ESR
Science for Communities

ESR's response to *Te Ara Paerangi Future Pathways Green Paper on Research, Science, and Innovation*

Contents

Executive summary

ESR welcomes the review of the science system. It is our hope that the *Te Ara Paerangi* process can work to advance the science system's contribution to the health and wellbeing of people and communities in New Zealand.

The principle that lies behind funding of science and technological research is **benefit to New Zealand**. For the last 30 years, the science system has aimed to improve the sustainable wealth and wellbeing of New Zealand across five domains: economic, environmental, social, health, and knowledge. But well-intended changes to the system have blurred our focus on **impact** – creating measurable changes in the wellbeing of our people and our land, Aotearoa New Zealand.

For ESR, the health, environmental, and forensic services we deliver are supported by research. It was **research-led science delivery** that provided new tools (whole genome sequencing, wastewater testing) to help our frontline health service manage the pandemic and protect our people. Our scientists are focused on impact. Their commitment drove our innovations – and saved lives.

A whole-government approach is needed for strategic science planning to ensure the government can deliver on the aspirations of the Living Standards Framework – 'sustainable wealth and wellbeing' by another name. It is timely to re-consider the premises on which New Zealand's science and technology research is based. The purpose of public good research must continue to be **benefit to New Zealand**.

There is considerable potential for improvement and rationalisation to achieve it, and many opportunities to do more with less. In the drive toward developing a system that will benefit New Zealand, we are pleased to present thoughts and ideas that ESR believes will support informed decision making. ESR case studies are utilised to contextualise the ideas presented and emphasise 'real-life' scenarios within the system. Some of these ideas do come from a unique ESR experience but many themes are commonly shared across the science system.

PART 1:

ESR and its operational context

New Zealanders depend on the science undertaken by ESR for their health and wellbeing. As the COVID-19 pandemic has revealed, ESR's research-led science delivery of infectious disease surveillance has contributed disproportionately to the government's ability to protect its citizens, from whole genome sequencing to wastewater testing for the virus. Yet there is a gap in funding for the research that underpins ESR's science delivery.

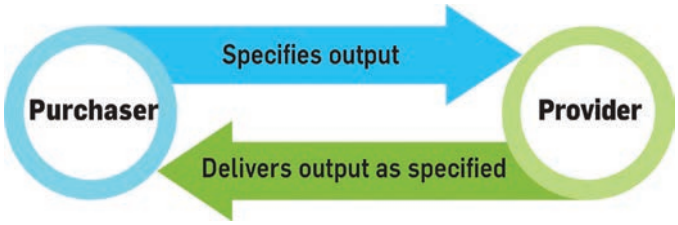
ESR's central focus is 'protecting and improving the health and wellbeing of communities'.[1] Its purpose is to 'deliver enhanced scientific research services to the public health, food safety, security, and justice systems'.[2] ESR therefore takes a broad system approach and acts to benefit New Zealand. It offers research-led science delivery, rather than merely delivering the services or outputs specified in a contract.

Impact for Māori is critical to protecting and improving the health and wellbeing of communities. ***He Pūtaiao, He Tāngata*** is ESR's strategy and action plan for impact for Māori. Our approach recognises the need for focus in multiple areas - Māori leadership, Māori-led research, recognition of the value of mātauranga, and cultural capability building. We recognise that innovative and uniquely Aotearoa New Zealand mātauranga, science and research solutions are enabled by valuing both Māori and contemporary knowledge to increase the wellbeing of communities and the environment.

Like other CRIs, ESR is required to respond to the Minister's annual letter of expectations for the year ahead. Its national role requires it to maintain specialist expertise, e.g. with respect to emerging national and international threats, to demonstrate science leadership, and to share its scientific expertise with key partners and government agencies. ESR plays a critical national role in **public health, forensics**, and **biosecurity**, and leads international representation in specialised networks. It is accountable for providing a robust health surveillance system for New Zealand. Its role as a national reference laboratory demands time-critical responses. Its public health mandate has become more prominent over the past two years because of the lead it has taken in the national pandemic response.

What is research-led science delivery?

The concept that underpinned the science reforms of 30 years ago was agency theory. It proposed a clear split between the three key functions of policy advice, purchase of outputs, and provision of outputs. This was because the **principal-agent problem** held that, when information is asymmetric, an individual agent (such as a research provider) is motivated to act in its own best interests, rather than that of the principal (the purchaser). The influence of agency theory has ebbed from its high-water mark in the late 1980s, but lingers.



The Living Standards Framework provides a different paradigm. It sets out Four Capitals for future wellbeing (natural, social, human, and financial/physical). MBIE's **results-chain framework**, with its focus on the economic, environmental, and social impact of research, belongs within the wellbeing paradigm of the Living Standards Framework. If the purchaser requires the delivery of outputs that will likely generate certain outcomes, and contribute to future economic, environmental, and social wellbeing, the outputs cannot be precisely specified. A focus on impact requires intelligent purchasing. Desired outcomes are described in broad strokes, not precisely specified. The research provider has considerable freedom to determine how to undertake the research. It is expected to apply its expertise, use foresight, and respond to changing conditions as necessary. This is **research-led science delivery**.

[1] ESR, *Statement of Corporate Intent 2021-26*, p. ii.
[2] ESR, ibid., p. 5.

PART 2:

ESR's response to the questions in *Te Ara Paerangi*

CHAPTER 1: **RESEARCH PRIORITIES**

Prioritise with Te Tiriti embedded at the delivering core, to the benefit of New Zealand.

