would create more jobs in a new area -developing a national expertise with people learning to specialise and provide answers to "NZ specific" sustainability issues.
Research components	Needs would need to be identified - what are the main areas where the best

	improvements could be made to maximise impact. e.g. would improving farming technologies and techniques to improve waterway quality be a good area or would developing new quickly biodegradable packaging that minimised landfill be better, how would investing in development of more energy efficient devices for those in healthcare settings compare to the first two etc. The sustainable technologies would need to be developed - this would be a huge research input requiring people with a range of expertise due to the number of different areas covered. Existing technologies would also need to be researched to see which ones would suit NZ conditions best. Research on how best to implement these technologies/practises would need to be carried out and a plan developed We would need a pool of scientifically literate people to be aware of the needs and the developments and facilitate groups involved in each of these things to interface We would need people a lot of cross communication - sustainable technology innovators and implementers would need to talk with those in academia, industry, farming, natural resource managing and people going about their daily lives to identify the needs and areas where improvements could take place. These people would have to have strong and broad ranging science backgrounds and be experience.
Theme 2 **Having the scientific infrastructure in place that enables us to have the resources and expertise to respond quickly and efficiently to biological, health, geological & environmental threats**	
Importance to New Zealand	NZ needs to be able to respond to threats to its wellbeing (be they environmental, biological, health related etc.) without relying on other countries. We are very vulnerable if we cannot do this. In some cases it will issues primarily affecting NZ (e.g. PSA in kiwifruit). In other cases it might be a global health threat e.g. pandemic - and other countries might be overwhelmed. If NZ has a pool of its own experts it can call on in these situations ready to hand they can find out the problem and deal with it a lot sooner - hopefully minimising damage and lives lost.
Research components	A pool of specific experts in fields relating to microbiology, virology, plant sciences, agriculture, medicine, molecular biology, genetics, geology, environmental science etc. who are available when needed to pool resources and research the particular threat faced - find out as much as they can and propose/develop solutions (e.g. find out what was killing kiwifruit/other crop and how to treat it; identify what bacteria/virus has causes an outbreak and source/develop treatment for it; identify and be able to find out how best to treat antibiotic resistant bacteria; find out what mysterious organism was responsible for killing dogs on our beaches and why; be able to identify and deal quickly with damage from toxin spills/ discarded biological weapons waste dumped our oceans and suddenly leaking etc.) An organisation to co-ordinate these people - with research expertise in overall threat management/ likely risks to NZ
Theme 3 **Supporting scientific personnel - enabling us to retain a pool of capable researchers in NZ and to tap their expertise efficiently**	

Importance to New Zealand	Improving NZ sustainable practise and response to threats (biological/ health/ environmental etc.) requires we have researchers on-hand that have a varying range of skills. The benefit to NZ of having this resource within our own country is huge. This resource if tapped correctly could improve standards of living.
Research components	Supporting general research in NZ in a wide range of areas - enabling us to have the expertise on hand when we need them. Often science in NZ can be undervalued and many top scientists leave. Support and value these people and also tap into their expertise when needed. Perhaps we need look into how we could better do that than we currently do? Perhaps developing specific careers or research institutes that bring people with different research backgrounds together to work on problems like sustainable practise or pool their knowledge and research skills to deal quickly with various biological/health/geological/environmental threats.
Theme 4 **Improve general science education/awareness to allow us all to work together to understand new sustainable technologies, biological threats etc. better**	
Importance to New Zealand	If we improved the overall scientific literacy in NZ then many ideas people might currently be suspicious of they might understand better. This would lead to greater uptake of newly developed technologies and ideas as people felt more comfortable with them. This would enable NZ to become a country of "early adopters" of beneficial technologies and would also encourage innovation. It might also help when facing things like pandemics or disease outbreaks in crops if people understood more about why they needed to do something (wash hands, clean boots off etc.) or get vaccinated etc. and how those things actually worked. It could mean those in industries/areas where pollution was a problem might understand better the need for moving to more sustainable practises instead of seeing it as unnecessary. It might mean people approach scientists more and more mutually beneficial collaborations are fostered.
Research components	Researchers realise that an important part of their research is "outreach" - putting what they do out into the community and facilitating schools etc. to access them. Not direct research as such but hugely important. Empowering all of us in NZ to be a little more aware of the science that affects our day to day life and work. This does also involve research though someone needs to do the work to figure out what New Zealander's need to know more about and how best to get this message out!
Research Gaps and Opportunities	Communication - between scientists and NZ general public, schools, specific industry and political groups. Scientific research needs to be made approachable and accessible. If we can do that better we can work together better to produce good outcomes in a huge range of areas. People will learn what is possible and scientist will learn about specific needs and requirements. Development of a national institute or organisation that is able to pool scientific expertise/equipment along with other resources when dealing with specific threats/emergencies so they can be dealt with quickly and efficiently. Don't leave things as was the case with

	the mystery bug killing dogs on Auckland beaches as there was no-one with funding or in charge to say we need to figure out what is going on here.

Entry ID	151
A clean and healthy sea: New Zealand's native land animals and plants are almost entirely gone. Our marine resources are going the same way due to overfishing and by catch, lack of protection, global climate change, and pollution	
Summary	This challenge proposes a variety of ways with which the various threats to our marine biota can be combatted such as; reducing the pollution of freshwater which enters the sea, establishing 'no-take' marine reserves to preserve marine populations, and investigating and mitigating the effects of climate change.
Theme 1 **Improve water quality entering the sea from the land**	
Importance to New Zealand	Improvement of water quality entering the sea has obvious benefits to coastal health, diversity, fisheries, and recreation. It is likely to have a side-benefit of improving freshwater environments and biodiversity as well.
Research components	Development of robust and inexpensive methods for measuring water quality. Development of water treatment methods. Policy development regarding effective methods of encouraging good water-management practices across sectors. Policy development for funding of water treatment in small communities.
Theme 2 **Protecting important and representative ecosystems along all of New Zealand's coasts**	
Importance to New Zealand	Nothing conserves and retains biodiversity as effectively as no-take reserves. The results of protecting an area spill over into neighbouring ecosystems and improve both fisheries and biodiversity over a much wider area. No-take reserves are insurance against large scale disasters. No-take reserves are a significant drawcard for visitors, tourists and locals and can greatly improve the economy nearby. No-take reserves gazetted today may someday attain the lost biodiversity our coastline once had. People today talk about what their grandparents remember but we have lost what their great-great-great grandparents once had.
Research components	What are the effects of No-Take Coastal Reserves? Data and analysis necessary to ensure reserves are large enough and in the right places. Revised policy where MPI is not part of the decision-making team on no-take reserves.
Theme 3 **Evidence-based decision-making regarding resource extraction from the sea**	
Importance to New Zealand	It's time we stopped ignoring science when making decisions. It's time to listen when data shows a species is in danger. It's time to set fisheries limits and decide appropriate levels of protection based on data and knowledge instead of political ideology and guesswork.

Research components	Development of good-quality robust methods of population modelling for commercially fished species. Development and analysis of the effects of a range of fisheries management tools including mataitai, taiapure, bag limits, seasonal limits. Research into by-catch issues and fishing methods that might address them. Increasing research into effects of aquaculture and ways to mitigate them. Research into the extent of recreational catches.
Theme 4 **Examining ways to reduce the effects of global changes to the sea**	
Importance to New Zealand	Global warming will change what lives in our seas, and how they work, as well as weather patterns and ocean currents. An effect of warming is to lower oxygen levels across the sea, reducing productivity. On top of that, ocean acidification looks like it will reduce the capacity of many organisms to live and thrive in the sea, including many commercially important species. The only way to address this "triple whammy" is to cut CO_2 emissions around the world. New Zealand needs to do its part, perhaps even be a leader, in finding ways to live our lives and keep our economy going but also stop creating so much CO_2. This is the best possible use of "Kiwi Ingenuity" -- to develop ways for the whole world to cope with a crisis it is only just coming to understand.
Research components	Research into reducing CO_2 production in all sectors of society. Research into modelling ways that global warming might affect New Zealand fisheries and climate. Research into the likely effects of acidification on our coastal ecosystems. Multidisciplinary research, monitoring and modelling to address the combined effects of warming, acidification and deoxygenation. Development of new and innovative ways to create energy (tidal power, wave power, wind power) without creating CO_2.
Comments	Some people look at the sea and just see the surface. But it is imperative that our research and policy looks below the surface and realises the role the ocean plays in our lives. The ocean has spiritual, recreational, economic, transport, and nutritional values that it contributes to our lives every day. The greatest challenge facing marine science today is achieving the funding and policy attention that the marine environment needs to survive. Because people certainly need the sea to survive.

Entry ID	**202**
The Coastal Marine Area (CMA) - In a world of extensive exploitation of terrestrial resources, but with increasing demands for primary needs (food, water, energy) there is a vast potential of untapped productive and ecosystem resource in the marine environment	
Summary	This goal of this proposal is to maximise the productivity and protection of the Coastal Marine Area (CMA) by developing tools, information and national recommendations for anthropogenic inputs, lack of national strategy and global

	environmental changes. The programme proposes the following themes: 1. Understanding and managing anthropogenic impacts on water quality in the CMA 2. Improve national planning for the CMA recognising New Zealand's need for productivity as well as protection 3.Predicting and planning for impacts on CMA productivity from global environmental changes
Theme 1 **Understanding and managing anthropogenic impacts on water quality in the CMA**	
Importance to New Zealand	Integrated catchment management recognises that upstream inputs have an effect on downstream activities. This approach should be expanded into the CMA where anthropogenic inputs can have negative effects on CMA water quality thus preventing the efficient use of the CMA for conservation, recreation or food production. Unfortunately at this time New Zealand lacks some of the tools necessary to identify inputs, sources and effects.
Research components	Research component 1a: Develop tools to monitor inputs (nutrients, sediments etc.) to and changes in the CMA and identify the source of inputs. Research component 1b: Understand nutrient inputs and nutrient balances in the CMA in the context of oceanic and anthropogenic sources. Research component 1c: Develop tools to identify, track and mitigate sources of pathogen (faecal coliforms, human viruses) entry into the CMA to safeguard food production and recreational water safety.
Theme 2 **Improve national planning for the CMA recognising New Zealand's need for productivity as well as protection**	
Importance to New Zealand	There is a lack of national information and strategy on values and potential of the CMA for conservation, recreation and food production. A region by region approach risks either under-protecting or over-protecting ecological values for the country as a whole, but appears to invariably under-deliver on the potential productivity of the CMA for primary production. Investigation of tools, values and the interplay between them, on the basis of national benefit, is critical in addressing this issue.
Research components	Research component 2a: Develop tools to understand and prioritise values in the CMA (conservation, fisheries, aquaculture, recreation, etc.) Research component 2b: Identify key areas critical for each value, and determine maximum and minimum essential areas for each value for New Zealand as a whole, rather than at the regional level. Research component 2c: Investigate the critical interplay of competing CMA resource use in the context of delivering maximal national value.
Theme 3	

Predicting and planning for impacts on CMA productivity from global environmental changes	
Importance to New Zealand	Understanding the effects of global environmental changes (e.g. water temperatures or ocean acidification) on identified conservation, primary production and recreation values is essential to allow meaningful adaption or mitigation measures to be developed. This may include recognition that values and areas may change across New Zealand and to ensure continued protection of all legitimate uses of the CMA that a national approach may be necessary.
Research components	Research component 3a: Develop tools to determine spatial distribution and expected quantum of likely CMA changes given global environmental trends. Research component 3b: Identify risks from environmental changes to CMA productivity at all trophic levels, and develop models to quantify impact on CMA ecosystems, fisheries and aquaculture resources. Research component 3c: Develop recommendations and tools to mitigate effects of environmental change in the CMA where meaningful New Zealand intervention is possible e.g. relocation of aquaculture sites, commercialisation of different species, changes to fishing effort, enhancement of wild stocks etc.
Research Gaps and Opportunities	There are a number of projects funded around New Zealand looking at integrated marine spatial planning, models, predicting plankton, nutrient changes etc. that could form a core of research in this challenge, However the main gap is that it is not integrated at a NATIONAL level. Not considering the values, science and modelling at a national level (but at each of the regional levels) risks both over-protecting and under-protecting values whilst almost invariably under-utilising productive resources.
Comments	Whilst the Resource Management Act does place the control and onus on territorial authorities, this challenge is an attempt to deliver the science, tools and decision support systems to facilitate either National Resource Management Guidelines or changes to Resource Management legislation.

Entry ID	**203**
Development of realistic and affordable national water and land management resources as a foundation for the increase of primary production development for domestic and export markets	
Summary	The goal is to protect profitability from primary production in New Zealand, themes include identifying the impacts of urban spread on primary production, developing and assessing the impact of high tech systems that reduce costs and improve primary production (e.g. GM), managing risks associated with intense farming practices.
Theme 1 **Develop regional plans that provide realistic and profitable systems for increased primary production for domestic and export markets**	

Importance to New Zealand	Understand the long term impact of urban spread on the cost of primary production. Maintain and encourage increased primary production as a base for economic growth for New Zealand
Research components	Identify current urban spread hazards on primary production as well as the associated economic & social costs. Water, air and quality waste management
Theme 2 **A focus on the issues around the reduction in profitability through increased compliance costs for primary producers standpoint**	
Importance to New Zealand	Agriculture and horticulture are the bases on which our economy was born and form an important fabric of New Zealand society. It continued existence as a foreign currency earner for New Zealand is important
Research components	Identify risks associated with reduced primary production growth. Develop new high tech systems to reduce costs and improved production. test true impact of genetically modified organisms on New Zealand and how our impact would be perceived internationally
Theme 3 **Management of risks associated with the intense farming practises**	
Importance to New Zealand	It would support the aim introduced by Hort New Zealand in reaching $10 billion by 2020.
Research components	water recirculation, energy creation, pest incursion control
Research Gaps and Opportunities	Domestic plant breeding to support increased production. Robotics to fruit harvest. Post-harvest technologies for sea freight of perishable goods

Entry ID	**277**
To enable New Zealand society to live sustainably	
Summary	This proposes a research programme to allow New Zealand society to live more sustainably. The themes include the development of a research programme to (a) quantify New Zealand biodiversity (and a strategy for reversing the decline), (b) identify limits to the consumption of non-renewable resources, (c) identify the effects of climate change (and develop a subsequent strategy) and (d) identify barriers to societal change
Theme 1 **To reverse the loss of New Zealand's biodiversity**	
Importance to New	New Zealand has a high rate of species extinction. A resilient ecosystem is dependent on maintaining a high level of biodiversity. Not only does our “Clean,

Zealand	green" international image depend on a healthy ecosystem, our ability to survive potential future climatic catastrophes may also depend on access to a broad spectrum of plant and animal genomes.
Research components	• A complete catalogue of New Zealand's biota. • A study of the drivers of species extinction. • Identification of strategies to reverse species extinction.
Theme 2 **To understand the limits to the consumption of non-renewable resources and how these will affect New Zealand in coming decades**	
Importance to New Zealand	Liquid hydrocarbons and rare-earth elements are examples of resources that underpin much of our lifestyle. The fact that they are non-renewable resources that are rapidly being depleted has implications on the long-term viability of many of our current technologies.
Research components	It is common to look at each of the non-renewable resources in isolation when considering the impact of shortages. However important synergies exist between these resources, with shortages of any one resource potentially impacting on a wide range of processes. An early attempt to understand these inter-relationships was presented in "The Limits To Growth" (Meadows et.al., 1972). A systems-level approach based on the latest science will help pinpoint potential future bottlenecks.
Theme 3 **An identification of the likely impacts of climate change**	
Importance to New Zealand	A changing climate is arguably the greatest threat to our way of life. If carbon emissions continue to increase the mean temperature is likely to increase by at least 2^{o} C this century, and there may be an increase in extreme weather events. Sea level rises, coupled with storm surges, are likely to cause serious disruption to infrastructure and may force relocation of low-lying.
Research components	Develop a strategy that defines the needs and priorities for New Zealand-based climate research. Conduct measurement programmes of relevant climate variables. Advance understanding of key components of the global climate system and the processes that connect anthropogenic emissions of greenhouse gases and changes in land use to changes in climate. Provide robust scenarios of potential future changes in regional extreme climate events. Generate scenarios of likely future changes in surface climate that are important to agricultural productivity. Quantify the potential impacts of future climate change on hydropower generation. Collect the data needed to establish a carbon footprint calculator for New Zealand conditions.
Theme 4 **Understand societal resistance to change**	
Importance to New Zealand	Even when the unsustainable nature of many aspects of our modern society is acknowledged, prudent changes are commonly rejected. The numerous 'denialist' groups associated with many issues including the dangers of smoking, the existence of climate change, and the finite nature of hydrocarbons resources are

	examples. The issue of intergenerational equity, although frequently commented on, is commonly disregarded.
Research components	The Stern Report ("The Economics of Climate Change: The Stern Review", Cambridge University Press, 2007) considered both the economic and social implications of various discount rates when considering the needs of future generations relative to our own. The application of more sophisticated tools such as hyperbolic discounting has been suggested. An extension of this work for very long time scales (e.g. in excess of 100 years) is needed to provide a guide for public expenditure on very long term issues such as climate change.
Research Gaps and Opportunities	Establish a unified approach to solving these problems. Research is frequently fragmented across a range of organisations, and a national strategy would lead to efficiencies and to a better identification of gaps in current knowledge.

Entry ID	**294**
(Epi)genetic instructions for organism assembly are highly conserved across all life-forms, but research effort is fragmented. Coordination of (epi)genetic research while allowing end-user customisation of new knowledge would be advantageous	
Theme 1 **Decoding life forms**	
Importance to New Zealand	The functioning of all life forms is derived from the (epi)genetic code. New Zealand has a unique set of organisms upon which it is dependent for economic prosperity. We also have unique organisms with conservation value and the demographic make-up of New Zealanders is unusual. This uniqueness of New Zealand's fauna and flora, and of New Zealanders, suggests that we need science capability in decoding the life forms that constitute New Zealand.
Research components	Fundamental science capability to unravel the (epi)genetic code. New (cheaper/faster?) technologies to read the code will be largely generated outside of New Zealand. However, some New Zealanders are world-leaders in describing the physical arrangement of genetic material which in turn is known to affect how the code is read. In addition, understanding the influence of non-coding genetic material is clearly an important step in understanding which parts of the genetic material are utilised in difference cell lineages.
Theme 2 **Interpreting the code**	
Importance to New Zealand	Having deciphered the (epi)genetic code of organisms of unique interest to New Zealand, the next challenge is to turn that information into 'useable' knowledge about how the organism functions. In addition we will need to know how species to species interactions at the genetic level influence phenotypic outcomes.
Research	An integrated research programme will be required to turn the (epi)genetic code

components	into useful knowledge for application in theme 3. This includes, for example, developmental biology, metabolism and physiology through to population genetics and evolutionary theory. Each element of such a programme will require access to technologies to support the various -omic disciplines. Cross disciplinary fusion will occur at the interfaces with technology development and application
Theme 3 **Applying new knowledge**	
Importance to New Zealand	While some of the research in themes 1 and 2 might be undertaken outside of New Zealand, it is inescapable that we must take responsibility for the application of new (epi)genetic knowledge to benefit New Zealand(ers).
Research components	The application of new (epi)genetic knowledge will vary by end-user. Thus application of new genomic knowledge to improved breeding decisions in the New Zealand dairy sector will differ tremendously from how similar new knowledge will be applied to ameliorate the human obesity epidemic or to conserve native flora in the Urewera National Park. That said, there will be common underlying threads such as genotype-phenotype mapping, species-species interactions, population dynamics and theory of systems biology.
Research Gaps and Opportunities	It is impossible for New Zealand to fund all potential research activities covered by the 3 themes. The establishment of a coordinated programme of research entitled “Genetics for New Zealand(ers)” across biologically research-active institutions in New Zealand (Universities, CRIs, CoREs, conservation entities, health organisations) will identify and secure focus around the critical areas for New Zealand to invest in. There is a shortage of suitably qualified young people in a number of disciplines, notably bioinformatics, systems biology and quantitative / population genetics. National coordination will identify where these shortages are most critical, thereby enabling more targeted investment in tertiary education and the associated structures which underpin the infrastructure.

Entry ID	**300**
New Zealand will improve the management of land and water to increase wealth and environmental integrity.	
Summary	This challenge proposes to develop best-practice management approaches, tools and technologies to enable optimal use of land and water in order to increase wealth and environmental integrity. Key targets for research will include; agronomic technologies/techniques to optimise productivity/profitability, better management of soil quality/nutrient levels, effective water allocation, and managing greenhouse gas emissions. This research will be complemented by studies looking at alternative approaches to wealth creation which draw upon New Zealand's inherent advantages, thereby ensuring prosperity and improved wellbeing.

Theme 1 **Develop best-practice management approaches, tools and technologies to enable optimal use of land and water resources at catchment- and farm-scales.**	
Importance to New Zealand	It is estimated that New Zealand loses 200-300 million tonnes of soil per annum, a rate 10x the rest of the world, and in monetary terms costs >$127 million p.a. Recent studies show significant amounts of soil organic matter are being lost under flatland dairy grazing. This loss reduces the soil's capacity to filter contaminants, retain nutrients or resist pugging. The effect is twofold, impacting on the quality of farming operations and the underpinning resource. Elite and versatile soils provide disproportionate value to our economy, just 0.4% of land supports 14% of the total contribution the primary sector makes to GDP. But these soils are currently disappearing to tar-seal and life-style development. Given the very slow rates of soil formation there is mounting concern over the availability of productive soil ('Peak Soil'). Contamination of groundwater with nitrate and/or microbial pathogens occurs in many regions. Water availability is also a problem in some regions due to the withdrawals needed to support agriculture and/or seasonal fluctuation in supply and demand. Our primary industries are therefore under extreme pressure to maintain (or increase) their profitability, protect the resources they and future generations depend on, whilst simultaneously meeting the requirements of markets and government policies (e.g. National Policy Statement for Freshwater). Science has a significant role to play in helping these industries find the 'sweet spot' to reduce operating costs, grow wealth and protect the integrity of soil, land and water assets, through information, tools and technologies.
Research components	The research in this theme provides a robust scientific framework for explaining variability in the vulnerability and potential of soil, land and water resources. This provides a scientifically credible basis to inform appropriate best-practice approaches, tools and technologies to ensure profitable use and retain land and water resources for future use. Research components reflect the scale of implementation and the major challenge around getting uptake and adoption of best practice. Key research components include: On-farm tools and farm systems: Including agronomic techniques to optimise productivity and maximise long-term profitability for NZ; Plant and animal breeding – the genetic characterisation of traits and genetic manipulation; Agricultural technologies and precision techniques; soil attributes to enable better management of soil quality, productivity, nutrient management and greenhouse gas emissions; minimising waste and maximising re-use. Catchment-scale approaches: Including optimising land use at multiple scales and across multiple co-benefits; More effective water allocation and use; Integrated land management approaches; Mitigating nutrient loss and impacts of contaminants in soil and groundwater; Reducing erosion and sediment loss; Mitigating the impacts of extraction and use of aggregates, limestone and fertiliser; Drivers and barriers to uptake: Including economic analysis and cost benefit; farmer behaviours and value; methods to diffuse best practice across

	primary industries.
Theme 2 **Advance New Zealand's economy and enhance environmental integrity by using science to identify, realise and protect the unique advantage provided by our land and water resources.**	
Importance to New Zealand	The land economy currently represents more than 25% of GDP. But with a large focus on intensification, commodity export and single species (e.g. trees and crops) it is a fragile economy. Potential or actual threats include a decreasing natural resource base (e.g. 'Peak Soil'), changing market preferences and conditions, fraudulent products in overseas markets claiming to be of New Zealand origin, and devastating infectious diseases (e.g. PSA or Foot & Mouth). The Government's Business Growth Agenda calls for export earnings from the land to increase by 40% by 2025. But this goal should not be met without considering how to increase the resilience of the economic, environmental and social systems on which it is based. And while making more optimal use of land and water resources i.e. sustainable production (Theme 1) is important, new paradigms have a role to play in creating a green, wealthier New Zealand. Significant intellectual effort by government and business leaders has been devoted to exploring new paradigms including Pure Advantage, Vision 2050 NZ and the Maori Economic Growth Strategy. However, this transformation is not without risk and must draw from emerging science and innovation. Science therefore has a role to play in: • Identifying New Zealand's natural and cultural advantages • Putting into practice approaches to leverage those advantages (that are restorative and promote shared-value) • Developing tools and technologies to protect and give credence to these advantages as part of the New Zealand brand.
Research components	The research in this theme provides the foresight, underpinning data, testing and validation to support alternative approaches to wealth creation, drawing upon New Zealand's inherent advantages. The contribution of knowledge draws on a number of currently disparate science domains. Research components include: Identification of natural and cultural advantage: Including characterisation and valuation of resource potential; Food technologies to support new products and product values; Mātauranga Maori and cultural values; scenario analysis and visualisation technologies; land use optimisation modelling; Realising natural and cultural advantage: Including research to underpin new land uses and primary produce, reuse of waste and increased ecosystem service provision; understanding principles behind successful co-management and governance models; and social and economic modelling. Tools and technologies to protect NZ advantage: Including life-cycle analysis, foot-printing and eco-verification; use of environmental tracers and identifiers; enhanced surveillance for continued consumer trust and market access.

Theme 3 **Deliver an appropriate evidence base, participatory processes and uptake methods to facilitate more effective land and water resource governance and decision-making at catchment-, regional- and national scales**	
Importance to New Zealand	To ensure New Zealand's prosperity and improved wellbeing, it is critical land and water governance and decision-making is inclusive, collaborative and gains confidence from a range of interested parties. Adversarial approaches and contention incurs considerable costs associated with the time taken to arrive at a decision, as well as the multiple impacts of delaying action. Even a modest reduction in time taken to make decisions or number of stakeholder submissions/legal appeals will save millions of dollars in terms of legal analysis, addressing submissions and stakeholder engagement. But governance in New Zealand is complex. With a significant proportion of the Maori asset base in land and water, and the importance of these resources to cultural identity, Maori are a significant stakeholder. The Maori Court challenge over proprietary rights over water illustrates the potential for contention. Another complexity unique to New Zealand is the simultaneous dependency on the land economy (compared with OECD peers) but large percentage of urban dwellers (>80%). This can often manifest publicly as a clash of values: 'greedy farmers' vs. the community interest. Land and water resources must therefore be effectively managed to account for the range of interests and preferences, as well as the capability and capacity of the resources themselves. This requires taking into account both economic and non-economic values, working towards a shared vision of the outcomes required at catchment-, regional- and national-scale; and validating the progress towards those outcomes through planning, monitoring, reporting and adaptive management.
Research components	Significant research progress has been made in this theme in recent years. Science offers the potential to provide the evidence base, participatory processes, and policy instrument design to facilitate effective decision-making. But to do so it will need to resolve the challenges of working with uncertain data, considering non-economic values alongside economic values, and improving the way science is communicated to stakeholders. Underpinning research components thus include: Values and participatory processes: Including resource valuation and values; socio-ecological and socio-economic systems; Mātauranga Maori; economic, social and futures modelling and analysis (including integrated modelling/analysis); analysis of trade-offs between economic, social, environmental and cultural values. Evidence and monitoring: Including biophysical monitoring and data collection; uncertainty analysis; cultural indicators; scenario analysis. Uptake and implementation: Including participatory processes, collaborative learning and other decision-making processes; Knowledge transfer processes; adaptive management; governance structures; behavioural and organisational analysis; instruments to support policy development and their design.

Theme 4 Establish credible information at appropriate scales to characterise the state, trend, impacts and opportunities for land, water and associated ecosystem services	
Importance to New Zealand	Comprehensive and fit for purpose data and information on the state of New Zealand's environment is fundamental to land and water research and underpins all other themes and goals of this Challenge. Similar to the way in which the New Zealand Treasury's monthly and annual (year-end) financial statements provide information on the government's economic assets and liabilities, to inform government spending, priorities and policies, robust quantitative and scientific data is needed to assess the overall health or state, likely trend, threats and opportunities of New Zealand's natural land and water assets. There is still considerable uncertainty about how far we can push land and water until tipping points are reached and the environmental benefits derived from natural resource systems diminish. Credible information at appropriate scales is needed urgently, in order to ensure we can respond to risks rapidly as well as to manage the balance of needs and sometimes conflicting goals between economic development and environmental integrity. So, theoretical modelling, data collection and interpretation is more than stamp collecting – it is about establishing an evidence base on the land and water system, and all the connections and complexities within it, to drive all other themes and outcomes. Examples of good quantitative data include improved soil variability mapping in the Mataura which resulted in savings for farmers and reduced leaching into groundwater; the existence of a long data record about Taupo Basin, made possible to implement science-based decisions for improved land use management and enhanced prosperity for all New Zealanders.
Research components	This theme will deliver the fundamental understanding and primary data on soils land cover, land use, terrain, freshwater and ecosystem services, including understanding state, trend, risk and opportunity. This basic science is needed for operational, tactical and strategic decision-making at national, regional and local scales. Research components underpinning this theme include: Component characterisation: Including soil, geological and geochemical characterisation; groundwater characterisation and management; characterisation of ecosystem service conditions and trend; spatial and longitudinal data on economic, social and cultural systems; measuring uncertainty; data on behaviour, behaviour change and preference over time and space. System understanding: Including system function and cumulative impacts across time and space – e.g. nutrient flows, water transmission through the system; ecosystem interactions; spatial, integrated and predictive modelling; data stewardship, visualisation and delivery: Including data life cycle management; data retrieval and semantics; dealing with data provenance, quality and erosion; measuring and communicating uncertainty and risk; Integrated modelling, syntheses and analyses to recommend practical real-time solutions; service, interoperability, and information visualisation; communicating data limitation and uncertainty.

