Development of a Wellbeing Performance Framework for Asset Management Investment Analysis on Three Waters Infrastructure Networks

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Abstract

Water infrastructure world-wide is facing a number of pressures, including increasing demand due to population growth and urbanisation, increasing legislative requirements, climate change, and ageing infrastructure. Making decisions on infrastructure investments have become more complex and fraught with wider implications to society than just simple delivery outputs. The need for a three waters wellbeing performance monitoring framework for infrastructure investment analysis is needed now more than ever to help decision makers better understand the performance of their three waters infrastructure in relation to delivering on our community's wellbeing. Current performance and decision-making frameworks and assessment tools rely heavily on economic analysis and frameworks that utilise sustainable and wellbeing variables tend to be limited in scope and focus on macro, policy, and micro, infrastructure, level performance. The issues we are experiencing in water infrastructure investment originates from an asset (physical base), infrastructure decision making (holistic investment analysis), and the ability to comprehensively analyse and query information (data type and quantity). This thesis works to understand the problem created by a lack of a holistic investment decision-making model considering social, environmental, economic and infrastructure variables leading to investment decision that are unable to deliver sustainable intergenerational wellbeing in three waters infrastructure. Significant work has been undertaken by organisations to develop macro-level wellbeing frameworks that support policy setting at the national level. The development of a novel meso level wellbeing performance framework and a suite of indicators that will integrate with macro and micro levels will provide a valuable resource for decision-makers when considering performance and investments in the three waters infrastructure. The initial development of a three waters wellbeing performance framework and conceptual model has been completed with the identification of indicators and measures that cover the environmental, social / cultural, human, economic and infrastructure wellbeing capitals. This research and initial testing with Stats NZ and the Waikato Regional Council has identified the value of utilising a framework like the NZ LSF and how it could be integrated with the UN SDGs for use at a regional/local level to understand the most appropriate three waters infrastructure solution and the impact on intergenerational wellbeing. This initial work has successfully developed a wellbeing performance framework and conceptual model and identified the potential usefulness for three waters infrastructure asset managers and owners in assessing wellbeing performance and investment decisions but

requires further research to develop a supporting mathematical model and analysis of the data obtained from the two agencies to test and further develop the framework and conceptual model. This is only the first step in the development journey, with further work required to explore the concepts and better define the interactions, systems dynamics, modelling, and indicators that can be utilised to understand the current and future state of wellbeing.

Acknowledgements

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Chapter 1. Introduction

1.1. Background

Water infrastructure is under stress around the world. Potable drinking water, stormwater, and wastewater management are vital to ensuring our communities' health and well-being. However, these essential services are under increasing pressure from pollution, climate change, urbanisation, intensification of food production, and population growth (Litman & Burwell, 2006; Otto et al., 2016; Padilla-Rivera & Guereca, 2019; Padilla-Rivera et al., 2016). Infrastructure assets cover the physical specialised facilities, systems and networks that provide essential public services that are held for use in the production or supply of services (Lombardi et al., 2021) In a literature review covering 2000 to 2019, Gebre et al. (2021) identified that the topmost ranked water problems were water shortages, water use management, and water quality. The pressure that the society faces with three-waters requires solutions focused on intergenerational well-being; but are currently challenged by traditional investment decision-making. Decision-makers have traditionally relied on conventional evaluation techniques to make investment prioritisation decisions that primarily consider engineering assessments and cost benefit assessments with a focus on economic outcomes (Balkema et al., 2002; Zietsman et al., 2006). These assessments tend to utilise technical, financial, and environmental indicators that are easy to measure and have easily accessible data sources, ignoring variables that are hard to show their impact, such as social and cultural outcomes (Balkema et al., 2002; Litman & Burwell, 2006; Padilla-Rivera & Guereca, 2019; Padilla-Rivera et al., 2016).

Having worked for many years with both private and public organisations that design, build, and maintain three waters infrastructure assets it has become increasingly apparent that understanding the performance of this infrastructure from perspective that includes the concept of ‘wellbeing’ is critical. The definition of wellbeing has matured from a focus on the ‘positive aspects of health that people could achieve, beyond simply avoiding sickness’ to one that considers ‘the ability to appropriately respond to expected and unexpected stresses in order to be healthy, happy and prosperous in work and in life’ (Scaria et al., 2020). The foundation of modern societies wellbeing is based on an extensive network of interconnected infrastructure assets, ranging from transport, water supply, waste, energy, telecommunications, and community facilities. These infrastructure assets support a nation's ability to provide a modern

lifestyle and increase wellbeing to the society (IPWEA, 2015). However, infrastructure services have historically been developed in isolation from other infrastructure services, creating inconsistencies in linking and interrelating to each other. This siloed approach has also lacked the ability for cross-service evaluation and understanding the impact on wellbeing. It has also led to investments in infrastructure assets that are overly influenced by political and economic drivers, wherein the decisions can significantly shift and change over time without understanding the consequences on society's current and future wellbeing (Otto et al., 2016). Infrastructure investment decision making in water, wastewater and stormwater require an integrated approach to ensure sustainable development as defined at the end of this paragraph; this approach needs to consider social, cultural, environmental, and economic variables (Balkema et al., 2002; Padilla-Rivera & Guereca, 2019). The trade-offs between the sustainable variables (as defined below) are hard to assess because it can be more of a political process rather than a scientific one (Balkema et al., 2002). The Netherlands Scientific Council for Government Policy stated, 'Estimating environmental risks objectively or uniformly is not scientifically possible. To translate the concept of sustainability into an operative policy concept, it is necessary to make explicit normative choices related to identified risks and uncertainties' (WRR, 1994). The challenge of understanding the positive and negative impacts on current and future well-being in three-waters infrastructure asset investments is growing. The public is showing a growing interest in more sustainable development, and consideration of sustainable factors such as social equity, safety, and social, cultural and environmental outcomes is increasing in importance (DPMC, 2003; Litman & Burwell, 2006).

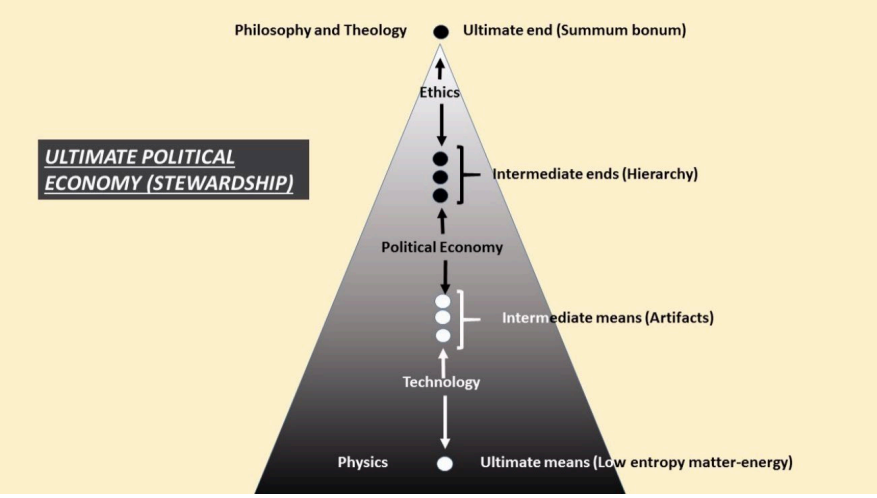
The concept of sustainability and sustainable development is not new; it has been discussed and debated internationally for decades. The United Nations World Commission on the Environment (The Brundtland Report) defining sustainability and sustainable development as, 'to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (W.E.C.D., 1987). This particular definition was captured and further used in New Zealand's sustainable development policy in 2003 (DPMC, 2003). The Brundtland Report (W.E.C.D., 1987) went on to indicate that there are limits to development, 'not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities…sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life'. Litman (2006) states in his work, "Sustainability emphasises the integrated nature of human activities and

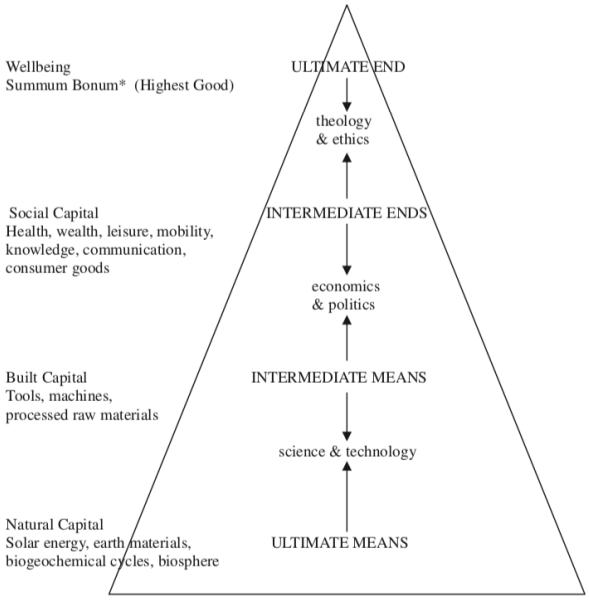
therefore the need to coordinate planning among different sectors, jurisdictions and groups. Sustainability planning is to 'development' what preventive medicine is to health: it anticipates and manages problems rather than waiting for crises to develop. Sustainable development strives for an optimal balance between economic, social and ecological objectives." Despite the growing interest in utilising sustainable variables (social, economic, and environmental) in decision making, few studies have provided a generic framework that can be used for wastewater, water or stormwater investment decision making (Padilla-Rivera & Guereca, 2019). Even fewer studies have tried to embed the use of cultural indicators. However, there is an increasing trend to engage with indigenous cultures to research and collaborate in resource management decisions and new frameworks that consider indigenous values and beliefs (Harmsworth et al., 2016).

Building on the growing public interest in sustainable development and increasing pressure on infrastructure, many public agencies are now recognising a responsibility to acknowledge and consider a wider range of impacts that affect both users and non-users when making investment decisions. There is an increasing trend to consider broader sustainability factors in prioritising decisions at a project and network level. The concern about sustainability is rooted in the growing awareness that human activities have significant impacts that can impose economic, social, and environmental costs. Sustainability emphasises how human activities are integrated and the need to ensure coordination with planning among different sectors, jurisdictions and groups (Litman & Burwell, 2006). Studies are also identifying the importance of integrated infrastructure planning and development, recognising the importance of infrastructure as the foundation for enabling economic activity and contributing to human wellbeing (Otto et al., 2016).

When developing a performance framework involving wellbeing aspects, one needs to consider sustainability from a broader perspective. The transference of capital (natural, human, built, or social capital) is limited by the finite resources of the world and society's desire to elevate toward our ultimate end. For example, Daly's Hierarchy of Means and Ends (Daly, 2014) (Figure 1 & Figure 2) helps us to understand how the transferability of capital moves from the natural base (ultimate means), to built capital (intermediate means), to social capital (intermediate ends), and to our highest good or wellbeing (ultimate end) (Costanza et al., 2016; Daly, 2014 ; T. Morgan et al., 2012). Daly (2014) postulates that the goal is to unite the material of this world with our best vision of the good and considers a world with finite resources. This

good needs to consider intergenerational equity, the welfare of humans and the environment no matter the time or place in the world (Litman & Burwell, 2006).





Ends-means pyramid showing the interaction of the wellbeing's, reproduced from (T. Morgan et al., 2012)

According to Daly, stewardship occurs through the best use of ultimate means to achieve the ultimate end goal, as shown in Figure 2. This vision of stewardship holds that technology, political economy, and ethics are not a given but needs to be considered in reaching the end goal. Our struggle to work our way through this pyramid provides us with some direction on how we gauge the goal (ultimate end) and help us validate and prioritise it (Daly, 2014).

Another critical aspect in decision making is understanding how our view of the world affects how we make decisions and how the cultures we live in have historically shaped this view. Our world views play a significant role in shaping how we think and make decisions and can support or undermine decision making frameworks considering current and future wellbeing and sustainable development. How we view the world is shaped by the cultures and societies we are born and live in. A worldview is an abstract concept of reality that becomes a reality and is accepted as truth. The leading world view in western society is founded on economic rationalism and challenges our perceptions of sustainability and sustainable development. Economic rationalism considers that matter-energy (ultimate means) exists to be used to gain wealth and growth. This concept helps to justify infinite resource exploitation to maximise the wealth to be passed onto future generations (T. Morgan et al., 2012). Daly (2014) states that the goal (ultimate end) cannot be assessed by Gross Domestic Product (GDP) and suggests a better place to start is with 'life' and 'maximising the cumulative number of lives ever to be lived over time at a level of per capita wealth sufficient for a good life.' Understanding what is meant by a 'good life' is an open question to explore. It has the potential to lead us to more sustainable outcomes than continually wanting 'ever more things for ever more people forever' (Daly, 2014). Costanza's (2016) work on using the UN Sustainable Development Goals (SDG) shows how the utilisation of Daly's Means and Ends hierarchy to show the relationship of the 'ultimate end of sustainable, equitable and prosperous wellbeing and the intermediate means of the economy and society, and the ultimate means of the environment' can be utilised.