ESR endorses a Tiriti–led priority setting approach, as described in *Te Pūtahitanga*[3], that would strategically invest in research, science, and innovation for equitable health and wellbeing outcomes, while addressing the ongoing harms caused by colonialism and racism. New Zealand must therefore support (and provide resources for) autonomous Māori science advice and decision-making alongside iwi-Crown partnership approaches.

What principles could be used to determine the scope and focus of national research priorities?

Before New Zealand can set research priorities, we need strategic clarity about what we want to achieve. The principle that lies behind our funding of science and technological research is benefit to New Zealand. It was the first principle defined in the Crown Research Institutes Act 1992. The science system had four goals directed to improving the sustainable wealth and wellbeing of New Zealand: economic, environmental, social, and knowledge. This is also the intent behind the Living Standards Framework. Implicit in the Living Standards Framework is equity and equitable design must underpin all future prioritisation frameworks. In the short-term, research that addresses current inequities is a priority.

A whole systems approach based on the Living Standards Framework requires a whole-government approach to prioritisation, in partnership with Māori, industry and communities. The approach to priority-setting must move beyond the classical philosophy of environmental health as a linear process encompassing cause, exposure, and effect to identify remedies that lessen adverse health effects. It must also understand the knowledge gaps with respect to national security, which have no commercial or academic application.

ESR's experience

ESR works across government to deliver science with the necessary data to make the best decisions possible. But a coordinated system would support better outcomes. ESR supports evidence-based policy that recognises the complex non-linear process with feedbacks between health, environmental, social, economic, and technological (HESET) domains of society. The recent report from the Prime Minister's Chief Science Advisor[4] rightly points out that tackling complex issues such as infectious disease and Antimicrobial Resistance requires unity, across human, animal, plant, and environmental health bringing everyone along on the journey. Research-led science delivery gives a system scope to apply its expertise, use foresight, and respond to changing conditions as necessary.

Priority-setting must recognise the value of recombinant, cross-sectoral, and trans-disciplinary skills, and their importance in the development of comprehensive solutions. Prioritisation of singular science approaches without understanding the connections limits the development of comprehensive solutions. Examples at ESR demonstrate the value of recombinant science:

[3] http://www.maramatanga.co.nz/publication/te-p-tahitanga-tiriti-led-science-policy-approach-aotearoa-new-zealand

[4] https://cpb-ap-se2.wpmucdn.com/blogs.auckland.ac.nz/dist/f/688/files/2020/01/Full-report-FINAL-15122021-V2-PDF-160222.pdf

- **Wastewater epidemiology:** Thanks to connectivity of sciences, delivering national benefit in one area such as Public Health is not always linear. Take ESR's wastewater surveillance tool. It had its origins in environmental health, was initially utilised for drug detection, and came to the fore in the COVID-19 response. Our trans-disciplinary, solutions-focused approach makes it easy for us to adopt and adapt different sciences for national benefit.
- **Computational and social sciences:** Any prioritisation of the sciences must consider the computational sciences that support delivery including genomics and bioinformatics, data science and other emerging leading-edge sciences. The development of science-based solutions to support public health or justice outcomes will have limited impact without better integration of social systems thinking into delivery. Prioritisation requires broad-based thinking.

View to the future

To embed te ao Māori at the core of national priority setting requires a fundamental change in approach. We advocate dedicated resourcing and funding be committed to support this change.

Delivery of public good science requires accountability at multiple levels – auditing and evaluation of what is delivered and its impact. National Priority Setting can provide transparency and coordination. It also requires integrity, assuring independence of our science, and developing trusted relationships so that there is confidence across the system. Metrics as measures of success must be appropriate to the work and its objective in delivering national benefit.

Inter-generational strategic planning is a necessary tool for understanding and responding to challenges such as climate change; and partnership in research (that provides impact) with our neighbours through the Pacific Nations can support this and use it to direct efforts such as adaptation and mitigation actions.

ESR's recommendations for chapter 1

- Priority setting must embed Te Tiriti and a te ao Māori approach, embracing the voices of the people and their communities to encompass public good research. This can be enabled by funding for Maori to participate in decision making at the front of the process, articulating needs, developing relationships where knowledge can be shared and creating research programmes unhampered by the limitations of the current funding round process.
- A whole systems approach for science prioritisation can be developed through a wellbeing lens and investing in partnership with community to ensure a comprehensive assessment of research priorities. Equitable by design must underpin all future prioritisation frameworks.
- Any prioritisation must be cognisant of the value of research-led science delivery, assigning clarity in mission and accountability. Failure to do so will be detrimental to national security systems, national progress and adaptability and the ability to respond to national emergencies.

Achieve genuine partnership

What are your thoughts on how to enable and protect mātauranga Māori in the research system?

Any future system must aim beyond engagement to achieve genuine partnership with Māori this is key to enabling and protecting mātauranga Māori in the research system.

ESR's experience

Commitment to Māori as an equal partner in science and research programmes demands proper resourcing and clear focus.

Any future system must aim beyond engagement to achieve genuine partnership with Māori, this is key to enabling and protecting mātauranga Māori in the research system. For mātauranga Māori to thrive and realise its potential in the Aotearoa New Zealand research system there must be a respect coupled with effort made to learn and understand, and through this understanding the benefits of a research system based on two knowledge systems can be advanced.