Research Gaps and Opportunities	A large opportunity is to better understand landowner behaviour and the triggers that will cause farmers to implement best practice – and then to engage these triggers. There are also very significant science and technology challenges, ranging from the relatively easy to the extremely difficult and with their respective low to high rewards for success. At the extreme end is for science to come up with innovative and cost-effective ways to decouple productive land from the receiving water. The new science will need to deal with multiple stressors and cumulative impacts and ensure that productive and profitable farming at the top of the catchment has relatively low impact on other values downstream.
Comments	There is currently a significant disconnect between researchers focusing on increased production of existing commodities and the opportunity to develop new crops, new products, and the integral value chains that can provide assurances of product integrity (safe food and sustainable practices). The opportunity is to bring these research efforts together, potentially in a new centre for sustainability research. As a country we have the skills and the scientists to increase productivity and develop new products, and others that have an excellent grasp of sustainability and environmental protection. The opportunity is to bring them together to develop higher value and sustainable productive systems that will enable New Zealand to become a world leader in sustainability and product integrity. (This is Strategy 4 out of the Call to ARMS publication).

Entry ID	**305**
Using science, innovative technologies and tools to improve our production from land while maintaining or enhancing our freshwater quality	
Summary	The goal is to use science, innovative technologies and tools to improve land productivity while maintaining or enhancing our freshwater quality. The proposed research programme themes include development of (a) best practice land management to reduce leaching of contaminants and reduce impacts on receiving waters to within limits for environmental sustainability (b) robust understanding and assessment of the assimilative capacity of New Zealand's freshwater systems so that they can be utilised and managed to achieve a better (c) an integrated model to include the farming system (including economics), transport and attenuation processes through the soil, unsaturated zone, and (d) a shared ownership of the issues concerning land productivity while achieving environmental limits by a broad spectrum of society.

Theme 1 Development of best practice land management to reduce leaching of contaminants and reduce impacts on receiving waters to within limits for environmental sustainability	
Importance to New Zealand	A large proportion of New Zealand's export earnings come from agriculture and derived products and there is pressure to increase the productivity of this sector. However, the intensification of land use that has occurred over the past few decades has resulted in environmental stresses such as poor water quality, erosion and loss of biodiversity. The importance of achieving and maintaining a balance between land productivity and environmental impacts has been recognised by the NPS for Freshwater and the reports from the Land and Water Forum.
Research components	Scientific research is needed to inform best practice in the following areas: •Development of integrated land & water (i.e. catchment) management that operates within the framework of environmental limit setting and sustainable, yet profitable land-use •New or refined products from plant and animal species •Setting of robust and appropriate limits for freshwater and near-coastal systems at the national, regional and catchment scales. •Incorporation of water quality into natural capital evaluations. •Contributing technical information to the integrated modelling of the whole system from top of catchment to the sea (theme 3) •Development of farming systems to take advantage of new knowledge, technologies and insights from the other themes in this challenge
Theme 2 **Robust understanding and assessment of the assimilative capacity of New Zealand's freshwater systems so that they can be utilised and managed to achieve a better outcome of productive land within environmental limits**	
Importance to New Zealand	Freshwater systems have varying levels of resilience and assimilative capacity. In order to maintain or increase productivity while remaining within environmental limits there needs to be much better understanding of these factors and the incorporation of these concepts into land management and farming systems. For example, there is significant assimilative capacity in groundwater systems for nitrate where groundwater flows through a reducing environment (no oxygen present). In these conditions nitrate will be reduced to innocuous nitrogen gas which is the major component of the atmosphere. Increasing land intensity in these areas would result in no increased levels of nitrate impacting receiving waters. This is analogous to applying effluent to soils where there is sufficient capacity for treatment and minimising application to stony soils where there is little treatment capacity.
Research components	Scientific research is needed in the following areas: •Robust assessment of assimilative capacity of groundwater systems •Enhancing and managing subsurface removal processes through novel engineered remediation systems. •Reductions in nutrients at the groundwater–surface water interface •Assessment of the in-stream assimilative capacity •Incorporation of new knowledge, technologies and insights from this theme into the other themes in this challenge

Theme 3 **Develop an integrated model to include the farming system (including economics), transport and attenuation processes through the soil, unsaturated zone, and groundwater, groundwater-surface water interface, in-stream processes and estuarine environments**	
Importance to New Zealand	There are models available for many farming systems (dairy, other pasture, crops, horticulture) which indicate likely levels of leaching to groundwater or runoff to surface waters. NIWA have developed some models for surface water transport for a number of key contaminants. Key missing components for most of these models are the transport and attenuation processes within the unsaturated zone and groundwater system, and what happens at the groundwater – surface water interface. All these aspects needs to be included if land productivity is to be maintained or increased while achieving environmental limits. A whole system integrated model will enable researchers, resource managers, farmers and the public to examine issues, opportunities and consequences in a more informed manner. This will assist in the adoption of new management systems and policies necessary to maintain productivity while achieving environmental limits.
Research components	Scientific research is needed to develop models in the following areas: •transport and attenuation processes through the soil, •transport and attenuation processes through the unsaturated zone, •transport and attenuation processes through the groundwater, •groundwater-surface water interface, •in-stream processes •natural capital evaluation of water quality •economic and social impacts of proposed developments and scenarios •linking of these components in a sensible and sufficient manner so that key processes are appropriately represented in a whole system model
Theme 4 **To gain a shared ownership of the issues concerning land productivity while achieving environmental limits by a broad spectrum of society so that a range of innovative solutions can be assessed in a grounded manner to give the desired outcomes.**	
Importance to New Zealand	The issues of land use and productivity and environmental quality affect everyone in New Zealand society, either directly or indirectly. Direct impacts include those who make an income from farming and associated activities, those who depend on rivers and lakes for a living, and those who enjoy various water based recreational activities. Indirect impacts are the general standard of living which is affected by exports and environmental costs that are borne by the general public through taxes. Māori have a key role in both resource development and stewardship. A major problem with many “solutions” is a failure of implementation. This can have a number of causes but a key reason is a lack of ownership of the issue and proposed solutions by the full spectrum of stakeholders. The Land & Water Forum has explored a consensus based approach which shows promise. More work is needed in this area to examine potentially workable solutions and how they can be owned and implemented by New Zealand society. There needs to be equity with respect to both benefits and costs for any proposed solution.

Research components	Scientific research is needed in the following areas: •Economic and social consequences and modelling of proposed solutions •Assessment of key societal values regarding land productivity and environmental quality •Development of clear communication of all relevant issues, including how things like standard of living, sustainability of activities, and likely future scenarios, are impacted by the issues and proposed solutions •Demonstration of efficacy of (engineered) mitigation measures for water contaminants
Research Gaps and Opportunities	There is significant research effort being undertaken in the area of best practices for land management and much of this effort needs to be maintained. There is opportunity to focus some of this effort from areas where processes are well known to areas where the knowledge is less well-established. There is some work being carried out by ESR and LVL into groundwater assimilative capacity, there is some work being carried out by ESR, LVL, GNS, AquaLinc and NIWA on groundwater- surface water interactions, and the There is some work on in-stream assimilative capacity being carried out by NIWA. The work on in-stream assimilative capacity is more advanced than the groundwater work. There is significant opportunity to advance understanding in these areas and incorporate the concepts into land management and farming systems. There are further opportunities to boost the assimilative capacity of a hydrological system through engineered remediation measures, the effectiveness of which remains to be properly examined in New Zealand. There is a good body of research available for the soil processes throughout New Zealand. Much less information is available for the unsaturated zone and groundwater systems and little is known about processes in the groundwater-surface interface. AgResearch, Landcare Research and Plant & Food have expertise in soils, ESR and LVL have expertise in unsaturated zones, ESR, LVL and GNS have expertise in groundwater systems, ESR, GNS, LVL and NIWA have some expertise in groundwater-surface water interface processes. NIWA (& Cawthron?) have expertise in in-stream attenuation processes. Modelling expertise lies with all these agencies but putting together a whole system model would require an inter-agency approach.

Entry ID	**318**
Oceans Management - getting the best from our ocean	
Summary	This challenge proposes that to properly manage the multitude of uses the EEZ has/might have, various data collected (i.e. ecological, climactic, human related) needs to be integrated into one place. Concurrent to this is setting objectives for oceans management, such as establishing ecological limits for resource use, and finding the best ways of measuring of these limits. Developing these limits will require a legal framework to be developed, which should take into account New Zealand-specific contextual factors (such as treaty obligations.)

Theme 1 Bringing Together Data on Ocean Ecosystems and Human Activities/ Impacts	
Importance to New Zealand	New Zealand has the 5th largest EEZ in the world, the ocean provides valuable ecosystem services and it is potentially a massive economic resource. Fish stocks already are worth in excess of $4 billion. To manage the multiple uses of the oceans we need to bring together all the oceans data into one place.
Research components	Integrating all existing data on oceans ecosystems and human activities into one place, so that the data can be used to inform spatial oceans management.
Theme 2 **Setting objectives for oceans management**	
Importance to New Zealand	New Zealand has the 5th largest EEZ in the world, the ocean provides valuable ecosystem services and it is potentially a massive economic resource. Fish stocks already are worth in excess of $4 billion.
Research components	In order to manage economic use of the ocean we need to establish ecological limits, and find ways of measuring and managing those limits. This will ensure that the ecosystem services of the ocean are not adversely impacted by use of the ocean, which will ensure sustainable use.
Theme 3 **Legal and economic system of oceans management**	
Importance to New Zealand	New Zealand has the 5th largest EEZ in the world, the ocean provides valuable ecosystem services and it is potentially a massive economic resource. Fish stocks already are worth in excess of $4billion. Freedom in the commons brings ruin to all - we will need a legal and economic system of oceans management to prevent a tragedy. We have this for fish, but nothing else.
Research components	We need to take the best international good practice, and contextualise it for New Zealand (particularly Treaty obligations) to work out the best way forward. This must include a way of managing conflict between different ocean users, and ways to protect key ecosystems and ecosystem services.
Research Gaps and Opportunities	This will become clear when the first two themes are completed - once we know what is important to know, and brought together what we know, we will have a gaps analysis showing the research needed to better manage the ocean.

Entry ID	**324**
Rehabilitation and conversion of land and waterways currently deemed as unsafe for productive utilisation due to the presence of Dioxin and other persistent organic poisons. Extension of the current bioremediation project	
Summary	This challenge proposes to perform research to identify how environmentally-dumped organic poisons have (and continue to) negatively affect those that are exposed to them and how that risk to population health and environment can be

	managed. Bio-remediation is seen as an attractive avenue to combat this pollution, and in some tests has already shown great promise (which might be built upon with proposed further research).
Theme 1 **Understanding the impact of persistent organic poisons on the productivity of land, soil and waterways**	
Importance to New Zealand	In Whakatane alone there are at least 36 known contaminated sites associated with the Sawmill and its use of Pentachlorophenol and the dumping of waste around Whakatane .There are many other potential similar sites in Tokoroa, Pūtāruru, Rotorua and other sawmill host communities. The land and streams associated with these dump sites which are contaminated by the presence of persistent organic poisons remain unproductive and the streams lifeless and no longer able to be utilised for productive activity or harvest. Many of these areas and streams were traditional providers of kaimoana for the Māori of our country. Return of the viability of such treasures must be critical to the health of the whenua and Papatuanuku. The potential benefit in respect on mana, sustainable traditional food-baskets and the environment are difficult to quantify but will provide enormous benefit to the population and country as a whole. With increasing urbanisation and rapidly increasing populations the ability to maximise all remaining areas of productive land and waterways becomes an important imperative. Rehabilitation of currently barren land and waterways therefore becomes a critical component of a sustainable future for our coming generations and their mokopuna.
Research components	Early research evidence from Whakatane bio- remediation project has shown the potential for up to 87% rehabilitation of the soil by conversion of dioxin to its less dangerous by products. Extension of this research to the larger environmental application of the technology within the real world environment will not only provide further evidence of benefit but potentially deliver a remedy to already affected lands and rivers in whakatane. Current research has utilised black fungi, Poplar trees and a combination of fungi and Poplar trees in a limited set of soil samples. There is opportunity to extend the armamentarium of bio remediation options if such research is supported and funded into the future.
Theme 2 **Maintenance of the Health of the population and understanding the evidence of harm from persistent organic poisons**	
Importance to New Zealand	Maintenance of the health of the population and understanding the evidence of harm done and potentially still to be done to future generations as the result of exposure to pentachlorophenol, its persistent by- product of dioxin, and other persistent organic poisons will assist in managing present and future threats to the well-being of whanau and whenua. There is evidence of the damage to and consequences of exposure of Vietnam war veterans to agent orange and more recently evidence of harm to subsequent generations from exposure of veterans from Malaya to paraquat. Understanding the impact of dioxins and other persistent organic poisoning on our populations here in New Zealand is therefore

	a critical research project as these persistent organic poisons have a similar chemical structure to those aforementioned poisons. The health of our current and future generations depends on clearer understanding of the impact and potential impact of the chemicals residing within the land and streams and ensuring these remain free of potential detrimental chemicals and poisons. Understanding these impacts will also allow proactive treatment and management of illness and harm within the individuals directly and indirectly exposed to the persistent organic poisons present.
Research components	Research into the health data of those known to be directly exposed to pentachlorophenol through their workplace. There has been some already reported evidence in the New Zealand research literature. A current cohort study is potentially underway comparing Whakatane and Masterton populations to attempt to show disparities in health outcomes between districts. This is research that should continue to be supported and expanded to a larger population study. Medical examination and establishment of individual medical and health related data on those individuals who have worked in or been associated with sawmill sites and the associated whanau of these sawmill workers will contribute to broader understanding of difference of prevalence of specific illnesses or physiological changes as compared to the general population. Long term follow up research studies of these identified families monitoring the potential generational effects would provide opportunities to initiate preventative health care measures for affected whanau
Theme 3 **Managing the future risk to Papatuanuku and whenua**	
Importance to New Zealand	Research and expansion of the bio remediation tools exploring wider options and choices of remediation, research into improved monitoring mechanisms and the use of health data flags within the national data identifying populations and whanau at risk would provide New Zealand with information to pro-actively improve the well-being of Papatuanuku and the population as a whole. Additional research support would accelerate the assessment and implementation of a project with the potential to return significant arable land and clean healthy waterways to the nation.
Research components	Implementation of the current pilot model of bio remediation and further research into development of additional research projects supporting sustainable bio remediation activities will provide options for our community to maintain a healthy environment and contribute to a sustainable future. The current capacity of the local bio remediation team including Environment Bay of Plenty, the Whakatane District Council, Waikato And Massey Universities, limits the scope and impact of such essential activity. Research measurements on the health of the waterways and a return of common and traditional species and inhabitants of the waterways would demonstrate a return of the health of the Kaimoana. Tools to measure and ensure the safety of the return of previously contaminated soils to arable land would provide confidence for the sustainable use by future generations
Research	The current bio remediation project is limited in scope and support to extend the

Gaps and Opportunities	research to a larger project. Support for larger areas of implementation of the current research project and the exploration of additional bio remediation approaches to soil and water rehabilitation is essential
Comments	I have tried to reflect the Kaupapa of the current bio remediation project into this submission though my involvement has been recent. There are years of experience and commitment to the larger Kaupapa of the health of papatuanuku within the people who are interested in this proposal and its submission who are able to continue discussion should this be considered. The combination of Matauranga Māori and western Science as partners in finding a solution to heal Papatuanuku is inherent in this kaupapa

Entry ID	**326**
To develop a theoretical basis for understanding the undesirable physiological trade-offs that occur when plants and animals of agricultural importance are subject to genetic selection for production traits.	
Theme 1 **To understand the process of portioning energy in organisms and the links to gene expression**	
Importance to New Zealand	Energy partition to productive traits underpins the production of meat and milk, but also serves in reproduction and in the response to environmental insult. The trade-offs between these traits is central to the interaction between productivity, resilience and animal welfare. These issues are of increasing importance to New Zealand agriculture.
Research components	1. Develop dynamical models of the important components of the energy management physiology. 2. Understand the pathway from (multiple) gene expression to how the physiology of energy management is altered in response to environmental stimuli 3. Determine how trade-offs e.g. between milk production and reproduction in the cow are related to changes in the dynamics of the physiology of energy management. 4. Investigate the potential for external manipulation for favourable outcomes.
Theme 2 **Determine the mechanism of Developmental Programming and the link to the trade-off between traits. Investigate how this link is mediated**	
Importance to New Zealand	The importance of developmental programming, particularly in early life has recently been realised in medicine. The knowledge from medicine has directed attention to the importance of this phenomenon to agriculture. The impact of early life developmental programming appears to be at the heart of raising animals and plants that are resistant to environmental insult. An understanding of the role of developmental programming would guide scientists towards breeding resilient animals and alleviate some animal welfare concerns.

Research components	1. Identify the mechanism whereby environmental variation guides developmental programming. There is evidence that this is mediated by epigenetics. The epigenetic "code" that links environmental variation and subsequent gene expression needs to be identified. 2. It is likely that the responses from several genes which have been epigenetically modified determine the physiological response. How such a system of genetic responses operates needs to be determined. 3. How the responses from a system of genes operate to alter the physiology to determine a trade-off must be investigated. A leading hypothesis is that the dynamic nature of such a response is the key issue, resulting in a qualitative change in the response of the physiological dynamics. This could result in a discontinuous change in the energy partitioning of the physiological system.
Theme 3 **Apply the results of themes 1 and 2 to develop a breeding strategy for organisms which are productive and resilient**	
Importance to New Zealand	Emphasising both resilience and production in agricultural plants and animals meets New Zealand's goals of better productivity and increased animal welfare. Reducing animal deaths through increased resilience provides a clear monetary benefit to farmers, while the animal welfare benefit is also clear. Better resilience in plants addresses a problem preventing the wider introduction of newly developed pasture species.
Research components	Assuming that the molecular and physiological pathways of the trade-off are identified in themes 1 and 2, the investigation of how to manipulate these pathways at the farm level needs to be addressed. In particular, the problem of how to reverse an undesirable influence is of central importance. The work from themes 1 and 2 will suggest a number of opportunities for intervention, and designed experiments will need to be constructed to investigate their feasibility. This is the task of this theme. It will be important that this work is carried out with the practicalities of adoption on-farm in mind.
Research Gaps and Opportunities	1. The mechanism of developmental programming that links an environmental signal to a physiological outcome underpins the success of this challenge. It is likely that a number of pathways are involved, then the need becomes of identifying the path with sufficient influence to make a difference to the goal of more resilient animals. 2, Because of the variety and complexity of likely physiological responses it seems axiomatic that nonlinear dynamics are involved. Identifying the key nonlinear attributes of the energy management system would help to focus studies on those factors most likely to make a difference.
Comments	The ideas expressed in this challenge have been developed with colleagues in the Centre of Research Excellence "Gravita", which represents a vehicle for implementation by bringing together agricultural scientists, animal breeders, molecular biologists, evolutionary biologists and mathematicians.

Entry ID	339
New Zealand needs to grow the economic value gained from its land and natural capital and resources while reducing the environmental impact of agriculture and forestry	
Summary	The goal is to increase agricultural/forestry productivity while reducing the environmental impact. This is proposed via a research programme with the following themes: (a) The goal is to increase productivity from agricultural land in a way that is socially and environmentally sustainable and acceptable to New Zealanders, and to the markets/consumers on which our exports rely.
Theme 1 **The goal is to increase productivity from agricultural land in a way that is socially and environmentally sustainable and acceptable to New Zealanders, and to the markets/consumers on which our exports rely**	
Importance to New Zealand	Agriculture is New Zealand's most important export industry (worth $21.6 billion in the year to July 2012, or 46% of merchandise exports). If New Zealand's economy is to grow significantly, either the productivity of the agriculture sector will have to grow substantially, both agriculture and smaller sectors would have to grow, or the smaller sectors by themselves would have to grow enormously. The first two options (which would require growing agricultural productivity) seem to be the most promising. However, out of 31 countries for which OECD Stat provided agricultural GDP data and agricultural workforce numbers for the year 2009, New Zealand was ranked 15th in the key productivity measure of agricultural GDP per worker. This was a substantial decline from 1998 when New Zealand was 8th out of 29 countries. If agriculture is to make a major contribution to economic growth in New Zealand, it is vital that we greatly increase the rate of agricultural productivity improvement. Agriculture is also our most important land use after native vegetation, taking up 39% of New Zealand land area, a major user of our water resources and potential polluter of our waterways. Agriculture thus has a major influence on the New Zealand environment and society. Agricultural productivity improvements must go hand-in-hand with reduced environmental impact and improved resource use efficiency, including improved nutrient management.
Research components	The following components are needed: 1. Improved production from home-grown feed. 2. Improved productivity in dairy, meat and fibre-producing animals. 3. Improved animal health and welfare. 4. Adoption of new farm management practices which improve productivity. 5. Improved on-farm productivity in Māori agribusiness enterprises. 6. Practical policy solutions for economically, environmentally and socially sustainable agriculture. 7. Reduced environmental footprint of pastoral farming operations. 8. Practical policies and strategies to improve on-farm water and wastewater management. 9. Improved understanding of ecology of farm land so the resilience of underpinning soil and water systems can be sustained

Theme 2 **The goal is to increase the real value we derive from the food, beverage and fibre we export. In doing so we will be adding value and also getting a bigger slice of the value that is created**	
Importance to New Zealand	New Zealand's food, beverage and fibre exports make up about $26 billion per year, or about 55% of merchandise exports but we only supply dietary energy for 20 million people, the protein requirements of 45 million people and the dairy product requirements of 165 million people. Thus, New Zealand is a niche producer of food, beverage and fibre products that has the opportunity to target the high end of world markets rather than having to compete with larger food-producing countries on price. To earn premium prices from the products we sell to those high-end markets, we must produce foods, beverages and natural fibre products that are of the highest and most consistent standard, are most appealing to the world's most discerning customers, and have the greatest functional benefits for those customers. At the same time, we must capture a greater share of the value chain that secures for New Zealand a greater percentage of the price paid by the consumer for the final product. This requires that the products we sell have attributes that are rarely or never found in competing products, that allow us to command premium prices, or that New Zealand owns a large fraction of the offshore value chain – up to the retailer or even up to the consumer her/himself. The latter requirement would have to be met by business and investment strategies rather than research, but research can certainly deliver attributes whose uniqueness or rarity can be secured by intellectual property or appellation.
Research components	The research components required are: 1. New high-value dairy and food solution products and processes. 2. Meat and processes which consistently meet the needs of existing and new markets. 3. New products from Māori agribusiness enterprises. 4. Higher value wool products. 5. Products that consistently comply with demanding international food safety regulations.
Theme 3 **The goal is to develop better models of rivers and lakes to ensure the impacts of draw-offs enable recovery**	
Importance to New Zealand	Maintaining and enhancing New Zealand's water resources is vital as businesses rely on water. Making the best use of water resources is important to ensure sufficient water is available for the cultural, social (recreational), environmental and economic activities New Zealand wishes to take. Better understanding is needed of the flows of rivers and lakes. Such understanding will enable modelling of these waterways and the setting of minimum flows and other settings to ensure the ecosystems within the waterways can continue to exist even with the use of water from those other waterways for other purposes. The outcome of this understanding will be continued practice of agriculture and forestry in New Zealand which will maintain or boost the economy. In addition natural ecosystems will be protected, enhancing New Zealand's integrity as a clean green nation. New Zealand may also be able to share the knowledge it develops through modelling to other countries which would itself provide a contribution to the economy.

Research components	Research is needed to better model rivers and lakes and the effect of draw-offs on these water bodies and associated ecosystems.

Entry ID	**351**
The integration and reconciliation of environmental and economic benefits to support a hybrid approach to prosperity and well-being for New Zealand society	
Summary	The goal of this proposal is to develop methods/measures to eliminate the current trade-offs between economic performance and management of environment (i.e. the negative environmental impacts that accompany improvements in primary production). 1. Measuring the state, trends, and limits of our natural resources 2.Understanding and prioritising values around natural resources within an inclusive society 3.Develop creative and innovative solutions to 'wicked' problems 4. Providing a feedback loop for learning how to deliver integration, allowing us to evaluate progress of implemented measures. This theme provides assurance that both Government investments in research and changes to primary sector practices are delivering against this challenge.
Theme 1 **What have we got – Measuring the state, trends, and limits of our natural resources**	
Importance to New Zealand	The theme provides an underlying stocktake of our greatest asset – the New Zealand environment – and how that asset provides flows of benefits, including economic wealth as well as social values and cultural identity. The New Zealand economy remains focused on land-based primary industry; the New Zealand identity is focused on our relationships with the land and our use of that, through farming communities, tourism, recreation, and spiritual values. Without knowing the starting point - how that natural assets are performing - it is impossible to set a credible strategy for future growth. The story of New Zealand agriculture over the past two decades is one of expansion and intensification. All primary industries have strategies of growth which are running up against the limits of natural resources. At the same time, New Zealand's key overseas brand of "100% Pure New Zealand" is suffering from the reality of our over-use of our natural assets. Resolving this tension is the linchpin of continuing to gain value from both.
Research components	1. Increase the value of current baseline and trend data by continuing work to assemble, validate, and make available existing information into consolidated databases with suitable metadata and custodian-ship. 2. Carry out a state of the knowledge survey through a literature survey supported by research-provider survey to identify not just gaps in knowledge but evaluate the quality of the knowledge that is available. Some quantification and evaluation

	of economic and ecological values has already occurred or can be inferred from published and unpublished works towards other purposes but not all previous work is equally useful. Some retrospective evaluation will be required to inform a synthesis of current knowledge. The survey provides a benchmark to identify research needs. Our current understanding of the state and trends of natural resources is rich for some resources but poor for others. There is an opportunity to build on that knowledge to bench-mark future progress, allow a comparison of past rates and trends with future outcomes, and to provide a base to detect outcomes from policy and management decisions. Our current understanding of how environments translate into economic benefits is well developed for a few key resources but absent for many others – especially those where the link is indirect e.g., sense-of-place values. Advances in accounting and economic models which incorporate other non-monetary can be achieved with these types of detailed study but are not possible without them.
Theme 2 **How do we value it – Understanding and prioritising values around natural resources within an inclusive society**	
Importance to New Zealand	The goal of this theme is to understand how people value the benefits that come from our natural assets, including the economic value that intensive use creates and the supporting services provided by less intensive use, as well as how people rate and assess the state and trends of these resources. We will need better understanding therefore of what makes up New Zealand identity, how that depends on our environment, and how those identity values act as a lens to judge economic propositions. This research allows us to understand how to reconcile development and protection. It seeks out our opportunities for development to deliver increased value and prosperity from natural resources and identifies the win-win options. It provides valuations of our natural capital and informs the optimisation of the set of benefits and co-benefits that flow from that capital, with the ultimate goal of informing and improving management and development decisions across a wide range of timescales and spatial scales. It provides an appreciation of the risk to the biosphere and associated social sub-systems from a wide range of biophysical and socioeconomic stressors, allowing a desired degree of resilience to be identified and achieved. This research informs the efficiency and effectiveness of policy implementation and management actions.
Research components	1. Quantify and qualify the values held by user groups. Quantification instruments can be informed by previous work but there are many ways of saying how our natural environment is valued. Seeing it as capital and valuing it as an economic asset is one way, but there are others that should be included, such as spiritual and traditional values. 2. Researching how socio-cultural values can be implemented as targets or normative reference values for biophysical indicators.

	3. Researching method of integration and reconciliation for differing sociocultural, socioeconomic, and biologically focused values. What kinds of social processes are needed to re-image these ideas and deliver a social transformation where these disparate value sets are assembled or re-constituted? We need to focus in on this question of integration. It comes back to what we mean by 'wealth' and what we choose to measure. How can we maximise economic growth while not maximising resource and energy use beyond biophysical limits? What social processes are needed to re-imagine these ideas of wealth and prosperity? How does this kind of social transformation occur? For example, do we need role models/champions/living examples which demonstrate these principles and inspire others to act? Do we need financial incentives? These component contribute to how natural capital is valued by all sectors of society, we must understand and document those value systems. The components above integrate to provide a holistic picture of the value of natural capital across traditional, spiritual, economic and other value systems.
Theme 3 **What can we do about it – Integration by creative and innovative win-win solutions to wicked problems**	
Importance to New Zealand	This theme comprises the research and delivery of solutions to the tension between economic and environmental outcomes by exploring integrated approaches to governance, policy, management, business and operations through innovative strategies, science, technology, technology transfer and uptake, and social knowledge transfer. Actually delivering on the promise of integrated solutions will be necessary to resolve the tensions between demands for continued growth from the primary sector and the stricter limits placed on that sector by the rest of New Zealand society. Primary production still dominates the New Zealand economy and each sector of primary industry has a strategy based around on-going and accelerating growth. These clashes directly with the constraints on the New Zealand biosphere. Integrating and reconciling these factors would allow us to have our cake and eat it, to create new forms of growth for both the primary sectors and the rest of the nation.
Research components	1. Research aimed at delivering new strategies for futures thinking, collaborative governance, creativity, and practical resilience. 2. Delivering innovative and integrative solutions in partnership with primary sectors that provide and demonstrate win-win advances. 3. Understanding social and technology change in the primary sectors, the particular sociocultural and economic constraints on the rate of solution uptake, and models of innovation delivery that take into account the availability of innovativeness, capital, expertise and the appetite for risk in primary producers. Modelling new behaviours and solutions will lead directly to the outcomes sought here, through a process that combines social, technological and economic research with a process of 'learning by doing'. Trialling new partnerships across the primary sector will provide allows the practical testing of research ideas and will lead to workable new solutions.