1.2. Problem Statement

The use of analysis tools and incorporating wellbeing into a holistic performance framework creates challenges on many dimensions. Analysis tools, like cost benefit analysis or multi-criteria analysis need to consider a set of actions which must either choose a single action as the best output, select a subset of actions considered good, or order the actions from best to worst (Roy & Vincke, 1981). The analysis tool used can be simple (i.e. cost benefit analysis) and take a single point of view or use more complex approaches (i.e. multi criteria analysis) that consider several points of view (Roy & Vincke, 1981). The use of multi criteria analysis takes a more holistic approach, considering the complete system and not the simple analysis of parts of the system, but creates a level of complexity where contradictions between different points of view can develop (Roy & Vincke, 1981). The desire for simplicity can lead us to find it easier to think about economic outcomes, public service, cultural connections, and

environmental quality more simplistically from a single point of view and not understand the value of integrating the more complex concept of wellbeing and factors that consider multiple points of view (Favager, 2019). This leads analysis approaches to rely heavily on the use of economic analysis and consider only a few factors. This potentially results in poor investment decision making that could lead to adverse environmental, social, and cultural outcomes.

Also, internationally, best practice asset management tends to focus on net present value, benefit cost analysis, and risk as the primary means for decision making with a lessor focus on non-monetary variables (primarily environmental impact and quality of build), and uses multi-criteria analysis (MCA) to identify and compare policy options to assess risk and cost performance (IPWEA, 2015; Morgan, 2006). Gebre et al. (2021) identified that over the past two decades, the use of multi-criteria analysis has increased in the area of water allocation, particularly after 2014, showing a growing focus on trying to understand and develop mechanisms that support more holistic investment decision making and understanding performance. Decision making for water infrastructure is a complex problem requiring a combination of regulations, policies, and mechanisms to support water management (Gebre et al., 2021). A compounding challenge in assessment and performance approaches for wellbeing's and capitals is taking into account indigenous values and their ancestral water rights (T. Morgan et al., 2012).

The issues we are experiencing in water infrastructure investment originates from an asset (physical base), infrastructure decision making (holistic investment analysis), and the ability to comprehensively analyse and query information (data type and quantity), as shown in Figure 3.

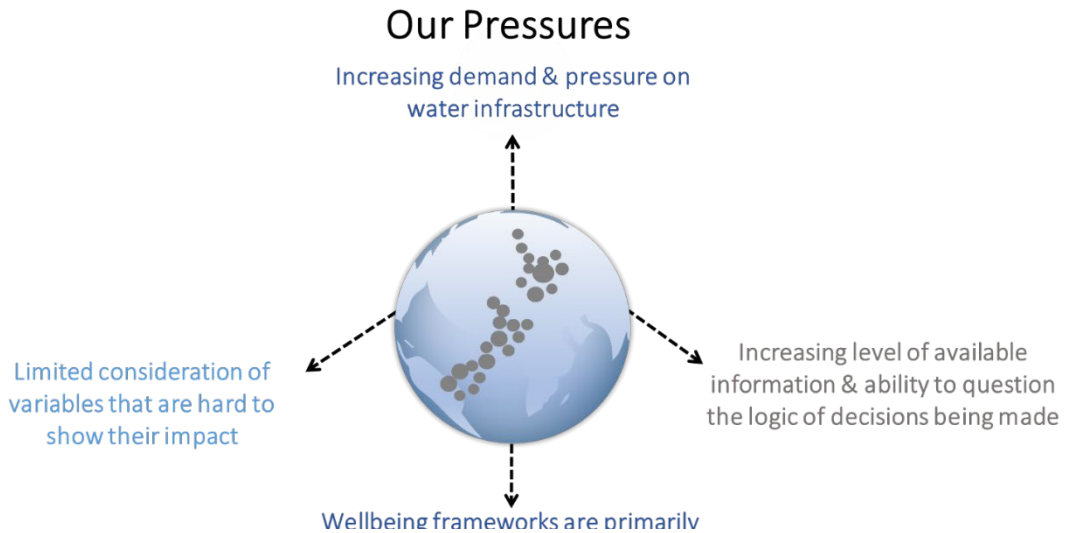


Figure 3. Pressures leading to our problem statement

Therefore, this research focuses on developing a performance framework model for three-waters infrastructure that considers social, cultural, environmental, economic, and infrastructure variables as well as intergenerational wellbeing and sustainability (See Figure 4).

Figure 4. Research problem statement

1.3. Objectives of the Research

This research presents a novel holistic performance monitoring framework and a conceptual model for three-waters infrastructure (drinking water, wastewater, & stormwater); giving due consideration to the New Zealand Treasury Living Standards Framework (NZ LSF) and the United Nations Sustainable Development Goals (UN SDG).

The NZ LSF and UN SDG guide policy and investment that focus on improving societal outcomes for the nation. The UN SDGs provide goals and targets, while the NZ LSF was developed to track changes to the wellbeing outcomes over time and improve public policymaking, lift living standards and improve intergenerational wellbeing. However, both NZ LSF and UN SDG work at a macro level, and their linkages to localized infrastructure development are weak.

The aim of this research is, therefore, to develop a holistic performance reporting framework that considers the four wellbeing's (social, cultural, environmental, and economic) and asset (infrastructure and/or technology) variables at a meso (local/regional) level. This research supports the development of the framework and tests the availability and fitness of data that would support the conceptual model utilising data from a national data source, Statistics New Zealand, and a regional data source (Waikato Regional Council).

The research will help decision-makers better understand the impact of their decisions on intergenerational wellbeing and help address the pressures that are leading to our identified problem statement. To achieve this, the objectives are:

- Integrate with the New Zealand Living Standards Framework and United Nations Sustainable Development Goals (macro-level);
- Demonstrate the development of a novel three-waters wellbeing performance framework and conceptual model that could be adopted at a regional, district, or city council level (Meso level);
- Identify initial potential indicators and measures that could be used to understand the performance of the wellbeing three-waters framework;
- Explore the availability of data and fitness of the data for the performance framework utilising a sample taken from Statistics New Zealand and the Waikato region; and
- Identify future development potential, which includes finding the impact of investment in three-waters on the community's wellbeing and conducting a performance analysis.

1.4. Scope

This research focuses on developing a three-waters framework, considering drinking water, wastewater (sewage), and stormwater infrastructure. The scope of this research is limited to exploring the New Zealand Living Standards Framework and United Nations Sustainable Development Goals as the critical macro policy models.

The development of well-being decision making performance framework for three-waters infrastructure considers the following six areas:

1. **Activity flows** through the wellbeing frontier, capitals, and infrastructure.

2. **Connectivity** to United Nations Sustainability Goals and New Zealand Living Standards Framework.

3. **Systems approach** considering wellbeing frontiers and infrastructure performance over a range of time and future conditions.

4. **Spatial scale interaction** across the macro, meso, and micro levels.

5. **Living standards** and how people want to live their lives.

6. **Indicator and measurement model.**

Though the problem statement identifies the broader issue surrounding decision making this research focuses on the development of a performance framework as an initial step. Decision making is explored in the context of understanding the underlying problem further and starts to help frame what making a good decision (a decision produced by a quality decision making process) or making a good decision outcome (the consequence of the decision from the viewpoint of the decision maker) would mean in the future development of a decision making framework (Seppälä et al., 2001). Decision making is explored through the literature review and following chapters linking to the development of a performance framework and model the helps us understand the performance of infrastructure assets considering the wellbeing's. The focus on performance in this research is a key foundation to building a future decision making model, as infrastructure asset performance is an integral part of ensuring the long term outcomes desired from any investment in infrastructure is viable and delivering on the desired outcomes (Parida, 2012).

While this research involves the initial development of a novel performance framework and testing available data for fitness, it, however, does not include the development of a decision making framework or the analytical model or analysis of the data to test the framework and conceptual model to understand the intergenerational impact of investment in three-waters on wellbeing.

The initial results clearly suggest that the wellbeing framework provides an excellent monitoring and governance performance framework for water infrastructure at a meso level. Further research and analysis of the data to test the framework will be required to confirm this novel research and development work.

Chapter 1 provided the background context of the thesis, my motivation for the research, the problem statement, objectives, and scope of the research. The chapter set the scene around the UN SDGs and NZ LSF macro level frameworks where the UN SDGs provide the goals and targets, while the NZ LSF was developed to track changes to the wellbeing outcomes over time and improve public policymaking, lift living standards and improve intergenerational wellbeing. Both NZ LSF and UN SDG work at a macro level, and their linkages to localized infrastructure development are weak. Therefore, the aim of the research was to develop a holistic performance framework that considered the four wellbeing's (social, cultural, environmental, and economic) and asset (infrastructure and/or technology) variables at a meso (local/regional) level. Chapter 2 will consider the problem and the elements that could contribute to addressing the problem through a literature review.

Chapter 2. Literature Review

2.1. Context to Investment Decision Making in Asset Management

Developing a novel wellbeing framework for three-waters investment decision making requires an understanding of the elements that contribute to the formation of the framework and the boundaries of the activities that fall within the field of research. At the core of this research are the foundational concepts of asset management and investment decision making, primarily in asset management. The International Infrastructure Management Manual (IIMM) (IPWEA, 2015) defines infrastructure assets as '…asset systems or networks that serve defined communities where the system as a whole is intended to be maintained to a specified level of service by the continuing maintenance and replacement of its components, for as long as the service is still required'. The International Organisation for Standardization indicates that 'asset management translates the organization's objectives into asset-related decisions, plans and activities, using a risk-based approach (ISO, 2014a). The benefits of asset management identified in ISO 5500:2014 include (IPWEA, 2015; ISO, 2014a):

- Improved financial performance
- Informed asset investment decisions
- Managed risk
- Improved services and outputs
- Demonstrated social responsibility
- Demonstrated compliance
- Enhanced reputation
- Improved organisational sustainability
- Improved efficiency and effectiveness

The traditional approach to investment decision making in asset management consists of stepping through a decision flow processes from defining the problem or goal to evaluating the outcome of the decision (see Figure 5).

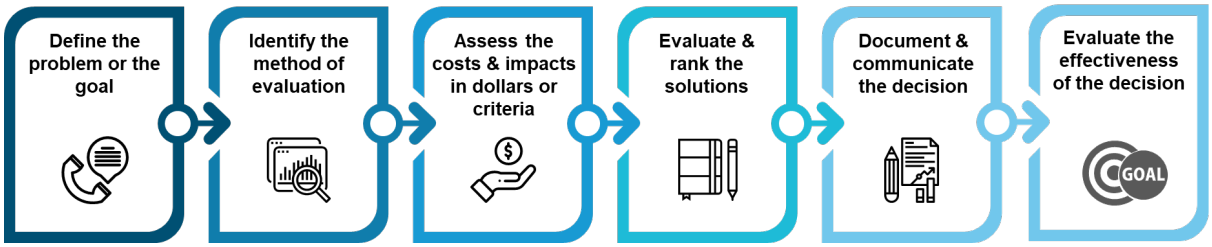


Figure 5. Asset management decision making process, adapted from IPWEA, 2015

Definitions of asset management can be wide-ranging, considering a broad scope to include the physical asset, general management, operations, production and financial and human capital aspects (Amadi-Echendu et al., 2010). ISO 5500:2014 indicates that 'asset management involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organizational objectives' and that 'balancing might need to be considered over different timeframes (ISO, 2014a). Further, it defines asset management as the 'coordinated activity of an organisation to realise value from assets' (ISO, 2014a). The International Infrastructure Management Manual (IPWEA, 2015) expands on this definition by signifying the goal of asset management is 'to meet a required level of service, in the most cost-effective manner, through the management of assets for present and future customers'. At the base of the definition of asset management is the focus on the total management of the physical asset as opposed to the financial aspects. However, it is also recognised that you cannot separate the two without compromising the effective overall management of the asset life-cycle (Amadi-Echendu et al., 2010). The definitions of asset management and the broader focus required to deliver value to customers effectively show the complexity required to understand the appropriate investment for assets over their life cycle. The recognition that a broader definition that captures an interdisciplinary approach is required to ensure an appropriate mix of skills, experience, and knowledge can be brought together to address increasingly complex problems and issues over the short and long term time horizon (Amadi-Echendu et al., 2010; IPWEA, 2015).

The move to utilise broader factors in asset investment decision making has not only grown from engineering asset management but has also grown from the global financial sector. The intersection between infrastructure asset management and investment (financial) management is becoming a stronger consideration for financial investors and large infrastructure asset

owners (Lima et al., 2021). As organisations seek to improve the value of their investments from infrastructure assets the asset management processes and infrastructure asset performance efficiency and effectiveness become more critical and need to more closely align to an organisations overall strategy and intended outcomes from the investment in the infrastructure asset (Lima et al., 2021). As the importance of improved value and wellbeing outcomes has increased, the consideration of environmental, social, and governance issues in investment decision making has steadily grown over the past decade (Beeching et al., 2020). The Principles for Responsible Investment was launched in 2006 through a United Nations initiative to bring a group of the world's largest institutional investors together to develop responsible investment principles. Since the launch in 2006, over 3,000 signatories have come on board to embrace the Principles of Responsible Investment (Beeching et al., 2020; PRI, 2021) (see Figure 6). This shows the growth in assets under management from $6.5 US trillion in 2006 to $103.4 US Trillion in 2020 utilising the principles of responsible investment (PRI, 2021) and the growing desire to change how we invest with a more sustainable focus.