Our focus has been on both growing our workforce of Māori scientists and growing our cultural capability across the organisation so that we are able to build enduring relationships with Māori, and can deliver increasing value and impact for Māori.

CASE STUDY: **HE WAI MĀPUNA**

Our multi-year flagship programme, ***He Wai Māpuna,*** brings together mātauranga Māori and modern science in Māori-led research opportunities relating to wai (water). ESR supports iwi partners to achieve their aspirations for wai through community-based and led research projects.

Impact for the local Māori community is the focus and strong, enduring relationships are central to our programme. A multi-year programme allows us to focus on the relationship, supports all parties to develop their capability, and provides the space to understand the value and contribution of mātauranga through seeing it in action. Taking the time to develop a mutual understanding of what is important to each individual iwi whānau – and what ESR's researchers and scientists can offer – we believe will help us deliver together research and services that will make a difference.

Now with a deeper mutual understanding of aspirations and capabilities, we are beginning to design a pipeline of projects. We believe that continued and respectful engagement will foster an environment of shared knowledge and innovative outcomes. Dedicated funding will continue to be essential to the journey.

View to the future

The future funding model must recognise the importance of relationship building and provide resources for the engagement that will foster respect and understanding for the place of mātauranga Māori in the Aotearoa New Zealand research system.

Dedicated resourcing is critical to achieving the fundamental shift in thinking and approach to embed te ao Māori as a core part of any future system's philosophy of delivery.

Although the He Wai Māpuna programme is only beginning, we can see benefits of creating a focus on Impact and relationships rather than funding.

ESR's recommendations for question 2

- We must resource, enable, and protect mātauranga Māori in the future research system at all stages. We must be prepared to change the way we run the system in terms of time horizons and acknowledge building relationships towards partnership is a key investment.

CHAPTER 3: **FUNDING**

Fund for public good

Most of the world's knowledge is created by the rest of the world. It is useful to us, and we import it in the form of finished technologies (cars, mobile phones, solar panels, software, machinery). New Zealand collaborates internationally to create world-class, science-based solutions.

But there is some research that benefits New Zealand that only New Zealanders can and will do. Only we will undertake the research we need to protect our environment, our communities, and our health, or that will support our firms and develop our economy. **Benefit to New Zealand** is therefore a valid and robust rationale for spending tax-payers' money on research.

Further, New Zealand recognises the Treaty of Waitangi as the basis of its nationhood. That brings with it the understanding that benefit must be shared in partnership, and funding models must be reflective of this partnership (see our response to Question 2).

Mission-led research

Mission-led research is essential for New Zealand to reach its potential. By mission-led, we mean outcome-focused science and its application to solve real-world problems. A funding system that rewards the novel over the essential and considers excellence before impact will not protect our environment or the wellbeing of our people. We have already seen its effects.

Do you think a base grant funding model will improve stability and resilience for research organisations, and how should we go about designing and implementing such a funding model?

Some degree of contestability can refresh our research with new ideas and new approaches, but not at the expense of delivering the mission-led research we are mandated to do. ESR is not afraid of changes in the structuring of science funding if national priorities are adequately supported. Our science is agile, and it is reasonable to expect that agility is also needed in the structures that underpin science delivery.

If we have learned anything from the COVID-19 pandemic it is that, in responding to national priorities, we need to have flexibility to respond when things change.

Understanding knowledge gaps for national security: Prioritisation requires an understanding of the knowledge gaps with respect to national security, which have no commercial or academic application. For example, ESR forensics maintains both dedicated skill and instrument capability to support the regional

CWALN (Chemical Warfare Agent Laboratory Network). The Network brings together forensic experts in chemical agent analysis with the aim of capability building, information sharing, education and training and quality assurance. The Defence Scientific and Technical Group (DSTG) provides training, collaborative trials, and reference standards for the Network. This security readiness capability has no direct funding.

ESR's experience

ESR Forensic Services have been widely accepted as a core function that is required to ensure that New Zealanders and our communities are kept safe through the resolution of crime and to support the wider criminal and social justice systems. The challenges in protecting the NZ public are however not static and constant innovation is required to ensure that Forensic Services is able to address the ever more complex criminal and justice challenges that are often not confined within individual ministerial boundaries.