Theme 4 How do we evaluate progress – Providing a feedback loop for learning how to deliver integration	
Importance to New Zealand	The tension between economic and environmental goals is not a static one, nor are solutions clear. Thus the approach taken must be an iterative model, with feedback, learning, and response built into the process at all levels and timescales. For the wicked problems that this challenge addresses, solutions are more likely to come from flexible and evolving initiatives as the ideal design for initiatives is difficult to define in advance, thus evaluation will play a key role in providing direction. This theme also plays a role in knowledge transfer amongst and between researchers and user groups, providing an interactive pathway where the success of new initiatives depends upon the social knowledge and uptake that those initiatives create within their user groups. Effective evaluation depends on the work towards previous themes being structured by an adaptive-management framework. Goals, techniques, and measurement are applied by the consensus of diverse stakeholders in ways that simplify evaluation and interpretation. Recent advances in evidential (cf. frequentist or Fisherian) statistics can then be applied to structure transparent, public, and stakeholder evaluations of progress. The process towards evaluation, therefore, is itself a research project designed to inform and guide future iterative research towards themes 1-3. Innovation, by definition, explores new processes and new outcomes. Without evaluation to provide a feedback loop, it is not apparent whether innovative changes are effective changes.
Research components	This theme provides assurance that both Government investments in research and changes to primary sector practices are delivering against this challenge. The first two themes, 'What have we got?' and 'How do we value it?' provide a robust and quantifiable basis for assessing the value of our natural capital. The third theme provides a set of strategies for increasing that value. The research component of this fourth theme is to monitor the natural capital identified in theme one, evaluate changes in natural capital according to the criteria developed in theme two from implementing the strategies in theme three. Direct evaluation allows us to assess, both quantitatively and qualitatively, what level of progress is being made.

Entry ID	362
Increasing agricultural output whilst improving freshwater quality	
Summary	Increase agricultural productivity by improving nutrient use efficiency in plant-based production systems and improving downstream processing of agricultural outputs and decreasing post-harvest losses. While doing this, also maintain water and soil quality, by gaining a clear understanding of the interactions between intensive agricultural systems and freshwater quality to be able to manage adverse effects, and by collecting detailed data about New Zealand's soil

	resources and making it available to agricultural decision support systems to enable sustainable intensification of production
Theme 1 **Understand interactions between agricultural activity and freshwater quality**	
Importance to New Zealand	Increasing agricultural productivity can be associated with degradation in freshwater quality from diffuse agricultural pollutants e.g. nutrients such as nitrate and phosphate. A clear understanding of the interactions between intensive agricultural systems and freshwater quality will be essential to enable development of effective mitigation strategies.
Research components	Developing methods for monitoring diffuse pollution from agriculture. Elucidation of attenuation processes between pollution source and receiving water body. Establishing current baseline for diffuse pollution impacts on freshwater quality.
Theme 2 **Understand soils and soil processes in New Zealand**	
Importance to New Zealand	Detailed characterising of the chemistry, ecology and geology of New Zealand's soils resources, and making these data available in way that can be 'mined' by a range of agricultural decision support systems, will be essential to enable sustainable intensification of production.
Research components	Improve mapping of New Zealand soils. Improve understanding of biological processes, including nitrogen cycling, in New Zealand soils. Improve understanding of drainage and leaching risk of New Zealand soils.
Theme 3 **Improve nutrient use efficiency in plant-based production systems**	
Importance to New Zealand	Fertilisers represent a significant financial and environmental cost in plant production. Improvements in efficiency of nutrient use will deliver both economic and environmental benefits.
Research components	Develop precision agriculture approaches to improved targeting of nutrients according to crop needs. Optimise production systems, integrating crops and livestock where appropriate. Use plant breeding and genomics to improve resource use efficiency in crop plants.
Theme 4 **Improve downstream processing of agricultural outputs and decrease post-harvest losses**	
Importance to New Zealand	Reducing waste is a key target for increasing productivity.
Comments	Many aspects of this proposed challenge are also relevant to livestock systems but time has not permitted proper consideration of this here. Thanks for the opportunity to contribute.

Entry ID	411
Generating sustainable growth, wealth and resilience from land by managing land and water resources to increase productivity while maintaining environmental integrity	
Summary	Deliver primary data on soils, land cover, land use, terrain, freshwater and ecosystem services in order to understand the variability and limitations to productivity for New Zealand's primary industries and to develop ecosystem perspective on productivity gains from land. Use data to manage the balance between economic development and environmental integrity, finding solutions with efficiency gains from land and water resources and low environmental footprints and integrating solutions across environmental, economic, social and cultural dimensions
Theme 1 **Establish and maintain credible information at appropriate scales to characterise the state, trend, threats and opportunities of land, water and associated ecosystem services in relation to land use, land-use change and climate change**	
Importance to New Zealand	Primary production from agriculture, horticulture and forestry is at the core of the New Zealand economy and is critically dependent on the country's land, water and biological resources. Success in primary production is underpinned by management of the land resource, but this resource is increasingly under pressure from alternative land uses. With more pronounced intensification of farming practices there are increasing demands on availability of resources, such as water and nutrients, and more intense scrutiny on managing losses such as sediment, nutrients and pathogens into freshwater systems through surface runoff and leaching into groundwater. There remains considerable uncertainty about how far we can push these resources until tipping points are reached and the environmental benefits derived from natural resource systems diminish, as is already happening to water quality in many lakes and rivers. New Zealand will benefit from credible information at appropriate scales for land resource status, trends, threats and opportunities, in order to manage the balance between economic development and environmental integrity. Success in managing this balance will involve a diversity of land resource issues (water quality and quantity, carbon, erosion, biodiversity, waste etc.). This can only be achieved by the development of policy instruments at national, regional and district scales to establish best practice and report performance to diverse stakeholders. This theme will deliver the primary data on soils, land cover, land use, terrain, freshwater and ecosystem services, including understanding state, trend, risk and opportunity needed for this decision making. This research, therefore, underpins all the other themes in the challenge.

Research components	Provide the evidence base for land use and land management decision making by: • Developing and standardising methodologies for quantifying the natural capital stocks that support and underpin the values and services of the terrestrial productive sector in relation to land use, land-use change and climate change; • Augmenting credible datasets, filling gaps to give appropriate temporal and spatial coverage, and accounting for uncertainty, error and risk. Achieve information richness and resolution through innovative data capture and analysis of land use and characteristics, resource availability (including soil properties, water and nutrients), productivity (agriculture, horticulture, cropping and forestry). This provides both for the near-term and future requirements of our sectors; • Curating collections, maintaining data, and managing nationally significant databases for scientific and research data in a sustainable manner, incorporating uncertainty and maximising the reusability and inter-operability of datasets for a range of science users • Measuring and monitoring inputs and losses of resources (such as nutrients or soil erosion) and the impacts on freshwater quality and net greenhouse gas emissions; • Monitoring and forecasting changes in carbon storage in forest and shrubland and long-term changes in soil carbon storage under different land-use, land-use-change and climate-change scenarios; • Defining appropriate environmental limits for licence to operate at a range of scales, identifying and forecasting tipping point; • Making data and information more accessible and available by developing new and efficient methods for synthesising and visualising land resource data and information, including the design of online and interactive services and visualisation technologies. The theme provides all the primary, spatially-specific and temporal data needed for the other themes in the challenge. This will provide maximum benefit from the use of existing data and models on land capability for different uses, including social, cultural and economic values.
Theme 2 **Provide a robust scientific framework for explaining variability and limitations to productivity, developing innovative solutions for improved management and resource use efficiency and new opportunities for increasing productivity within environmental limits**	
Importance to New Zealand	The government's economic growth agenda calls for export earnings from the land to increase by 40% by 2025. To meet this goal while not degrading the resources that support agriculture, horticulture and forestry (including capacity for future use), is a significant challenge. With limits for resources being reached, New Zealand's land-based industries are now approaching tipping points. There is an urgent need for efficiency gains with lower environmental footprints (low input, high output) that increase the intensity of productivity (e.g. economic return per unit of natural resource used), while avoiding the depletion of natural capital. New Zealand will benefit from the development and implementation of innovative practices based on credible research to increase productivity while ensuring

	efficient use of land and water resources. While there is considerable research emphasis globally on sustainable intensification and food security, New Zealand's agricultural, horticultural and forestry systems differ from those elsewhere. The opportunities and environmental limits for land management and use need to be determined under our own conditions and from forecasts of future global trends in the costs of energy and other inputs such as pesticides and fertilisers. Improvements in productivity will be achieved through management of resources (including soil, water and genetic resources) at a farm system scale. This theme provides the scientific understanding of the key processes that will explain variability and limitations to productivity in the context of New Zealand's primary industries.
Research components	Quantify how variability in climate, soils and water availability and management regulate potential productivity and determine the environmental limits on production by: • Quantifying the effects of management practices on productivity and resource use efficiency, inputs, and losses including water, nutrients and carbon, and the consequences for ecosystem services; • Quantifying the storage and losses of water, carbon and nutrients (including run-off, leaching and net greenhouse gas emissions); • Developing integrated tools and technologies for defining the physiological limits of grassland, crop and forest production and identifying the critical soil and environmental factors needed to meet those limits without adversely impacting on the wider environment; • Developing and implementing biocontrol strategies to mitigate against risks from invasive weeds, pests and diseases; • Exploring opportunities for productivity gains and/or environmental benefits from genetic improvement of plants and animals; • Developing innovative methodologies and products to increase production efficiencies; • Determining the risks and opportunities of reaching the environmental limits of productivity.
Theme 3 **Collaboration for sustainable land use and integrated resource use: threats & opportunities**	
Importance to New Zealand	Sustainable land use requires a consideration of economic, social, cultural and environmental issues. With increasing primary production and economic benefits, there is a risk that ecosystem exploitation and land-use intensification drives widespread biodiversity loss, declines in the natural capital stocks and services supplied by different ecosystems and the associated non-market benefits people obtain from ecosystems. There are additional risks to productivity and ecosystem services from climate change and biosecurity threats. Because catchments and landscapes are heterogeneous and contain multiple, coupled ecosystems, these risks need to be assessed ultimately at the catchment or landscape scale, for both production land

	and the conservation estate. New Zealand will benefit from the development an ecosystem perspective on the productivity gains that can be obtained in relation to the provision of other ecosystems services and forecasts of future threats.
Research components	Develop tools that integrate the impacts of environmental and management practices on productivity, incorporating environmental limits, threats and trade-offs with other ecosystem services at large spatial scales by: • Enhancing tools to scale productivity and resource use from farms up to landscapes and from landscape-scale limits back to farms; • Matching spatial mapping of resource availability, inputs and losses with scenarios for land-use change and improved land management practices; • Developing spatial forecasting for productivity and soil and water management with changing climate, land use practices and land use intensification; • Assessing land use capability and best options for land use to enhance productivity while minimising environmental impacts and the loss of other ecosystem services; • Identifying and forecasting uncertainty, threats and risks associated with climate and land-use change, erosion, invasive weeds, pests and diseases and input availability, then identifying which geographic areas, land uses and land practices are most vulnerable to those threats; • Identifying adaptation measures to reduce risks; • Identifying issues that might enable or constrain land managers (identified as vulnerable to risks) from adopting those measures and coping with change (social resilience); • Developing tools and methodologies to monitor productivity, economic and environmental performance; • Integrating research across landscapes to understand how to optimise land uses against landscape capability, and cope with cumulative effects, for example on water quality and in the coastal zone.
Theme 4 **Contribute to growing wealth by developing coordinated national, regional and industry strategies and policy to incentivise land uses and implement the adoption of practices to maximise the environmental, social, cultural and economic benefits from the landscape**	
Importance to New Zealand	To achieve both increased economic prosperity and improved environmental well-being, it is essential that New Zealand's industries and organisations increase in profitability, develop within environmental limits and meet market and community requirements. The sustainable business approach is aligned with the green growth concept of decoupling growth from ever-expanding resource use and environmental impacts. This approach is key to maintaining licence to operate from the community and maximising profitability through adding value for New Zealand in overseas markets. Given the increasing complexity and inter-relatedness of natural resource issues, we need new approaches to engage and analyse these issues, new policy processes and instruments to resolve issues and approaches to adapt to manage our natural resources.

	New Zealand will benefit from integrated solutions across environmental, economic, social and cultural dimensions that add value to industry by demonstrating compliance with regulatory and international market requirements, reduction in costs of production, and providing measurable benefits to local communities.
Research components	• Analyse environmental, economic, cultural and social consequences of policy scenarios, including human health and employment opportunities to assess the effectiveness and efficiencies of policy; • Develop new and refine existing methodologies to enable monetary and non-monetary values for ecosystem services to be incorporated and compared for decision making; • Research how to value the economic and social/cultural dimensions of natural resources, including the opportunities to share resources using market mechanisms but also the implications of market failure; • Evaluate and identify critical future trends that can impact terrestrial landscapes, including key drivers, barriers to social, institutional and technological change, and options to mitigate against or adapt to multiple trends; • Value ecosystem services to provide the value proposition for business to protect and enhance these as well as the means by which they can be provided; • Provide effective media for communicating thresholds and limits and the implications of these on the environment and cultural, social and economic values; • Introduce effective processes for balancing competing values and developing robust policies and strategies; • Incorporate Māori cultural perspectives, develop mātauranga Māori, indigenous branding and elements of cultural identity (values, principles and ethics) to enhance market access. This research is cross-cutting across all themes within the challenge. Opportunities include: • Developing and implementing innovative methodologies through discovery research to increase productivity, improve resource use efficiency and minimise losses of resources; • Reviewing, testing and validating the range of models used to assess productivity, resource use efficiency, inputs and losses including water, carbon and net greenhouse gas emissions, leading to an agreed suite of models to be developed and utilised nationally; • Fostering processes for better development and use of models among researchers and end-users, especially supported ensemble-based approaches that take advantage of multiple models operating in the same domain to improve the robustness of the analysis; • Using models to inform the design and analysis of critical laboratory and field experiments that address and allow integration of the responses of productivity to multiple variables; • Taking advantage of opportunities for ‘closing the loop’ by making connections among different productive land sectors such that output from one becomes the

	input for another Gaps include: • Fundamental understanding of interaction of processes and variables regulating productivity and resource use efficiency at a range of scales from individual management units (such as paddocks) to whole farm systems and catchments; • Response of productivity and resource use efficiency to multiple environmental variables; • Revealing the genetic basis for regulation of productivity and opportunities for breeding and genetic manipulation; • Understanding interactions between the carbon, water and nutrient cycles that define the limits and opportunities to increase the resource use efficiency and profitability of production systems; • Reviewing, testing, validating and agreeing on a set of models and tools to assess and manage water use so as to enhance soil and water quality; • Knowledge of the stocks and services that regulate water, carbon and nutrient losses (i.e. run-off, leaching and greenhouse gas emissions) at farm/forest scales and methodologies for mitigating them; • Capturing and translating new knowledge to implement new methodologies and innovative practices.
Research Gaps and Opportunities	• Developing and implementing methods to quantify the natural capital stocks and services that are critical to supporting New Zealand's economic, environmental, social and cultural values in the terrestrial productive sector; • Implementing national monitoring programmes using the standardised methodologies identified above; • Enhancing the quality and spatial coverage of and access to soil data to enable government, scientists, industry and land managers to understand soil variability and thereby improve agricultural land management; • Developing and implementing improved mapping and data synthesis methods to assess state and trend in land cover and land use to enable central and regional government to easily and cost-effectively monitor and report on the implications of land use change; • Quantifying the errors and uncertainty associated with a key land resource dataset, identifying the key sources of uncertainty across scales, and determining how best to communicate this to end-users to improve the use of land resource science as an evidence base for policy, planning and resource management; • Developing and implementing readily accessible, online, interactive services to deliver appropriate, timely and tailored information for end-users, including visualisation. Gaps include: • Significant omissions in nationally significant datasets for soil and water, especially for soil hydraulic parameters and nutrient characteristics; • Data that can be used to quantify changes in freshwater and soil quality through time using nationally applicable state-of-environment data on natural capital stocks and services;

	• Systematic evaluation of the status and trend of a range of other ecosystem services, including the potential to link to the status and trend of biodiversity; • Systematic assessment of changes in soil carbon storage, greenhouse gas emissions and nutrient dynamics due to agricultural management and intensification and their impacts on productivity.• Development and testing of models that allow integration across ecosystem services for assessing the multiple benefits and consequences of land use and management decisions; • Assessment of the distribution of productivity at a range of spatial scales to match end-user needs; • Ability to forecast the cost-effectiveness and environmental consequences of intensification on productivity, including irrigation and fertiliser application; • Identify trade-offs in productivity, resource use and ecosystem services in relation to environmental limits and define environmental limits to operate at landscape scales; • Ability to forecast changes in productivity and consequences for other ecosystem services, including uncertainty, in response to climate change and pre- and post-border biosecurity (invasive weeds, pests and diseases) at farm to landscape to national scales. Identification of potential risks; • Developing options for sustainable land use for land and other economic resources being returned to Māori through treaty settlements. Decision making by Māori organisations usually takes a holistic approach, linking the environment with people, history, culture and the economy. Gaps include: • The urgent need for fully integrated, multi-dimensional, agent-based modelling for analysis of the impacts of multiple variables on environmental and economic performance on the productive sectors; • Methodologies for understanding connectivity of land and water across landscape scales, identifying choke points (sites and times critical for management) within catchments; • Collaborative processes that support integrative modelling for decision making. Opportunities include: • Robust methods to balance monetised and non-monetised values in decision-making frameworks for policy evaluation; • Development of robust models that integrate across environmental, economic and social dimensions; • Development of collaborative processes that deliver enduring solutions to land and water challenges at catchment, regional and national scales; • Integrated frameworks and models that link land to fresh water and coastal zones to address sustainable development of resources; • Integration of Māori cultural perspectives and cultural identity (values, principles and ethics) across environmental, economic and social issues to enhance market access. This research is cross-cutting across all themes within the challenge. Gaps include: • Tools to value the economic and social/cultural dimensions of natural resources that incorporate market mechanisms, to identify opportunities to share resources

	and forecast the implications of market failure; • Robust methodologies to value ecosystem services that can be used for decision making by businesses; • Processes for effective engagement with the public and stakeholders on thresholds and limits and reconciling and trading off values; • Effective processes for removing barriers to adoption of research findings and options to mitigate against or adapt to multiple trends.

Entry ID	**412**
New Zealand increases wealth from natural capital while maintaining or improving its environmental integrity	
Summary	Collect information about state, trend, impacts and opportunities for land, water and ecosystems. Use information and science to identify and maximise New Zealand's natural and cultural advantages in the land and water sectors, reduce operating costs, grow wealth, and protect the integrity of soil, land and water assets at primary industry level, and provide the evidence base, participatory processes, and policy instrument design to facilitate effective decision making
Theme 1 **Develop best-practice management approaches, tools and technologies to enable optimal use of land and water resources at catchment and farm scales**	
Importance to New Zealand	Fifty-five per cent of New Zealand's land area is under primary production, providing more than 25% of New Zealand's GDP. Primary industries therefore play a key role in sustaining rural communities and stewarding landscapes. However, the backbone elements of farming success – land and water resources – are showing signs of stress. It is estimated that New Zealand's annual rate of soil loss is 200–300 megatonnes, a rate 10 times higher than the rest of the world, which in monetary terms costs >$127 million p.a. Recent studies show significant amounts of soil organic matter are being lost under flatland dairy grazing. This loss reduces the soil's capacity to filter contaminants, retain nutrients or resist pugging. The effect is twofold, impacting on both the quality of farming operations and the underpinning resource. Elite and versatile soils provide disproportionate value to our economy: just 0.4% of land supports 14% of the total contribution the primary sector makes to GDP. But these soils are currently disappearing to tar seal and life-style development. Given the very slow rates of soil formation there is mounting concern over the availability of productive soil ('Peak Soil'). Trends in national river water quality data between 1998 and 2007 (http://www.mfe.govt.nz/publications/water/analysis-of-national-river-water-quality-data-1998-2007/page10.html) show an overall degradation in water quality in our major rivers. Over that period, nitrogen and phosphorus – key plant

	nutrients added in fertilisers – increased strongly at many sites. Contamination of groundwater with nitrate and/or microbial pathogens occurs in many regions. Water availability is also a problem in some regions due to the withdrawals needed to support agriculture and/or seasonal fluctuation in supply and demand. Our primary industries are therefore under extreme pressure to maintain (or increase) their profitability yet still protect the resources they and future generations depend on, while simultaneously meeting the requirements of markets and government policies (e.g. National Policy Statement for Fresh Water). Science has a significant role to play in helping these industries find the 'sweet spot' to reduce operating costs, grow wealth and protect the integrity of soil, land and water assets, through information, tools and technologies.
Research components	The research in this theme provides a robust scientific framework for explaining variability in the vulnerability and potential of soil, land and water resources. This provides a scientifically credible basis to inform appropriate best-practice approaches, tools and technologies to ensure profitable use and retain land and water resources for future use. Research components reflect the scale of implementation and the major challenge around getting uptake and adoption of best practice. Key research components include: • On-farm tools and farm systems (including forestry and horticulture): agronomic techniques to optimise productivity and maximise long-term profitability for New Zealand; plant and animal breeding – the genetic characterisation of traits and genetic manipulation; agricultural technologies and precision techniques; soil attributes to enable better management of soil quality, productivity, nutrient management and greenhouse gas emissions; minimising waste and maximising reuse • Catchment-scale approaches: optimising land use at multiple scales and across multiple co-benefits; more effective water allocation and use; integrated land management approaches; mitigating nutrient loss and impacts of contaminants in soil and groundwater; reducing erosion and sediment loss; mitigating the impacts of extraction and use of aggregates, limestone and fertiliser • Drivers and barriers to uptake: economic analysis and cost benefit; farmer behaviours and value; methods to diffuse best practice across primary industries.
Theme 2 **Advance New Zealand's economy and enhance environmental integrity by using science to identify, realise and protect the unique advantage provided by our land and water resources**	
Importance to New Zealand	The land economy currently represents more than 25% of GDP. But with a large focus on intensification, commodity export and single species (e.g. trees and crops) it is a fragile economy. Potential or actual threats include a decreasing natural resource base (e.g. Peak Soil), changing market preferences and conditions, fraudulent products in overseas markets claiming to be of New Zealand origin, and devastating infectious diseases (e.g. Psa or Foot & Mouth). The Government's Business Growth Agenda calls for export earnings from the land to increase by 40% by 2025. But this goal should not be met without considering how to increase the resilience of the economic, environmental and social systems on which it is based. And while making more optimal use of land

	and water resources, i.e. sustainable production (Theme 1), is important, new paradigms have a role to play in creating a green, wealthier New Zealand. Significant intellectual effort by government and business leaders has been devoted to exploring new paradigms including Pure Advantage, Vision 2050 New Zealand and the Māori Economic Growth Strategy. However, this transformation is not without risk and must draw from emerging science and innovation. Science therefore has a role to play in: • Identifying New Zealand's natural and cultural advantages • Putting into practice approaches to leverage those advantages (that are restorative and promote shared-value) • Developing tools and technologies to protect and give credence to these advantages as part of the New Zealand brand.
Research components	The research in this theme provides the foresight, underpinning data, testing and validation to support alternative approaches to wealth creation, drawing upon New Zealand's inherent advantages. The contribution of knowledge draws on a number of currently disparate science domains. Research components include: • Identification of natural and cultural advantage: Including characterisation and valuation of resource potential; food technologies to support new products and product values; Mātauranga Māori and cultural values; scenario analysis and visualisation technologies; land use optimisation modelling • Realising natural and cultural advantage: Including research to underpin new land uses and primary produce, reuse of waste and increased ecosystem service provision; understanding the principles behind successful co-management and governance models; and social and economic modelling • Tools and technologies to protect New Zealand advantage: Including life-cycle analysis, footprinting and eco-verification; use of environmental tracers and identifiers; enhanced surveillance for continued consumer trust and market access.
Theme 3 **Deliver an appropriate evidence base, participatory processes and uptake methods to facilitate more effective land and water resource governance and decision making at catchment, regional and national scales**	
Importance to New Zealand	To ensure New Zealand's prosperity and improved well-being, it is critical that land and water governance and decision making is inclusive, collaborative and gains confidence from a range of interested parties. Adversarial approaches and contention incur considerable costs associated with the time taken to arrive at a decision, as well as the multiple impacts of delaying action. Even a modest reduction in time taken to make decisions or number of stakeholder submissions/legal appeals will save millions of dollars in terms of legal analysis, addressing submissions, and stakeholder engagement. But governance in New Zealand is complex. With a significant proportion of the Māori asset base in land and water, and the importance of these resources to cultural identity, Māori are a significant stakeholder. The Māori Court challenge over proprietary rights over water illustrates the potential for contention.

	Another complexity unique to New Zealand is the simultaneous dependency on the land economy (compared with OECD peers) but a large percentage of urban dwellers (>80%). This can often manifest publicly as a clash of values: 'greedy farmers' vs. the community interest. Land and water resources must therefore be effectively managed to account for the range of interests and preferences, as well as the capability and capacity of the resources themselves. This requires taking into account both economic and non-economic values, working towards a shared vision of the outcomes required at catchment, regional and national scales; and validating the progress towards those outcomes through planning, monitoring, reporting and adaptive management.
Research components	Significant research progress has been made in this theme in recent years. Science offers the potential to provide the evidence base, participatory processes, and policy instrument design to facilitate effective decision making. But to do so it will need to resolve the challenges of working with uncertain data, considering non-economic values alongside economic values, and improving the way science is communicated to stakeholders. Underpinning research components thus include: • Values and participatory processes: Including resource valuation and values; socio-ecological and socio-economic systems; mātauranga Māori; economic, social and futures modelling and analysis (including integrated modelling/analysis); analysis of trade-offs between economic, social, environmental and cultural values • Evidence and monitoring: Including biophysical monitoring and data collection; uncertainty analysis; cultural indicators; scenario analysis • Uptake and implementation: Including participatory processes, collaborative learning and other decision-making processes; knowledge transfer processes; adaptive management; governance structures; behavioural and organisational analysis; instruments to support policy development and their design.
Theme 4 **Establish credible information at appropriate scales to characterise the state, trend, impacts and opportunities for land, water and associated ecosystem services. This theme underpins all other themes by providing baseline state-and-trend data**	
Importance to New Zealand	This theme underpins all other themes by providing baseline state-and-trend data, as well as the theoretical understanding to minimise risks, realise opportunities and support new paradigms. Science is conducted and data held about land and water resources by many agencies who will thus be contributors to this theme. The National Land Resource Centre, Landcare Research, NIWA, GNS Science, AgResearch, Plant & Food Research, and ESR, as well as public service departments who are increasingly involved in data creation, management and data provision. With respect to informatics/information science, Landcare Research, NIWA, GNS Science, ESR, the University of Auckland and Victoria University of Wellington would play important roles.