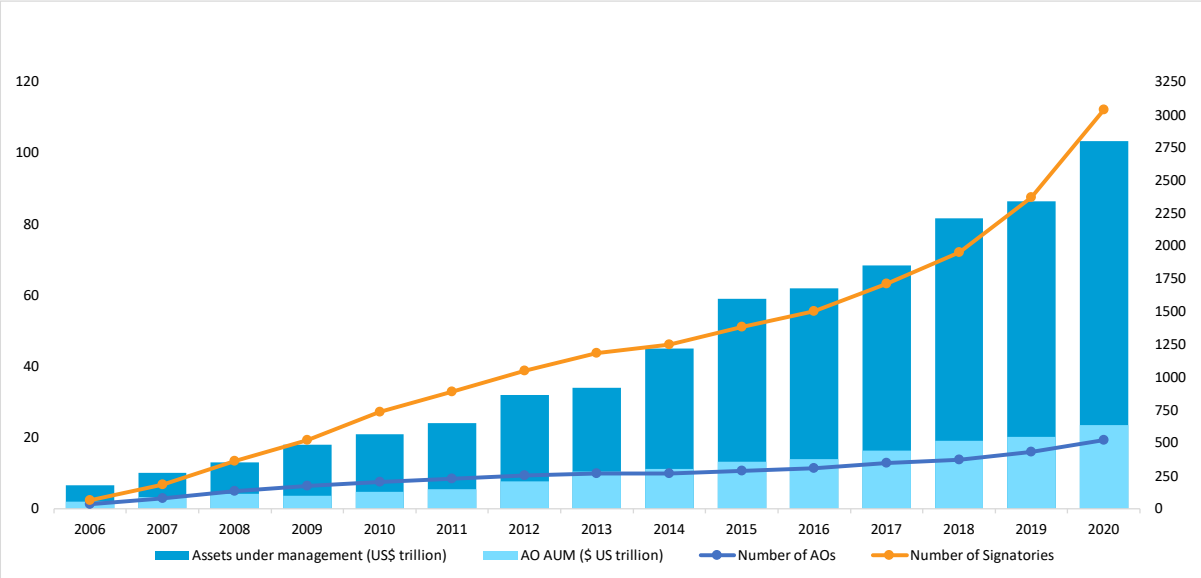


Figure 6. Principle of Responsible Investment signatory growth, from 2006 (year of inception) to 2020 (AO = Asset Owners; AUM = Assets Under Management), reproduced from PRI, 2021

The United Nations work in supporting the development of the principles of responsible investment allowed the investors to discuss, develop and agree to six principles by themselves for use by investors to develop a more sustainable global financial system (PRI, 2021). The six principles include (Beeching et al., 2020; PRI, 2021):

- **'Principle 1** - We will incorporate Environmental, Social and Corporate Governance (ESG) issues into investment analysis and decision-making processes.

- **Principle 2 -** We will be active owners and incorporate ESG issues into our ownership policies and practices.
- **Principle 3 -** We will seek appropriate disclosure on ESG issues by the entities in which we invest.
- **Principle 4 -** We will promote acceptance and implementation of the Principles within the investment industry.
- **Principle 5:** We will work together to enhance our effectiveness in implementing the Principles.
- **Principle 6:** We will each report on our activities and progress towards implementing the Principles.'

The mission of the Principles for Responsible Investment is stated as, "We believe that an economically efficient, sustainable global financial system is a necessity for long-term value creation. Such a system will reward long-term, responsible investment and benefit the environment and society as a whole. The PRI will work to achieve this sustainable global financial system by encouraging adoption of the Principles and collaboration on their implementation; by fostering good governance, integrity and accountability; and by addressing obstacles to a sustainable financial system that lie within market practices, structures and regulation (PRI, 2021)." The use of environmental, social, and governance factors (See Table 1) in investment decision making has increased in the financial sector primarily due to the growing awareness that analysis of more responsible factors can unearth risk and opportunities, (particularly over the long term), regulatory changes from the 2008-2009 financial crisis urging financial institutions to address economic uncertainty driven by climate change, and the increasing concern from clients and asset owners of the environmental and social impacts of investments (Beeching et al., 2020).

Table 1. Environmental, Social, and Governance factors commonly considered in investment decisions, adapted from Beeching et al., 2020

Environmental issues	Social issues	Governance issues
• **Climate change** • **Biodiversity** • **Energy resources and management policy** • **Biocapacity and ecosystem quality** • **Air/water/soil pollution** • **Natural resources management**	• Labour relations • Human rights • Community/stakeholder relations • Product responsibility • Health and safety • Diversity • Consumer relations • Access to skilled labour	• Shareholder rights • Incentives structure • Audit practices • Board expertise • Board independence • Financial policy • Business integrity • Transparency and accountability

The growth of both asset management and the global financial investment sectors move to more responsible investment shows the change across multiple disciplines toward a desire to understand, manage and invest, considering environmental and social outcomes.

2.2. Sustainability and Wellbeing Capitals

Sustainability, living standards, and wellbeing commonly consider similar aspects with a slightly different focus when utilised in assessment frameworks. Sustainability is usually defined by three dimensions; economic, social/cultural, and environmental, and in sustainable assessments, they are assessed to identify the trade-offs of one against the others (Balkema et al., 2002). The concept of wellbeing is complex, multi-faceted, and any indicators used to describe wellbeing is subject to value judgements and can make the underlying issues clouded (King et al., 2018). The term well-being tends to capture dimensions such as the human, social, environmental, and natural capitals (Dr Anita King, 2018; Girol Karacaoglu, 2019; King et al., 2018).

Defining what is meant by wellbeing takes a more complex approach than simply defining the word in isolation. Wellbeing can be defined as the objective and subjective conditions that lead to "the good life" (King, 2018). A 'good life' or quality of life is multi-dimensional and needs to consider how objective and subjective indicators integrate with a broad range of life domains and individual values (Felce & Perry, 1995). In this definition subjective wellbeing is measured by life satisfaction and includes 'how people feel about their lives as a whole rather than their current emotional state (Karacaoglu et al., 2019)' while objective wellbeing is measured objectively by biological, material, social, behavioural, or psychological indicators (Felce & Perry, 1995). Wellbeing can also be defined as comprehensive consumption, which not only includes standard marketed consumption goods but also includes, leisure, arts, health services, and environmental services provided by nature (Karacaoglu et al., 2019). Comprehensive consumption can be considered as a function of comprehensive wealth, which comprises capital stocks. Subjective wellbeing refers to positive and negative affect (positive affects refers to experiences of pleasant emotional states such as joy and peace and unpleasant emotional states such as fear and sadness), life satisfaction and eudaimonia (relates to the sense of purpose or value in one's life) (King, 2018).

The United States Centres for Disease Control and Prevention (CDC) states that there is no consensus defining wellbeing, but a general agreement that wellbeing includes the presence of

positive emotions and moods (i.e. happiness), absence of negative emotions (i.e. stresses), satisfaction with life, fulfilment and positive functioning (Prevention, 2020). Wellbeing in the sense of building a wellbeing framework that incorporates indicators and measures increases the level of complexity on what we mean by wellbeing. Karacaoglu et al. (2019) define wellbeing in 'terms of people's abilities to live the kinds of lives they have reason to value' and is based on the interaction between environmental, social, and economic influences. Broadly the objective of individual and community wellbeing is to make it possible for people to live the lives they want to live, today and in the future, without impacting on others' ability to do the same (Karacaoglu et al., 2019). Wellbeing is a positive outcome and helps tell how people perceive that their lives are going well and include many different aspects: physical wellbeing, economic wellbeing, social wellbeing, development and activity, emotional wellbeing, psychological wellbeing, life satisfaction, domain-specific satisfaction, and engaging activities and work (Prevention, 2020). The US CDC (2020) expands on their definition of wellbeing in relation to the promotion of health, indicating it is more than the absence of disease and that it is a 'resource that allows people to realize their aspirations, satisfy their needs and to cope with the environment in order to live a long, productive, and fruitful life'. To fully understand wellbeing in the context of allowing people to live the kind of lives they value and to realise their aspirations, we need to consider the hierarchy that enables people to improve and consider their wellbeing.

Maslow's hierarchy of needs helps us understand human needs and how lower needs must be satisfied before attaining higher-level needs. Maslow's hierarchy is a motivational theory comprising five motivational levels, ranging from the basic needs at the bottom of the hierarchy defined as physiological and safety needs, moving to psychological needs in the middle defined as belongingness/love and esteem needs, to the highest level of self-fulfilment needs defined as self-actualisation (see Figure 7) (Maslow, 1987; McLeod, 2020). Further work has been done considering Maslow's original intent and from writings prior to his death, this has led some researchers to identify an additional level to self-fulfilment defined as self-transcendence (see Table 2). This moves the highest motivational level one can obtain from a well-adjusted individual and has fulfilled the self/ego to the highest level of human development to a transpersonal level where the self/ego needs are transcended (Koltko-Rivera, 2006). The movement from one level to the next is not necessarily linear, nor is it an all or nothing approach, as one meets the needs at one level to their level of satisfaction, the motivation to

meet the needs at the next level arises, this does not require them to meet the prior level to a 100% (McLeod, 2020).

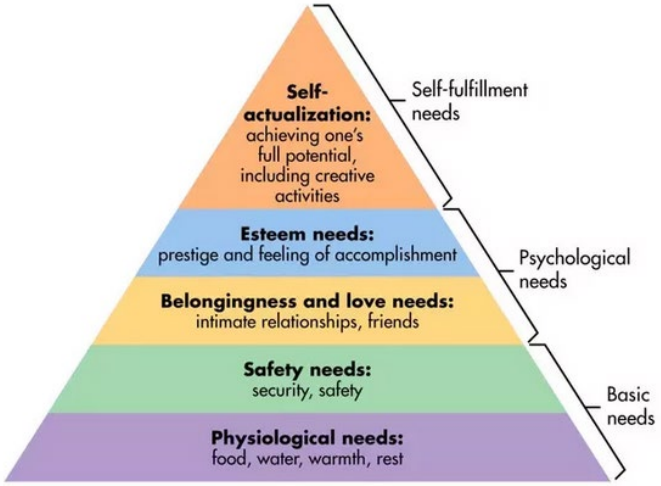


Figure 7. Maslow's Hierarchy of Needs (original five motivational levels), reproduced from Maslow, 1987; McLeod, 2020

Table 2. Updated version of Maslow's Hierarchy of Needs – including his later writings on Self-transcendence, reproduced from Koltko-Rivera, 2006

Motivational level	Description of person at this level
Self-transcendence	Seeks to further a cause beyond the self[a] and to experience a communion beyond the boundaries of the self through peak experience.[b]
Self-actualization	Seeks fulfillment of personal potential.
Esteem needs	Seeks esteem through recognition or achievement.
Belongingness and love needs	Seeks affiliation with a group.
Safety needs	Seeks security through order and law.
Physiological (survival) needs	Seeks to obtain the basic necessities of life.

Note. The earliest and most widespread version of Maslow's hierarchy (based on Maslow, 1943, 1954) includes only the bottom five motivational levels (thus excluding self-transcendence). A more accurate version of the hierarchy, taking into account Maslow's later work (especially Maslow, 1969a) and his private journal entries (Maslow, 1979, 1982), includes all six motivational levels.

[a] This may involve service to others, devotion to an ideal (e.g., truth, art) or a cause (e.g., social justice, environmentalism, the pursuit of science, a religious faith), and/or a desire to be united with what is perceived as transcendent or divine.

[b] This may involve mystical experiences and certain experiences with nature, aesthetic experiences, sexual experiences, and/or other transpersonal experiences, in which the person experiences a sense of identity that transcends or extends beyond the personal self.

The next sections consider the sustainable or capital variables that comprise wellbeing in this research. The sections will look at economic and financial, environmental and natural, social/cultural and human, and sustainable infrastructure and technology.

2.2.1 **Economic & Financial Sustainability/Capital**

The use of economic aspects in sustainability refers to being able to pay for itself with the costs not surpassing the benefits. In this context economic sustainability is mainly focused on increasing human wellbeing through the optimal allocation of resources to satisfy human needs. (Balkema, 2002). From a wellbeing capitals perspective the financial capital relates to the economic growth to accumulated assets and how shocks effect the economy and the production of goods and services that lead to various standards in material living (Janssen, 2018). The OECD defines economic capital in terms of both produced capital (tangible assets) and financial capital (intangible assets, i.e. knowledge based) (Janssen, 2018; OECD, 2011).

The concept of sustainability in economic or financial sectors has been explored through the concept of ecological economics, which is the 'ideas concerning the interlinkages between ecology and economic and described through the analysis of the flows and stocks of energy and matter, including their economic implications for the processes of social provisioning and cultural development' (Franco, 2018). The concept of ecological economics has been around a long time, dating as far back as the 1880s and has been shown to have connections and relevance to our thinking today with the increasing need to utilise the wellbeing in our decision making better. Franco (2018) has shown how this thinking helps understand energy as the determinant of cultural development, use and distribution of resources, social ideals and policy development. Ecological economics considers the inter relationships between ecology and economics and that economic reasoning is fixed to the natural sciences, utilising analysis that embraces flows and stocks of energy/matter and the implications on economics, social, and cultural growth. Recent work in this field has focused on these inter relationships between humans and nature, and how economic processes affect natural processes and energy flow. Franco's research into the history of ecological economics notes that the beginnings of this thinking started around the 1880s through to the 1930s. Following which, there is very little research on the topic until a resurgence in the 1960s. The resurgence in the 1960s saw the breakdown of barriers between disciplines and a desire to consider the impacts across society and the social drivers. Franco concludes his research by arguing that this body of ideas falls short of reaching a scientific paradigm' (Franco, 2018).