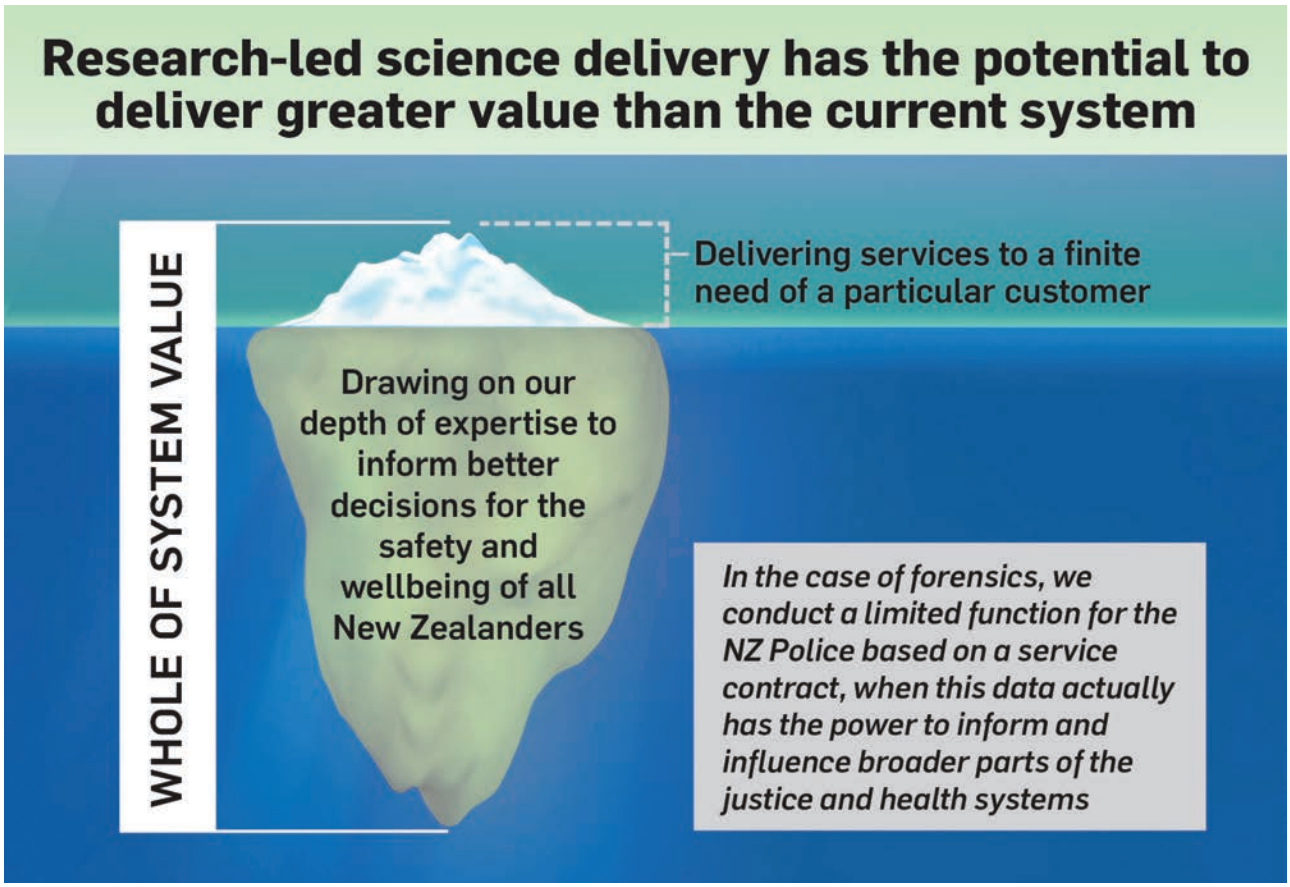
This type of research-led science delivers much more value to New Zealand than the narrow specification of science services delivered via ESR's contracts with the Ministry of Health, the NZ Police, and the Ministry for Primary Industries.

Take drug testing, for instance. A tiny percentage of cases go to trial. But if the results from a single test could be shared beyond NZ Police (the client), the data could be used to help an individual access health advice, inform the provision of health and social services in the community, and be used to reduce the harm to society from illegal drug use.

Our communities would be healthier and safer.

Why is this not currently possible? Because individual government contracts fund only the service to be delivered, rather than the societal impact and national benefit generated. We need better co-ordination of research and service delivery – this is especially true if increased investment is being considered as part of any reform.

Research-led science delivery is often not profitable for the organisation, but it delivers huge Impact – see case study on next page. There is now a systemic bias against research-led science delivery, and little understanding of its value.



CASE STUDY: **WASTEWATER TESTING**

Mission-led science can be both strategic and nimble. Wastewater testing provides an instructive example. From mid-2020, ESR's scientists developed and applied a new test to identify SARS-CoV-2 in sewage. This became an important part of COVID-19 surveillance from mid-2020.

But it didn't arise *de novo*. The test had its origins in a test that ESR's environmental scientists originally developed for environmental monitoring. In 2014, it was applied to drinking water to address a public health issue, the outbreak of campylobacteriosis in Havelock North.

Next, following the successful use overseas of wastewater testing to spot the presence of illegal drugs in sewage, ESR modified the test for New Zealand use, to assist Justice and Police.

Finally, in mid-2020, New Zealand needed another surveillance tool for SARS-CoV-2. PCR testing and whole genome sequencing of nasopharyngeal swab tests taken from a person with symptoms are lag indicators for a disease outbreak. But ESR's scientists reasoned that detecting and amplifying tiny traces of COVID-19 RNA in a sample of sewage could be a ***lead*** indicator. They modified the test, conferred with international colleagues, developed new laboratory and sampling techniques, and gave public health officials another tool to detect and stamp out outbreaks.

This was critical to New Zealand's effective management of COVID-19 in 2020 and 2021 and contributed to our success in managing the Delta outbreak.

View to the future

Benefit to New Zealand, improving the sustainable wealth and wellbeing of New Zealand and its people, is the over-arching goal. This implies that we need to measure the impact of our research in terms of its contribution to specific dimensions of national benefit. The funding structure should support research, science, and innovation (RSI) to achieve equitable health and wellbeing outcomes, whilst addressing the ongoing harms caused by colonialism and racism.

Funding needs to be removed from political cycles as the returns to investment in research are typically long-term. Funding needs to be allocated within the broad goals of economic, environmental, social, health, and knowledge research by domains, with five-year and ten-year priorities established by domain reviews. Enabling research-led science delivery to create whole system impact.

A funding system that rewards the novel over the essential and considers excellence before impact will not protect our environment or the wellbeing of our people. Mission-led research must also be responsive to emerging threats. A step towards achieving this would be establishing a system capability response fund for response to rapidly emerging high-impact threats of national significance.