	Comprehensive and fit-for-purpose data and information on the state of New Zealand's environment is fundamental to land and water research and underpins all other themes and goals of this Challenge. Similar to the way in which the New Zealand Treasury's monthly and annual (year-end) financial statements provide information on the government's economic assets and liabilities, to inform government spending, priorities and policies, robust quantitative and scientific data are needed to assess the overall health or state, likely trend, threats and opportunities of New Zealand's natural land and water assets There is still considerable uncertainty about how far we can push land and water until tipping points are reached and the environmental benefits derived from natural resource systems diminish. Credible information at appropriate scales is needed urgently, in order to ensure we can respond to risks rapidly as well as to manage the balance of needs and sometimes conflicting goals between economic development and environmental integrity. So, theoretical modelling, data collection and interpretation is more than stamp collecting – it is about establishing an evidence base on the land and water system, and all the connections and complexities within it, to drive all other themes and outcomes. Examples of the power of good quantitative data include: improved soil variability mapping in the Mataura Valley, which resulted in costs savings for farmers and reduced leaching into groundwater; the existence of a long data record about Lake Taupo Basin, which made it possible to implement science-based decisions for improved land use management and enhanced prosperity for all New Zealanders
Research components	This theme will deliver the fundamental understanding and primary data on soils, land cover, land use, terrain, freshwater and ecosystem services, including understanding state, trend, risk and opportunity. This basic science is needed for operational, tactical and strategic decision-making at national, regional and local scales. Research components underpinning this theme include: • Component characterisation: Including soil, geological and geochemical characterisation; groundwater characterisation and management; characterisation of ecosystem service conditions and trend; spatial and longitudinal data on economic, social and cultural systems; measuring uncertainty; data on behaviour, behaviour change and preference over time and space • System understanding: Including system function and cumulative impacts across time and space – e.g. nutrient flows, water transmission through the system; ecosystem interactions; spatial, integrated and predictive modelling • Data stewardship, visualisation and delivery: Including data lifecycle management; data retrieval and semantics; dealing with data provenance, quality and erosion; measuring and communicating uncertainty and risk; integrated modelling, syntheses and analyses to recommend practical real-time solutions; service, interoperability, and information visualisation; communicating data

	limitation and uncertainty.
Research Gaps and Opportunities	New Zealand has a long history of agronomic expertise, and many of the difficult questions on how to optimise productivity, and more importantly maximise profitability, have been answered through scientific discovery. Infertile landscapes have been transformed into highly productive and profitable systems, but often at an environmental cost. Landowners have logically been most interested in implementing the science that will increase profit, with less focus on ensuring a healthy and sustainable productive system that will provide prosperity for future generations. As New Zealanders, and also overseas' markets, become more concerned about environmentally sustainable production and stewardship of resources there will be a demand for a greater focus on ensuring production within sustainable limits, not only at an individual farm level, but also at catchment, regional, and national levels. In many situations the answers to wise and profitable land use are known by scientists and leading farmers, but are not implemented uniformly across the landscape. Therefore, a large opportunity is to better understand landowner behaviour and the triggers that will cause farmers to implement best practice – and then to engage these triggers. However, there are also very significant science and technology challenges, ranging from the relatively easy to the extremely difficult and with their respective low to high rewards for success. At the extreme end is for science to come up with innovative and cost-effective ways to decouple productive land from the receiving water. There are relatively low tech solutions to this in existence (e.g. animal housing with effluent collection), but science can do more. The new science will need to deal with multiple stressors and cumulative impacts and ensure that productive and profitable farming at the top of the catchment has relatively low impact on other values downstream – both for production (e.g. aquaculture) and conservation. The challenge isn't easy, and the risks of failure are high. Therefore it is mandatory that the correct environment is provided so that scientists have the freedom to think laterally and try new approaches. There is a very large potential, not only to increase the production (and profitability) of existing commodities but also to make greater economic gains by targeting high-value products to new, mainly Asian, markets. A key opportunity is to optimise the value of our land and water resource and to develop value chains (from soil to market) that enhance the value and integrity of our products. Associated with this is the opportunity to become world leaders in sustainability and product integrity (Call to Arms 2012; A Report from the Riddet Institute Agri-Food Thought Leadership Team). Achieving this will require a substantial change in thinking and strong leadership from both government and industry. There is currently a significant disconnect between researchers focusing on increased production of existing commodities and the opportunity to develop new crops, new products, and the integral value chains that can provide assurances of

	product integrity (safe food and sustainable practices). The opportunity is to bring these research efforts together. As a country we have the skills and the scientists to increase productivity and develop new products, and others that have an excellent grasp of sustainability and environmental protection, by bringing these disciplines together New Zealand can develop higher value and sustainable productive systems that will enable it to become a world leader in sustainability and product integrity. New Zealand has a rich heritage in basic disciplines such as soil characterisation, conservation ecology and biosystematics, together with emerging research expertise in lifecycle assessment, visualisation and genomics. At the time of writing, this theme is not well-structured or defined, but is included to provide a home for such science innovation. Potential ideas emerging from the community involved in drafting this submission include: • Identifying the health-benefits of indigenous food products to deliver added value and access new markets • Scenario analysis to identify new landscape configurations that offer greater resilience to financial and natural risks • Developing pathways to use waste as a resource: e.g. waste with high metal content, to metal-deficient land to fortify crops for animal and human health; or forestry by-products, to increase productive capacity (e.g. soil macroporosity) and use within processing industries (e.g. to replace fossil fuels for heat generation) • Increasing biodiversity within productive and urban landscapes to improve aesthetic appeal and deliver broader landscape benefits (e.g. use of native species as indicators of environmental damage) • Advancing rural land-based producers through the collaborative action of multiple landowners, e.g. prioritising high value activities on elite and versatile soils fragmented across multiple enterprises • Designing new socio-economic production systems with shared capital infrastructure and co-governance • Incentives and behaviours to achieve a paradigm shift to a more prosperous and resilient future (including economic, social and cultural incentives) • World-class surveillance systems combining real-time genotyping with spacio-temporal data to assure market access, maintain trust and resolve problems where they occur • Reporting and certification to demonstrate improved environmental, social and cultural performance for markets and the New Zealand public and ensure the ‘licence to operate’. A continual challenge is reconciling the time frames of research development with policy need. This necessitates versatile tools and techniques that can be adapted and reused to provide timely answers to policy questions, as well as dedicated funding for longer-term research. Major gaps exist around evaluating: • How much information do you need to make a defensible decision?

	• What are the best institutional and governance processes to inspire confidence from a range of stakeholders in a decision? • How do we better couple biophysical data to value-driven goals such as 'swim-ability' or Māori values for water such as 'life-giving essence' and spiritually? • How do we better incorporate mātauranga Māori within a range of policy-based research to help facilitate embedding of Māori values within decision making and facilitate the process and agreement on outcomes? • How can we encourage and support research that is scientifically sound but also timely, comprehensible and relevant to policymakers? • How do we make trade-offs between values? • How do we design more robust policy to adaptively manage the landscape? Much of the current data upon which we are reliant are limited by coverage, currency or quality. There is a lack of statistically viable data to identify trends over time, particularly data directly addressing environmental change. The data we have are not of a quality, quantity or coverage to meaningfully answer the questions being posed today. Many national databases and collections are vulnerable and we are not maximising their potential use. Emerging technologies can be used to improve data collection, synthesis and analysis, adding data richness and resolution. Increasingly they will allow us to implement new flexible end-to-end electronic capture, transmission and transformation infrastructures to acquire data from the environment and efficiently measure and monitor. New technologies and analysis methods will allows us to get more out of the data we already hold, while improving national field sampling coordination across institutions, and indeed sectors, will lead to more cost effective and complete data collection. Integrating data from a range of sources for trends, monitoring and decision making is a complex process, introducing issues around different levels of uncertainty, scale and provenance in the data. Quantification of the errors and uncertainty in data, and communicating this to end-users, is a major opportunity to increase the use of science as an evidence base. Future modelling and prediction of the impacts of multiple variables on environmental and economic performance on the productive sectors will rely on sophisticated, multidimensional models and more collaborative approaches to environmental data infrastructure. Of significance is the need for review, evaluation and validation of the range of models currently in use for diverse purposes such as forecasting primary productivity, optimising on-farm management, and understanding basic soil, water and nutrient cycles. This is a key opportunity to collect, assess and make available existing modelling capability and to encourage the further utilisation and development of a national suite of models that can be shared among institutions. An effective and comprehensive infrastructure for gathering, sharing and managing for the long term data and observations on land, water and associated ecosystem services is required. Such an infrastructure could link to similar infrastructures for biodiversity, biosecurity, and health statistics. The technologies and standards for building such platforms are mature but research is required into

	how to bring data together in way that is meaningful to users, while maintaining data integrity and validity.
Comments	Research effort is distributed across a number of organisations including: Landcare Research, ESR, Lincoln University, Massey University, University of Auckland, Cawthron, MOTU, New Zealand Institute of Economics Research, AgResearch, Plant & Food Research, Scion, GNS Science as well as regional councils and central government agencies. The success of this theme is dependent on leveraging New Zealand's inherent uniqueness and advantage and as such requires New Zealand based research effort. Potentially, this is one of the best offerings the New Zealand science community can make – and one that could be exported overseas. But it holds the largest gaps in terms of research contribution. Because of the disparate nature of the research components, much of the effort is distributed over a number of organisations including: Lincoln University, AgResearch, Landcare Research, Plant & Food Research, Scion, ESR, GNS Science, Massey University (including Riddet Institute) as well as the National Land Resource Centre and business community.

Entry ID	**418**
Green land, blue water and prosperous people for the next millennium	
Summary	Promoting community based decision making regarding management of land, freshwater and coastal resources and making ecosystem data available for use by stakeholders to facilitate better informed decision making. It is also important to develop new tools and approaches to monitor how ecosystems in these areas are being maintained and to identify and evaluate potential approaches for increasing primary sector returns (e.g. crop and animal selection)
Theme 1 **Enable the integrated management of land, freshwater and coastal resources through partnerships between resource managers, iwi, catchment communities (including e.g. private, commercial, and lobby or/and special interest groups) and scientists building on the collaborative approach taken by the Land and Water Forum**	
Importance to New Zealand	Export earnings based on our environment, including agriculture, seafood and forestry (~$32billion in total) are the backbone of New Zealand's economy and will continue to be important for maintaining living standards of New Zealanders. However, recent intensification of agriculture and requests for increased allocation of space for aquaculture (e.g. New Zealand King Salmon) have led to issues with and concern about contamination of groundwater, surface water and coastal environments with sediment, nutrients and faecal bacteria. This has the potential to seriously harm values cherished by most New Zealanders. Strengthening our clean green image is also a hugely important economic

	advantage and will become even more important in the future. Intensification in small parts of catchments can have unforeseen detrimental social, cultural, environmental and economic effects downstream and off the coast. We need a better understanding of how land use intensification will influence downstream and coastal areas and how the community can make enduring resource management decisions. Similar challenges arise for activities in marine environments – coastal or off-shore. Failure is not an option. The economic consequences of New Zealand's primary sector either going backwards in a productive sense or of New Zealand's exports (direct or indirect) from environmental sources being rejected by our markets would be dire. Increased certainty for long term planning and investment in the primary sector would ease investment planning and operational decisions as well as improving regulatory and resource management.
Research components	Kaitiakitanga: facilitating involvement of iwi in resource co-management and decision making. Increasing involvement of iwi as we strive towards long term economic and environmental resilience is essential. Understanding and predicting movements of sediment, nutrients and faecal bacteria from the mountains to the sea. This includes not only understanding natural processes but also understanding the effects of differing land use etc. on the overall system. For example, what are the limiting factors generated by one primary industry or land use for other developing primary industries, business opportunities or needs? How does upper catchment development and land use affect eco-tourism, potable water supply or healthy aquaculture development? Promoting community-based decision making – a bottom up approach: building on the Watershed Talk process that was used in the Motueka Integrated Catchment Management project. This component will necessarily draw on the other components of the various themes to ensure that the community understands the decisions it must make. Understanding the cumulative effects of stressors on New Zealand's ecosystems.
Theme 2 **Identify and evaluate potential approaches for increasing primary sector returns in order to determine what actions should be taken to realise the desired gains**	
Importance to New Zealand	As a nation we lead the world in the efficiency of our production systems. But are we growing the optimum crops and animals given the range of challenges (economic, trade, climate, environmental, social, cultural etc.) we are facing?
Research components	Crop and animal selection. Accounting for all of the consequences (including e.g. climate change, knowledge and tools re pastoral greenhouse gases, market demands): - Are there crops/animals New Zealand is growing that it should not be growing? What, where and why? (Need to consider all options: land, sea, water, fish, shellfish…) - Are there crops/animals New Zealand is not growing (or not growing commercially) that it should be growing? Or not growing enough? What, where and why?

	- Can crops/animals be improved for New Zealand conditions? - Is there a significant role for algae and/or algae bio-products for New Zealand? - Food security is a factor, both for domestic consumption and re on-going export revenue - Food safety, including provenance/traceability, contamination etc. Farming systems and practices Just as important as crop/animal selection is how we farm on the land, in freshwater or marine environments. What are the optimal approaches for farming different species in different environments, now and in the future? Maximising uptake of optimal practices. Lifting the performance of the average New Zealand farming operation, in all facets, will produce a direct economic gain for the country with, for example, increased production, lower costs and reduced environmental degradation per unit output. What are the systems and practices that maximise uptake of optimal practices, are they being applied – and if not how should New Zealand ensure they are applied?
Theme 3 **Ensure that all stakeholders have access to the environmental data they need to be actively involved in decision making**	
Importance to New Zealand	Considerable amounts of data are collected on our freshwater and coastal ecosystems. However, much of this data has restricted access, is tied up in inaccessible databases and/or only digestible by experts. Information on the state and trends in these ecosystems needs to be made available in new and accessible formats to encourage more involvement in maintaining and improving ecosystem health. In addition there are cases where New Zealand has insufficient data to enable smart, informed compromises to be made. Better informed participants in decision making processes should significantly reduce conflict and make it easier to determine acceptable compromise solutions for all parties.
Research components	Establish monitoring frameworks. Ensure appropriate status and trend monitoring is carried out in terrestrial, aquatic, coastal and marine environments over required timeframes. New technology and data dissemination – web developments/mobile apps/video/YouTube. With the ever increasing power, flexibility and accessibility of computing power and data it should be possible to enable stakeholders to not only have visibility of raw data but also to have the ability to interpret, use or combine data in ways that enable faster and smarter interpretations, understanding and therefore decision making. Build, for example, on the work with councils, ref. www.landandwater.co.nz , e.g. under water quality, which enables access to data but also shows scope for improvement in usability and accessibility for non-technical users.

Theme 4 Determine which tools and approaches for ecosystem health monitoring New Zealand should use and deploy them	
Importance to New Zealand	The National River Water Quality network has provided a good picture of changes in water quality in a selection of New Zealand's larger rivers over more than 2 decades. Smaller rivers, lakes and coastal environments have largely been overlooked. New tools and approaches will help ensure that New Zealand can carry out the monitoring needed to determine how the values and services that are provided by our freshwater and coastal ecosystems are being maintained. Developments in data logging technology enable a new approach to monitoring including continuous measurements and molecular technology so that the parameters that are measured are more relevant to the decisions we need to make
Research components	Continuous monitoring, for example, temperature, oxygen, coastal monitoring buoys, and associated data distribution and maintenance. New instrumentation as well data communication approaches mean that we are now in a better position than ever before to capture the data required. Molecular methods, e.g. MST (Molecular Source Tracking). The development and, where necessary, the refinement of molecular methods will significantly improve New Zealand's ability to determine the causes of problems and therefore to correctly identify the appropriate reaction to take (see e.g. http://www.cawthron.org.nz/aquatic-biotechnologies/microbial-source-tracking.html). Linking monitoring parameters with key ecosystem services. Understanding which parameters are critical in understanding ecosystem services and when and where they should be monitored. Enabling proof that our export products are produced in a healthy environment. Systems and processes are increasingly required to satisfy export market requirements for environmentally friendly/sustainable production methods. New Zealand has led the world in primary sector production efficiency and could also lead the world in the development of systems and processes to verify production methods to end customers/consumers. Such systems and processes will be of huge value not only to our own primary sector but could also become expert earners in their own right as they could be applied and used by the primary sector value chain worldwide.
Comments	We welcome the opportunity for experts from our staff to be actively involved in the development of this or related challenges, or in reviewing suggested challenges.

Entry ID	434
Promote the sustainable use of the New Zealand's marginal agricultural lands and protect the quality, supply and image of New Zealand's high-value products and allow the development of regional industry clusters.	
Summary	The goal is to increase benefits for New Zealand from our plants. Themes include developing chemical typing processes to authenticate New Zealand manuka honey products and eliminate mislabelled products, establishing trial leptospermum plantations in riparian margins and monitoring improvements to water quality, while generating honey derived income for land owners, develop bee hive management strategies that minimise contamination of honey products and improve the image of New Zealand honey products internationally, creating sustainable clusters of employment in rural regions based on New Zealand endemic plant species
Theme 1 **Authenticity of product involving sample collections by industry:** **To ensure that honey that is labelled as originating in New Zealand has been sourced from New Zealand, an independent collection of a New Zealand wide set of reference honey samples is necessary. These samples can be used to create sets of data that allow chemical typing and identification of the honeys**	
Importance to New Zealand	The New Zealand Manuka honey industry is coming under at increased pressure from opportunist marketers exploiting public goodwill towards the Manuka brand. To ensure the on-going health of the industry, it is perceived that chemical typing of genuine New Zealand product is necessary to identify and eliminate mislabelled products. The Manuka honey industry currently has a retail value in the order of NZD$100 million however this figure could rapidly be undermined without a robust set of identifiers. In association with this work, it would be prudent to protect other emerging markets in New Zealand speciality honeys for the good of the entire industry.
Research components	Development of independent honey collection with the beekeeping industry throughout New Zealand where floral source is identified. 1- Identification of floral markers 2- Collection of nectars from principal floral sources to establish chemical links with honeys with New Zealand universities.
Theme 2 **Leptospermum plantations, improving New Zealand environmental image:** **Leptospermum plantings in riparian margins with other suitable indigenous plant species are most likely to significantly limit or even eliminate agricultural run-off. The establishment of trial plantations and the monitoring of improvements to water quality would demonstrate the value of this model**	
Importance to New Zealand	The New Zealand agricultural sector currently receives a degree of adverse publicity regarding current farming practices. Whether this perception is correct, it

	would be timely to research and promote our management strategy for riparian margins that would improve water quality as well as generate honey derived income for land owners.
Research components	Establishment and monitoring of Leptospermum and other species in riparian margins to quantify improvements in water quality.
Theme 3 **Sustainable bee management and product quality:** **To develop a bee management strategy that eliminates the need for cane sugar syrup and protein supplements feeding to improve the quality of product or industry**	
Importance to New Zealand	Internationally New Zealand honeys have recently received a reputation for adulteration with cane sugar syrup. Whilst there is not much evidence that a deliberate post-harvest adulteration occurs, there are indications that the current management of beehives throughout the industry promotes contamination of products. New Zealand honeys are marketed internationally under the image of purity and undermining this concept has a detrimental effect on honey industry as a whole and the general perception of New Zealand.
Research components	Treatments of hives with a range of management strategies to identify methods for successful honey harvest eliminating artificial feeding regimes.
Theme 4 **Development of economically sustainable opportunities in regions** **The development of self-supporting economic clusters of opportunities around endemic plant species**	
Importance to New Zealand	In many rural regions of New Zealand there has been a consistent drift of the population to the larger centres. This has left the aging remnant population alienated because of the lack of local opportunities for the younger generations. It may be possible to create sustainable clusters of employment using simple and transferable technologies and capturing the values exhibited by the New Zealand endemic plant species. Classic examples of this would be harvesting the essential oils present in a range of the New Zealand Myrtaceae species and this approach could be coupled to skills improvement around farming, business and land management. It may also be that such clusters would bring about environmental improvements in regional bases.
Research components	Establish yields and bioactivities of extractions from a range of New Zealand plants. - To determine suitability of plantation of the selected New Zealand plants. - Selection of varieties that exhibit elevated levels of desired compounds.
Research Gaps and Opportunities	Theme 1: For the data from a study such as this independent and credibility of the collection and subsequent analysis is essential. Currently the industry recognises the need for accurately describing honeys however on-going collections over three years would allow seasonal variations to be described. Theme 3: Currently, the industry has not addressed the on-going problem of contaminants in products.

	Theme 2: Leptospermum is not currently being trialled on a large scale in these environments. Theme 4: Whilst many New Zealand plants have been examined for extractives, the low tech commercial application has not been examined.
Comments	Theme 1: Unique Manuka Factor Association is affiliated with the research undertaken under theme 1.

Entry ID	**435**
Urea production from wood waste	
Summary	The goal of this proposal is to manufacture urea from carbon based material (including the three grades of coal, natural gas and from wood waste to export green urea at a premium price. Suggested research includes: literature/web search, contact with people discovered in the literature search, calculation of the true cost-benefit to New Zealand, laboratory trials, pilot plant.

Entry ID	**454**
Land, Water and Coasts - "Achieving integrated management of land, water and coasts, which incorporates the connections between them and leads to productive resource use and sustainable, healthy ecosystems."	
Summary	(This submission was 4000 words and mainly summarised here.) The goal is integrated management of land, water and coasts leading to productive resource use and sustainable ecosystems. Themes include increased resource productivity for land and water use while enhancing environmental quality; e.g. improving irrigation technology, investigating aquifer recharge, improving management of connection between land use and freshwater to increase productivity and enhance water quality, e.g. develop ecological models, improving productive and native fisheries by enhancing the habitat that supports them, e.g. determining catchment discharges to river mouths and coastal waters, identifying barriers to fish migration, high quality drinking water for all New Zealanders, e.g. determining source and pathway of contamination, investigating algal blooms in water supply, establishing a monitoring system for integrated land, water and coastal management, e.g. defining a sustainability performance framework, incorporating matauranga Māori indicators, developing cost-effective rehabilitation techniques for land, water and coastal environments, e.g. restoration goals for aquatic environments, recreation of wetland environments, identifying governance and organisational arrangements that facilitate integrated resource management and incentivising sustainable approaches, e.g. national frameworks for water governance, crown/iwi governance models

Theme 1 Increased resource productivity for land and water use while enhancing environmental quality.	
Importance to New Zealand	Water availability is becoming the limiting factor for further agricultural productivity gains from irrigated agriculture. Also the cumulative adverse effects upon water quality, indigenous diversity and aquatic ecology health from land use intensification are becoming a limiting factor in further land use intensification. Strategic studies like the Canterbury Water Management Strategy have identified the high cost of storage and sustainability issues associated with mainstream storage. The seven possible storage projects in Canterbury have been estimated to involve a capital expenditure of $5.2 billion. However the strategic studies have also shown that there are substantial inefficiencies associated with current water management systems. The potential improvements in efficiencies are associated with irrigation technology, managing irrigation application to soil moisture demand, irrigation water distribution, increasing reliability of supply and use of surface water for irrigation (or aquifer recharge) in the upper catchments to enhance recharge. Irrigation inefficiency is also related to increased runoff to surface water and leakage to groundwater. There is a substantial opportunity cost associated with irrigation inefficiency in terms of lost resource productivity. There is also a substantial environmental cost and loss of ecosystem services from inefficient use of water.
Research components	1. Improve water use efficiency: Efficiency gains can be achieved through improved irrigation technology; better management of irrigation application in relation to soil moisture, crop type and rainfall availability; irrigation distribution systems; reliability of supply; and enhanced recharge through greater use of surface water as the source of irrigation in upper catchments. 2. Develop measurement technology to support improved management of water and its effects: The efficiency of irrigation can be improved by better management. However for the better management to occur more robust measurement is needed to make informed decisions (e.g. soil-moisture measurement). Similarly with managing adverse effects there is a need for improved measurement with feedback to prevent ongoing contamination (e.g. warning devices when effluent storage is approaching overflowing). 3. Increase resource productivity: Much of current research is focussed on increased production rather than increased productivity. With water as the constraining factor in much of New Zealand decisions should be based on the resource productivity of water use. 4. Investigate aquifer recharge: Preliminary investigations indicate that aquifer recharge is about two/thirds the cost of surface storage; involves less risk of dam failure and reduces evaporation losses. The lack of scientific investigations of its feasibility is limiting further consideration of this cost effective alternative to surface storage. 5. Develop consent arrangements to facilitate efficiency: RMA consent conditions are designed for placing upper limits on use and impacts of use.

	There is a need to develop consenting arrangement that facilitate water use efficiency and minimisation of effects.
Research Gaps and Opportunities	Reliable field measurement of water use efficiency and improvements achieved by technology and management changes in water use efficiency is a gap. This includes the integration of metering of use with soil moisture measurement, crop type, and soil type. It also includes the integration of irrigation equipment efficiencies and application rates. The field testing of aquifer recharge methods to ascertain their practicality. While inefficient irrigation indicates the occurrence of aquifer recharge, more systematic measurement is needed for the design of aquifer recharge as a means of storage. Resource productivity analysis. There is a need for an analytical framework for systematic analysis of potential improvements. Compatibility of farming activities for a region's climate and geography. Broader sustainability analyses of water storage options. Assessments of environmental effects tend to focus on downstream effects on flow and ecology. However damming of rivers and diversions of water have implications for nutrient, sediment and trace element cycles on a broader scale such as coastal environments with the potential wide-ranging regional and even national effects.
Themes 2-7 **Land use, groundwater and surface water interactions** **Catchment and coastal waters interactions** **High quality drinking water for all New Zealanders** **Nested system of sustainability performance indicators for integrated land, water and coastal management** **Remediation and rehabilitation techniques for land, water and coastal environments and their interconnections** **The institutional arrangements and behaviour changes to facilitate integrated management**	
Research goals	To improve management of connections between land use and freshwater for increased productivity of land and water use, enhanced water quality and aquatic ecosystems, and greater achievement of social and cultural values associated with land and water. To improve productive and native fisheries by enhancing the habitat that supports the fisheries and reducing the adverse effects of contaminants, reduced flows, barriers and habitat loss from land and water use. To protect the health and safety of people and communities by promoting adequate supplies of safe and wholesome drinking water from all drinking water supplies. To establish a system of monitoring that reflects the economic, environmental, social and cultural well being for land, water and coasts and their interconnections over multiple spatial and temporal scales.

	To develop cost-effective techniques for rehabilitating and remediating land, water and coastal systems for improved productivity and enhanced indigenous diversity and ecosystem resilience. To identify governance and organisational arrangements that facilitate integrated resource management and incentives for behaviour change to adopt and implement sustainable approaches.
Comments	Further to the goal of theme 1: 1). We need to enhance and expand existing tools for environmental data assimilation environmental sensors, GIS, LIDAR, environmental sensor and environmental and economic model applications; 2). Link experimental research programmes in the environment to policy development and end-user requirements 3. Integrating the data obtained in (1) to provide an open data inventory and suite of models to greatly increase knowledge of the links between the natural environment and agricultural productivity

Entry ID	**398**
To have an integrated suite of environmental tools which are used for benefiting all New Zealanders through optimising agricultural productivity whilst being used to enhance biodiversity and optimise water quality	
Summary	This challenge proposes to develop an integrated suite of environmental tools which will enable us to optimise agricultural productivity whilst simultaneously enhancing biodiversity and water quality. Research themes include enhancing environmental sensing and economic modelling applications so that they seamlessly assimilate the vast amount of relevant data which is generated. Enhancing and innovating experimental programmes to address specific challenges for improving efficiency, optimising biodiversity and minimising nutrient losses in agricultural systems. Integrating these programmes so that they provide information on best value for money in the application of environmental mitigations and provide whole-of-landscape efficiencies that optimise agricultural productivity whilst concurrently providing suitable ecological connectivity to achieve biodiversity and water quality goals.
Theme 1 **To have an integrated suite of environmental tools which are used for benefiting all New Zealanders through optimising agricultural productivity whilst being used to enhance biodiversity and optimise water quality**	
Importance to New Zealand	New Zealand faces one of its greater ever environmental challenges; how to optimise agricultural productivity whilst preserving and enhancing the natural capital, biodiversity and ecosystem services inherent within its unique ecosystems. Failure to meet this challenge will compromise New Zealand's global competitiveness through restrictions in agricultural production both at a regional level and in overseas markets. Furthermore, failure to act decisively will drive

	increasingly acute environmental legacies as poor land-use practices accrue costs for future generations. It will lead to loss of credibility for our environmental branding ('green New Zealand'). World leading science is integral to achieving the overarching environmental objectives for this challenge. The benefits relate to critical aspects of the environmental, social and economic capital of New Zealand.
Research components	1. Enhancing existing remote sensing, GIS, LIDAR, environmental sensor and environmental and economic model applications so that they seamlessly assimilate the vast amount of environmental data that is available from these tools. 2. Enhancing and innovating experimental programmes to address specific challenges for improving efficiency, optimising biodiversity and minimising nutrient losses in agricultural systems. 3. Integration of these programmes so that they provide information on best value for money in the application of environmental mitigations and provide whole-of-landscape efficiencies that optimise agricultural productivity whilst concurrently providing suitable ecological connectivity to achieve biodiversity and water quality goals. Examples of the way in which the science tools can be integrated and reinforce the catchment-based design includes, for example: •use of LIDAR, remote sensing and environmental models (OVERSEER) to identify critical source areas on agricultural landscapes where soil and nutrient loss is greatest; •use of environmental models (e.g. existing lake models or river models) to plan a limit-based approach for meeting minimum environmental goals on a catchment-by-catchment basis, beginning with those catchments that are most at risk from intensive agricultural development. •making sure that there is not a discontinuity within catchments where agricultural intensification is being supported through public money concurrently with restoration measures at the bottom of the agricultural landscape (e.g., in lakes), also funded with public money.
Research Gaps and Opportunities	New Zealand has developed leading science programmes in Geographic Information Systems (GIS), remote sensing, LIDAR for land surface elevation mapping, sensor system and networks, and environmental models. It also has leading programmes in experimental research to benefit the environment and agricultural productivity. Each of these methods or tools has been applied in a somewhat ad hoc fashion in terms of their integration at whole system scale although there have been excellent applications and delivery of some products (e.g., the environmental model 'OVERSEER' or the GIS database 'Land Information New Zealand'). The difficulty is that these applications do not have the critical mass, funding or integration to achieve environmental goals and on-ground actions. The rapid development and application of these tools in recent years now offers a major opportunity to link them together and exponentially increase environmental information. The integration of the information from each of these tools will allow for planning and engineering of landscapes so that they are productive, biodiverse and efficient in their recycling of materials such as nutrients and sediments.