2.2.2 **Environmental & Natural Sustainability/Capital**

Environmental sustainability considers the long term capability of the ecological system to be maintained while supporting the long term development of human societies way of living. This leads to an ethical discussion between the extent to which policies and decisions are more anthropocentric than the extent to which nature has its own endemic qualities (Balkema et al., 2002). The New Zealand Treasury defines natural capital as 'all aspects of the natural environment. It includes individual assets such as minerals, energy resources, land, soil, water, trees, plants, and wildlife. It also includes broader ecosystems and their services' (van Zyl & Au, 2018).

2.2.3 **Social/Cultural & Human Sustainability/Capital**

The use of social/cultural aspects in sustainability considers the human relationships and institutions that support the equitable security of their spiritual needs (Balkema et al., 2002). The New Zealand Treasury defines social capital as, 'the social connections, attitudes and norms that contribute to societal wellbeing by promoting coordination and collaboration between people and groups in society' (Frieling, 2018). The use of social and cultural elements in policy analysis are critical to ensure governments can account for social risks and opportunities when making decisions. The use of social and cultural elements in policy decisions is a good predictor of 'economic performance, democratic functioning, public safety, educational outcomes labour market outcomes, and individual health and wellbeing' (Frieling, 2018). An individual's skills, knowledge and health (mental and physical) is normally considered as a part of the social/cultural aspects of sustainability. However, where social and cultural aspects are separated, the social capital focuses more on society as a whole. In contrast, human capital focuses on 'an individual's skills, knowledge, mental and physical health that enable them to participate fully in work, study, recreation and in society more broadly' (Morrissey, 2018). The OECD also defines human capital in terms of the individual, stating, human capital is 'the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic wellbeing' (Morrissey, 2018; OECD, 2001).

2.2.4 **Sustainable Infrastructure and Technology**

Infrastructure (i.e. transport, wastewater, water, energy) has been identified in studies as providing the fundamental services that contribute to human wellbeing and have over time been

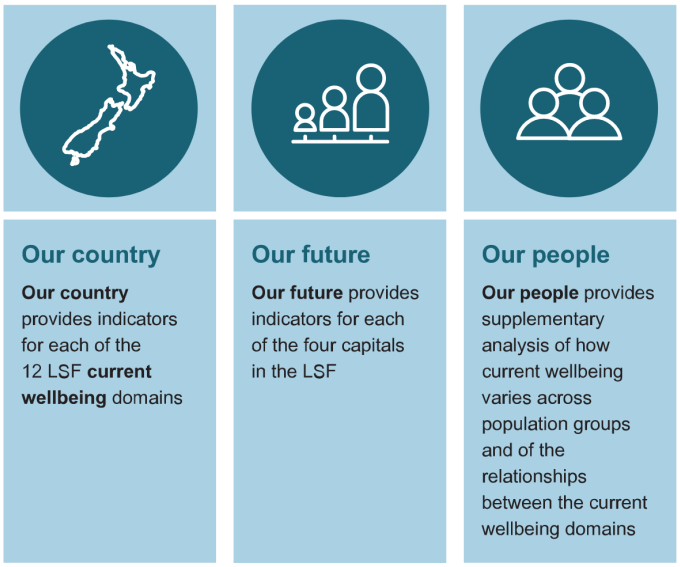
developed in a fragmented manner and mostly managed independently (Otto et al., 2016). This fragmented approach, decision making on the value of individual infrastructure assets in isolation from other infrastructure assets and the larger value or impact on society has led to a desire for more sustainable infrastructure. The concept of sustainable infrastructure and technology has been defined as 'appropriate technology, namely technology that is compatible with or readily adaptable to the natural, economic, technical, and social environment. That offers a possibility for further development. Sustainability adds the long-term and global view' (Balkema et al., 2002). Physical capital includes the tangible elements of infrastructure and technology that contribute to producing goods and services linked to material living conditions (Janssen, 2018).

2.3. Consideration of Wellbeing Frameworks

Much of the current effort in studying wellbeing is in developing frameworks for policy level decision making, defining and measuring wellbeing. There are many international frameworks available for wellbeing, including the Organisation for Economic Cooperation and Development's (OECD's) "How's Life?" framework and related Better Life Index (BLI) (OECD, 2011, 2017), the United Nations Development Programme's human development index, and development against the United Nation's Sustainable Development Goals (UN SDG) (Desa, 2016; Ul-Haq, 1990), The World Bank's Human Capital Index (Kraay, 2018), and the New Economic Foundation's Happy Planet Index (Abdallah et al., 2009).

Looking at wellbeing frameworks, we will consider how the frameworks manage the complexity of incorporating sustainability and wellbeing's into different decision making and performance models. Considering this complexity, a study completed by the New Zealand Treasury identified two schools of thought regarding the measurement of wellbeing: one focused on measuring subjective wellbeing and then determining the impacts on the result, with the second considering wellbeing as a multi-faceted concept that cannot be summarised by subjective assessments of their life satisfaction. The New Zealand Treasury has taken on the second multi-faceted approach and has worked to combat the issues with complexity of using wellbeing's in decision making by developing a dashboard approach that covers objective and subjective measures (see Figure 8) (King et al., 2018). This study is a good example showing the complexity surrounding the use of wellbeing factors in decision making at the policy level. The complexity is further increased when an additional factor of technology or infrastructure assets is introduced. This not only adds an additional variable to consider, it

also incorporates a different level of decision making required, i.e. decisions that impact at the asset or individual technology level (micro-level).



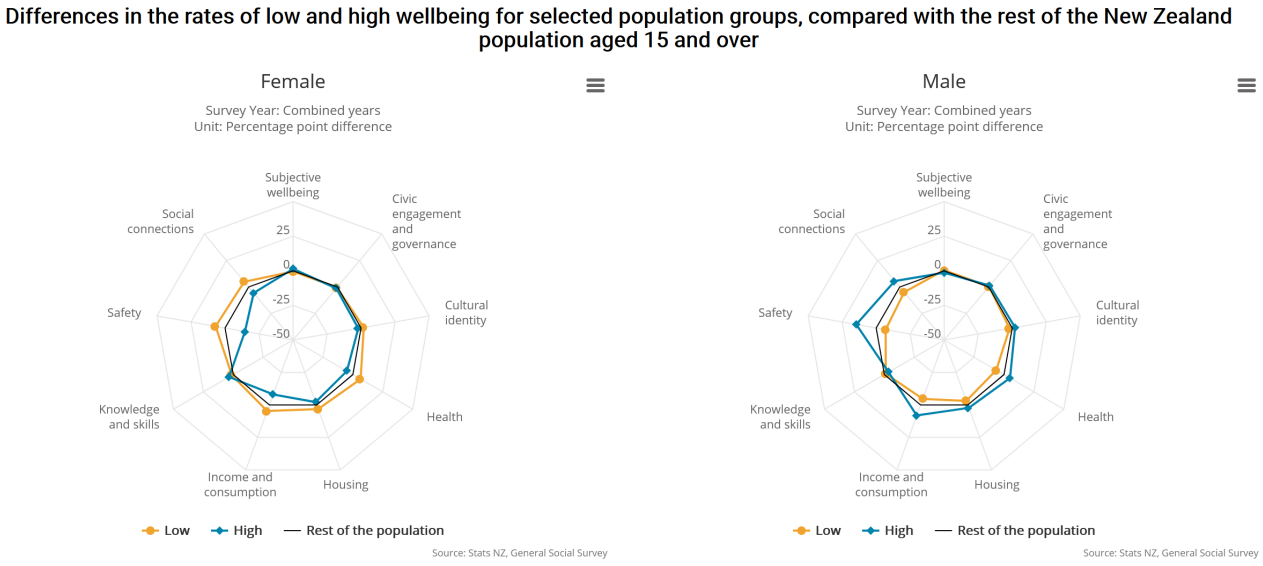


Figure 8. New Zealand Living Standards Framework Dashboard approach, reproduced from Treasury, 2021

We need to think differently when considering the wellbeing's or sustainability in the investment and management of wastewater, drinking water, and stormwater infrastructure assets. We need to expand our decision making to think beyond just the physical outcomes the services provide (Balkema et al., 2002) as well as how we look at incorporating wellbeing factors. We also need to think clearly on what we want the framework to do, is it for developing policies, monitoring, or is it for making investment decisions? The framework needs to be

transparent and founded on robust evidence that provides some logic that people can understand (Favager, 2019). Consideration of frameworks that utilise social, cultural, environmental, and economic variables for decision making can be viewed at three levels, macro, meso, and micro. The macro-level considers the larger overall scale, while the meso level considers the intermediate or middle scale, and micro-level focuses on the very small scale (Merriam-Webster, 2021). The literature is not always clear around defining what level decision-making frameworks have been developed explicitly for, with many trying to blend elements of each together. Most of the work identified in the literature review focused on the macro and micro levels.

Governmental frameworks such as the United Nations Sustainable Development Goals (UN SDG), New Zealand Living Standards Framework (NZ LSF), and Organisation for Economic Co-operation and Development (OECD) Better Living frameworks focus on the macro-level providing evidence around the domains of wellbeing and identification of suitable indicators. However, the underlying concepts and linkages across the framework can guide our choices and what we prioritise (Favager, 2019). The United Nations work on the SDG's also recognised that work was required to develop measurements of progress toward sustainable development. This is seen in part by SDG Target 17.19, which states: 'By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries' (Costanza et al., 2016; Desa, 2016). However, the majority of three-waters infrastructure frameworks have been developed to focus at the micro, or individual infrastructure asset/scheme level (Opher & Friedler, 2016; Padilla-Rivera & Guereca, 2019; Padilla-Rivera et al., 2016; Rena & Liang, 2017; Wang et al., 2017). Frameworks that consider the meso or regional/network level are harder to find and mainly focus on governance decision making and cultural aspects of infrastructure investment (Gustafsson, 2017; Larson, 2012; T. Morgan et al., 2012; Morgan, 2006).

2.4. The New Zealand Context

New Zealand has had a long history of promoting sustainability in decision making, especially when it relates to Central Governments legislative directive to Local Government entities. New Zealand's sustainable development policy 'recognises that its decisions should ensure the wellbeing of current and future generations and 'it will take account of the economic, social, environmental, and cultural consequence (DPMC, 2003). Central Government in New Zealand

indicated that it would involve thinking and working differently in achieving sustainable development. It requires decision-makers to 'look after people; taking the long-term view; taking account of the social, economic, environmental and cultural effects of our decisions; and encouraging participation and partnerships (DPMC, 2003).

The Local Government Act 2002 was developed with the purpose 'to provide for democratic and effective local government that recognises the diversity of New Zealand communities' (Government, 2007). The Act, 'provides for local authorities to play a broad role in promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach' (Government, 2007). The 2002 Act (2007) stated that the purpose of Local Government (sect 10) is to:

a) 'To enable democratic local decision-making and action by, and on behalf of, communities'; and

b) 'To promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future'.

The LG Act 2002 purpose (sect 3) and purpose of local government (Sect 10) was amended on 5 December 2012, by the Government of the day, to provide more focus on providing good quality infrastructure, local public services, and performance of regulatory functions. The then Government removed the focus on community wellbeing's and stressed delivery of 'good-quality' infrastructure, services and performance that are- (a) efficient; and (b) effective; and (c) appropriate to present and anticipated future circumstances' (Government, 2012). The Act (sections 3 and 10) was changed back to the original wording on 14 May 2019 with the election of a new Government. This promoted the focus on communities' social, economic, environmental, and cultural well-being (Government, 2019a). The initial focus on embedding the wellbeing's into decision making at the local level has matured since 2002, with New Zealand embracing the concept of embedding sustainable variables into policy decision making using the wellbeing domains and capitals in the NZ Treasury Living Standards Framework (LSF). This framework has been utilised for the first time at a national level providing the basis for New Zealand's first Wellbeing Budget in 2019 (The Treasury, 2019). Rt Hon Jacinda Ardern, Prime Minister of New Zealand, has indicated in the 2019 Wellbeing Budget, "…while economic growth is important – and something we will continue to pursue – it alone does not guarantee improvements to our living standards. Nor does it measure the quality of economic activity or take into account who benefits and who is left out or left behind…Growth alone

does not lead to a great country. So it is time to focus on those things that do…we have broadened our definition of success for our country to one that incorporates not just the health of our finances, but also of our natural resources, people, and communities" (The Treasury, 2019). The New Zealand Government defined wellbeing in the Wellbeing Budget as, "… when people are able to lead fulfilling lives with purpose, balance, and meaning to them" (The Treasury, 2019).