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Reporting of SARS-CoV-2 in wastewater samples

Communities and industry must be able to make their own decisions about their priorities and working with researchers to achieve community and productive value outcomes. Future pathways and funding in science should include ways for communities and industry to apply for funding to work with the science system. Better engagement by communities will result in a greater value being placed on science and thus provide a mandate for future investment.

Future funding for core functions should consider options where the capabilities for specialised services have stability that is not set at static levels. This requires governance and oversight to direct sustainability of services and build in research to develop capability for the future needs of entire sectors (e.g., supporting New Zealand's criminal and justice systems).

ESR's recommendation for chapter 3

- Funding for research to benefit New Zealand should be allocated within the broad goals of economic, environmental, social, health, and knowledge research by domains, with five-year and ten-year priorities established by domain reviews. But there must also be room for communities and industry to set their own priorities, and work with researchers to achieve them. Understanding research led science delivery and its place within the funding system is key for national wellbeing.

CHAPTER 4: **INSTITUTIONAL DESIGN**

Assemble autonomy of science for integrity in innovation

How do we design collaborative, adaptive and agile research institutions that will serve current and future needs?

Research organisations require autonomy to innovate and respond to critical threats and needs. Proximity with the frontline also allows for quick recognition and effective understanding of challenges faced by end users. The innovation culture developed within science entities constantly engaged at the front engenders desirable values of connection and collective benefit to New Zealand.

ESR's experience

Systems benefit from scientists that can identify potential solutions before their stakeholders can, detecting the weak signals from the leading edge of change. Professional foresight helps scientists identify where next we must pay attention.

The Productivity Commission in quoting the Doblin framework Keeley *et al.* (2013) suggest that product innovation on its own provides the lowest return on investment and the least competitive advantage. Sometimes competitive advantages involve incremental technological innovation, combined with innovations in business processes and models, and in marketing [5]. STRmix™ is a great example, it is a world-leading expert forensic software designed by researchers at ESR and Forensic Science South Australia. Before STRmix™ scientists were not able to draw conclusions from complex mixed DNA samples, rendering much evidence inadmissible. Experience at the frontline drove the breakthrough to produce this technology in helping authorities solve criminal cases.

A unique and highly regarded forensic service model that sits separate to the justice system continues to ensure independence yet accessibility to all. While the focus for forensic services has been primarily enforcement and justice, there have been notable overlaps with other sectors, particularly, and increasingly, with health. An example of this has been the change in focus of our drug testing services away from identification of illicit drugs for prosecution to a more harm reduction focus – with drugs increasingly seen as a public health issue not a justice issue.

ESR's unified organisational structure together with health and environmental science supports these overlaps and drives synergistic innovation. See also chapter 3 case study: wastewater testing.

[5] https://www.productivity.govt.nz/assets/Documents/Final-report-Frontier-firms.pdf

CASE STUDY: **BIOSECURITY**

ESR was able to draw together a multidisciplinary team quickly and effectively in response to the largest recorded campylobacteriosis outbreak in the world. In 2016, heavy rain caused faecal matter to enter Havelock North's untreated water supply, causing an outbreak of campylobacteriosis in the town. The outbreak infected 40% of the town's residents and contributed to a death.

ESR mobilised a range of expertise (epidemiologists, clinicians, molecular biologists, microbiologists, environmental and groundwater scientists, and public health experts) in a multi-agency response. Working with the public health sector to deliver, faster than traditional surveillance methods permit. Adapting innovations (such as whole genome sequencing and new surveillance techniques) that can now be used in reducing the impact of future public health emergencies. Sourcing the various science response services individually from a range of different agencies would have caused delays and resulted in more severe health and economic impacts.

The challenge with co-location

Co-location of research institutions is a factor in collaboration and access to shared infrastructure, but it is not essential to either. Co-location is most valuable if it is supported by a shared strategic purpose and a long-term commitment to the arrangement. Co-location is not appropriate for facilities requiring very high physical security (such as PC3 labs), data security or where chain of custody applies to the science being conducted.

National safety and security challenge at ESR

ESR's activities include transport, receipt, storage and analysis of illicit drugs, firearms, ammunition, radioactive material and samples of highly infectious diseases. Because of the nature of these services, much must be conducted outside of a lab environment and involves interaction with the NZ Police, dangerous goods freight handlers, and couriers. Our science services carry with them requirements for infrastructure, access, and customer service components that are incompatible with an academic environment.

For example, while there are some elements of our analytical capability that can be found in other institutions and research organisations, they would be difficult to divert to a forensic use, with the necessary stringency to be utilised for court purposes. In part, our specialist accreditation, both of our staff and our infrastructure, requires segmentation of expertise and instrumentation and also the highly trained interpretation of data and evidence. Many of our functions also operate under strict legislative requirements – such as the reporting requirements for controlled drugs or roading accidents. Security measures are also strictly defined.