Comments	Further to the goal of theme 1: 1). We need to enhance and expand existing tools for environmental data assimilation environmental sensors, GIS, LIDAR, environmental sensor and environmental and economic model applications; 2). Link experimental research programmes in the environment to policy development and end-user requirements 3. Integrating the data obtained in (1) to provide an open data inventory and suite of models to greatly increase knowledge of the links between the natural environment and agricultural productivity

Entry ID	**469**
Balancing increased agricultural production and environmental concerns	
Summary	The goal is to improve the efficient and effective use of inputs required to deliver high quality primary products while protecting the environment that underpins future production endeavours. Themes include 1. Adding value to primary exports, 2. Reducing impact on the environment,3. Impacts of climate change, 4. Wellbeing derived from the environment. Measurable outcomes include improvement of New Zealand's ranking on the Environmental Performance Index and increase in yield per unit of nitrogen lost to the environment

5 Marine Resource Management

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 3: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
273	An extreme endurance, multi-tasking, oceans information gathering network. Its primary mission is Fisheries Protection but is also capable of environmental monitoring, survey and scientific research, search and rescue, national and regional defence.	1. The construction and production of extreme endurance, autonomous robotic ocean going craft. These are the key link in the proposed system. They offer a multitude of small, geo-synchronised, field replaceable information gathering units 2. The construction and production of autonomous robotic aircraft. These craft are a vital link in the proposed system that offer a multitude of small, field replaceable information gathering and communication relay units 3. A robust communications system with linked sensor arrays, capable of independence from satellite based systems
419	Understanding, preserving and benefiting from our Exclusive Economic Zone	1. Ensure New Zealand has sufficient knowledge to make and monitor sound decisions in the EEZ 2. As a nation we need to understand the range of potential approaches to securing economic benefit from the EEZ. Without this understanding our ability to make optimal decisions will be compromised 3. Establish a New Zealand specific management framework for the EEZ. The framework must enable smart decisions to be made effectively and efficiently, bearing in mind the significant scale of the EEZ compared to the current size of New Zealand's economy and therefore its capacity to manage such a system
426	Wealth and stewardship of our oceans - 95% of the New Zealand estate is under water, making it one of the largest ocean estates in the world	1. Understanding New Zealand's undersea mineral resources and how to minimize the impacts of their extraction 2. Food from the sea: sustainable ocean ecosystems 3. Management of coastal and estuarine habitats: understanding the impacts of multiple stressors
458	Increased Wealth from and Stewardship of our Oceans: Goal: Accelerate development	1.Environmentally sustainable extraction of marine geological resources 2. Growing seafood production and value

Entry Id	Challenge	Themes
	and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides.	3. Anticipating the effects of ocean change 4. Managing multiple-uses of the marine environment

Entry ID	273
An extreme endurance, multi-tasking, oceans information gathering network. Its primary mission is Fisheries Protection but is also capable of environmental monitoring, survey and scientific research, search and rescue, national and regional defence.	
Summary	This challenge proposes to research the production of highly durable, robotically controlled, ocean-faring vessels that will allow the government to efficiently perform a multitude of tasks that maximise New Zealand's presence in our surrounding waters. Tasks performed by these vessels might include scientific research, fisheries protection, and search and rescue. Construction will need to combine several new and existing technologies, with extensive R&D into the use of advanced composite materials, robotic systems, and communication relays.
Theme 1 **The construction and production of extreme endurance, autonomous robotic ocean going craft. These are the key link in the proposed system. They offer a multitude of small, geo-synchronised, field replaceable information gathering units**	
Importance to New Zealand	Extreme endurance, low maintenance information gathering tools that can be mass produced offers a cost effective way to extend government presence into the oceans both nationally and regionally. Activities include environmental monitoring, survey and scientific research, fisheries protection, search and rescue, national and regional defence. These multitasking craft thus offer a wide variety of benefits to national government ministries and regional council bodies, saving costs by removing duplicity of operations, allowing coordinated multitasking operations and maximising information sharing opportunities, whilst offering large amounts of fact based data on which to make sustainable policy decisions. Operation of these craft can be integrated into existing organisations such as NIWA, GNS and the NZDF, saving costs by allowing existing assets to be focused on their primary tasks, particularly relevant to the fisheries protection role. It is a true capability multiplier based on indigenous logistical strength. Both craft and system is exportable. A primary capability is solving the issue of fisheries protection. Illegal fishing for Pacific nation states is currently estimated to be around two billion US dollars per annum in lost revenue and this figure will continue to rise. There is currently no effective long term solution to this problem.

	These craft include a range of high end technologies, components of which can be exported without compromising the security of the system as a whole. Exports to allied nations and integration into their systems offers trans-national cooperation and foreign policy benefits.
Research components	These robotic craft combine several existing and emerging technologies. Research and development of advanced composite materials and their construction techniques in New Zealand are recognised as world class. This is particularly true in the marine industry where current composite construction techniques are seen as being at the leading edge of this industry. The Centre for Advanced Composite Materials at Auckland University and IRL are currently operating in this area. This craft is designed to utilise artificial muscle technology as a method of propulsion. This incorporates the field of hybrid and intelligent materials, many of which have applications in a variety of industries. Work is currently underway in New Zealand in this area, particularly in University medical research laboratories. The incorporation of a hybrid power system, utilising hydrogen, solar and wave energy are all areas that have received attention in New Zealand research. This is particularly true in the long standing research projects from the Christchurch branch of IRL. Robotic autonomy has several important aspects which are currently being undertaken in New Zealand. These range from data storage and processing power to hierarchical decision making processes and situational awareness in the marine environment. Many call this century "the robotic age" and robotic systems, particularly autonomy, will be at the heart of these developments and emerging industries.
Theme 2 **The construction and production of autonomous robotic aircraft. These craft are a vital link in the proposed system that offer a multitude of small, field replaceable information gathering and communication relay units**	
Importance to New Zealand	Autonomous aircraft are the fastest growing sector in the aerospace industry. These craft are of an ideal scale that New Zealand industry is realistically capable of achieving global market traction. The vast scale of New Zealand's maritime regional responsibilities can only be adequately monitored from the air. This can be achieved by a multitude of small airborne robotic systems. It is the only financially realistic method capable of achieving this task. Automated aircraft offer operational capabilities comparable to existing systems but at reduced cost. This is particularly relevant to an aging fleet of aircraft that will soon require replacements costing substantial figures. Operations can include a range of tasks include environmental monitoring, survey and scientific research, fisheries protection, search and rescue, national and regional defence. Thus saving costs by removing duplicity of operations, allowing coordinated multitasking operations, maximising information sharing opportunities, offering fact based data on which to make sustainable policy decisions. This includes a multitude of benefits for a variety of national government ministries and regional council bodies. Operations of these craft can be integrated into the existing organisations. It is a true capability multiplier based on indigenous logistical strength. The craft include a range of high end technologies which can be exported globally without

	compromising the security of the system as a whole. This includes allied nations and integrated into their systems offering trans-national cooperation and foreign policy benefits.
Research components	Autonomous aircraft are already operational in New Zealand. We have aircraft capable of achieving designated tasks in this information gathering system. Nevertheless there are several areas of research and development that will offer increased capability to existing systems as well as open export market potential, capitalising on this rapidly growing aerospace sector. Hybrid power systems, particularly solar electric systems to offer increased efficiency and endurance over existing systems. Particularly relevant to development of ultra-thin solar arrays and energy storage systems. Acoustic control of engines and propellers for stealthy operations. Use of intelligent, hybrid materials and smart systems, particularly in self repairing composites and shape morphing materials for increased endurance, reliability and stealthy operations. Further development of autopilot systems, particularly in the realm of "swarm", multi-unit operations, expands potential application of multiple small units on specific tasks such as search and rescue or disaster relief operations. Enlarging data storage capacity and computational power will allow these systems better tools for analysis and pre-communication processing thus ensuring maximum efficiency, clarity and accuracy of data which is transmitted. This will also assist in efficient and reliable self determination during operational procedures. Advancing sense and avoid technology, the heart of which all safe airspace operations hinge and an area offering substantial rewards in the global market.
Theme 3 **A robust communications system with linked sensor arrays, capable of independence from satellite based systems**	
Importance to New Zealand	As New Zealand does not have its own satellite system, it therefore relies on other nations satellites for many important communication tasks. In a recent review our national search and rescue organisation has highlighted both the operational vulnerabilities of this reliance and the high cost of use. From a Defence operations point of view this vulnerability is also exacerbated by the rapidly growing range of technological hardware, particularly from some Asian nations, that is aimed at militarising space. Any system reliant on satellites for communication or military command and control systems will hold a tenuous link in times of large scale regional conflict. If New Zealand is able to develop a robust system that is not reliant on other nations satellite systems we will be better able to enhance the opportunity for a low cost, indigenous alternative that is focused on prioritising solid links within our region of national interest. Development of a national wireless system capability would enhance the potential of remote sensing for a variety of tasks, from environmental monitoring to remote industry operations such as wind farms. The establishment of semi-permanent sensor arrays will offer substantial cost savings and increases in information gathering productivity compared to existing methods, particularly in difficult or remote environments. Having sensor arrays on geo-synchronised sea craft means this potential can be easily redeployed and thus cover vast areas, simultaneously,

	with great accuracy. Developing an alternative communication and remote sensing system would offer potential system export opportunities to small, poor or emerging nations.
Research components	The proposed system is easily capable of linking into satellite systems. It is intended that satellites are a fourth tier of communications in this information gathering system. What is suggested here is to develop a system that can still operate effectively without the necessity of having this link and therefore offer an extremely robust, reliable and ultimately cheaper alternative. The proposed system has multiple lines of communication, between all the craft in the system, both air and sea based, with any air, land or sea based command and control centre. Ensuring the reliability of these communication links is the first priority for this area of research and development. Once this communication system is robust, the inclusion of satellites in the system will be optional rather than mandatory. The SERC organisation at Canterbury University and IRL are ideally placed to pursue this task. Research and development into the operation of ocean based sensor arrays, along with the SWARM operation of multiple sea based craft is already in progress. Further work in this area will ideally be as a joint venture between Australia's CSIRO, who already have considerable experience in this field, IRL and Wellington's Victoria University.
Comments	With an exponential growth in the world's population, increasingly limited resources, challenges of global warming and environmental damage from over extraction, the issue of Fisheries Protection will increasingly grow more acute. Our Pacific neighbours are already under severe economic pressure from losses of their primary resource asset. As these losses grow they will increasingly rely on the aid of other nations. Inevitably those countries will be forced to seek greater assistance and with that will grow the influence of outside nations in their economic and political self determination. As those Pacific Nation's stocks decline the focus for more fishing resources will move south. We currently have no comprehensive, long term solution to this threat and therefore no adequate tools to ensure a strong, sustainable oceans governance policy. If we cannot convincingly maintain an effective role in protecting the extended economic zones granted by the United Nations, not only may our own resource opportunities be threatened but we may also forfeit our exclusive rights to these territories of seabed. Additionally, if we wish to utilise these territories for our own nation, be it for fishing or mineral extraction, there is an increasingly urgent need to gain scientific data on which to base informed, sustainable policy for our future management of our oceans. Currently our capabilities fall short of being able to achieve this anywhere but in the distant future. The Hydra Project is a proposal that offers long term solutions to these currently intractable problems. The success or failure of achieving these tasks will be one of the most powerful factors in the wealth and well-being of New Zealand's future.

Entry ID	419
Understanding, preserving and benefiting from our Exclusive Economic Zone	
Summary	This challenge proposes to carry out preliminary research which is required to properly understand how to harvest resources within the EEZ, which will allow us to maximise economic benefit at minimum environmental/ecological cost. To ensure that harvests are sustainable, management strategies and limits need to be developed and defined, that consider both economic and ecological factors.
Theme 1 **Ensure New Zealand has sufficient knowledge to make and monitor sound decisions in the EEZ.**	
Importance to New Zealand	Our EEZ covers more than 5.8 million square kilometres – more than 20 times the land area of New Zealand. This is a very extensive area for a relatively small country to manage. This area contains huge potential wealth in both living and non-living resources – we have the responsibility of ensuring that the benefit of these resources is sustained for the long term benefit of our people. For example, within New Zealand's EEZ there are significant hydrocarbon and mineral reserves including phosphates, sulphide deposits and iron sands. New Zealand's mineral and hydrocarbon resources are currently conservatively estimated to be worth $500 billion. However we have limited knowledge of what the environmental risks of extraction are or how to mitigate those risks. Within New Zealand we have some knowledge about deep-water species and ecosystems but in general our understanding of these ecosystems is inadequate. Deep-water environments have immense value, supporting sustainable fisheries ecosystem services such as sequestering carbon, as well as holding their own intrinsic worth. It is crucial that we do not inadvertently irreparably damage our EEZ.
Research components	Research component 1: Geology Including oil, gas, gas hydrates, minerals. Within New Zealand's 200 nautical miles of EEZ there are significant hydrocarbon and mineral reserves. These include hydrocarbon reserves and iron rich mineral sands (iron sands) off the Taranaki coast, phosphate deposits on the Chatham Rise, sulphide deposits on the Kermadec Ridge and sources of methane gas hydrates. Extraction of seabed mineral resources has not occurred to date, but exploration of these reserves is on-going. Currently the primary offshore mining activity that is occurring in the EEZ is offshore oil and gas production. The oil and gas industry is New Zealand's fourth largest export earner, generating $400 million in petroleum royalties in 2011. Research component 2: Ecosystems and ecosystem services Including food (fisheries value), climate regulation (including both carbon sequestration and nutrient cycling), nutrient regulation (sources, limits, quotas, management), recreation, cultural, pharmaceuticals, chemicals. Our EEZ also has intrinsic and bequest values for future generations. Research component 3: Climate effects

	How will the changing climate affect our EEZ and the diversity of ecosystems it currently contains?
Theme 2 **As a nation we need to understand the range of potential approaches to securing economic benefit from the EEZ. Without this understanding our ability to make optimal decisions will be compromised**	
Importance to New Zealand	New Zealand already generates significant economic benefit from its EEZ and this could be grown significantly. The potential options could include: - Oil and gas extraction - Energy generation - Mineral extraction - Fisheries - Aquaculture - Tourism - Other novel ideas Each of these areas needs to be understood before any meaningful debate is possible on whether or not New Zealand wishes to progress them. In particular the cumulative effects of the various potential activities must be understood if the best possible decisions are to be made.
Research components	Research component 1: Mineral - How could minerals be extracted, and of the potential methods which would be acceptable where and why? - What would be the environmental, cultural and social impacts of extraction be? - Would extraction be economically viable for New Zealand? Research component 2: Energy What forms of energy could be accessed? How would they be used? What would the impacts of this be? Research component 3: Natural products (including food) - Establish baseline understanding of current ecosystems - Determine impacts of extractions from that ecosystem - Determine impacts of farming approaches - Determine cumulative effects - Determine areas of conflict (e.g. sentinel benthic fisheries habitats and seafloor mining) Research component 4: Other potential economic benefits, including tourism
Theme 3 **Establish a New Zealand specific management framework for the EEZ. The framework must enable smart decisions to be made effectively and efficiently, bearing in mind the significant scale of the EEZ compared to the current size of New Zealand's economy and therefore its capacity to manage such a system**	
Importance to New Zealand	Currently New Zealand does not have an EEZ management framework in place that enables efficient, effective management and decision making although this is being created (ref. http://www.mfe.govt.nz/issues/oceans/current-

	work/index.html). If New Zealand is to make sound decisions on the use of the resources in its EEZ it is critical that a suitable management framework is established. Current adversarial approaches are proving expensive in both financial and social senses and there appears to be significant potential for New Zealand to establish a more effective framework than is typically evident in Westminster style systems.
Research components	Research component 1: Assess alternative framework structures and determine optimum for New Zealand. The Resource Management Act 1991 (RMA) provides the regulatory framework for management of natural resources on land and in the territorial sea - out to 12 nautical miles. In order to assess whether environmental management in the EEZ is adequate, the Ministry for the Environment (MfE) has reviewed the current legislation (Marine Mammals Protection Act, Wildlife Act, Maritime Transport Act and Fisheries Act) and identified gaps in the environmental management of existing activities. These activities include shipping, petroleum activities (including prospecting and extraction), laying and maintenance of submarine cables and pipelines, fishing, scientific research (biological and non-biological), dumping, and prospecting for minerals. This analysis indicates that there are few procedures in place for assessing the environmental effects of current activities past the 12 nautical mile boundary of the RMA. The report concluded that in New Zealand's EEZ there are no procedures in place for assessing the environmental effects of exploration or mining for petroleum and minerals or the cumulative effects of these activities. Proposed laws have been introduced to Parliament that will manage the environmental effects of activities such as mining within our Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS). Once passed, this environmental legislation will be the responsibility of the Environmental Protection Authority. Development of regulatory frameworks and a robust environmental monitoring plan for mineral exploration and extraction are urgently needed and have been identified as a significant gap by many organisations (Straterra, MfE, Maritime New Zealand, IPENZ and industry). Research component 2: Implement regulatory frameworks for New Zealand This research component would aim to develop regulatory frameworks that include international best practices based on environmental risk assessment and Environmental Impact Assessment (EIA) in developing an Environmental Monitoring Plan (EMP) for activities within our EEZ. Internationally many countries have developed environmental legislation frameworks (both policy and science based monitoring programmes) for industry sectors operating within their jurisdiction. Formalised decision frameworks are often based on risk assessment matrices for specific Valued Ecosystem Components. The development of formalised frameworks would ideally be integrated within larger scale spatial planning approaches to ensure that: i) effects of multiple anthropogenic stressors on the marine environment are considered and, ii) that sensitive habitats are protected when managing the expansion of mineral

	and energy exploration and production activities within the marine environment. Development of these frameworks will include adaptive management, the precautionary principle and assessment of cumulative impacts.

Entry ID	426
Wealth and stewardship of our oceans - 95% of the New Zealand estate is under water, making it one of the largest ocean estates in the world	
Summary	The goal of this proposal is to have a better knowledge of the New Zealand under water estate in order to exploit this wealth responsibly and sustainably. We understand very little about our vast mineral resources, and potential for food production. Scientific understanding is needed to exploit this wealth responsibly and sustainably The proposed research programme includes the following themes: (1) Understanding New Zealand's undersea mineral resources and how to minimize the impacts of their extraction - comprehensive stocktake of sea floor sediment deposits and sub-sea oil and methane reservoirs, develop measurement tools and predictive models to assess how mineral extraction will impact on oceanic ecosystems etc. (2) Food from the seas: sustainable ocean ecosystems - assess and understand the factors controlling the growth rate of the photosynthetic plankton at the base of the food chain etc. (3) management of coastal and estuarine habitats: understanding the impacts of multiple stressors, the physical or biological impacts of various activities, community involvement etc.
Theme 1 **Understanding New Zealand's undersea mineral resources and how to minimize the impacts of their extraction**	
Importance to New Zealand	We tend to think of New Zealand as a small country comprising a few islands. Yet our ocean estate occupies 5% of the global ocean, making us a major maritime nation. Despite active scientific efforts, the sheer scale of this estate means that our current knowledge of the nature and location of minerals, oil and other hydrocarbons is very limited. A scientifically-directed stocktake is needed. Lessons from recent disasters such as in the Gulf of Mexico, or Rena, show that the public expect valuable marine ecosystems to be protected from harm. A comprehensive stocktake of sea floor sediment deposits and sub-sea oil and methane reservoirs must take place to better assess development options. At the same time, we need to develop measurement tools and predictive models to assess how mineral extraction will impact on oceanic ecosystems.
Research components	For specific resources such as oil and gas, the hydrocarbon industry is well-advanced in its investment into exploration, both in New Zealand and elsewhere. However, this is not the case for other minerals, particularly when much of the

	seafloor has not been comprehensively explored. Marine research of this nature is of necessity very expensive, meaning that scientific efforts need to be multidisciplinary and well coordinated. Modern seafloor mapping techniques, together with various geological approaches, provide a mechanism for developing a directed approach to exploration. Scientific understanding of the vulnerability of marine ecosystems to the effects of sub-sea mining is already well-developed, but each instance depends on local factors (e.g., water depth, nature of reef systems, food webs). As with exploration, this requires a coordinated, interdisciplinary approach involving geologists, chemists, physicists and biologists. New Zealand's major players in this form of science, the CRIs NIWA and GNS, together with their university partners, are well placed and actively connected to contribute immediately to this Challenge.
Theme 2 **Food from the sea: sustainable ocean ecosystems. - Food from the sea is vital for the future of a growing global population. The oceans represent a new opportunity for New Zealand to align fisheries and aquaculture alongside its leading strengths in agriculture, horticulture and other land-based food production**	
Importance to New Zealand	It is estimated that the world needs to increase food production by at least 70% to meet projected population growth. At the same time, developing countries become wealthier, leading to increased demand for high-quality protein. As a country with a small land area, New Zealand has little scope to greatly increase agriculture without increased stress on land-based ecosystems and water resources. However, our vast marine estate clear offers the potential for New Zealand to become a major global exporter of seafood, just as it is currently a major exporter of dairy products. This can be achieved through a twin approach: the harvesting of wild fisheries and the development of aquaculture. Exploitation of traditional wild fisheries needs to be based on sound stewardship principles in which the long-term sustainability of the fishery is maintained. The potential for enhancing overall yield is probably limited, but there is great potential for adding value through the development of innovative foods involving fish species of low perceived market value (the kiwifruit approach). On the other hand, aquaculture offers the ability to tailor specific high value products suited to the market, and have greater control over production rates. Both approaches to marine food production require sound husbandry of the underlying marine resources, which means looking after the "soil and pasture" of the sea, namely the quality of the water, its constituent nutrients, the recycling of wastes and, most importantly, the photosynthetic plankton at the base of the food chain.
Research components	Fisheries science is now well-developed in New Zealand and underpins the quota management system. However, this is highly focused on individual species of economic importance, and does not address the underlying environmental systems that service the overall ecosystem. By analogy, it is a waste of time to farm extremely poor soils, or in areas where water supply is unreliable. Equivalent

	concerns apply to ocean ecosystems and fisheries. Thus a research component of primary importance is to assess and understand the factors controlling the growth rate of the photosynthetic plankton at the base of the food chain. This is the ultimate limit on the productivity of a marine ecosystem. The factors that influence this productivity are quite different from on the land, principally because phytoplankton are short lived (< 1 day). The delivery of nutrients through ocean currents, and their recycling in the uppermost surface layers of the ocean, mean that a sound understanding of the physics and chemistry of a marine ecosystem underpins the ability to model ecosystem response.
Theme 3 **Management of coastal and estuarine habitats: understanding the impacts of multiple stressors**	
Importance to New Zealand	Coastal and estuarine regions are only a small part of the overall marine estate, but because they are visible from land, they represent the "ocean" in the eyes of most members of the public. This region is subject to multiple uses: food gathering, aquaculture, recreation, transport, structures and engineering and cultural values. As a result, the nearshore region is subject to multiple stressors, and their management requires a multiplicity of competing interests, not least of which are personal attitudes towards what uses are proper and improper. Science is not the only answer to the dilemma of how to manage nearshore resources. However, science is necessary to understand the physical or biological impacts of various activities, and to inform the public about the consequences of different decisions. Predictive modelling is a valuable tool that science can provide for this purpose. At the same time, science needs to be better informed about the relevant societal attitudes and needs in relation to the multiple uses. What is needed for this is a more coordinated science-community-citizen approach that integrates community participation in science programmes at all levels. This is needed to an important extent in all three themes proposed here, but it is most relevant to this particular theme.
Research components	Scientists need to increase their engagement with local communities, iwi etc. in order to identify the key societal attitudes and needs in relation to the various recreational, cultural, food gathering and commercial uses of nearshore environments, particularly to better identify and societal concerns about human impacts on these environments. At the same time, scientists need to further develop measurement programmes that are simple and robust enough that on-going assessment of the marine system health is not prohibitively expensive nor technically too difficult for local authorities and communities to use for monitoring. The arrival of the "internet age" makes possible a host of new opportunities involving the networking of instruments that gather data and make it available for communities and authorities to use. Better coordination of such resources is needed on a national level, and good examples already exist with the temperature networks operated by NIWA, for

	example. This enhanced measurement programme, coupled with community involvement, will be greatly enhanced by the development of predictive models to quantify the impacts of various human activities as stressors of coastal environments. This is an important second research component of this Theme.
Research Gaps and Opportunities	Both climate change and ocean acidification are extremely likely to have a strong influence on the productivity of marine ecosystems. Therefore research into the effects of these factors is vital and should be integrated into an overall multi-disciplinary approach (with strong connection to [illustrative] Challenge 7: Climate Change). NIWA and its key partner, the University of Otago, have been leading providers of science in this area for many years, with conspicuous success on both the international stage and nationally (2011 Prime Minister's Science Prize).
Comments	95% of the New Zealand estate is under water, making it one of the largest ocean estates in the world. However, we understand very little about its vast mineral resources, and its potential for food production. Scientific understanding is needed to exploit this wealth responsibly and sustainably.

Entry ID	**458**
Increased Wealth from and Stewardship of our Oceans: Goal: Accelerate development and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides	
Summary	This challenge proposes to carry out preliminary research which is required to properly understand how to harvest resources within the EEZ, which will allow us to maximise economic benefit at minimum environmental/ecological cost. To ensure that harvests are sustainable, management strategies and limits need to be developed and defined that are considerate of both economic and ecological factors.
Theme 1 **Environmentally sustainable extraction of marine geological resources** **Goal: Through Government, industry and community collaboration, discover the full extent of petroleum and mineral resources within our EEZ, and advance extraction methods that minimise and mitigate environmental impacts while maximising economic return**	
Importance to New Zealand	In 2009, the United Nations Law of the Sea (UNCLOS) confirmed New Zealand's jurisdiction over an area of 5.6 million km2 of Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS), one of the largest marine territories in the world. It is estimated that this region contains many billions of dollars of petroleum and mineral resources, most largely unexplored for and yet to be quantified. For this endowment to be accessed for the benefit of all New Zealanders there is a need to provide critical resource data to attract prospective explorers, and to provide information to Government to allow them to make sound

	licensing decisions and enact effective regulatory policy. There is much yet to know regarding the petroleum prospectivity of the sub-seafloor sedimentary basins that comprise 30% of the zone, before they can become targets for exploration and, ultimately, petroleum extraction. Similarly, the extensive seafloor mineral deposits must be better mapped and their formation understood to reduce exploration risk. Commensurate with these investigations, there is an obligation to acquire baseline knowledge and develop predictive models to assess the potential ecological and environmental impact of any extractive process being considered. Research that provides useful information for the management of risks associated with deep-sea drilling, and the fragility of marine ecosystems, is a necessary precursor to the awarding of mining licenses and the gaining of public approval. Development of techniques and methods to minimise or mitigate the environmental impacts of extraction may also be needed.
Research components	1. Oil & gas (including gas hydrates): More and better quality data is needed on the petroleum prospectivity of our 17 known frontier sedimentary basins to attract international petroleum companies and encourage exploration and drilling programmes. Evidence from the Taranaki Basin, now a significant oil and gas producer, indicates that enhanced exploration activity in other prospective basins is highly likely to yield positive results in the medium term (at c. $6.5 billion pa, petroleum is currently among the country's highest export earners). 2. Seafloor minerals: Enhanced knowledge of the origins and extent of alluvial minerals, seafloor massive sulphides, iron sands, phosphorites and ferromanganese nodules and crusts, is needed to spur exploration interest by mineral exploration companies, especially in currently unexplored regions, such as the Havre trough and Colville Ridge to the north of New Zealand. 3. Environmental impact: Measurement tools and predictive models are needed to assess how mining and other seafloor activities will impact oceanic ecosystems and other resource users, and to assess the risks associated with extraction operations (deep-sea drilling, hydraulic fracturing, natural hazards).
Theme 2 **Growing seafood production and value** **Goal: Expand and diversify the aquaculture industry into high value species and products, maximise the sustainable catch and value from our wild fisheries, and develop ecosystem based management approaches to increase economic returns from New Zealand seafood**	
Importance to New Zealand	Our EEZ has 16 times the primary production of our land, and provides enormous opportunity to meet the growing global demand for seafood (over 3 billion people depend on seafood as a protein source). The wild fish catch has peaked yet the number of wild fisheries over-exploited continues to increase. Global aquaculture has grown 260% since 1992, and now produces the equivalent of half the global fish catch. There is a need, however, to ensure that improved seafood sector productivity and product attributes will meet the growing consumer demand for environmentally sustainable produce. Intensive aquaculture development has resulted in coastal environmental degradation in many countries and excess use of antibiotics for disease control.