In New Zealand, agencies with statutory obligations to manage resources, such as Territorial Local Authorities (NZ Local Government agencies), also have specific obligations under the Resource Management Act 1991. The purpose of this act is to promote the sustainable management of natural and physical resources. The New Zealand Resource Management Act 1991 defines *sustainable management* as the means of managing 'the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while—

> (a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
>
> (b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
>
> (c) avoiding, remedying, or mitigating any adverse effects of activities on the environment.' (Government, 2020)

The New Zealand Resource Management Act 1991 puts obligations on decision-makers to embrace a set of values associated with the environment and resource management. It also recognises the statutory obligations to consider Māori views through the Treaty of Waitangi. The Act indicates, 'all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall take into account the principles of the Treaty of Waitangi (Te Tiriti o Waitangi)' (Government, 2020). The Treaty of Waitangi is an agreement between the British Crown and Māori Rangatira signed on 6 February 1840. It is a founding document in New Zealand establishing New Zealand as a British colony and protecting Māori and British subjects. The Treaty was established in New Zealand law in October 1975 as the Treaty of Waitangi Act 1975 (Government, 1975).

Consideration of cultural values is a key aspect in New Zealand resource management and has been further extended into environmental health and decision-making assessments. For example, a study by Harmsworth et al. (2011) investigated the linkages of the unique set of values New Zealand Māori hold and the western philosophies of river health by comparing monitoring approaches. The Māori worldview acknowledges a natural order constructed around the non-living and living world and shapes how Māori think about, make decisions, and determine needs and priorities. Central to this view is the concept that all parts of the environment are interrelated or interdependent through the domains of Atua (god, deity, supernatural being). 'Traditionally, Māori believe that small shifts in the mauri or life force of any part of the environment, for use or misuse, will cause shifts in the mauri of immediately related components, which could eventually affect the whole system. Within this framework, spiritual qualities guide resource use through an elaborate system of ritenga/kawa, or customary rules, with goals to regulate and sustain the wellbeing of people, communities and natural resource. Guiding values and concepts include kaitiakitanga, tapu, mauri, rāhui, mana, noa, and wairua' (see Table 3 and Table 4) (Harmsworth et al., 2011).

Consideration of Māori values in decision making has progressed. For example, development of the Mauri Model by Morgan (2006; 2012) and Wilson's (2020) Wai Ora Cultural Monitoring Framework, to help meet the requirements by the New Zealand Government and Iwi leaders to develop ways to consider Māori rights, culture, and freshwater interests. The Wai Ora Cultural Monitoring Framework also considers the UN Sustainable Development Goals, specifically indigenous rights focusing on moving the discussion from infrastructure assets to a wellbeing approach (Wilson, 2020). While both frameworks embrace New Zealand specific indigenous Māori culture, their focus is also broader in showing how a framework considering indigenous beliefs and values can be utilised to better understand the wellbeing's in sustainable development and decision making.

Table 3. Glossary of Māori words (Harmsworth et al., 2011)

Māori term	Meaning
Atua	God, deity, supernatural being
Hapu	Sub-tribe, extended family
Iwi	Tribe
Kaitiaki	Guardians or the agent who practices kaitiakitanga
Kaitiakitanga	To exercise guardianship or stewardship of the environment and tikanga
Mahinga kai	Cultivation sites, gardens, places of food harvest and collection
Mana	Prestige
Marae	Social cultural centre, village
Mātauranga Māori	Māori knowledge
Mauri	Life force, metaphysical component of all things
Ngahere	Forest
Noa	Free from tapu, unrestricted
Puku	Stomach, centre
Rahui	Restrictions
Ritenga/Kawa	Rules, guidelines
Ronga	Traditional medicines and treatments, cure, heal
Tangata whenua	People of the land, having an ancestral link and authority to a given area
Tapu	Sacred, off-limits
Taonga	Something treasured, iconic, highly valued
Te Tau Ihu	Tribes of the northern part of the South Island (e.g. Ngāti Rarua, Te Āti Awa, Ngāti Tama, Ngāti Koata)
Tikanga	Customary values, rules, and practices
Wai	Water
Wairua	Spiritual dimension

Table 4. Traditional New Zealand Māori concepts and terms within a modern paradigm, adapted from (Harmsworth)

Key traditional concepts and terms	Definitions, modern explanations	Alignment with western and scientific thinking
Whakapapa	Creation stories, ancestral lineage, sequence, atua, genealogical sequence, Papatuanuku, Ranginui, taonga	Inter-relatedness between humans and ecosystems, inter-connection, integration, holistic approaches, genetic assemblage, relationships, flora and fauna
Atua	Nga Atua Kaitiaki, Divine forces, departmental gods, deities	Environmental, ancestral and cultural domains, frameworks
Tino rangatiratanga, mana motuhake	Sovereignty, control, autonomy, authority	Autonomy, self-determination, independence, control over the management of resources
Mana	A sense of prestige and authority	Pride, authority, self-esteem, respect
Mana Whenua	Relationship and ancestral links to land through whakapapa and occupation, rights of self-governance, rights to authority over traditional tribal land and resources	Strong established relationship or links to a defined geographic area
Mātauranga Māori	Traditional knowledge, wisdom, in the domain of Tohunga, understanding human-environmental relationships, understanding the world and universe from an indigenous perspective	All forms of knowledge used by a wide range of practitioners, traditional ecological knowledge, traditional, environmental, health, historical knowledge
Kaitiakitanga	Practice of spiritual and physical guardianship of the environment based on tikanga Active guardianship, custodianship, stewardship, sustainable management of resources, healing the land, environmental responsibility	Sustainable management of natural resources, sustainable development, integration, ecosystems, inter-connection of ecosystems, holism, intergenerational equity
Te Ao Tūroa	Notion of intergenerational equity	Sustainable management of resources, sustainable development
Kotahitanga	Unity, collective, community, inclusion, tribal, respect for individual differences	Participation, consensus, collaboration, unity, participatory decision making, networking
Tikanga	Custom, lore, cultural practice the correct way of doing something	Protocols, standards, procedures
Taonga	Valued possessions, highly prised, material or non-material – objects,	Natural resources, language, objects, sites, anything significant that

	things of cultural and spiritual importance under tikanga	has priority
Whenua	The land, the earth mother Papatuanuku	The land, the biosphere, terrestrial and coastal ecosystems
Mauri (*basis for mauri is whakapapa*)	Denoting health and spirit, a sustaining life force, intrinsic life source, an essential essence of being, an energy or element that permeates through all living things	Key concept for describing environmental quality, pristine condition, human relationships, cumulative effects, cause and effect, pollution, contamination – degradation, declining, loss of mauri, a genetic code
Ritenga	The area of customs, protocols, laws that regulate actions and behaviours related to the physical environment and people. Includes tapu, rāhui, and noa – everything was balanced between regulated and where tapu was sacred	Regulations, regulatory framework, rules, practical rules to sustain the wellbeing of people, communities and natural resources. Permitted activities versus restricted and prohibited activities
Tapu	Sacred state, ritual constraint or prohibition, all pervasive force, religious observance	Sacred, prohibited, protocols, highly regulated, burial sites, areas or sites off-limits, restricted access, special conditions
Rāhui	Restricted use of resources, regulated state	Regulation, controlled, sustainable management, laws
Noa	Relaxed access, unrestricted use of resources de-regulated state	De-regulated, permitted, discretionary use
Wairua	Spiritual dimension	Spiritual, sacred, religious belief, cultural values

2.5. Introducing New Zealand Wellbeing Framework and Connection to United Nations Sustainable Development Goals (SDG)

Based on the earlier work by the OECD, the NZ Treasury has also developed the Living Standards Framework (LSF) for measuring and analysing intergenerational wellbeing, covering current wellbeing, future wellbeing, and risk and resilience across a range of economic, social and environmental domains (Treasury, 2018). Here, intergenerational wellbeing can be defined as the discounted present value of the utilities derived by current and future generations from total consumption (Karacaoglu et al., 2019). The LSF is a practical application of national and international research around measuring wellbeing. The LSF has been designed relevant to NZ circumstances and is applicable in the NZ Treasury's policy advice work. To distil and structure this knowledge and to ensure international compatibility,

the NZ Treasury has used the OECD's approach and has linked this work to the UN SDGs. The NZ Treasury recommended adopting the OECD's base well-being framework with minor changes for the New Zealand context (King et al., 2018). This framework looks not only at aggregate living standards but also at their distribution across the population. The sustainability of living standards for both present and future generations is a key part of the framework (Gleisner et al., 2011).

The three elements of the LSF, as shown in Figure 9, are the domain of current wellbeing, the capitals that combine to generate future wellbeing, risk and resilience (Ormsby, 2018). The first element of the LSF is the current wellbeing of NZ, which is divided into 12 domains (as shown in Table 5 and Figure 9). These domains reflect wellbeing at a 'point in time' and are based on research about what is essential for people and their wellbeing (Treasury, 2018). The domains used in the LSF are interested in understanding both the levels of the domains overall and their distribution over different people and groups.

Table 5. New Zealand Living Standards Framework Domains of Wellbeing (Ormsby, 2018)

NZ LSF Domains	Definition
Income and consumption	people's disposable incomes from all sources (including employment, government transfers, investment returns and home production) and how much people spend and the material possessions they have.
Jobs	the quality of people's jobs and work environment, people's ease and inclusiveness of finding suitable employment and their job stability and freedom from unemployment.
Health	our mental and physical health.
Housing	the quality, suitability and affordability of the homes we live in.
Knowledge and skills	people's knowledge and skills.
Environment	the natural and physical environment, and how it impacts people today (this is different from the Natural Capital stock, which is measured elsewhere).
Cultural identity	having a strong sense of identity, belonging and ability to be oneself, and the existence value of cultural taonga.
Safety	people's safety and security (both real and perceived) and their freedom from risk of harm, and lack of fear.
Time use	the quality and quantity of people's leisure and recreation time (ie, people's free time where they are not working or doing chores).
Civic engagement and governance	people's engagement in the governance of their country and their civic responsibilities, how "good" New Zealand's governance is perceived to be and the procedural fairness of our society.
Social connections	positive social contact.
Subjective wellbeing	this includes three components: our overall life satisfaction; our day-to-day mood and emotion; and our sense of meaning and self. Life satisfaction is conceptually different from other components of current wellbeing as it can be interpreted as a proxy for a person's overarching sense of wellbeing.

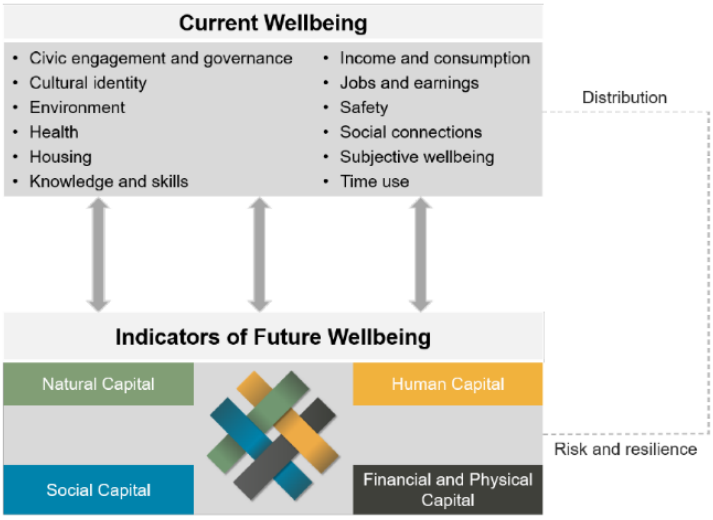


Figure 9: The Living Standards Framework. Adopted from Ormsby, 2018b; Treasury, 2018.

The second element of the LSF is the four capitals (as shown in Figure 9), which are the foundations of wellbeing that together generate wellbeing now and in the future (Gleisner et al., 2011). The capitals are called capitals in the LSF as they are the stock we use to produce the future flow of wellbeing (the means of production) (Ormsby, 2018). New Zealand's capital stocks include the skills and knowledge of their people, the natural environment they live in, the social connections, community and institutions they have and buildings and machines they use. These capitals combine to generate wellbeing, both current and future (see Table 6) (Ormsby, 2018).

Table 6. New Zealand Living Standards Framework Capital Wellbeing's (Ormsby, 2018)

NZ LSF Capitals of Wellbeing	Definition
Natural Capital	All aspects of the natural environment needed to sustain life and human activity
Financial/Physical Capital	The country's physical and financial assets that have a direct role in supporting incomes and material living conditions
Social Capital	The connections between people and the values that underpin society
Human Capital	People's skills, knowledge, physical and mental health.

The third element of the LSF is risk and resilience. NZ Treasury recognised the need to be more proactive and develop a more coordinated and evidence based approach to risk

management and resilience. The LSF is a step to help provide a national framework of risk factors offering a more integrated system for setting objectives, targets, actions, and evaluating the nation's resilience (Frieling & Warren, 2018). The intent of incorporating risk and resilience factors for each capital into the LSF is to evaluate policy impacts on risk and resilience for more sustainable wellbeing outcomes (see Figure 11) (Frieling & Warren, 2018). Risk and resilience directly relate to capital stocks. The number of capital stocks, which can be degraded or actively drawn down, influence the ability of people and the country to withstand shocks (Gleisner et al., 2011). This can be seen in how the LSF structures resilience in two dimensions (see Figure 10) (Frieling & Warren, 2018):

- Absorption capacity – 'comprises resistance and buffers that can reduce the depth of impact'.
- Adaptability – 'focuses on adaptability and innovation that maximises the speed of recovery'.