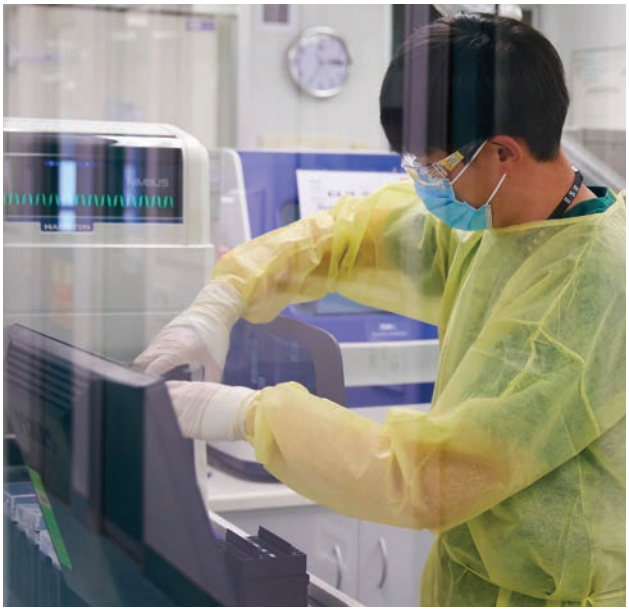
View to the future

What we have learned from our response to the COVID-19 pandemic informs our view of the future:

- Working to a common goal (protecting New Zealanders from the virus) developed national cohesion. Cohesion can also be attained through clear national priorities that make space for Public Good research. This builds a system-wide culture of common good and common goals.
- We learned the importance of having interoperability of data. Here, the pandemic revealed gaps. NZ needs to ensure the infrastructure is maintained to ensure we can stand up a response to the next biosecurity challenge.
- Research organisations must have sufficient autonomy to innovate and respond. A central government agency could never have had the foresight to invest in the technology nor the agility to pivot the skillsets to meet the need.
- Interconnectedness of system science that is purpose-driven. Co-location doesn't automatically confer benefits; it should be done only if it makes sense in terms of delivery against core purpose and technical requirements.
- Building in surge capacity and resilience when the demand is extended beyond a period of weeks to months and years.

ESR's recommendation for chapter 4

- Physical co-location can but does not automatically deliver benefits; this requires clarity of purpose and mission. Understanding when the synergies are greater than the transaction costs and weighing the value of specialised innovation against collaborative value will help determine when co-location can work. Additionally, vital, time-critical national science services have specialised requirements for infrastructure, access, and customer-service components that are largely incompatible with academic environments. Critical national services have stringent requirements for physical and data security.



DNA laboratory, Mount Albert Science Centre, Auckland

CHAPTER 5: **RESEARCH WORKFORCE**

Allocate accountability for housing capability needed for response to scientific challenges – the standing army

To deliver national benefit, research organisations need to have more accountability for growing and maintaining their capability to respond to challenges. In areas of critical need, where our role is to protect our people and environment, we must maintain a 'standing army' of expertise.

Furthermore, our commitment to embedding te ao Māori in what we do requires that the communities we are working with can participate in research design.

ESR's experience

The pandemic – and the case study examples above – have demonstrated that NZ must fund, retain, and empower critical science capability and capacity.

Multidisciplinary expertise is key to understanding what's happening on the frontline. We have an opportunity to embrace multidisciplinary expertise for the application of a dual knowledge systems approach using mātauranga Māori and modern science, making our science more accessible through partnership.

There must be a deeply collaborative mindset that spans the whole system. The intense competition for contestable funding, and the competition for students, is not conducive to delivering national benefit. ESR supports reforms where collaboration in the national interest is placed at the heart of the system. Systems that enable our scientists to freely collaborate across disciplines should be explored.

How should we include workforce considerations in the design of national research priorities?

Critical capability

Future systems must maintain nationally-critical science capabilities that adapt and respond to incidents and are used when responding to matters of national significance such as major disease outbreaks. At ESR our science capabilities include health science, genomics, forensic science, food, water and radiation science, social systems, and data science. The temporary loss of critical capability constitutes a risk that must be reported to the Shareholding Ministers. Any review of the requirements for a national Forensic Service for example needs to understand the specialist and organisational elements that need

to be in place to ensure the appropriate level of independence and to maintain trust and expertise.

ESR, like other CRIs, is a Crown entity company. As a company, it can direct its staff to undertake certain tasks and not to undertake other tasks. This is critical to public good, especially when delivering a time-sensitive response to public health or biosecurity issues where human health and lives are at risk.

CASE STUDY: ***SALMONELLA*** **ENTERITIDIS OUTBREAK OF 2021**

The combination of sequencing, epidemiological, bacterial typing, and food safety skills, as well as the close interaction of staff within ESR greatly aided the control of the *Salmonella* Enteritidis (SE) outbreak of 2021.

On behalf of the Ministry of Health, ESR has been the long-term custodian of national human case epidemiological data for infectious diseases: providing collation and specialist analysis and advice; as well as routinely performing whole genome sequence derived cluster analysis on isolates from all cases of SE since 2019.

The SE outbreak of 2021 was linked with poultry as a potential source when ESR compared whole genome sequencing data from bacteria obtained from clinical cases of illness with a bacterium obtained from a poultry source. The identification of a possible transovarian strain presented a high risk to consumers, as well as potentially being a barrier to exports.

ESR was able to provide public health advice to Ministries and co-ordinate the national epidemiological and laboratory investigations. The combination of ESR's intelligence reporting, including data collected by local Public Health Units and our food safety expertise assisted key Ministries with instituting risk management monitoring and controls.