	New Zealand's extensive clean coastal waters and internationally accepted fisheries quota management system provides a basis for significant growth in our seafood production in response to this global market situation. To realise this opportunity New Zealand will need to expand and diversify the aquaculture industry, through adding value to existing species and introducing new high-value species, explore and develop under-utilised wild fisheries, and increase certainty and confidence in fish stock management. Marine farming and wild fish catching techniques need to be developed that maximise product quality and minimise environmental impacts, especially damage to seafloor communities and unwanted by catch. Management of our aquaculture and fisheries needs to incorporate an ecosystem based approach if our seafood products are to meet international certification requirements and consumer preferences, and therefore command high value
Research components	1. Wild fisheries Management: Improved knowledge of the biology and populations of key fishery species is needed to better inform annual quota levels and in so doing meet product certification requirements for sustainability. Also, the potential to increase harvest of under-utilised species needs to be determined. 2. New aquaculture products and species: There is a need to develop and advance commercial production of high value species and products. This includes the development of new farming technology, managing environmental risks, trait selection through selective breeding, and development of tertiary aquaculture products. 3. Environmental impact: Measurement tools, predictive models, new management approaches and industry guidelines are needed to quantify, minimise and mitigate the environmental effects (e.g., water quality, nutrification, seafloor damage, unwanted by catch, marine food chain changes) of aquaculture and fisheries activities. Research will ensure that the sector is able to meet consumer demand for seafood of verifiable quality and ecosystem sustainability attributes. 4. Ecosystem management approaches. There is a need to develop new models and tools that show how ecosystems and seafood production interact to enable prediction of future productivity and enable an ecosystem based approach to development and management of the seafood sector.
Theme 3 **Anticipating the effects of ocean change** **Goal: Enable New Zealand to maintain the health of its marine ecosystems and associated resources through adapting to and mitigating the impacts of ocean change**	
Importance to New Zealand	New Zealand is dependent on, and derives a wide range of ecosystem services from, its marine environment. A range of existing and potential new industries depend on these services (e.g., fisheries, aquaculture, tourism and energy). The oceans influence our climate, support infrastructure, have cultural significance and are an important recreational resource. The health of the oceans has global significance, especially the Southern Ocean, as it drives the world's climate system, has a major influence on atmospheric composition (through the absorption or release of gases such as greenhouse gases and oxygen) and

	mediates the earth's temperature. The oceans are undergoing change, however, in response to climate change, rising atmospheric CO_2 levels, pollution, land-use change and intensification, and overfishing. As a result the health of coastal regions has deteriorated, the oceans are acidifying at an unprecedented rate, sea-level rise is accelerating, major currents are changing, the oceans are warming and levels of primary productivity in some regions have changed. Predicting the impacts of these changes on the marine environment will be essential if we are to grow economic benefit from our ocean resources sustainably, especially fisheries and aquaculture. Research will underpin development of mitigation and adaptation measures required to optimise the health of coastal and oceanic ecosystems and the management of associated natural resources. Determining the impacts of global changes in the oceans is also of international concern, and research associated in this area of science plays a key role in New Zealand's science diplomacy with many of our key trading partners.
Research components	1. Measurement: Monitoring of the changes in coastal and oceanic regions around New Zealand and the Ross Dependency to inform management response to ocean change. Data from this region is key to international efforts to monitor and predict changes in the global ocean, and assists New Zealand's participation in international fora and decision making associated with ocean governance. 2. Prediction: Development of predictive models of the multiple stressors (e.g., sea surface dynamics, current changes, acidification, coastal runoff) affecting our oceans to forecast its future health and changes to marine resources (e.g., fisheries, biodiversity, bio-invasions). 3. Resource management: Development of methods and tools, based on ocean monitoring and forecasts, to inform marine resource use and management. Such development will also assist New Zealand's contribution to international ocean governance.
Theme 4 **Managing multiple-uses of the marine environment** **Goal: Management systems that allow multiple uses of oceanic, coastal and estuarine habitats, incorporate environmental and human-derived stressors, and meet the needs of all stakeholders**	
Importance to New Zealand	New Zealand's oceanic and coastal ecosystems contain customary, recreational and commercial fisheries; energy, mineral, oil and gas resources; unique biota and areas with World Heritage status; ports, cables and pipelines; many opportunities for recreation and tourism, and spiritual significance; and a fantastically rich biodiversity that delivers numerous ecosystem services. Use of our marine environment and its resources, and conflict between users, has significantly increased. As a result policy makers and resource managers face difficult decisions: how can industries work within the environmental capacity of our marine ecosystems but not be needlessly hindered in their development?; how do we ensure that critical ecosystem services (the value of which is estimated to be twice GDP) and heritage species are protected?; how do we ensure that the

	spiritual values and enjoyment of society, including iwi, are not impaired?; how do we retain our green image by not degrading our marine environment?; how do we capture and accommodate the diverse range of values of all existing and potential users?; and how do we do all this in an environment subject to constant natural change?. A combination of ecological and social science is needed to provide an inclusive and transparent framework that facilitates economic growth, improves marine stewardship and ensures that cumulative stresses placed on the environment do not degrade the ecosystem beyond its capacity to adapt
Research components	1. Connecting ecosystems. A whole system approach is needed whereby all ecosystems (land to coast, river to estuary, seabed to water column, coast to deep sea) are appropriately understood and connected. Particularly important but poorly understood are the effects of land-derived inputs (sediment runoff, stormwater, pollution) on marine ecosystem function. 2. Marine ecosystems resilience. Measurement and development of predictive models to determine the resilience of marine ecosystems to the impacts of human activities, invasive species and global change. This is an essential prerequisite to developing tools to mitigate the impacts and enhance stewardship of our seas. 3. Stakeholder values. There is a need to identify the aspirations of all users of marine waters (including iwi) in relation to recreational, food and commercial uses and incorporate their differing perspectives of sustainability in a scientifically rigorous way into planning and management frameworks. Mechanisms for involvement of all stakeholders, rather than a sectarian approach, in defining acceptable limits of ecological sustainability is necessary to reduce conflict and enhances buy-in to management decision making. 4. Management frameworks and models. New management frameworks and interactive models to inform policy and management decision-making need to be developed that incorporate multiple uses and impacts, ecosystem resilience, and stakeholder values. The models need to include both spatial and temporal components.
Research Gaps and Opportunities	• Enhancing knowledge, skills and expertise of all marine stakeholders, including managers and regulators, policy makers, industry and Māori, to ensure uptake of research in the development and management of marine resources. • Developing effective outreach initiatives to inform and educate the youth and general public about the ocean realm to foster public participation in the stewardship, development and use of marine resources. • Enhanced coordination and support of marine research – establishment of large integrated research programmes, especially coastal research, that focus and leverage existing capability across all providers, encourage industry participation, and to ensure coordination and cost-effective use of infrastructure and resources. • Increased baseline seafloor mapping and ecological studies – there is a need to significantly expand the areas of quality survey data on seafloor resources and habitats and map all priority areas of potential resource use (e.g., sedimentary basins) to inform both economic and environmental impact assessments. • Our marine region offers a unique laboratory for ocean research (plate boundary, ocean trenches, underwater volcanism, major water-mass boundaries,

	western boundary currents, proximity to the Southern Ocean and Antarctica, marine biodiversity, deep water fisheries, sedimentary basins etc). New Zealand has a history of attracting overseas researchers and resources to our region through participation in international research initiatives. This has included vessels, equipment and data that New Zealand does not have access to, and represents millions of dollars of additional investment in marine science that New Zealand has been able to leverage. Investment to join such initiatives is considered critical to increased use and management of our ocean resources. Participation in international research programmes (e.g., IODP, Argo, SOLAS, ICED, OceanSITES, IMOS) also acts as a vehicle for enhancing and building diplomatic ties with other nations and increases New Zealand's credibility and ability to participate in international ocean governance.
Comments	New Zealand has the science infrastructure and skills to advance the goal and themes of this National Science Challenge. Infrastructure includes coastal vessels (universities, NIWA), a world class deep-water research vessel (Tangaroa) and associated equipment, high performance computing and databases (GNS Science, NIWA, universities), aquaculture research facilities (Cawthron, NIWA, universities) and laboratory facilities (all providers). Opportunities exist to leverage and gain access to expensive specialist offshore resources such as submersibles, and deep seismics and ocean drilling based on this capability. Development of this National Science Challenge has been undertaken collaboratively by NIWA, GNS Science and the University of Otago.

6 Higher Value Foods

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 4: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
206	Robust and defensible food supplies (Organic food studies)	1. Verifiable claims for organic food benefits
207	Leading the world with the honey bee	1. Sustained and secure pollination services for all crops/products that depend on pollination 2. Total domestication of the honey bee for the purpose of pollination security and sustainability of all industries depending on bee activities 3. In addition to providing pollination security, the bee industry will make a significant contribution to export revenue from a range of food, health & well-being and medicinal products
239	Population projections state by 2050 there will be 9 billion persons to feed. The aquatic environment will have to produce much more than the present 2% food and biomaterials. Marine studies will have move into 21st century science.	1. Seaweed has been utilised by humans for thousands of years. While other countries are researching new uses, New Zealand is spending very little science time. As a country, land based research rules - this must change and aquatic research be given more importance. 2. Seaweed digests for plant and animal growth and health. 3. Seaweed has several compounds that produce above average health benefits in humans
302	Increasing the success of New Zealand foods - To leverage New Zealand's national identity, efficient and sustainable primary production base, scientific capabilities, and innovative culture to provide consumers with foods that promote mental and physical health.	1. Enabling New Zealanders to form new dietary habits to support long and productive lives. GOAL: Promoting mental and physical health through diet, exercise, housing, connectiveness, education and an understanding of the importance of community 2. More New Zealand-foods eaten around the globe. GOAL: To develop consumer-relevant foods that are valued in the global market and that leverage the New Zealand identity, thereby adding value to, and increasing the wealth of, all stakeholders associated with New Zealand's primary sector.
338	Enable New Zealand to be a powerhouse producer of market-defining, world-beating food and beverage	1. Enable New Zealand industries to lead in the production of foods that promote health 2. Enable New Zealand industries to produce high-protein foods of superior functionality and value to

Entry Id	Challenge	Themes
	products	the consumer 3. Enable New Zealand industries to take novel approaches to meet significantly increasing global demand for animal-based protein 4. Enable New Zealand industries to take novel approaches to meet the nutritional requirements of a very significant portion of the global population (c. 2 billion) described as “the bottom of the pyramid” in terms of standard of living
354	International competitiveness of agriculture requires export in high value foods. Manufactured food exports, uniquely sourced from New Zealand, with innovative manufacturing and highly-valued (health) targeting markets is a national science challenge.	1. Theme 1: New Zealand100% Pure Foods – Understanding and protecting the unique opportunities and attributes of New Zealand agriculture 2. Theme 2: Building better foods - Ingredients, processing and value-enhanced products 3. Theme 3: Harnessing Health - Building value through valued health claims
373	Growing economic value and our economy from New Zealand’s land and natural capital/resources	1. Increase productivity from all types of primary production in a way that is socially and environmentally sustainable and acceptable to New Zealanders, and to the markets/consumers on which our exports rely 2. Increase the real value we derive from the food, beverage and fibre we export – adding value, but also getting a bigger slice of the value that is created 3. Healthy land and healthy people in rural communities. Connecting people with the land and its ability to provide economic, social, environmental and cultural growth
394	The Food & Nutrition Challenge	1. People and Food 2. Providing choice for wellbeing 3. Process efficiency 4. Demands on agricultural production
421	Develop New Zealand’s agribusiness sector towards smart* foods for wealth and health benefits	1. Increasing the export potential of the agri-food sector sustainably, in climate change conditions, is an obvious goal for New Zealand. Food exports earn over $20 billion per annum, representing about two-thirds of New Zealand’s export income and 10 percent of total New Zealand employment 2. To satisfy increased demands from customers for safe, health-promoting foods; maintain the reputation of New Zealand food quality and develop

Entry Id	Challenge	Themes
		a growing market for new exportable technologies for food safety and quality assurance 3. To enhance development and marketing of novel food products through improved understanding of customer drivers
427	Future Foods - New Zealand contributes only a small percentage of global food production. Rather than competing solely in undifferentiated commodity markets, New Zealand needs to:	1. Understanding and translating market signals 2. Generating high value future foods — on-farm 3. Generating high value future foods — off-farm 4. Delivering evidence based functionality and bio-efficacy 5. Delivering value chain integrity through authenticity and safety
479	Food Prosperity Wealth from Healthy, Safe and Sustainable Foods	1. Managing environmental impact; developing regional food and beverage characteristics and projecting future intensification needs 2. High Value Foods– enhancing medicinal and health impact from growing, processing and validating high value foods 3. Future foods – driving innovation in high value food development to meet future consumer needs 4. Models of Ownership/Property Structures to develop an eco-economy
484	Food For Health Evaluation Centre - Development of foods for health is a rapidly growing industry reliant upon marketing and not science. An opportunity exists in New Zealand to create the first international “one stop shop” food for health evaluation centre to assess the health benefits and uniqueness of New Zealand foods, food products and nutraceuticals.	1. Harnessing Health – Foods targeting health provide opportunity for value-add. Health claim substantiation needs scientific assessment of foods for health through a readily accessible “one stop” centre 2. New Zealand100% Pure Foods – Research to trace the origins, unique attributes of and integrity from paddock to plate is required to enhance the New Zealand-brand. New Zealand requires global recognition for production of safe, sustainable and innovative food products

Entry ID	206
Robust and defensible food supplies (Organic food studies)	
Summary	The goal is to create robust and defensible food supplies through a research programme that identifies and verifies the benefits of organic foods produced in

	New Zealand
Theme 1 **Verifiable claims for organic food benefits**	
Importance to New Zealand	Need to provide evidence to underpin price premiums
Research components	Nutritional studies; Microbiological safety studies; Storage life toxicity studies
Research Gaps and Opportunities	Organic claims have not received rigorous evidence-based examination and false claims will damage New Zealand's food reputation. There is some, but inadequately explored, evidence that some organic food may carry definite health risks. There is a global perspective that creates a tension between low productivity of organic food and the need to feed the world - this is a moral question - where does New Zealand wish to position itself?

Entry ID	**207**
Leading the world with the honey bee	
Summary	The goal is to ensure New Zealand's economic security (by ensuring the on-going pollination of all agricultural crops/products) with a research programme that (a) identifies ways to ensure pollination (i.e. improve bee varroa tolerance, resistance to disease, bee-friendly management of insecticides and pesticides, bee nutrition, optimised bee husbandry etc.) and (b) develops a means to allow total domestication of the honey bee (separated from the wild honey bees) through comprehensive selective breeding, bee molecular biology etc. and (c) increase productivity and export revenue of the bee industry through a range of food, health well-being and medicinal products etc
Theme 1 **Sustained and secure pollination services for all crops/products that depend on pollination**	
Importance to New Zealand	Pollination security is an issue of national economic significance (Frans Laas et al.: NBA report on Pollination Security to Parliamentary Local Government and Environment Subcommittee, 8 June 2011). In 2011, the horticultural industry depending on pollination by the honey bee generated $1.8 billion export revenue per year (http://www.freshfacts.co.nz/file/fresh-facts-2011.pdf). Pollination of clover contributes a significant but difficult to measure value to the meat and wool industry. In total, $5 billion pa of New Zealand's economy is attributable to the honey bee pollination service (http://nba.org.nz/about-bees/interesting-facts). The honey bee is under threat from pests, diseases, insecticides, loss of balanced diet due to intensification of agriculture, stress from industrial –type husbandry, biosecurity break-downs. Pollination alternatives either don't exist (feral honey

	bees are essentially extinct as a result of Varroa introduction) or are risky (cf Psa in Kiwifruit was probably introduced with imported pollen). Because of biosecurity risks, New Zealand cannot depend on the importation of bees. In order to guarantee the security of a mandatory service for some of New Zealand's biggest export industries, we need to be able to sustain a large and healthy bee population.
Research components	Varroa tolerance, resistance to disease, bee-friendly management of insecticides and pesticides, bee nutrition, optimised bee husbandry for the future.
Theme 2 **Total domestication of the honey bee for the purpose of pollination security and sustainability of all industries depending on bee activities**	
Importance to New Zealand	Although the honey bee has been used for millennia it is still essentially a wild animal. It may well be the one wild animal that makes the biggest contribution to human well-being. New Zealand will play a key role in the research leading to total domestication. This means that the domestic bee population will be completely uncoupled from the wild bee population. As with other domesticated animals, we will optimise the genetic make-up of the bees for their purpose, ensure the appropriate bee population size, manage their health and performance. The benefits will be sustained pollination security, a much bigger industry based on honey and other bee products, and possibly a new industry based on the sensory capabilities of the honey bee. Another big benefit will be the revenue from export of bees with certified performance characteristics.
Research components	Comprehensive selective breeding, bee molecular biology, genetic variety and specialists
Theme 3 **In addition to providing pollination security, the bee industry will make a significant contribution to export revenue from a range of food, health & well-being and medicinal products**	
Importance to New Zealand	The total domestication of the honey bee will allow the growth of other bee-based industries. Honey production will be optimised (probably treble the current volume). Honey will again be earning a substantial 'organic' premium. The honey market will become more segmented leading to opportunities for higher revenue (cf wine). The health benefits of honey and other bee products (eg propolis, venom) will increase demand and value. Beneficial effects of specific plants will be amplified through nectar and pollen collection. As the second totally domesticated insect (after the silk moth) the honey bee or parts of it will be used in high-tech sensory applications. Bee products will form the basis of a significant New Zealand industry that combines modern biology and high technology: New Zealand is good at that. Export specialised bees. Export revenue from IP licensing. Add another billion dollars p.a. to export revenue.
Research components	Carrying capacity: determine how many bees a region/season can optimally carry, throughout New Zealand: measure honey production ass a function of region and bee density. The result will indicate the bee population size that will give the

	highest honey return for effort. Important for the development of the Manuka honey industry. Organic honey: demonstrate that bees that have been bred for Varroa tolerance can produce organic honey with a commercially tolerable risk. Further develop organic Varroa treatments to support the selectively bred Varroa tolerance. Honey varieties: Augment the seasonal and regional opportunities for monofloral or otherwise special honey with selective breeding for preferential nectar collection. This is considerable stretch but would make for excellent science and may have benefits in the application of bee sensory capability. Important for the development of the Manuka honey industry. Active ingredients: determine the identity and mode of action of ingredients in bee products (honey, pollen, propolis, venom, wax etc). Use this knowledge for the development of high-value food, health and medicinal products. Use the knowledge to develop chemical processes for industrial production of ingredients in non-biological products. Bioactive plant substances: An example is tutin. Bees will be used to collect/ concentrate specific beneficial plant substances via collection of nectar, honeydew, pollen, propolis. Test this idea with known bioactives. Describe the sensory capability of the honey bee at all levels down to molecular regulation. Combine the knowledge with modern electronic and information technology to arrive at new specific detection technology.
Research Gaps and Opportunities	Theme 1: Methods for bee selective breeding based on quantitative genetics; methods for measurement of Varroa tolerance or other phenotypes that correlate with Varroa tolerance; selective breeding for Varroa tolerance; Varroa biology research underpinning supporting biological means of Varroa control; selective breeding for disease resistance; correlate bee diet with pollination performance; determine minimum diet requirements for satisfactory pollination performance and colony sustainability; correlate husbandry practices with pollination performance; determine minimum husbandry requirements for satisfactory pollination service and colony sustainability; quantify the interactions between husbandry, stress, diet, insecticides and pollination performance, colony sustainability; develop rapid disease detection methods; survey of bee health and performance over time and space to measure trends, detect emerging issues, measure success of R&D to outcomes. Theme 2: Selective breeding methodology, bee-specific quantitative genetics, methods for trait quantification, molecular knowledge (eg gene mapping, application of molecular selection methods to the honey bee), cater for overseas client needs. Theme 3: Methods of measuring carrying capacity, mapping of carrying capacity for all New Zealand, optimisation of bee population movements in both space and time, develop organic or other alternative non-miticide Varroa treatments for their suitability as treatments in support of selectively bred Varroa tolerance, demonstrate the commercial feasibility of organic beekeeping in a wide range of situations, develop methods and standards in support of a more segmented

	market, analytical chemistry and pharmacology of bee product ingredients, bee product development, synthetic chemistry leading to chemical processing and product formulation, test bees as collectors of high-value dispersed substances, bee sensory biology, development of hybrid sensory technology.
Comments	I am known for my work towards the total domestication of the Greenshell mussel and the New Zealand Pacific oyster, and I helped New Zealand to the international forefront of marine biotoxin research and associated food safety regulation. I like to initiate disruptive technology change. As a hobby beekeeper I have become aware of the Varroa issue through my own experience. I have helped Rainbow Honey Ltd to take over the SFF-funded VSH selective breeding programme from Plant & Food Research Ltd. I am appalled by the lack of Government funding for R&D that supports a biological service of considerable national significance (pollination). I am disturbed by the lack of cohesion between the stakeholders in the bee-dependent industries. Beekeepers seem to emphasise the economic potential of honey when pollination is much more important for the national economy, and those dependent on pollination services seem to think that the beekeepers will take care of pollination security. Beekeepers can't do that on their own. Some of the proposed work is quite a stretch. However I am convinced that the work is largely feasible and the goals are largely achievable. I am also convinced that New Zealand can do this work better and cheaper than most other countries in the world. We can benefit from the considerable existing knowledge. If the IP is handled right then there are big opportunities for overseas revenue. This challenge will be too small/specific on its own but its goal should get specific mention within a bigger challenge.

Entry ID	**239**
Population projections state by 2050 there will be 9 billion persons to feed. The aquatic environment will have to produce much more than the present 2% food and biomaterials. Marine studies will have move into 21st century science	
Summary	This challenge proposes to research seaweed as a way to meet predicted future demand for food/nutrients. Nutrients beneficial to human health can be extracted from harvested sea weed as well as nutrients and products that are beneficial to both plant and animal stocks as fertilisers/supplements.
Theme 1 **Seaweed has been utilised by humans for thousands of years. While other countries are researching new uses, New Zealand is spending very little science time. As a country, land based research rules - this must change and aquatic research be given more importance.**	
Importance to New Zealand	While our oceans cover 70% of the earth's surface they produce only 2% of our food and bio materials. Many Countries are utilising more and more of the aquatic resources around them. Nova Scotia, an area smaller than New Zealand, sells

	seaweed products to 50 countries, farms Salmon, and shellfish mops up the nutrients with seaweed culture. New Zealand has to concentrate on both the marine and freshwater ecosystems so they are better understood as they may well hold the future food and bio-material resources for an expanding population. There are reports from around the world that state soils are being eroded faster than they can be replaced; the point being that terrestrial agriculture is not looking currently sustainable. New Zealand tends mainly to look at land based production: this has to change if we wish to have increased food and employment security in the future. From time memorial the nutrients from the land are being leached in to the oceans through rain, rivers and sand storms. Seaweeds are known to concentrate several fold the nutrients available in their habitats. The utilization of seaweed as Liquid Seaweed is an excellent means to get the lost nutrients back to the land improving the yield of crops and animals.
Research components	While seaweeds take up all the minerals in the water they also produce several other compounds that protect them from the stressful environment. The most important of these biologically active compounds are the sulfated polysaccharides and depending on the type of seaweed, eg brown, red or green will give different health and protection benefits to humans, animals and plants. The other compound is the carotenoid from the brown seaweed fucoxanthin that has bioactive potential far greater than any other carotenoid The research challenge for New Zealand is to firstly find the extraction method that not only gives the best amount but also allows that several different biologically active compounds to be retrieved from the same sample. While other researchers have extracted most seaweed compounds none have obtained what can be called ideal. New Zealanders in the past tended to look outside the square to solve science problems this one such problem.
Theme 2 **Seaweed digests for plant and animal growth and health**	
Importance to New Zealand	Seaweeds not only contain naturally balanced trace minerals in a chelated form but also contain betaines that impart frost protection and improves chlorophyll synthesis. The improvement of the nutritional quality and flavour of crops is an added advantage. Plus elicitors that protect plants and increase the defence enzyme activity. In recent times synthetic chemicals have become prevalent in our farming activities to an extent that some countries are now banning synthetic products. Seaweed biostimulants are loosely defined as non-fertiliser products that have beneficial effects on animal and plant growth and health. Liquid Seaweeds also have chelate agents that have the ability of bio-sorption of other minerals when added to the liquid. Animal health seaweeds are well reported for the benefits imparted to livestock.
Research components	The challenge here is to test one of two New Zealand produced liquid seaweed products on our plants and animals: eg olives, berries, apples, kiwifruit; plus vegetables; lamb parasites, milk fever, facial eczema, milk production, solids etc. The main advantage is that this is a natural, non toxic product from New Zealand marine waters.

Theme 3 Seaweed has several compounds that produce above average health benefits in humans	
Importance to New Zealand	Metabolic syndrome, a major risk factor for heart disease and stroke as well as an important contributor to atherosclerosis, kidney disease and blindness, is a cluster of symptoms including obesity, dysilpidemia, hypertension, and glucose dysregulation. The products in brown seaweed have shown to produce results in helping to combat these problems. The sulfated polysaccharide fucodan is one and the carotenoid fuoxanthin with lipids (18:4:3) is another, not forgetting alginates.
Research components	The challenge here is firstly to extract these compounds in a safe quick manner from our locale brown seaweeds. (See Theme 1) The next challenge is to test these and decide the best method of administering to (a) reduce obesity (b) reduce cancers. The published papers on these seaweed extracts are getting close to closing the gap as to what makes these compounds so effective. Again these are safe nontoxic natural products.
Research Gaps and Opportunities	There is no doubt that the culture of seaweed (brown, red and green) and the extraction of their biologically active compounds will play an important role in the globally changing environment. The gap- for seaweed is the culturing. An IRL group did culture a red seaweed; why it stopped is not known. [Name and comment removed to protect privacy; OIA 9(2)(a)] Seaweed is the plant for the 21st Century. There are thousands of research papers on the benefits gained from seaweed not only for human health and wellness but animal and plant health, growth and nutritional quality. The gap- in New Zealand is the lack of research into seaweed extraction methods and the benefits for animal and plants. We have a product ready for testing. The evidence to hand from science papers establishes that the benefits from the use of liquid seaweeds can be indisputable in agriculture. However we have a gap in that no research papers used New Zealand seaweed or our different production methods. Seaweed has a very long history of being used by humans both for themselves and their animals. The time has arrived to bring the marine eco systems into 21st Century Science. One must not forget the oceans are the cornerstone of the earth's life support system vital for the survival of humankind. A World Bank Project on seaweed stated 3 tonnes of wet seaweed utilises 1.27 tonnes of carbon dioxide, 0.22 tonnes of nitrogen and 0.03 tonnes of phosphorus. This is all good plant growing material.
Comments	There is an urgent need for certain selected high schools to have aquaculture added to their science subjects. The Golden Bay High School at Takaka is one that stands out. The sea floor of this area has been decimated from years of scallop, oyster dredging and trawling. The bay has 5 types of shellfish, a large salmon hatchery, and mussel farms with seaweed also growing on these. There was a crab fishery. Soft shell crab is a high priced delicacy overseas - one has to know how to produce them. This is a perfect location to operate artificial reefs to show that marine life can be restored. These would be run and monitored by the school marine science students. No doubt the local community would also help with funding for this venture. These would be students that will become the

	scientists and managers in 2050 when it is estimated the population will exceed the food supply if nothing is done for the eco systems' ability to improve. Artificial reefs are being constructed in Europe, Americas, Asia, Africa and Australia and proven themselves. Nature has shown how it works, we now need to follow.

Entry ID	**302**
Increasing the success of New Zealand foods - To leverage New Zealand's national identity, efficient and sustainable primary production base, scientific capabilities and innovative culture, to provide consumers with foods that promote mental and physical health a	
Summary	The goal is to develop consumer foods that promote mental and physical health by leveraging New Zealand's national identity, sustainable primary production base, scientific capabilities and innovative culture.
Theme 1 **Enabling New Zealanders to form new dietary habits to support long and productive lives. GOAL: Promoting mental and physical health through diet, exercise, housing, connectivity, education and an understanding of the importance of community**	
Importance to New Zealand	Expected Benefit: Adopting an integrated holistic approach to health and well-being can help all New Zealanders lead long and productive lives. This approach can transform health care and reduce the significant impact that poor health (including sickness and disease, allergies, sleeping habits, physical fitness and stress) has on peoples' productivity, happiness and the New Zealand economy. Food choices provide an opportunity to prevent the occurrence of prominent New Zealand health risks (e.g. diabetes - 5 times higher in Māori, obesity, mental health, cardiovascular disease, cancers) or mitigate their effects. Taking an holistic approach to mental and physical health through a multidisciplinary research (physiological, social, environmental) will ensure that the health and well-being of the general population is maximised to benefit our aging population, support cultural diversity, and ensure the growth and development of our young people – this is a considerable challenge for New Zealand. Technological breakthroughs in terms of food design, production, promotion and marketing of healthy foods for New Zealanders will enable New Zealand food producers to identify opportunities to apply these technologies when targeting global consumers (Theme 2).
Research components	•Foods for wellness and prevention of illness and disease – specifically addressing an aging population, a culturally diverse population, Māori health issues, the growth and development of a physically and mentally healthier younger generation and the social needs of our community. •Foods that focus on prominent New Zealand issues (e.g. diabetes, obesity, mental health, cardiovascular disease, cancers).