The NZ Treasury identified three key themes that came out of in a discussion paper on risk and resilience in the LSF, and these included (Frieling & Warren, 2018):

- Risk management needs to take a future-focused, agile, and inclusive approach due to the dynamic nature of the capital wellbeing's.
- The capital stocks have interdependencies between risk and resilience; and
- Coordinated multi-agency, multi-stakeholder response is growing in importance.

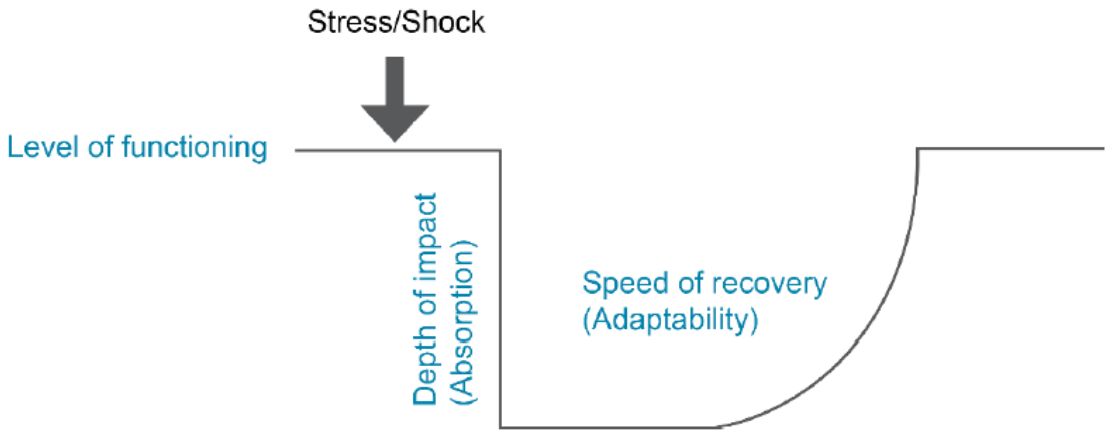


Figure 10. NZ LSF dimensions of resilience, reproduced from Frieling & Warren, 2018

The United Nations Sustainable Development Goals (SDG) were agreed by all member nations in 2015. Seventeen SDGs were developed to be a comprehensive, people centred set of universal and transformative goals and targets (see Appendix A). The commitment by member nations is to achieve sustainable development through a balanced and integrated manner considering economic, social, and environmental dimensions (UN, 2015). The 2030 Agenda For Sustainable Development (2015) resolved, that by the end of 2030, 'to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls; and to ensure the lasting protection of the planet and its natural resources.'

Though the NZ LSF (a framework for thinking about wellbeing in New Zealand) and UN SDGs (set of goals among member nations) are different, there is good alignment between the two (Ormsby, 2018). Table 7 indicates the relationship that NZ Treasury has identified between NZ LSF 12 domains and capitals and the UN SDG. Note that only the primary relationship to SDG is indicated. Both the NZ LSF and UN SDG's are tools to support policy development and advice to decision makers (Ormsby, 2018). NZ Treasury states, 'One can take an LSF approach to policy by thinking about how a policy impacts the dimensions of wellbeing and the four capitals; while one could take an SDG approach to policy by thinking about how a policy impacts each of the SDG's', which shows how the two align and also how they differ in their perspective and use (Ormsby, 2018).

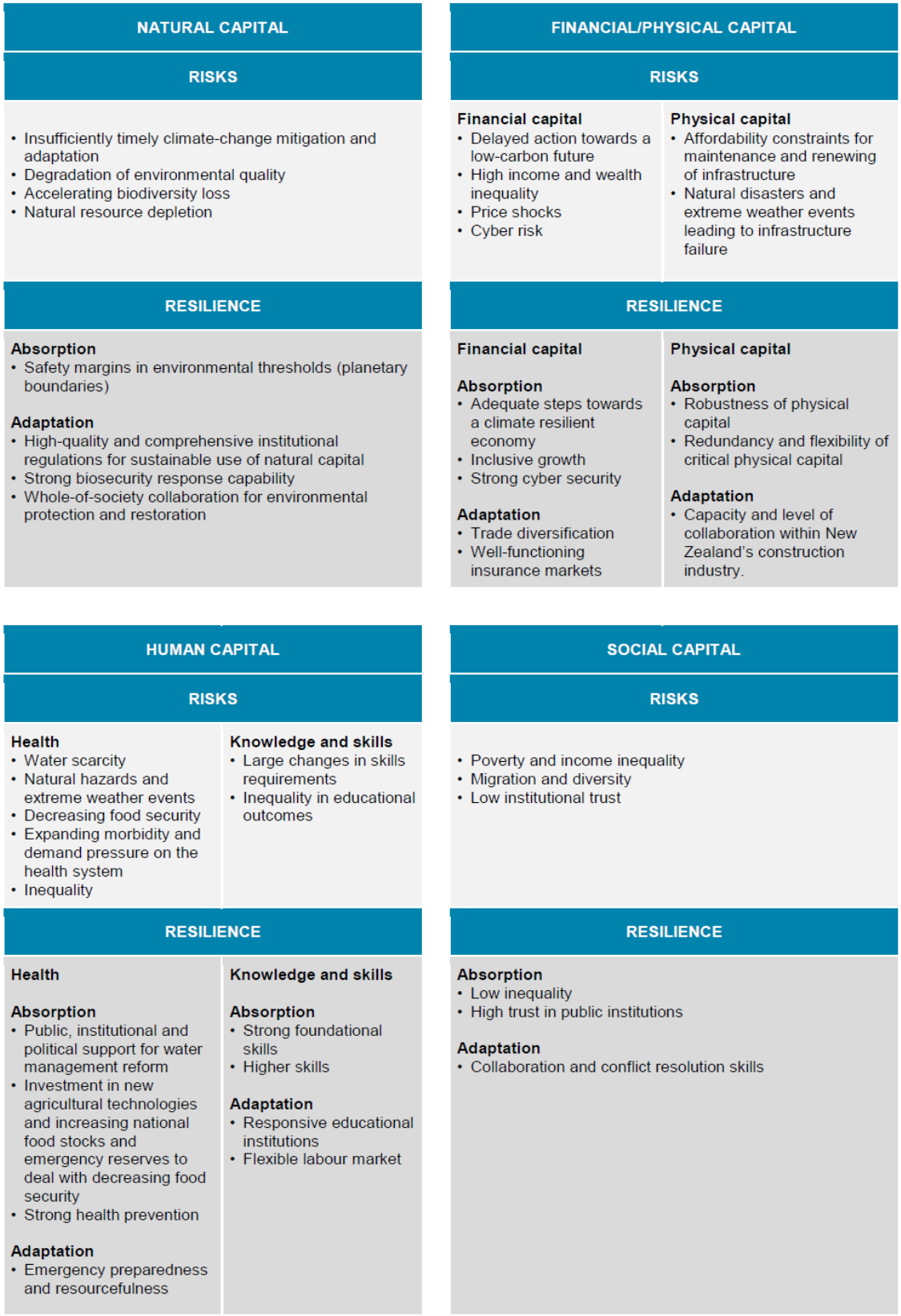


Figure 11. NZ LSF risk and resilience factors identified for the four capitals, reproduced from Frieling & Warren, 2018

Though the linkages between the NZ LSF and UN SDG's are closely aligned, several NZ LSF domains and UN SDG's do not link to one another. The NZ LSF domains, subjective wellbeing, social connectedness, and time use do not specifically link to an SDG. While the UN SDG's Gender Equality (SDG 5) and Reduced Inequalities (SDG 10) do not link to an NZ LSF domain. The NZ Treasury notes that the lack of linkages to gender equality and inequalities is due to the NZ LSF considering the distribution of equality issues to cut across and apply to every domain (Ormsby, 2018). The domains that do not specifically link to SDG's do not necessarily mean they are not important or absent. It is more about the specificity of the linkage with the domain being focused on NZ cultural aspects and the SDG targets and indicators not having specific reporting related to current NZ LSF domain reporting, the UN SDG's are flexible enough to allow member nations to include additional commentary on these domains if desired (Ormsby, 2018).

Table 7: Mapping Domains of NZ-Wellbeing to UN Sustainable Development Goals (SDG), adapted from Ormsby, 2018

NZ LSF Wellbeing Domains	**SDG**
Civic Engagement and Governance	
Environment	
Health	
Housing	
Knowledge and Skills	
Income and Consumption	
Jobs and Earnings	
Safety and security	
Subjective Wellbeing	None
Social Connectedness	None
Time Use	None
Cultural Identity	None
NZ LSF Wellbeing Capitals	**UN SDG**
Natural Capital	
Social Capital	
Human Capital	
Financial and Physical Capital	

Chapter 2 encapsulated the literature review for the thesis. The literature review considered understanding the problem statement further and the elements that could contribute to the development of a novel wellbeing framework for three-waters performance monitoring and the boundaries of the activities that fall within the field of research. The literature review considered sustainability and the concepts of wellbeing. The chapter identified the complexities of utilising the wellbeing's (natural, social / cultural, human, and economic) in a wellbeing performance framework for infrastructure assets. The consideration of subjective and objective conditions that allow people and societies to live a life in the means they would see value in living it was explored by considering different frameworks from a policy perspective (NZ LSF and UN SDG), social sciences (Maslow's hierarchy of needs), economics (Daly's means and ends, UN Principles of for Responsible Investment), and from an asset management perspective. The chapter identified the foundation of the novel wellbeing performance framework with the NZ LSF capitals and domains of wellbeing, the linkages to the UN SDGs, and relevance to use in New Zealand indigenous culture. The literature review identified a range of frameworks focused on different decision-making levels from the high level (macro), intermediate level (meso), and individual level (micro). A gap was identified in the performance and decision-making investment frameworks, with the majority of frameworks working at the micro (individual asset or scheme) level or macro-level (international or national), and not a meso level. Also, the literature review identified gap between the macro frameworks, which focused more on policy direction and national wellbeing performance, and micro-level, which focused on individual asset performance or investment assessment. Chapter 3 will provide an overview of the research methodology.

Chapter 3. Research Methodology

A wellbeing performance framework and a conceptual model for three-waters infrastructure (drinking water, wastewater, & stormwater) did not exist prior to this research. The conceptual model will be formulated by a composition of concepts and prior research to help users of the model to understand and simulate the wellbeing performance of three waters infrastructure. The development of the framework and conceptual model involved a series of investigative steps that include:

- explore and test the validity of the problem statement,
- assess existing performance monitoring frameworks and models for three-waters infrastructure assets,
- development of a novel holistic framework and model,
- identify potential indicators/measures for the model, and
- test the data availability and fitness of the available data with a national and regional sample.

Personal experience in the industry identified a gap in how investment decisions were being made on three-waters infrastructure. This gap was seen in how infrastructure asset owners (i.e. Central and Local Governments) understood the performance of their three-waters infrastructure in delivering intergenerational wellbeing. The focus of most governance and asset managers was to invest in three-waters infrastructure based on simple asset factors like demand, asset condition, and economic returns on investment and, to a lesser extent, on the environmental, social and cultural dimensions. The inclusion of social and cultural aspects was more of a 'gut feeling' or political driver and not based on a systematic or evidence-based approach. Through personal experience, the problem articulated was a lack of a holistic investment decision-making model considering social, cultural, environmental, economic, and infrastructure variables are leading to investment decisions that are unable to deliver sustainable intergenerational wellbeing in three-waters infrastructure (Figure 12).

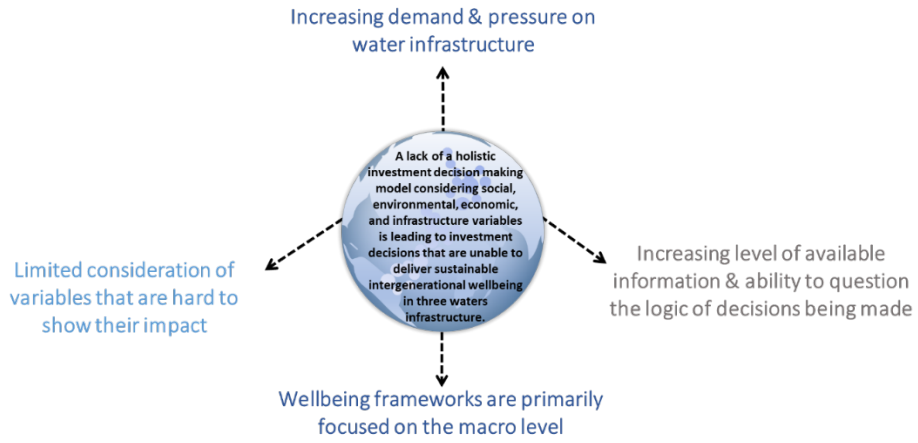


Figure 12. Research pressures and problem statement.

The problem identified the need to investigate if there was a better way to understand, assess, and identify the performance and investment requirements that consider not only the infrastructure assets functional outputs but also the intergenerational impact (positive or negative) on our wellbeing. Therefore, the research methodology for this thesis aimed to:

- **Confirm the validity of the problem statement** - Conducted a general literature review of performance and investment decision making frameworks and models for three-waters.

- **Assess and analyse existing wellbeing frameworks** – Conducted a review and assessment of established sustainability and wellbeing frameworks to identify if they could address the identified problem statement and identify the gaps with these existing frameworks.