Computational capability

For ESR, Computational science includes genomics and bioinformatics, data science, and other emerging leading-edge sciences. These sciences demand highly specialised skillsets that are rare in NZ (transcending the research sector into the corporate setting). Yet ESR and other CRIs depend heavily on them for research, experimentation, and service delivery. The current workforce is under pressure, as key people retire, and others move within the very small NZ community of experts or are recruited overseas. We need to focus on retention of key staff within the system and to start training graduates for the long-haul (an expected 5+ year development cycle) – but to do this ESR requires additional funding. While movements within the research system (researchers moving between different types of organisations e.g., shorter term secondments, joint appointments, or changing roles) can be beneficial to career and capability development, due to the rarity of Computational science skills sets, staff movement can be very disruptive to the delivery of essential services and may be detrimental to an organisation.

View to the Future

The science system needs to be reoriented around public good, delivering benefit to New Zealand across health, environment, social, economic, and knowledge. Critical national capability must be preserved.

Better understanding of the role of specialist scientific expertise within core functions such as forensic science is required, together with the appreciation that this expertise must be maintained at an appropriate level alongside professional and accreditation standards.

To achieve this, the best approach for science organisations is:

- Collaboration between organisations
- Sharing knowledge and staff where possible
- Ensuring that staff are given development opportunities and are properly compensated for their skills and delivery
- Taking a long-term view of training and developing new and emerging talent, and retaining them in the face of competition from overseas

- Encouraging staff development in expert areas by supporting PhDs, innovation, and publications
- Positioning to attract scientists to the NZ science community, avoiding as much as possible losing scarce staff overseas
- Recognise and support iwi, hapū, and diverse Māori communities as knowledge holders, policymakers, and critical enablers of individual, collective (including whānau) and environmental wellbeing.
- Invest in Māori-trained researchers who work in the RSI sector and beyond – for example, in Iwi Research Centres – as decision-makers exerting their rangatiratanga.

ESR's recommendation for question 5

- Long-term and stable science funding builds confidence. Greater confidence in the importance of science and research to New Zealand's future will ensure that scientists stay within the sector and encourage students to pursue science subjects. Universities must collaborate with Mission-led research organisations to build appropriate skills within the workforce better suited to the demands of a dynamic economy and to support innovation.

CHAPTER 6: **INFRASTRUCTURE**

Data is critical so is e-infrastructure

Investment in efficient secure data infrastructure that safeguards capabilities while also ensuring interoperability between datasets will contribute to the flow of data to provide new opportunities for innovative research and community impact.

This architecture will only succeed when coupled with good governance frameworks that are Māori led and can lead to thoughtfully constructed management systems for the future.

ESR's experience

Computational Biological Sciences are a key component to the delivery of impact through genomics, this requires continued investment in both wet-lab as well as data science domains which are critical national capabilities. ESR has made major strategic investments in computational science disciplines to deliver outcomes for New Zealand of national significance.

Physical and data security requirements

To undertake its critical national roles, any future system must maintain the highest standards of physical and cyber security.

Public Health and Forensics responsibilities require that ESR's facilities and the infrastructure equipment that supports its service delivery must be rigorously maintained. In particular, the core elements that distinguish forensic services and ensure their independence are the physical and data security requirements that need to be in place, and that are re-enforced by appropriate quality systems and accreditation standards.

Physical facilities must be secured, and both physical and digital access needs to be appropriately controlled. There are further restrictions to maintain the integrity of all items, such as the samples submitted for analysis along with the standards or reference samples that they are compared with and analysed against. Only approved personnel may access and handle this material. All transport and usage information is meticulously recorded.

Equipment must be operated within defined parameters, in keeping with several ISO standards, and calibrated on a regular basis. Calibration and servicing are completed only by those authorised to complete these processes under the standards and all records are maintained for auditing. Changing equipment or the parameters of an instrument will require a revalidation of protocols required for service delivery which would significantly compromise delivery times and confidence (perceived or real) by the customer.

There are limitations on what can be centralised and shared when working under accreditations. The integrity and confidence in the outputs, data, and reports generated from forensic investigations and analyses for example, must be above reproach. Stakeholders must be assured that operational practice aligns with the requirements of the standards and accreditations to perform these services to the highest level, to be confident that the reports and data they receive meets their needs and can stand up in court.

Forensic work starts with crime-scene investigation to support front-line policing. A future system must ensure the integrity of the chain of evidence presented in court. Enabling research-led service delivery ensures the system benefits from much more than a service under contract. Scientific experts are responsive and flexible to anticipate future needs and respond fast to emerging threats, as the next case study shows.

CASE STUDY: **FORESIGHT AND FORENSICS**

ESR's work gave consumers of NZ milk products at home and abroad the assurance that products were safe, protecting many millions of dollars of export revenue.

In 2014, Fonterra and Federated Farmers received anonymous letters threatening to contaminate New Zealand's milk powder and infant milk formula exports to China with 1080 poison. Fortunately, several years earlier, ESR had the foresight to develop a specific test for 1080 poison as part of its role in Chemical, Biological, Radiological, and Explosive incident preparedness, and had maintained it against future need. The test was crucial to establishing the threat, examine store products and test formulas used in homes. It should be noted that no other country in the world had developed such a test (the way 1080 was used in NZ was unique) as there was no commercial or academic value.

ESR joined forces with Landcare Research and University of Otago to narrow the pool of suspects using Forensic Isotope Ratio Mass Spectrometry (FIRMS) testing. It was then ESR's testing of DNA samples obtained by NZ Police that provided crucial evidence which led to a successful prosecution.

In delivering patient-oriented disease services, forensic services to matters of law, and Māori data, ESR has specific data security requirements that apply to the complete process: from sampling to laboratory processes to data science and genomic HPC and storage.