	•Role of human physiology, life stage, genes and environment – how can low-tech personalised health risk profiles be used by people to make dietary changes and improve their health and wellbeing status? •The role and impact of community/demography on the success of foods for health. •Hauora Māori – health issues for iwi and the role of access to traditional diets, food production and preparation practices and the cultural significance of kai. •Through health education, create wide understanding among New Zealanders of the importance of a healthy diet and the motivation to make healthy choices. •Maintain accurate and accessible databases for use by food researchers, health practitioners and the community. •The influence of maternal nutrition, genes and environment on the incidence and severity of allergies in the New Zealand population understood in order to identify ways to reduce the risk to the future generations.
Theme 2 **More New Zealand-foods eaten around the globe. GOAL: To develop consumer-relevant foods that are valued in the global market and that leverage the New Zealand identity, thereby adding value to, and increasing the wealth of, all stakeholders associated with New Zealand's primary sector**	
Importance to New Zealand	Enhancing the value of New Zealand's primary sectors (horticulture, arable, seafood, meat, dairy) and food and beverage industries, will contribute significantly to the country's economic growth (some 41% of New Zealand's exports are sourced from these sectors). Enabling New Zealand growers, food manufacturers and exporters to profitably produce and successfully market fresh and processed foods that meet well-defined global food mega trends (e.g. health, provenance, convenience, novelty, sensory appeal) in a culturally diverse global market is a significant challenge that can be addressed through scientific research and the strong integration of that science with postharvest and transportation pathways and business investors. Success will see lower costs across the supply chain, greater efficiency in resource allocation, innovation in food science and the ability to produce foods that grow New Zealand's share of existing markets while also successfully creating new opportunities in growth areas. It will also ensure the products and systems developed in New Zealand are adaptable for new environments in 'behind the borders' opportunities for New Zealand producers.
Research components	Research Components •Higher value manufacturing applications and novel technologies in supply chain for efficient and effective delivery to distant markets. •Leveraging the New Zealand identity (safe food, sustainable production, clean ecosystem) to access markets and encourage consumers to purchase New Zealand-food. •Leveraging New Zealand's unique bioresource (e.g. genetics, land, sea resources) •Understanding the consumer food choices in a culturally diverse global marketplace. •Improved quality, value and benefits of New Zealand-foods. •Finding new food production opportunities for Māori growers. •Understanding the

	value proposition of foods from the consumer perspective – is there really anything beyond price? How do we make healthy foods affordable? Research Gaps And Opportunities •Value-added innovation for foods sourced from our primary sectors. •Functional foods with substantiated health and wellness claims. •Seamless integration of robust production, manufacturing, distribution and marketing platforms. •Deep and fundamental understanding of the biological potential of our food resource base (bio-prospecting) and the systems that ensure its value is captured sustainably. •New and more sophisticated methods of food preservation (the 'indestructible' sandwich). •Growing a focus on and awareness of indigenous foods/food ingredients coupled with global awareness of New Zealand's cultural food identity. •Considering a transition to GM crop production in New Zealand if we are to contribute to feeding the increasing global population.
Research Gaps and Opportunities	•Holistic approach to health and well-being – integration of nutrition, food functionality and knowledge of human responses. •Building stronger connections between research providers and the community (particularly Māori) in the area of health and wellbeing. •Enabling New Zealanders to form new dietary habits to support long and productive lives through a greater understanding of eating behaviours, physiological needs and psychological states. •Addressing the diets of our vulnerable young people to stem obesity, the onset of Type II diabetes and mental health disorders in future generations. •Is there true cultural diversity in food choices related to foods for health? How can we leverage food choice preferences to improve New Zealand's health statistics? •What are the proportional roles of human physiology, genes and environment – are personalised health risk profiles the key to a healthier future for New Zealanders? •Designing a new generation of functional foods based on holistic human physiology models with substantiated health and wellness claims. •Develop scientific evidence that explains and supports the mechanisms behind traditional health beliefs of Māori, Pacific Islanders and our growing populations of Indian, Asian and Middle Eastern peoples to support the development of innovative new foods. •Seamless integration of robust production, manufacturing, distribution and marketing platforms. •Deep and fundamental understanding of the biological potential of our food resource base (bio-prospecting) and the systems that ensure its value is captured sustainably. •New and more sophisticated methods of food preservation. •Considering a transition to GM crop production in New Zealandif we are to contribute to feeding the increasing global population.
Comments	Western styles and tastes of food do not translate directly within other cultures (e.g. Asian, Indian, Arab) and this practice has led to misguided product development and failure of products in the market. By addressing our limited understanding of dietary and cultural preferences of different cultures (addressed here in theme 1. We have the potential to deliver unique opportunities to New Zealand's horticulture, arable, seafood, meat, and dairy sectors as well as food and beverage manufacturers 2. Many Asian local food companies are bigger than multi-nationals so New Zealand has to engage with them directly as collaborative research providers

	rather than focus solely on global multi-nationals. PFR has a programme of developing Māori PhD students and post docs who have existing links to Hauora (Māori health centres). This provides an opportunity for scientists to develop effective relationships with Hauora, to engage with research nurses and gather information regarding nutrition and food choices as well as linking in with patients for education and to ensure preventative health. The position and thinking on research themes relating to sustainable production to support food production are further outlined in the challenges 'Increasing land productivity within environmental limits' 'Reducing greenhouse gas emissions from agriculture New Zealand while supporting the sector's prospects for growth and generation of wealth for all New Zealanders', 'Biosecurity with open borders' - these challenges are integral to our challenge of 'increasing the success of New Zealand foods'.

Entry ID	**338**
Enable New Zealand to be a powerhouse producer of market-defining, world-beating food and beverage products	
Summary	The goal is to increase New Zealand's production of market-defining, world-beating food and beverage products. This is proposed through a research programme with the following themes: 1. Enable New Zealand industry to lead in the production of foods that promote health 2. Enable New Zealand industry to produce high-protein foods of superior functionality and value to the consumer 3. Enable New Zealand industry to take novel approaches to meet significantly increasing global demand for animal-based protein and 4. Enable New Zealand industry to take novel approaches to meet the nutritional requirements of a very significant portion of the global population described as "the bottom of the pyramid" in terms of standard of living.
Theme 1 **Enable New Zealand industry to lead in the production of foods that promote health**	
Importance to New Zealand	There is a significant international market of health-conscious consumers selecting health-promoting products. One segment of this market, the functional foods market, is worth over US$100 billion a year, and Omega-3 offerings alone are worth US$34 billion p.a. Retiring 'baby-boomers' in developed countries and consumers in emerging markets in Asia and South America are driving this demand.
Research components	Structuring foods to function effectively during ingestion and digestion to optimise the rate and quantity of uptake in the gastro-intestinal tract of nutritious and healthy food components and 'smart' active ingredients. Protecting the stability

	and activity of these ingredients throughout the production and supply chain, is also a key research component.
Theme 2 **Enable New Zealand industry to produce high-protein foods of superior functionality and value to the consumer**	
Importance to New Zealand	It is becoming more widely understood that quality protein nutrition throughout life is a key to health and wellness. It is not only key to physical development and performance (e.g. infant nutrition, sporting and leisure pursuits), but critical to healthy ageing. Foods for the ageing to preserve muscle will be the "next big thing". The availability and absorption of essential amino acids is not necessarily well managed in diets at various stages of life, in particular later in life. High-protein foods and beverages are a key to providing the necessary nutrition profile for health, and the market drivers in Theme 1 apply to this category of foods and beverages.
Research components	Structuring foods to deliver effective levels of quality protein is a significant science challenge. The design and production of high-protein foods and beverages which optimise nutrient delivery and achieve high consumer acceptability for taste, texture and palatability will be the focus of this research platform.
Theme 3 **Enable New Zealand industry to take novel approaches to meet significantly increasing global demand for animal-based protein**	
Importance to New Zealand	New Zealand is one of the world's most trusted suppliers of animal-based protein (meat, seafood, dairy). The global demand for these high-quality desirable protein-rich foods is projected to more than double by 2050. As New Zealand clearly cannot meet this demand from current provision it must capture the opportunity to extend its base of animal protein with quality plant and alternative source protein, thus enabling a larger and wider global market to be serviced from the same animal-derived protein production base. Alternative sources should include current waste streams from the meat and seafood industries, and fungal, algal and insect protein sources.
Research components	Allied to the research components in Theme 2, structuring foods to deliver effective levels of quality protein combining both animal and plant sources (in order to extend or substitute the animal source) is a significant science challenge. The critical issues that need addressing are: nutritional balance (indispensable amino acids), texture and flavour (e.g. many vegetable and cereal proteins have off flavours), use of currently underutilised by-products from our animal-based industries. Such foods and beverages need to be designed and investigated to achieve both production and consumer expectations of taste, texture and palatability.

Theme 4 Enable New Zealand industry to take novel approaches to meet the nutritional requirements of a very significant portion of the global population (c. 2 billion) described as “the bottom of the pyramid” in terms of standard of living	
Importance to New Zealand	New Zealand is unable to supply increasing demand levels for protein, including supplying the nutritional requirements of the significant population of malnourished or “just enough nutrition but needing more” at the “bottom of the pyramid”. However, with the right food technology and components, it is possible to design nutritious and affordable food and beverages at a price point suitable to a very low standard of living. Key opportunities included the fact that these products can be more profitable and in much higher volumes and smaller pack sizes. After India, Africa is the next great emerging world market.
Research components	Allied to the research components in Themes 2 and 3, structuring foods to deliver sufficient levels of protein, lipids, carbohydrates and minerals in an acceptable ‘value-added’ format at an affordable price point, is a significant science challenge. Further challenges lies in the fact that often no cold chain exists, especially in the tropics, thus the need for ambient stability and novel preservation/ protection technologies. The knowledge and IP that can be developed and incorporated into such foods (manufactured in New Zealand and locally in-market), is of great value to New Zealand industry and can potentially be leveraged overseas.
Research Gaps and Opportunities	The main gap in the research landscape is human clinical trials to validate the health claims of functional foods.

Entry ID	**354**
International competitiveness of agriculture requires export in high value foods. Manufactured food exports, uniquely sourced from New Zealand, with innovative manufacturing and highly-valued (health) targeting markets is a national science challenge	
Summary	The goal for this proposal is to improve the international competitiveness and value of New Zealand agricultural food exports through innovative manufacturing and targeting high-value (health) food markets. The proposed research programme includes the following themes: (a) understanding and protecting the unique opportunities and attributes of New Zealand agriculture (b) building better foods by development of less environmentally hazardous, minimal technologies and improved modelling, monitoring, engineering and construction of better food production facilities and (c) building value through valued health claims.

Theme 1 **New Zealand100% Pure Foods – Understanding and protecting the unique opportunities and attributes of New Zealand agriculture**	
Importance to New Zealand	Processed and packaged foods is in excess of a US $2 trillion global market, with annual growth exceeding 7%. The New Zealand agricultural sector has strong export growth, but limited geography and remoteness to growing Asian markets limits long-term competitiveness as a commodity supplier. Understanding the uniqueness (including compositional characteristics, harvesting, environment), how this uniqueness traffics through the supply chain and ends with the consumer product contributes to key aspects of Asian food demand - safety and benefit.
Research components	1.1: Substantiation of unique compositional characteristics of New Zealand foods. Traceability of these characteristics through the food supply into manufactured foods to retention of 'uniqueness'. There is no science on the uniqueness of many New Zealand agricultural products despite unique soils, cultivars and animal feeding strategies that cannot be matched worldwide. 1.2: Contaminant detection, including dilution/substitution, environmental, microbiological and chemical in New Zealand food ingredients and products. High throughput detection methodologies provide unheralded sensitivity and precision in all aspects of tracing highly labile, trace minerals and contaminants in the food supply.
Theme 2 **Building better foods - Ingredients, processing and value-enhanced products**	
Importance to New Zealand	Value capture requires innovative food processing. Investment in novel technologies to harvest, retain, enrich and synergise the 'unique' benefits within New Zealand sources primary produce is limited. Novel next-generation technologies for efficiency, product development, low-pollutant and retention of bioactives requires coordinated research from Universities through CRI's to businesses.
Research components	2.1: Development of less environmentally hazardous, minimal (including non-thermal processing technologies) 2.2: Modelling, monitoring, engineering and construction of better food production facilities.
Theme 3 **Harnessing Health - Building value through valued health claims**	
Importance to New Zealand	Health is a major driver of consumer purchasing patterns and increasingly a feature of Asian purchasing patterns with increasing urbanization. Health-benefit foods can provide high margin profits, but require considerable effort and time to generate the substantiated link between the food ingredient and the medical substantiation. Once generated food regulatory agencies worldwide have been reluctant to allow communication directly to the consumer on packaging and advertising. Food Standards Australia and New Zealand (FSANZ) is close to

	agreement of regulatory standards to enable health claim substantiation, yet capitalising on this regulatory framework requires a coordinated science investment substantiating food-health connections. Internationally, research has not progressed due to regulatory uncertainty.
Research components	3.1: Generating international recognized medical science in the substantiation of the relationships between food and health. Leading from novel biomarker discovery through the clinical intervention studies to achieve internationally recognized health claims. 3.2: Leading the coordinated approach to health claim regulatory frameworks with SE Asia.
Research Gaps and Opportunities	Despite the importance of food for health, few national strategies exist to build export-value from the paddock to the plate. Several European and Asian economies (most notably Switzerland and Singapore) with limited agricultural capacity have generated the best performing food-export branded food business, based on unique characteristics (ie. Swiss chocolate; regional hub/ automation/skilled worker base). Yet New Zealand, despite having far greater natural resources, with many examples of unique/pure food ingredients and a recognized international reputation in food exports, is yet to fulfil the promise of generating high-value branded products that 'drive' consumer demand. A national research strategy from the uniqueness of the New Zealand ingredient through to the high value health claim that substantiates the generation of health claims are major research gaps requiring leadership and investment.

Entry ID	**373**
Growing economic value and our economy from New Zealand's land and natural capital/resources	
Summary	The goal of this proposal is to grow value from New Zealand's primary sector with a research programme that includes the following themes : (a) increase socially and environmentally sustainable productivity from all types of primary production (b) Increase the value derived from exported food, beverage and fibre (c) Connecting people with the land and its ability to provide economic, social, environmental and cultural growth
Theme 1 **Increase productivity from all types of primary production in a way that is socially and environmentally sustainable and acceptable to New Zealanders, and to the markets/consumers on which our exports rely**	
Importance to New Zealand	Agriculture is New Zealand's most important export industry (worth $21.6 billion in the year to July 2012, or 46% of merchandise exports). If New Zealand's economy is to grow significantly, the productivity of the agriculture sector will have to grow

	substantially, both agriculture and smaller sectors would have to grow, or the smaller sectors by themselves would have to grow enormously. The first two options would require us to grow agricultural productivity. However, out of 31 countries for which OECD. Stat provided the required data for the year 2009, New Zealand was ranked 15th in the key productivity measure of agricultural GDP per worker. This was a substantial decline from 1998, when New Zealand was 8th out of 29 countries. If agriculture is to make a major contribution to economic growth in New Zealand, it is vital that we greatly increase our rate of agricultural productivity improvement. As our most important land use after native vegetation, taking up 39% of New Zealand land area, agriculture also has a major influence on the New Zealand environment and society. Agricultural practices are increasingly becoming subject to regulation to manage their environmental impacts, so it will be essential that agricultural productivity improvements go hand-in-hand with reduced environmental impact and improved resource use efficiency, including improved nutrient management. Other important land uses include horticulture (10%) and forestry (9% of merchandise exports). Both share challenges and opportunities with pastoral agriculture. An appropriate allocation of land between each of these land uses and native vegetation is also vital.
Research components	1. Improved plant productivity. Forage plants are a crucial driver of productivity in pastoral agriculture, while plant productivity is even more directly important to the horticulture and forestry sectors. 2. Improved productivity in dairy, meat and fibre-producing animals. Accelerated whole genome selection can produce animals with the attributes farmers and consumers need. Research to understand and manipulate the rumen ecosystem will redirect nitrogen and carbon into proteins and fats, rather than the greenhouse gases methane and nitrous oxide. 3. Improved animal health and welfare. Somatic cell counts and reproduction performance are key issues for the dairy industry. For sheep and beef, improved methods to control internal parasites are a high priority. 4. Biosecurity research strengthens our border security and develops new detection technology that reduces the cost of protecting against existing known threats. 5. Adoption of new management practices that improve productivity. Systems research is essential to develop resilient and adaptive farming and horticultural systems that are responsive to opportunities and challenges while remaining productive, profitable and environmentally sustainable. 6. Improved on-farm productivity in Māori agribusiness enterprises. An estimated 20% of Māori land is managed or administered by well-performing businesses but 80% have considerable room for improvement in either entity performance or land utilisation. 7. Practical policy solutions for economically, environmentally and socially sustainable land uses.

	8. Reduced environmental footprint of productive land uses. Strong environmental performance will enhance consumer confidence in New Zealand's primary products and, when integrated with farm business needs, reduce costs and improve productivity.
Theme 2 **Increase the real value we derive from the food, beverage and fibre we export – adding value, but also getting a bigger slice of the value that is created**	
Importance to New Zealand	New Zealand's food, beverage and fibre exports make up about $26 billion per year, or about 55% of merchandise exports, but we only supply dietary energy for 20 million people, the protein requirements of 45 million people and the dairy product requirements of 165 million people. Thus, New Zealand is a niche producer of food, beverage and fibre products that has both the challenge and opportunity to target the high end of world markets rather than having to compete with larger food-producing countries on price. To earn premium prices from the products we sell to those high-end markets, we must produce foods, beverages and natural fibre products that are of the highest and most consistent standard, are most appealing to the world's most discerning customers, and have the greatest functional benefits for those customers. At the same time, we must capture a greater share of the value chain that secures for New Zealand a greater percentage of the price paid by the consumer for the final product. This requires that the products we sell have attributes that are rarely or never found in competing products, that allow us to command premium prices, or that New Zealand owns a large fraction of the offshore value chain – up to the retailer or even the consumer. The latter requirement would have to be met by business and investment strategies rather than research, but research can certainly deliver attributes whose uniqueness or rarity can be secured by intellectual property or appellation.
Research components	1. New high-value dairy and food solution products and processes. The nutritional needs of mothers and babies, and healthy ageing, are two main areas of emphasis. Research collaborators include AgResearch, Plant & Food Research, Auckland, Massey and Lincoln Universities, the Riddet Institute and Fonterra Research. 2. Meat and processes that consistently meet the needs of existing and new markets. This will include the need for research to assist in product differentiation through the attributes of animals supplied and interventions during processing. AgResearch, Massey and Lincoln are major contributors in this research. 3. New products from Māori agribusiness enterprises. Extension along the value chain to create new and enhanced products is a significant opportunity for Māori agribusiness enterprises to create greater value from their asset base and the cultural values of Māori land owners and the way these are reflected in management practices provide opportunities to develop "Māori brands". This requires close partnerships between research organisations and Māori agribusiness enterprises. 4. Higher value natural fibre products. This will involve work on inherent properties of wool to improve its functionality, including science to understand the reaction of protein structures to light, using chemicals to photo-stabilise wool, and improving crimp in cross-bred wools. It will also involve work

	to improve the performance of plant-based fibres, including wood. Scion, AgResearch and several Universities contribute to this research. 5. Consistently complying with demanding international food safety and other regulations, including biosecurity to prevent pests and diseases that threaten our ability to trade from entering New Zealand.
Theme 3 **Healthy land and healthy people in rural communities. Connecting people with the land and its ability to provide economic, social, environmental and cultural growth**	
Importance to New Zealand	Despite the vital importance of rural land-based resources to New Zealand's economy, New Zealand is one of the world's most urbanised countries: 86% of the population lived in urban areas in 2010. It will be vital that economic growth from land and natural capital goes hand-in-hand with environmental, economic and social sustainability. If rural land is to be productive, the people who work that land must want to live in rural areas. That will require that they have access to publicly- and privately-provided services of a comparable standard to that obtained by urban dwellers, as well as having the rural lifestyle. With an estimated asset base of over $36 billion and a GDP contribution of $10.3 billion per year, the Māori economy (much of it rural) is a vital element of growing New Zealand's overall economy. While many Māori farming operations are highly productive, a significant number are under-performing. An estimated 80% of Māori land has considerable room for improvement in either entity performance or land utilisation. According to a recent Te Puni Kōkiri report, Māori land owners aspire: • To retain and improve existing long-term businesses associated with the land, especially farming, and for owners to use the land directly rather than through lease, and • To achieve sustainable financial return for owners, provide employment for the owners where possible and to build a financial base for coming generations. This theme aims to achieve these goals for all rural communities.
Research components	1. Research to develop approaches to improving productivity that are consistent with values associated with the land as a tāonga tuku iho, such as kaitiakitanga and manaakitanga. 2. Research to improve organisational governance and management capability, which is a barrier to achieving landowner aspirations. 3. Research that applies to large-scale landholdings, such as those administered by trusts and incorporations. Approximately 60% of multiple-owned Māori land is administered by 140 organisations. 4. Research emphasising the connection of Māori to land ownership. Work to date with a number of Māori organisations around the country suggests that bringing people back to their land delivered improvements in mental health and nutrition for the people while fragmented land was networked into useable farms with increased productive capacity. 5. Continued health of our productive and natural ecosystems requires that those biological systems be protected from the threat of invading pest animals, insects, plants, bacteria and viruses. Our country's island ecosystems are uniquely susceptible to catastrophic pest invasions that can cause hundreds of millions of

	dollars of damage per year. Biosecurity research strengthens our border security against known and previously unknown threats, and develops new detection technology that reduces the cost of protecting against existing threats. Biocontrol research delivers cost-effective techniques to manage existing pests without creating adverse environmental impacts such as those resulting from chemical control methods, for instance. The Better Border Biosecurity collaboration is the key New Zealand grouping of biosecurity researchers.
Research Gaps and Opportunities	Productivity: 1. Efficiency gains across the value chain. 2. Land uses that are well-matched to the landscape configuration. 4. Sophisticated monitoring systems that provide accurate and timely feedback to landowners on the performance of their productive land. 5. Adoption and practice change enhancement. The Primary Innovation collaborative programme in which MBIE commenced investment in 2012 is making a start in this area. 6. Nutritional enhancement of animals and plants. 7. Design of plausible transition pathways to ensure the twin goals of economy and environment are aligned and in step. Increased Value: 1. Integrated “lab to consumer” validation of food & ingredient functionality, sensory properties and safety. A “New Zealand Inc.” approach to carry out quality human nutrition research, show proof-of-function and complete clinical trials could substantiate claims with respect to nutritional value, biological functions that deliver desirable health and wellness benefits, and the bioavailability of these components. Auckland University, AgResearch, Plant & Food Research et al. collaborate in this area through the Nutrigenomics New Zealand programme. 2. Molecular mapping of food and fibre component modification from farm to consumer, with correlation to quality and function. There is potential to apply related techniques across different products and value chains, and so collaboration could be strengthened in future. Healthy Land/People: 1. How can we integrate biodiversity concepts with productivity requirements to balance productive and indigenous landscapes, build resilience into landscapes, and enable communities to exercise kaitiakitanga over native flora and fauna? As well as being culturally important, the latter are vital assets for New Zealand that create economic value through the international tourism industry. 2. How can we use modern technology to deliver the highest standard of services and lifestyle to rural communities?
Comments	Increasing productivity: • This is a zone of high societal tension and we can make gains through shifting the 75% quartile however that is a short term measure and

	science must work with the entrepreneurs who are setting and exceeding their own targets. • Science alone will not solve this issue. Society will have to re-define the goals that it sets and research should assist to develop plausible futures and transition pathways. • Emphasis should be placed on where the key interventions are required in the existing value chain to take that leap forward. Science to co-innovate will require new teams including practitioners and transdisciplinary teams that include people from diverse backgrounds. • Research to reduce the emissions of greenhouse gases from New Zealand agriculture is covered by the submission of the New Zealand Agricultural Greenhouse Gas Research Centre. • Landcare Research, AgResearch, Plant & Food Research, Scion, Massey University and Lincoln University contribute to this theme at present and/or have the capability to contribute in the future. Increasing Value: • Successfully meeting this challenge will require complementary maintenance and enhancement of the “New Zealand Brand”, particularly around considerations such as environmental impact and animal welfare. • Many CRIs and Universities contribute to this theme at present and/or have the capability to contribute in the future. Landcare Research, AgResearch, Plant & Food Research, Scion, Massey University and Lincoln University are particularly prominent. Healthy Land/ People: • Government agencies with major activities in this area include the Ministry for Primary Industries, Te Puni Kōkiri, Ministry for the Environment, Department of Conservation and others. • FoMA and the Māori Trustee are already engaged with this issue, along with many individual iwi, hapu and Māori-owned agribusinesses.

Entry ID	**394**
The Food & Nutrition Challenge	
Summary	This research programme proposes the following themes (a) people and food (b) providing choice for wellbeing (food for health claims effect of food processing on food quality food safety and security) (c) process efficiency by moving beyond the notion of ‘waste’ processing and focussing instead on ‘whole of resource’ processing, energy recovery from food waste via incineration, anaerobic digestion, pyrolysis or gasification technology presents a range of valorisation opportunities (d) demands on agricultural production whole of system management - defining environmental and social limits
Theme 1 **People and Food**	
Importance to New Zealand	Biological, chemical and radiological contaminants present a continuing threat to human health in the developed and developing world through inappropriate processing and handling, spoilage and contamination. Authenticity, control and

	better management of products, ingredients and mass flows through the food chain can be achieved by improvements to food analyses and diagnostics. Chemical engineers in the food process industries must be involved at an early stage. Hygiene and food safety can be improved by the application of chemical engineering and chemistry to improve hygiene through all stages of processing, including better design and management of thermal processing operations, disinfectants, non-aqueous cleaning methods and the use of novel materials for handling food.
Research components	We need to move beyond the notion of 'waste' processing and focus instead on 'whole of resource' processing. Reduction; reuse and recycling options should take priority in any food processing strategy. However, energy recovery from food waste via incineration, anaerobic digestion, pyrolysis or gasification technology presents a range of valorisation opportunities. All four routes are well understood by chemical engineers, but the applicability of each technology is very dependent on the quality and consistency of the waste stream. Chemical engineers must engage with initiatives on food waste management and contribute to strategies that explore ways of optimizing the use and/or reuse of waste streams. Effective risk assessment is paramount, as is the need for early public engagement and chemical engineers must mount persuasive arguments in support of the adoption of new technologies.
Theme 2 **Providing choice for wellbeing**	
Importance to New Zealand	In the developed world, overeating and consumption of unhealthy food have given rise to health issues including obesity and diabetes. Innovative chemical and process engineering can be deployed to design and deliver food products that are affordable and less harmful to health whilst maintaining consumer appeal through improved formulation and microstructure.
Research components	Food for health claims effect of food processing on food quality food safety and security
Theme 3 **Process efficiency**	
Importance to New Zealand	The entire food supply chain is energy and resource intensive. Chemical engineers can provide detailed life cycle analysis to assess energy consumption and material flow in every part of the chain. Process modelling, better process and product design and enhanced process management and control technology will improve the efficiency and sustainability of food production.
Research components	We need to move beyond the notion of 'waste' processing and focus instead on 'whole of resource' processing. Reduction; reuse and recycling options should take priority in any food processing strategy. However, energy recovery from food waste via incineration, anaerobic digestion, pyrolysis or gasification technology presents a range of valorisation opportunities. All four routes are well understood by chemical engineers, but the applicability of each technology is very dependent on the quality and consistency of the waste stream. Chemical engineers must

	engage with initiatives on food waste management and contribute to strategies that explore ways of optimizing the use and/or reuse of waste streams. Effective risk assessment is paramount, as is the need for early public engagement and chemical engineers must mount persuasive arguments in support of the adoption of new technologies.
Theme 4 **Demands on agricultural production**	
Importance to New Zealand	In the developing world approximately 13% of the population are malnourished. The growth in food demand is the result of the combined effects of world population growth to over 9 billion by 2050, rising incomes and dietary changes towards higher meat intake. Meat production is particularly demanding in terms of energy, cereal and water. Today, nearly half of the world's cereals are being used for animal feed. Expanding biofuels production brings new pressure. Chemical engineers can contribute to the development of new agriculture technologies and farming practices in order to meet this demand. A broader systems thinking approach is needed with a shift of emphasis from farm management to whole of catchment or even entire ecosystem management.
Research components	Whole of system management defining environmental and social limits mass and energy balancing with the system indicator variables and compliance monitoring
Research Gaps and Opportunities	Sustainability and the cold chain. The 'cold chain' is central to maintaining product quality and hygiene standards in the food industry. This activity is very energy intensive. Chemical engineers will deploy their fundamental knowledge of mass and heat transfer to develop new equipment and processes adapted to the different parts of the cold chain in order to enhance product life, improve food safety, whilst at the same time reducing energy costs and environmental impact. Carbon and water foot printing Food distribution is local and global; and simple or complex, depending upon the location and the lifestyle of the consumer. The 'food miles' debate highlights a clash between seemingly competing sustainable development agendas. From an environmental perspective, encouraging consumers to change their purchasing patterns by limiting transport emissions is seen by some commentators as a good thing. However, from an economic development perspective, the focus on 'food miles' may undermine essential industries in developing nations. Water is used for drinking, cooking and personal hygiene. Far greater quantities are used in food production. Water footprinting offers an indication of water utilization, taking into account direct and indirect water use. The water footprint of an individual food process activity is defined as the total volume of freshwater that is used to produce the finished food product. Chemical engineers can deploy robust lifecycle analysis to bring clarity to these debates.
Comments	see our policy paper http://www.icheme.org/media_centre/technical_strategy.aspx