- **Develop a novel holistic performance monitoring framework and conceptual model for three-waters infrastructure (drinking water, wastewater, & stormwater)** – The learnings from the initial literature review and gap assessment of existing frameworks and models were utilised to develop initial concepts of the novel framework. Subsequent research included cross-disciplinary fields such as economics, environmental sciences, psychology, and geography. The foundation of this novel framework is the New Zealand Living Standards Framework and United Nations Sustainable Development Goals that ensures the framework and conceptual model would be of practical value to the New Zealand industry. The novel framework in this research has been developed to address the gap identified in the problem statement linking the macro, meso, and micro levels but focused on addressing the gap of not

having a meso level framework that considered three-waters infrastructure assets and intergenerational wellbeing.

- **Identify potential indicators and measures** – Conducted a literature review of indicators and measures that have been used by researchers covering the four wellbeing's and three-waters infrastructure assets and identified potential indicators and measures from this research that could be used in the novel framework and conceptual model. The potential indicators were then mapped to each wellbeing capital, NZ LSF domains, and relevant UN SDGs and targets.

- **Test the availability and fitness of data –** An initial assessment was conducted of two data sources, one at a national level (Stats NZ) and one at a regional level (Waikato Regional Council). A data collection form was developed and sent to the two agencies. The data collection form listed each of the indicators and associated measure against each of the wellbeing capitals, asking the agencies to identify whether they collected the data or not and what type of data they held for the measure (if they collected it). Once the two agencies identified the availability of the data, a review of the fitness for using the available data in the conceptual model was conducted. The fitness of the data is defined as data that is fit for the intended purpose and was assessed to understand if the data was accessible and relevant to the identified conceptual model and indicator/measure identified. This was completed through an assessment against the conceptual model with data from Stats New Zealand and the Waikato Regional Council.

This initial research has focused on developing the framework and conceptual model and testing the availability and fitness of data to the identified indicators/measures. This initial work has successfully developed a framework and conceptual model and identified the potential usefulness for three-waters infrastructure asset managers and owners in assessing wellbeing performance and investment decisions but requires further research to develop a supporting mathematical model and analysis of the data obtained from the two agencies to test and further develop the framework and conceptual model.

Chapter 3 provided an overview of the research methodology for the development of the novel performance framework and conceptual model. Chapter 4 will expand on the literature review to further assess the gap between the macro frameworks (i.e., NZ LSF and UN SDG), which focus on policy direction and national wellbeing performance, and micro frameworks, which focused on individual asset performance or investment assessments.

Chapter 4. Decision Levels for Managing Wellbeing's

The literature review identified a range of frameworks focused on different decision-making levels from the high level (macro), intermediate level (meso), and individual level (micro). A gap was identified in the performance and decision making investment frameworks, with the majority of frameworks working at the micro (individual asset or scheme) level or macro-level (international or national), and not a meso level. Also, the literature review identified gaps between the macro frameworks, which focused more on policy direction and national wellbeing performance, and the micro-level, which focused on individual asset performance or investment assessment. Further research was conducted to assess this gap and gain a more in-depth understanding of the drivers leading to the development of the frameworks, their intended use, desired outcomes, and interrelationships between the levels. This research was used to better understand the problem statement identified in this thesis and the key elements required to develop a meso level performance framework that utilises the wellbeing's in three-waters infrastructure assets.

4.1. Macro-Level Decision Making – International or National Level

Macro-level decision-making frameworks and models work at the strategic or high-level direction setting level. These models are designed to provide an understanding of the impacts (positive or negative) on policy and/or understand the performance at a high level, usually a national level.

4.1.1 **New Zealand Living Standards Framework**

At the heart of this research was New Zealand's drive as a nation to embrace the concept of embedding sustainable variables into decision making using the wellbeing's in the NZ Treasury Living Standards framework. New Zealand has recognised that the use of economic indicators like GDP alone will not guarantee the wellbeing of all people in the country and that the complexity of dealing with issues like poverty, abuse, and climate change needs a new approach as our traditional methods are not working. The budget stresses the need to look beyond the immediate economic growth and the need to consider social, cultural, environmental, and economic impacts together. The Wellbeing Budget does this in three ways: removing agency silo's to assess, develop, and implement policies that improve wellbeing; focus on current and future outcomes, and tracking progress against broader indicators of success. The new process of forming the Wellbeing Budget can be seen in Figure 13. This is

just the start, and the New Zealand Government recognises that the new Wellbeing Budget is not perfect and is just the start of a more comprehensive programme of change across government to truly embed the concept of focusing on wellbeing (Government, 2019b).

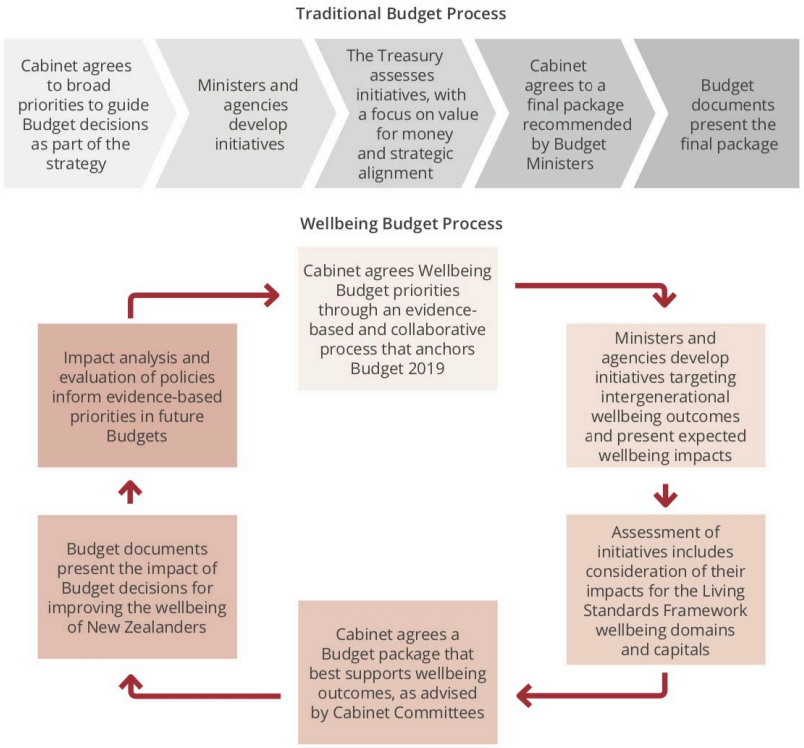


Figure 13. Developing the New Zealand Wellbeing Budget, reproduced from Government, 2019b

The Wellbeing Budget was developed utilising New Zealand's Living Standard Framework (LSF) that allows for the consideration of intergenerational wellbeing impacts on policies and proposals. The LSF was developed by the treasury to improve the quality of their advice to the government, improve the use of wellbeing evidence to better understand the trade-offs and interactions between policy choices (Government, 2018, 2019b). One of the strengths of New Zealand's wellbeing frameworks is the inclusion of wellbeing for individuals today and our future generations. The LSF achieves this with a clear focus on risk and resilience when using the four capitals as does other frameworks in New Zealand using Māori principles of intergenerational thinking that values whānau (extended family), land, and the relationship between the environment and its people (Figure 14) (Favager, 2019).

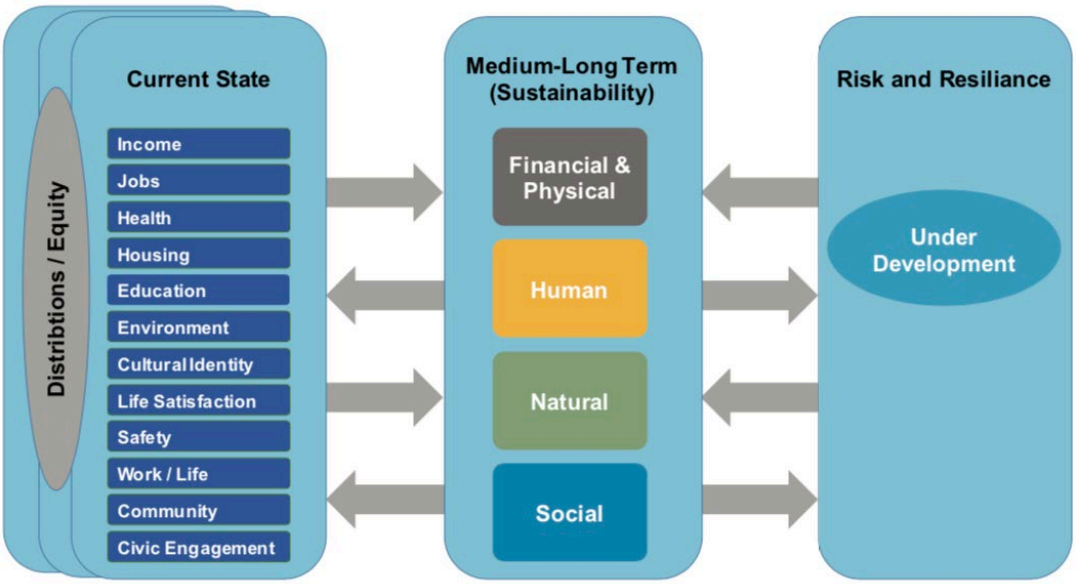


Figure 14. New Zealand Treasury Living Standard Framework and the wellbeing framework, reproduced from King et al., 2018

The development of the New Zealand Living Standards Framework considered several wellbeing frameworks during a refresh of the framework in 2018 (Figure 15). The Treasury assessment found there were a lot of similarities between the wellbeing measures, dimensions, and indicators being used. This assessment noted that the Organisation for Economic Cooperation and Development's (OECD's) framework used in the Better Life Index and How's Life? reports would meet New Zealand's needs closely, with some additions. It also noted that the United Nations Development Programmes Sustainable Development Goals (SDGs) are 'immature' as a framework for measuring wellbeing and the focus is on a binary achievement of the goals (either it is achieved or not) rather than measures. The review identified that with the UN SDGs upcoming development of new indicators (to total 232), this would potentially allow the framework to be more effective in measuring trends over time. The Treasury recommended adopting the base wellbeing framework developed by the OECD with minor changes for the New Zealand context, add in a cultural identity dimension, and additional measures for mental health, volunteering and corruption to capture the broader focus of wellbeing (King et al., 2018).

	International comparability	Dashboard approach	Coverage	Inter-temporal comparability	Data availability	Suitability for developed countries	Suitability for New Zealand context	Credibility
OECD Better Life Index	✓	✓	✓	✓	✓	✓		✓
OECD "How's Life?" Report	✓	✓	✓		✓	✓		✓
UNDP's Sustainable Development Goals		✓	✓	✓		✓		✓
UNDP's Human Development Index	✓			✓	✓			✓
Social Progress Index	✓		✓	✓	✓			
World Happiness Report	✓			✓		✓		
World Bank Genuine Savings	✓			✓	✓	✓		✓
Legatum Institute Prosperity Index	✓	✓	✓	✓	✓	✓		
Happy Planet Index	✓			✓		✓		
BCG Sustainable Economic Development Assessment	✓	✓				✓		
Good Country Index	✓		✓	✓		✓		
MSD Social Report	✓	✓		✓	✓	✓	✓	✓
Superu Family Wellbeing and Whānau		✓		✓	✓	✓	✓	
Salvation Army State of the Nation		✓		✓	✓	✓	✓	

Figure 15. New Zealand Treasury comparison of alternative frameworks, reproduced from King et al., 2018

4.1.2 **New Zealand Tax Working Group – He Ara Waiora Model**

Another macro-level model developed in New Zealand for measuring and analysing wellbeing is He Ara Waiora. This model was developed by the New Zealand Tax Working Group in partnership with Māori to inform reforms to the taxation system (McMeeking et al., 2019). The model was developed to connect with the New Zealand Living Standards Framework and integrate Māori cultural values and beliefs into a 'macro wellbeing framework to guide government policy as well as monitoring the state of wellbeing over time' (McMeeking et al., 2019). The model evolved through two versions (McMeeking et al., 2019) (see Figure 16):

- Version 1.0 – Conceptualised Tikanga (correct procedure, custom, practice (Moorfield, 2021)) Māori framework that would guide tax policy. 'Waiora anchors the framework in a conception of human wellbeing, that is connected to the four capitals within the LSF and expressed through four Tikanga derived values of wellbeing: Kaitiakitanga (stewardship of all our resources), Manaakitanga (care for others), Ōhanga (prosperity) and Whanaungatanga (the connections between us).'

- Version 2.0 – Conceptualised Mātauranga (knowledge, wisdom, understanding (Moorfield, 2021)) Māori approach to wellbeing that may be able to work as a macro framework with some alignment to the New Zealand Living Standards Framework. This version was expanded to clarify the conceptual relationship between elements of wellbeing and expand on the principles of mātauranga Māori in that: Wairua (spirit, soul (Moorfield, 2021)) is the centre of any approach to wellbeing; the model should not be human-centric and that the 'wellbeing of the Taiao (world, Earth, environment (Moorfield, 2021)) is a paramount and predeterminant of human wellbeing; the Māori approach to wellbeing is inherently rational and needs to include the 'ends and means of achieving wellbeing'.