- Data must be highly secure and controlled.
- Considerations such as whether data can be stored on backup tape become crucial.
- Protecting Māori sovereignty of data is crucial.
- With the explosion of novel uses of DNA, such as forensic identification for Police, personalised medicine, disease prediction and genealogy (exploitation), controlling access to parts of an individual's DNA, rather than the entire sequence, is likely to become an important requirement. This will require storage complexity not yet encountered in NZ systems to date but for which international bodies have generated appropriate standards like The Global Alliance for Genomics and Health (GA4GH). Services like NeSI are by design more fluid and open frameworks to allow collaboration and innovation, but this architecture and the potential threat to patient health information protection and other ethical and regulatory compliances means that hosting genomics data here is not appropriate nor sustainable.

How do we support sustainable, efficient and enabling investment in research infrastructure?

View to the future

- A future in which our research organisations share common domain expertise in Computational Science, including specialties in genomics and data science could provide economies of scale, foster the development of new scientists, and strengthen those already practising. For instance, ESR, Plant &

Food Research, SCION, AgResearch, and Manaaki Whenua all deliver genomics and complementary skill sets (albeit with domain differences and at different scales). ESR shares people and experience with other CRIs as the need arises, but with sustained funding this could and should be increased.

- CRIs and universities could take a coordinated approach to fostering portability of computing environments, including operating systems, tools, approaches, and design. This would include recognising and contributing to the worldwide open-source community that underpins Computational Biological Sciences.
- Data sovereignty, including Māori data, must recognised, and properly protected, stored, and processed. This includes properly securing selected parts of human DNA, which is emerging as an important demand.
- Sharing procurement processes can reduce costs and obtain better commercial rates on HPC and storage services and hardware. ESR already does this where possible, but other CRIs are often at different stages in their procurement cycles.
- Support Māori-controlled data infrastructure to meet best practice in Māori data sovereignty and support wise decision-making.

ESR's recommendations for question 6

- Collaboration where the whole is greater than the sum of the parts and the system must retain the flexibility needed to adapt to a non-linear future.
- Centres of excellence based on a federated model and focused on domains of science created where knowledge, expertise and compute capacity can be shared, to foster innovation and ensure everyone has access to the best enablers to support their research.
- Science delivery and research requirements are tightly coupled and occur on the same infrastructure platform.
- Legislation, national security needs, Māori data sovereignty and the responsibility to govern sensitive data including human genome data, considered above the advantages of sharing infrastructure.
- A coordinated research system approach to fostering compatibility and portability of computing environments.
- Continuation of the REANNZ service is essential to success.

APPENDIX:

Summary of ESR recommendations

THEME	ESR RECOMMENDATIONS
Research priorities *(refer chapter 1, pages 3–4)*	Priority setting must embed Te Tiriti and a te ao Māori approach, embracing the voices of the people and their communities to encompass public good research. This can be enabled by funding for Maori to participate in decision making at the front of the process, articulating needs, developing relationships where knowledge can be shared and creating research programmes unhampered by the limitations of the current funding round process.
	A whole systems approach for science prioritisation can be developed through a wellbeing lens and investing in partnership with community to ensure a comprehensive assessment of research priorities. Equitable by design must underpin all future prioritisation frameworks.
	Any prioritisation must be cognisant of the value of research-led science delivery, assigning clarity in mission and accountability. Failure to do so will be detrimental to national security systems, national progress and adaptability and the ability to respond to national emergencies.
Te Tiriti, mātauranga Māori, and Māori aspirations *(refer chapter 2, pages 5–6)*	We must resource, enable, and protect mātauranga Māori in the future research system at all stages. We must be prepared to change the way we run the system in terms of time horizons and acknowledge building relationships towards partnership is a key investment.
Funding *(refer chapter 3, pages 6–9)*	Funding for research to benefit New Zealand should be allocated within the broad goals of economic, environmental, social, health, and knowledge research by domains, with five-year and ten-year priorities established by domain reviews. But there must also be room for communities and industry to set their own priorities, and work with researchers to achieve them. Understanding research led science delivery and its place within the funding system is key for national wellbeing.
Institutional design *(refer chapter 4, pages 9–11)*	Physical co-location can but does not automatically deliver benefits; this requires clarity of purpose and mission. Understanding when the synergies are greater than the transaction costs and weighing the value of specialised innovation against collaborative value will help determine when co-location can work. Additionally, vital, time-critical national science services have specialised requirements for infrastructure, access, and customer-service components that are largely incompatible with academic environments. Critical national services have stringent requirements for physical and data security.
Research workforce *(refer chapter 5, pages 11–13)*	Long-term and stable science funding builds confidence. Greater confidence in the importance of science and research to New Zealand's future will ensure that scientists stay within the sector and encourage students to pursue science subjects. Universities must collaborate with Mission-led research organisations to build appropriate skills within the workforce better suited to the demands of a dynamic economy and to support innovation.
Infrastructure *(refer chapter 6, pages 13–15)*	Collaboration where the whole is greater than the sum of the parts and the system must retain the flexibility needed to adapt to a non-linear future.
	Centres of excellence based on a federated model and focused on domains of science created where knowledge, expertise and compute capacity can be shared, to foster innovation and ensure everyone has access to the best enablers to support their research.
	Science delivery and research requirements are tightly coupled and occur on the same infrastructure platform.
	Legislation, national security needs, Māori data sovereignty and the responsibility to govern sensitive data including human genome data, considered above the advantages of sharing infrastructure.
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