Entry ID	421
Develop New Zealand's agribusiness sector towards smart* foods for wealth and health benefits	
Summary	The goal of this proposal is to increase the value of New Zealand's primary sector products via a research programme with the following themes: (a) increasing the export potential of the agri-food sector sustainably in climate change conditions by identifying ways to maximise nutritional/phytochemical content while minimising environmental impacts and growing inputs (b) satisfy increased demands from customers for safe, health-promoting foods; maintain the reputation of New Zealand food quality and develop a growing by enhancing food function (to offer additional benefits) and assuring trust in New Zealand-produced food (c) to enhance development and marketing of novel food products through improved understanding of customer drivers
Theme 1 **Increasing the export potential of the agri-food sector sustainably, in climate change conditions, is an obvious goal for New Zealand. Food exports earn over $20 billion per annum, representing about two-thirds of New Zealand's export income and 10 percent of total New Zealand employment**	
Importance to New Zealand	Since New Zealand's agricultural sector is unlikely to be able to compete globally on cost in the long term we must be able to offer unique, value-added products to maintain and grow sustainable market niches. The increasing personal wealth, particularly in Asian markets, and emerging knowledge of the role of food in health present an opportunity to develop SMART* foods through both smart agricultural practices and smart manufacturing. These foods will draw on the emerging knowledge of the relationship between genomics, health and food. Not only will there be an export benefit but improved domestic health, reducing health costs and improving productivity, using evidence-based dietary practices.
Research components	• Identifying ways to maximise nutritional/phytochemical content while minimising environmental impacts and growing inputs, including, for example, managing water resources and bio-fortification • Using biotechnology, including genomic selection, to develop cultivars with tailored composition • Finding the most cost effective sources of selected nutrients e.g. potatoes produce the greatest amount of protein per hectare, much more efficient than cows • Identifying the interaction between genotype and environment effects • Maintaining food safety to ensure new systems do not introduce new risks

Theme 2 To satisfy increased demands from customers for safe, health-promoting foods; maintain the reputation of New Zealand food quality and develop a growing market for new exportable technologies for food safety and quality assurance	
Importance to New Zealand	Customers expect their food to be safe, but there are continued and emerging threats to both public health and market access. There is growing interest in foods that promote and sustain well-being in a busy world. Food products with assured safety and healthy attributes have a future in current and emerging markets, given major international safety breaches and an increasingly demanding and busy middle class in, notably, Asian markets. The research in this theme would focus on two major streams: 1. Enhancing function: Functional foods offer additional benefits that may reduce the risk of disease or promote optimal health. They can encompass a broad range of products but generally incorporate a particular functional ingredient, eg. Sterol-enriched spreads. Fermented foods with live cultures are also examples of functional foods with probiotic benefits. This is a rapidly expanding area within the food industry due to their increased popularity with health-conscious consumers. There is a need to authenticate such claims. 2. Assuring trust: New Zealand-produced food is trusted internationally as being of high quality, authentic and safe. To maintain and enhance this trusted position, New Zealand must seek to be ahead of the game in food safety and to implement systems that verify the authenticity of our food products. There is already evidence of foods being fraudulently traded as New Zealand brands and the incidence of this may increase as New Zealand moves to trading in increasingly high-value food products. Systems can be exported to generate revenue too.
Research components	• Developing novel and natural biocontrol strategies with fewer chemicals and preservatives, to ensure safety, extend shelf life and maintained food quality • Assurance of health claims for functional foods • Foods with a particularly New Zealand identity or attribute • Unique combinations, fortifications, protein analogues (meat substitutes) • Development of novel enzymes to assist in health and production • Co-products, utilising waste • Processing technologies, e.g. high pressure processing, etc • Smart packaging and labelling - pathogen/spoilage control; nutritional sensors to identify when vitamin C levels drop in a product for example. • Smart food labels - ultimately linking to nutrigenomics data online, for example • Consumer convenience and sensory attributes: Intelligent surveillance, data collecting and modelling systems to understand and provide early warning of potential food safety issues. A key aspect of New Zealand's unique environment is the absence or limited exposure to a range of diseases (human, animal, plant), pests and contaminants that are widespread in other countries. Novel food safety issues are constantly arising. New Zealand needs to develop modelling and surveillance systems that highlight new issues at an early stage. • Rapid risk assessment and effective risk communication: Fingerprinting or

	tagging New Zealand foods to allow positive authentication. Methods may identify a unique compositional aspect of the food that relates it to a specific geographical location, e.g. isoscaping. Alternatively, biological, microchemical or nanoparticulate tags may be used to brand products. • Intelligent tracking/tracing systems to demonstrate food 'history': Integrated systems that trace the movement and treatment of foods in a cost-effective manner
Theme 3 **To enhance development and marketing of novel food products through improved understanding of customer drivers**	
Importance to New Zealand	Smart or novel foods are generally successful when they meet a perceived consumer need or wish. This requires an understanding of consumer needs and consumer concerns about the food supply. For health-promoting foods this requires a good understanding of the interaction between food components and individual's physiology.
Research components	• Understanding the aetiology of food and health throughout the lifespan • Food consumption practices and exposure assessment • Understanding the social science of food choices and behaviours. People know they should eat more healthily but usually don't – how can we turn an individual's understanding into positive behaviour - snacking on fruit and vegetables instead of potato chips for example. • Ways of assessing food acceptability and efficacy • Risk/benefit communication
Research Gaps and Opportunities	Research is needed on the most appropriate beneficial factors to target, from both growing and health perspectives, in a New Zealand context i.e. what grows/will grow in New Zealand. This theme needs information from theme 3 (food and health) both domestically and from international markets. Because the science community in New Zealand is small, there is good opportunity for collaboration between willing scientists at Plant and Food, AgResearch, the Riddet Institute, ESR, Auckland University (Nutrigenomics) and the University of Otago health researchers. Exciting work is happening in phage bio-control of food spoilage organisms and pathogens. The use of encapsulation technologies is increasingly being used in the food industry and can be used to protect substances such as nutrients and antimicrobials or beneficial organisms (eg. probiotics) from the inhibitory conditions within a process or food. It is important to note that the market for new and effective methods for microbial decontamination is buoyant and that such products are themselves exportable. A recent report from PWC identified China, for example, as a major market. Smart packaging might incorporate sensors for nutritional quality, e.g. to know when vitamin C levels dropping in a product or something hits an optimal level, etc). Smart labelling might link to nutrigenomics data. Biofortification offers new and natural means of enhancing food nutritional attributes. It is essential that the evidence for a food's safety or functionality is substantiated as part of the New

	Zealand brand protection and promotion. Advances in genomics have opened possibilities in rapid and cost-effective profiling of both product and contaminants, making rapid real-time response to authenticity or safety issues a reality. This creates the need for databases to enable the appropriate response, such as assurance for market access, response to food safety issue. It is important to continue to research the relationship between food and health in our society and identify opportunities for change that will improve the wellbeing of the population in the future. This will necessarily require study of epigenetics and nutrigenomics to characterise benefits and risks for different groups of people. The scope is large and it will be important to identify which health outcomes are best for New Zealand and/or overseas markets to support selling functional foods. The challenge will require information on what might be acceptable/appropriate food preferences for target consumers (i.e. strong market influence). Smart foods will require evidence that the substance is safe, absorbed or reaches the site of action and that consumption of the food has a beneficial influence on the physiological function and effect on health. There is potential in this area too for smart technologies, for example wrist watch sensors to detect circulating levels of a substance to guide people on when and what they should be being eating.

Entry ID	**427**
FUTURE FOODS - New Zealand contributes only a small percentage of global food production. Rather than competing solely in undifferentiated commodity markets, New Zealand needs to sell high value foods	
Summary	The goal of this proposal is to increase the value of New Zealand's primary sector products via a research programme with the following themes: (a) gauging consumer requirements and translating these into new product development goals and parameters (b) generating high value foods -on farm (c) generating high value foods-off farm (d) delivering evidence based functionality and bio-efficacy (e) delivering value chain integrity through authenticity and safety
Theme 1 **Understanding And Translating Market Signals**	
Importance to New Zealand	Gauging consumer requirements and translating these into new product development goals and parameters. This requires intimate connection between industry and the research community to both understand the trajectories of demand, and to ensure any product or cultivar development coincides with these

	trajectories.
Theme 2 **Generating High Value Future Foods — On-Farm**	
Importance to New Zealand	New Zealand has a reputation for high quality natural produce and environmental sustainability. Primary production accounts for the vast majority of New Zealand's food sector, with agri-food exports predicted to treble by 2025, to around $58 billion. Innovative approaches that develop and utilise the knowledge of the biochemistry, metabolites and genetics of key New Zealand crops, pastures and animals is needed to underpin the development of new cultivars and high value products.
Theme 3 **Generating High Value Future Foods — Off-Farm**	
Importance to New Zealand	Complementing Theme 2 is the need to developed processes to rapidly produce/formulate new products that meet consumers' functionality, sensory and price point demands using existing produce/raw materials. Note: This will require pulling together multi-disciplinary teams covering raw material production, through to processing and its impact on taste or other sensory attributes. This strategy of considering the food and its development in the broader sense (without focusing unduly on a single attribute such as healthiness, sustainability or functionality) is fundamental to achieving a final product that finds acceptance by the consumers in the target market(s) - e.g., improved healthiness but that also delivers acceptable/desirable sensory experience and shelf life duration. In addition to final food products, this theme also includes the development of bioactive or functional ingredients (e.g., that may be used in or fortify other food manufacturers' products) using expertise and technology derived from human health and medical research and applying it into the food space.
Theme 4 **Delivering evidence based functionality and bio-efficacy** **Theme 5** **Delivering value chain integrity through authenticity and safety**	
Importance to New Zealand	Theme 4: Providing scientifically robust evidence to support any human health or other functionality claims (e.g., through in-vitro and in-vivo efficacy testing and intervention trials) is increasingly critical in a global market with harmonised food & therapeutic regulatory regimes. New Zealand has extensive human health capability that has been relatively unlinked from application to food production and development. This Theme would enable New Zealand to harness and apply this capability to develop added-value foods that meet market regulatory hurdles (e.g., supported health / efficacy claims) and consumer demand. Theme 5: Developing systems that verify place of origin and/or processing or treatment regimes and provides added assurance of product safety (e.g., microbiological safety; adulteration free) will increasingly become 'licence to

	operate' requirements in sophisticated (premium earning) global markets. New Zealand's relatively small size and scale of operations, coupled with its sophisticated scientific capabilities (including some world leading proof of origin analytical capabilities) could turn this requirement into a competitive advantage in these markets.
Research Gaps and Opportunities	Research Opportunities Food research expertise spans across many organisations, and this Challenge is likely to draw broadly from across a number of CRIs and universities. The University of Otago sees itself as playing a key supporting or co-leadership role in several of the themes noted above. In particular, its leading health sciences expertise (including nutrition, physiology, biochemistry, microbiology and medicine) lends itself to delivering world class human efficacy and intervention research. This in turn is coupled with leading genomic and bioinformatics capability (including that available through Otago hosting New Zealand Genomics Ltd) that open the door to the determination of biomarkers that might link food / nutritional products to specific disease or health outcomes. This could be further extended to understanding and influencing the role of food in optimising human physical and cognitive abilities by drawing on leading physical education and psychology expertise. The University of Otago is also uniquely placed to extend expertise in public health and the medical sciences, to add value and insight into future foods-for-health research. Otago can draw from long-run baseline data established through its Dunedin and Christchurch-based longitudinal studies, and its strong public health research (Wellington School Medicine). It can also bring to bear specific expertise and assays associated with human health such as: • Understanding the mechanisms of disease & disease prevention (free radicals and antioxidants); • Strong clinical research (e.g., Christchurch School of Medicine and Heart the Research Institute); • Whole body nutritional & immunological expertise, including probiotics (Dunedin & Wellington) • Organ-specific expertise (e.g., gut health and the gut microbiome). The University of Otago also hosts some of New Zealand's leading chemical, biochemical and molecular/genetic analysis capability, which provides an underpinning science platform for evidencing the safety, integrity and provenance of New Zealand produced food (i.e., the tools and capability to provide science-based evidence to substantiate, or disprove, marketing or regulatory claims). Its geochemical isotopic analysis expertise for examples underpins the commercial services of companies such as Oritain. The University of Otago's Food Science Department also offers post-harvest processing and product development expertise, and has a sophisticated sensory analysis capability (including both a sensory analysis suite and trained sensory panels). The ability of the Food Science Department to offer these services, as well as work in with the wider skills outlined above, makes it an ideal industry-facing conduit.

Comments	New Zealand contributes only a small percentage of global food production. Rather than competing solely in undifferentiated commodity markets, New Zealand needs to: 1. Future-proof and demonstrably differentiate its commodity products in a globalised marketplace. This will involve developing world class systems to: o Diversify its produce and food products offerings to meet emerging market trends; Ensure produce/product safety; and Provide assurance of authenticity. Note: Over-and-above these product focused traits it is critical that New Zealand's food production systems are also future-proofed, through world-class biosecurity and bioprotecton (refer Challenge 8), as well as ensuring on-going supply of fundamental services such as provision of pollination capacity. 2. Target high-end consumer segments — i.e., produce products specifically designed to meet the requirements of consumers who will pay the most for them. One high-end market segment of particular relevance for New Zealand is functional foods (foods that offer benefits beyond basic nutrition. Functional foods are one of the fastest growing segments of the global food industry. Foods and beverages that offer validated health claims account for around US$25 billion of global sales, mainly in the key markets of Japan, the USA and Europe. Emerging economies, particularly in Asia, are also beginning to demand more of these products. This demand for added functionality will come hand-in-glove with co-demands for world class systems for ensuring and proving safety and value chain integrity. Significant opportunities for New Zealand exist in: Developing or providing added value (not just added cost) products. This dimension includes: § Developing new cultivars/species; § Added value processing — e.g., processing milk powder (@ $41/kg protein) into lactoferrin (@ $2,330/kg protein). § Developing systems that enable optimum timeliness of supply (e.g., live lobster or fresh cherry exports to Asia). Demonstrating health-related efficacy, or related functionality, of New Zealand produce and products relative to competing product types from overseas or artificial supplements. This needs to go beyond extrapolating the presence of a compound(s) within a food that is a proxy for a health benefit, to evidencing the ability of the food to demonstrably deliver the benefit. 3. Capture the maximum value from global value chains — through understanding consumers' needs (e.g., health-related requirements; functionality; lifestyle/convenience; ethical considerations) and producing safe, cost effective products to meet those needs, and, in doing so, ensuring New Zealand industry is capturing significant market premiums on route. The above requires an integration of New Zealand's expertise from on-farm/ orchard, through the processors, product developers, food & sensory scientists,

	microbiologists, to the marketers and finally to the consumer. It requires an intimate understanding of the consumer's likes and dislikes so that all aspects (from production history, through to functionality, sensory attributes and final price) meet or exceed the consumer's expectations. It also requires development teams to be flexible, coming together (& disbanding) to bring the requisite skills to deliver on the identified market opportunities. And the seamless flow of researchers/product developers between academia and industry. "We are what we eat" is a fundamental truth. However, there continues to be a lack of accessible and scientifically validated knowledge as to the specific benefits that certain foods can provide. Some foods may protect against the development of disease and thus significantly reduce healthcare costs. Progressing this Challenge provides the opportunity to fill these knowledge gaps. In doing so, it will not only create premiums &/or increased market share for the foods involved, but also generate significant spill-over benefits in terms of improved health status for New Zealand consumers and the consequential health care system savings.

Entry ID	**479**
Food Prosperity **Wealth from Healthy, Safe and Sustainable Foods**	
Summary	The goal of this proposal is to increase the value of New Zealand's land and marine based food products. Research programme with the following themes: (1) Managing environmental impact; developing regional food and beverage characteristics and projecting future intensification needs, defining options for decreasing environmental impact; etc. (2) High Value Foods– enhancing medicinal and health impact from growing, processing and validating high value foods (3) Future foods – driving innovation in high value food development to meet future consumer needs (establishing a new food product development capability to pilot new food productions systems, species, post-harvest processing, evaluating sensory, flavour and ingredient combinations, long range economic and market research capability etc. (4) Models of Ownership/Property Structures to develop an eco-economy (evaluating economic models that investigate the implications of the Government ceding control of assets for New Zealand's environment etc.)
Theme 1 **Managing environmental impact; developing regional food and beverage characteristics and projecting future intensification needs**	
Importance to New Zealand	Indices of environmental degradation of productive and surrounding ecosystems are stabilised at current 2012 levels with improvements in soil loss and fertility measures as food production intensity increases Stocks of economically important

	marine species are maintained or improved on 2012 levels
Research components	7.1.1 Developing a Geofood Tool to identify the best locations to grow different foods, in order to maximise food productivity and quality 7.1.2 Blue Fields: Increasing New Zealand's aquaculture sustainably. Eg How can aquaculture learn from agriculture's issues/developing efficient and equitable water use and allocation mechanisms. 7.1.3 Agriculture: Defining options for decreasing environmental impact; trial interventions and develop best practice farming systems both for current production and future intensification needs 7.1.4 Linking ecological processes to sustainable production activities including in fishing, aquaculture, pastoral farming, agriculture and horticulture 7.1.5 Using the Hauraki Gulf, New Zealand's only marine park, as a natural laboratory for the development of science-based optimization of a marine socio/ecological/economic complex 7.1.6 Investigating options for creating and incorporating different values into the food products and processes derived from New Zealand's natural resources
Theme 2 **High Value Foods– enhancing medicinal and health impact from growing, processing and validating high value foods**	
Importance to New Zealand	Increase in proportion of export food products sold with scientifically validated health claims at a price premium over the equivalent standard product (by X% by 2025) Increased output (returns) to input cost ratios in primary food production, development and marketing (over 2012 levels)
Research components	7.2.1 Developing nationally coordinated capacities to quantitatively measure quality, safety, sensory and nutritive value, and substantiate health benefits of foods 7.2.2 Developing new technologies to make foods safer, increase shelf life, and preserve sensory, nutritive and health promoting characteristics. 7.2.3 Establishing state-of-the-art pre-clinical and clinical validation capability for food health claims including biomarker development and validation for health and disease targets 7.2.4 Establishing a national Foods for Health Institute to substantiate the impact of high value foods on health to gain legislative and/or regulatory approval in domestic and export markets.
Theme 3 **Future foods – driving innovation in high value food development to meet future consumer needs**	
Importance to New Zealand	Increase the proportion of branded food exports that attract a high premium from embedded knowledge of safety, health and other consumer benefits including claims to regulatory standards and the value consumers place on their origins. Increase the proportion of food exports from products launched into global markets within the last 5 years
Research	7.3.1 Establishing a new food product development capability to pilot new food

components	productions systems, species, post-harvest processing, manufacturing and packaging to accelerate new food product launches onto global markets 7.3.2 Undertaking research evaluating sensory, flavour and ingredient combinations with specific appeal to specific export markets 7.3.3 Establishing long range economic and market research capability to develop deep insight into food consumers and markets to guide long term research and development programmes
Theme 4 **Models of Ownership/Property Structures to develop an eco-economy**	
Importance to New Zealand	Definition of the relationship of time horizons, social responsibility and accountability dimensions on ecosystem wellbeing and distributional mechanisms from which measures that balance ownership and ecological viability can be established
Research components	7.4.1 Developing and evaluating economic models that investigate the implications of the Government ceding control of assets for New Zealand's environment and the prosperity of its people. The spectrum of the models should encompass Treaty of Waitangi/Iwi; Innovative approaches; Free Trade Agreements.
Research Gaps and Opportunities	Producing and exporting food costs a lot due to New Zealand's geographical isolation and the environmental impacts of intensive farming systems. Producing commodity foods which compete on global markets on price will not support the economic, environmental and social expectations of New Zealand in the long term. The natural resources and comparative advantages we have (isolation, rainfall etc) suggest a biological economy can remain a significant contributor to national wellbeing if we can address the issues of sustainable production and market value. There are three main ways of increasing the value of food exports – increasing volume, increasing the degree of processing in New Zealand and creating higher premium products, By researching, developing and exploiting IP in the area of sustainable food production, processing, preservation, nutrition and health, New Zealand will turn its strength in food production into a knowledge rich export industry. This will both leverage and contribute to the nation's green and healthy image, and will increase the sustainability and productivity of our land and water based food industries.

Entry ID	484
Food For Health Evaluation Centre - Development of foods for health is a rapidly growing industry reliant upon marketing and not science. An opportunity exists in New Zealand to create the first international "one stop shop" food for health evaluation centre to assess the health benefits and uniqueness of New Zealand foods, food products and nutraceuticals.	
Summary	The goal of this proposal is to increase the value of New Zealand's primary sector products via a national Food Health Evaluation Centre. The proposed research programme with to develop higher value health-related food. The proposed research programme has the following themes: (a) Harnessing Health – substantiation of food value added and novel health claims [from understanding disease-food interactions through to legislative enforcement and international validation] (b) New Zealand100% Pure Foods – research to trace the origins, unique attributes of and integrity from paddock to plate is required to enhance the New Zealand-brand.
Theme 1 **Harnessing Health – Foods targeting health provide opportunity for value-add. Health claim substantiation requires research that transitions from understanding disease-food interactions through to legislative enforcement and international validation.** **Identify novel health benefits that will enhance the premium value of New Zealand health foods and nutraceuticals to grow exports of premium New Zealand health foods. Attract international food companies to invest in New Zealand scientific assessment of foods for health, through a readily accessible "one stop" centre**	
Importance to New Zealand	Processed and packaged foods is in excess of a US $2trillion global market, with annual growth exceeding 7%. The New Zealand agricultural sector has strong export growth, but limited geography and remoteness of growing Asian markets limits long-term competitiveness as a commodity supplier. Targeted generation of branded products that; have a uniqueness derived from core ingredients, are value-added through smart manufacturing and packaging, but target the most profound of human drives – the optimisation of health.
Research components	Harnessing Health - Building value through rigorous scientific assessment to establish rigorous health claims. Component 1: Generating international recognized medical science in the substantiation of the relationships between food and health. Through a single virtual centre health evaluation of foods, food products and nutraceuticals can be made from lab bench (biomarkers of health) through to sophisticated clinical trials. No other such centre exists in South East Asia, thus this centre could become a regional monopoly provider for comprehensive assessment of food for health. Component 2: Leading the coordinated approach to health claim regulatory frameworks throughout Asia and Europe. Coordination is required between

	international regulatory processes for the registration of food health claims and design and methods of scientific assessment of foods for health to ensure science meets regulatory requirement. Accurate and informative health benefits of foods will greatly assist consumers in selecting reliably presented foods for health.
Theme 2 **New Zealand100% Pure Foods – Research to trace the origins, unique attributes of and integrity from paddock to plate is required to enhance the New Zealand-brand. New Zealand requires global recognition for production of safe, sustainable and innovative food products**	
Importance to New Zealand	New Zealand100% Pure Foods – Understanding and protecting the unique opportunities and attributes of New Zealand agriculture. Research Component 1: Substantiation of unique compositional characteristics of New Zealandfoods. Traceability of these characteristics through the food supply into manufactured foods to retention of ‘uniqueness’. Research Component 2: Contaminant detection, including dilution/substitution, environmental, microbiological and chemical in New Zealandfood ingredients and products.
Research Gaps and Opportunities	Despite the importance of food for health, few national strategies exist to build export-value from the paddock to the plate. Several European and Asian economies (most notably Switzerland and Singapore) with limited agricultural capacity have generated the best performing food-export branded food business, based on unique characteristics (ie. Swiss chocolate; regional hub/ automation/skilled worker base). Yet New Zealand, despite having far greater natural resources, with many examples of unique/pure food ingredients and a recognized international reputation in food exports, is yet to fulfil the promise of generating high-value branded products that ‘drive’ consumer demand. A national research strategy from the uniqueness of the New Zealandingredient through to the high value health claim that substantiates the generation a health claim’ are major research gaps requiring leadership and investment.

7 Market Access

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 5: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
31	Long term assurance of overseas markets for milk and meat. Achieve this through three major themes, (i) food safety, (ii) animal welfare, and (iii) human and animal health	1. Assuring food quality and safety of meat and milk 2. Improvement and assurance of animal welfare in New Zealandlivestock populations providing meat and milk for export 3. Improving human and animal health by reducing infectious diseases transmissible from animals to humans, so called zoonoses
443	Supplying premium agricultural products and technology to the world	

Entry ID	**31**
Long term assurance of overseas markets for milk and meat. Achieve this through three major themes, (i) food safety, (ii) animal welfare, and (iii) human and animal health	
Summary	Proposes assuring external markets for New Zealandmilk and meat products through a research programme to (a) reduce health risks associated with milk/meat products (pathogens, antibiotic residues/resistance etc.) (b) identify markets needs for animal welfare and design suitable responses and (c) improve the testing and monitoring of infectious diseases transmissible from animal to human
Theme 1 **Assuring food quality and safety of meat and milk**	
Importance to New Zealand	Food quality and safety hazards are recognised risks for New Zealand's export market that make up 30% of total exports from New Zealand. Milk powder exported from New Zealandcontributes 30% to milk crossing borders worldwide. Prime hazards for consumer health arising from New Zealand meats and milk include bacteria (*Mycobacterium avium* subspecies *paratuberculosis*, *Mycobacterium bovis, Campylobacter (C.) jejunum and C. intestinalis, E.coli O157*) and bacteria toxins (VTEC). Prime food quality hazards include

	antimicrobial residues.
Research components	(I.a) Risk analysis through source attribution studies of human pathogenic molecular pathogen strains in live animals (sheep, deer, beef and dairy cattle), and processed meat and milk; (I.b) Antibiotic residues in bulk tank milk and processed meat through population representative sampling; (I.c) prevalence studies of antimicrobial resistance using indicator microbes from the intestinal flora of live and slaughter stock of the aforementioned livestock species.
Theme 2 **Improvement and assurance of animal welfare in New Zealandlivestock populations providing meat and milk for export**	
Importance to New Zealand	The European Union has decided to reduce agriculture subsidies within five years starting 2014. It is forecasted that this will increase imports from food exporting countries such as New Zealand. Europe is one of the main clients for New Zealand food exports. Consumers in Europe are sensitive to the welfare of animals from which food is generated. This was evidenced by a parliamentary delegation from Germany visiting New Zealand in October 2008.
Research components	(II.a) Monitoring cohorts of livestock (sheep, deer, beef and dairy cattle) from birth to market for indicators of animal welfare including diseases associated with pain such as lameness and mastitis. (II.b) Development of a welfare code applicable to livestock and farming systems in New Zealand.
Theme 3 **Improving human and animal health by reducing infectious diseases transmissible from animals to humans, so called zoonoses**	
Importance to New Zealand	New Zealand is not free from specific notifiable diseases in humans that arise from exposure to animals. These include l*eptospirosis, campylobacteriosis,* bovine tuberculosis, and possibly *paratuberculosis*/Crohn's disease. The leptospirosis burden is as high as over 50% of all breeding sheep, beef cattle and deer in New Zealand with almost 100% farms having evidence of exposure to at least one of two Leptospira subtypes ('serovars'). Human intestinal diseases have been associated with pathogen strains of *Campylobacter jejuni* and *E.coli O157* in live animals and food products from ruminant livestock.
Research components	(III.a) Recent Massey trials demonstrated lower carcass weights at slaughter and poorer reproduction rates in infected farmed deer herds. A much underdiagnosed disease both in humans and animals, another area of research encompasses evaluating the value of a variety of diagnostic tests at differing stages of the disease in both humans and animals. Funding is now required to sustain this work and begin to develop an ecological understanding of the various infection sources (including rodents, wildlife) for humans in different occupations, i.e. farmers, veterinarians, stock workers (shearers, AITs) in comparison to findings in abattoir workers; (III.b) Development of mathematical models about leptospirosis to integrate infection sources in animals and rates of exposure, infection and clinical disease in humans that are based on survey and laboratory data. Such models are useful for developing solutions, such as rodent control or vaccination of

	livestock;(III.c) Source attribution studies quantifying the impact of various animal and environmental sources to infection of humans with *Campylobacter jejuni* and *E.coli O157*. Such research involves strategic sampling from a range of sources and comparison of molecular pathogen strains with strains from hospitalised human patients.
Research Gaps and Opportunities	The proposed set of research projects is likely to pre-empt constraints for accessing overseas markets that are likely to arise in the near future (5-10 years). Already occurring global market changes in demand for food types, food quality and safety set the scale for an imminent increase in quality standards. This relates to biological hazards in foods as much as to the conditions of primary production at farm level, such as animal welfare and environmental impacts of livestock farming. New Zealand needs to be prepared when such improved and, from an exporter perspective, more rigorous standards become a reality.
Comments	The 3-campus Massey research group through the newly formed Infectious Disease Research Centre (IDReC) and the Institute for Veterinary, Animal and Biomedical Sciences (IVABS) at Palmerston North is particularly experienced, suited and able to provide new knowledge and develop solutions for these challenges.

Entry ID	**443**
Supplying premium agricultural products and technology to the world	
Summary	The goal is that New Zealanders understand and are proud of the contribution of agriculture to our sustainable brand. Suggested research components are understanding pressures and opportunities affecting New Zealand from market, demographic and policy trends in other countries; reconciling increased value per hectare from the land and sustained ecosystem services; reconciling competing demands for land use – the agriculture/biodiversity/urban conflict; resolving animal welfare issues; resolving the sector's demographic challenges; resolving the sector's land capital and debt challenges.