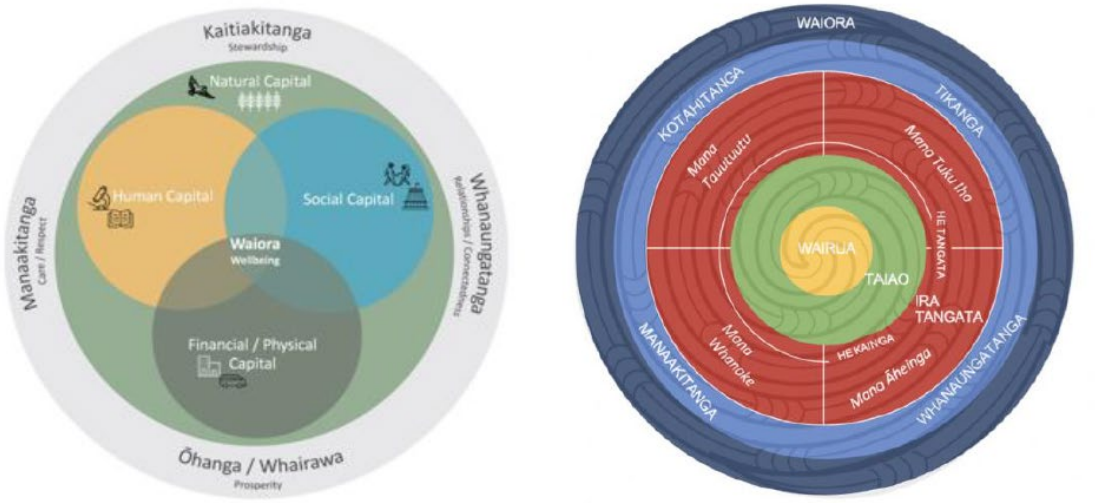


Figure 16. He Ara Waiora wellbeing model version 1.0 and 2.0 development, reproduced from McMeeking et al., 2019.

4.1.3 **Infrastructure System of Systems Framework**

At the macro level, it is important to understand how we define both well-being as well as infrastructure services. Otto (2016) defines infrastructure services 'as the provision of an option for an activity by operating physical facilities and accompanying human systems to convert, store, and transmit flow entities'. This definition is useful in understanding how we link the technical aspects of infrastructure, the services they provide, and delivery of wellbeing outcomes.

Alexander (2016) reasons that a more integrated approach to infrastructure development and management is required to meet the growing demand for interconnection of infrastructure systems and the growing uncertain challenges we are facing (i.e. climate change, technology, and growth pressures). A dynamic systems approach is required to model the long-term infrastructure performance and sustainability over a wide range of future conditions; taking into account the interdependencies of infrastructure services and the complexity of challenges from resource availability, diversification, technology, changes in socio-economic systems, and responses to climate change pressures (Costanza et al., 2016; Otto et al., 2016). Alexander's (2016) work sets aside the aspects of conversion and storage and focused on the flow of services, though this work is more focused on the transmission and flow of connected national services versus the local provision of services (i.e. use of a well for water or septic tank for wastewater versus a national/regional water and wastewater supply) and how to improve interconnected development. It is helpful for us to understand the systems linkages at a macro level in how it helps us connect to wellbeing outcomes in the delivery of these services from a stock and flow model, as explained in Chapter 5. This system-of-systems framework is designed to allow for a decision making process for infrastructure planning and policy development that integrates across multiple infrastructure services that considers performance trade-offs between these different services, over time to allocate limited resources (Figure 17 and Figure 18). This study noted that future innovation to this work would be to incorporate socioeconomic and technical systems (Otto et al., 2016).

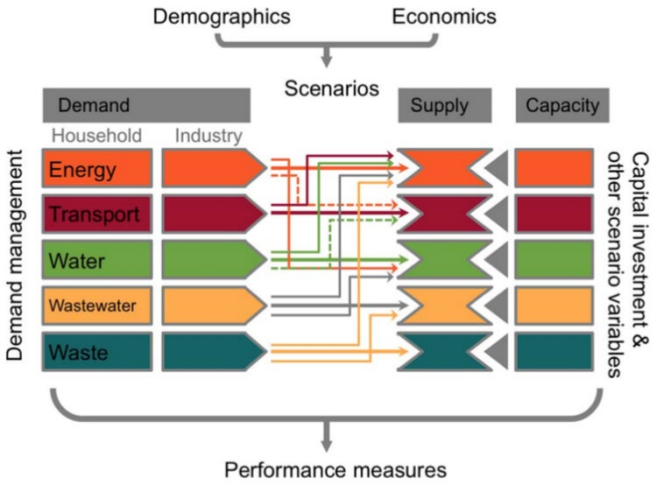


Figure 17. Infrastructure systems-of-systems framework, reproduced from Otto et al., 2016

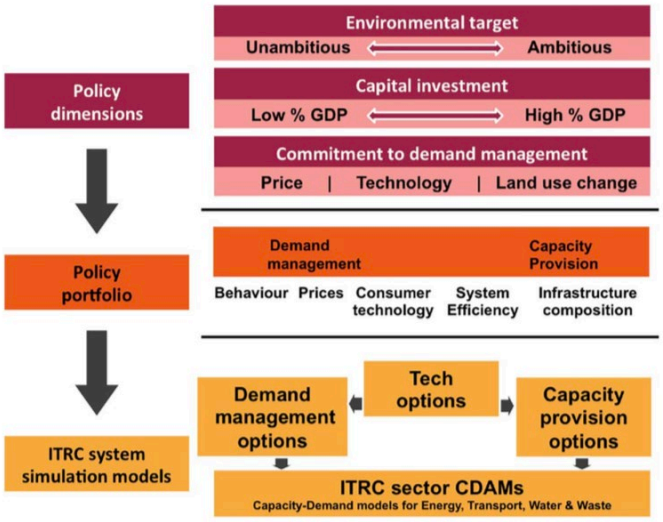


Figure 18. Infrastructure systems-of-systems framework – strategy generation process, reproduced from Otto et al., 2016

4.2. Meso-Level Decision Making (Regional and Local Level Investment Decisions)

Meso-level decision-making models comprise the middle area between the macro and micro levels and act as a key link to understanding both the performance of infrastructure assets at the micro-level and how it is delivering the policy outcomes at the macro level. Research in this area tends to be more limited and focused on specific desired outcomes like improved business performance from infrastructure asset owners to ensure investments (financial) provide a higher rate of return against their desired business strategies or how social and cultural outcomes are affected by infrastructure performance.

4.2.1 **Asset Management and Business Performance (AMBP)**

Infrastructure intensive businesses require extensive financial investment into new and maintaining existing infrastructure assets. This places immense pressure on the organisations to ensure their investments are aligned to their strategies and the infrastructure is performing as intended and delivering on the outcomes desired (Lima et al., 2021). Lima et al. (2021) has developed a model that helps establish the relationship between asset management, asset performance, and business performance. The AMBP is a theoretical model designed to link asset management, asset value, asset maturity, asset performance indicators, business performance and business key performance indicators (see Figure 19) .

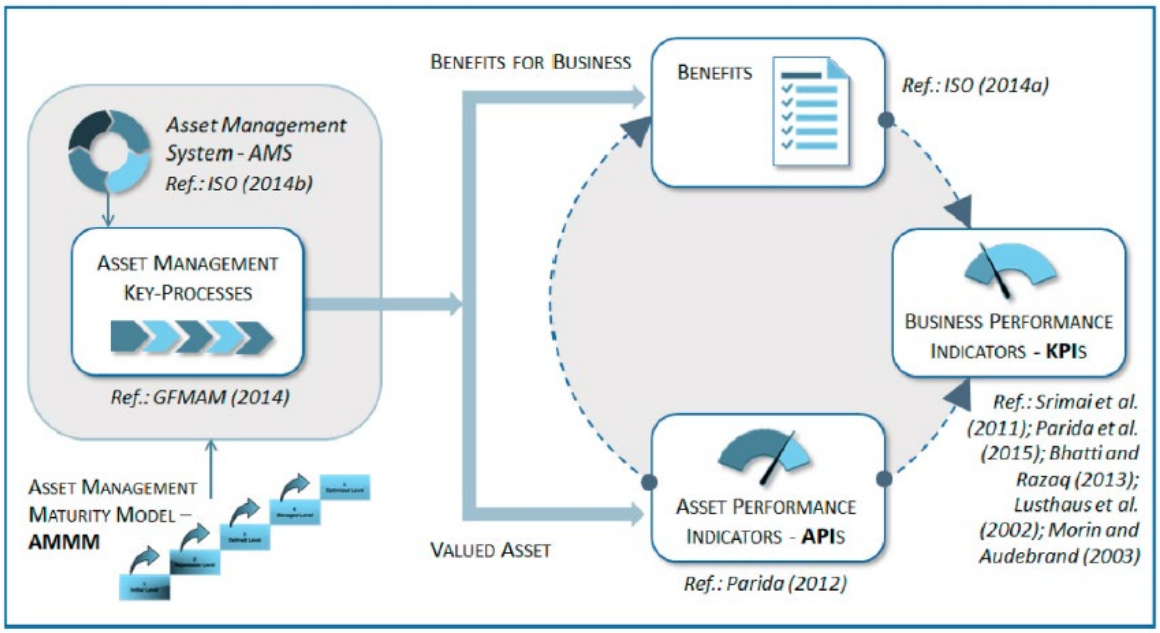


Figure 19. Asset Management and Business Performance (AMBP) theoretical models structure, reproduced from Lima et al., 2021

The AMBP methodologies objective is to establish links between asset management processes (evidence of asset management actions performed with the aim to solve a problem or meet business objectives) and business performance (evidence of benefits for business that are the consequence of the asset management actions) (Lima et al., 2021). An example of the analysis from this indicates that if an organisation desires to improve its environmental responsibility and safety business indicator, it should invest in asset management actions related to risk assessment and management. Lima et al. (2021) indicate the AMBP model is a first step in measuring the impact of asset management maturity on business performance and that it will enable higher confidence in asset management investment decisions against the desired performance level of a business. The AMBP helps answer the question, 'How does Asset Management maturity impact on business performance?' and what investments should be prioritised in relation to key asset management processes to obtain the desired strategic outcomes from the business.

4.2.2 **Mauri Model Decision Making Framework (MMDMF)**

The Mauri Model Decision Making Framework is a decision support tool that incorporates New Zealand indigenous (Tāngata Whenua – people of the land) values and beliefs into sustainability decision making model (Morgan, 2006). The concept of mauri (binding force) is included in the model to provide a culturally consistent measure of sustainability (Morgan,

2006). A key part of the model is the acknowledgement that sustainability assessments - 'need to follow the tradition of acknowledging the mountains, the waters and those that came before from the beginning of time' (Morgan, 2006). Morgan (2006) identifies in his research that though sustainability is a global challenge, the response requires local and regional solutions. The importance and connected relationship of water in Māori culture is significant - 'at the regional level, the indigenous people have an intimate understanding of the ecosystem characteristics specific to that place and over time' (Morgan, 2006). The MMDMF decision support tool looks to integrate and support the integration of the wellbeing's through a holistic approach at a meso level considering regional and local action. The model was developed in the context of the 1840 Treaty of Waitangi and incorporated Māori perspectives that are consistent with Tāngata Whenua and the treaty while demonstrating ecological integrity and the delivery of intergenerational equity (Morgan, 2006). The conceptual basis of the model is mauri or the 'binding force, power of the gods, the glue that makes it possible for everything to exist, by holding the physical and spiritual elements of being or thing together in unison' (Morgan, 2006). This model has identified the physical representation of mauri to allow for evaluation (Morgan, 2006). The physical representations for the wellbeing's include (see Figure 20): community for social wellbeing; the family unit (whanau) for economic wellbeing, ecosystem for environmental wellbeing; and clan group (hapū) for cultural wellbeing (Morgan, 2006).

Each dimension is provided with a weighting, and an assessment is based on whether the selected technological solution enhances (+2), maintains (+1), is neutral (0), diminishes (-1), or destroys (-2) the mauri of the dimension considered. This rating for each dimension is then multiplied by the agreed weighting and an overall sustainability rating to give a final score in

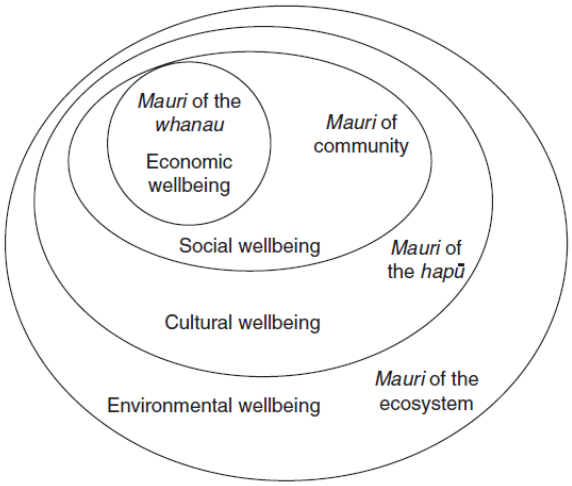


Figure 20. Mauri Model showing the four wellbeing dimensions, reproduced from Morgan, 2006

the range of -2 to +2. 'As mauri is an indicator of life force, how the mauri is affected is a direct indication of an option's long-term viability and sustainability' (Morgan, 2006).

4.3. Micro-Level Decision Making (Individual Asset/Scheme or Project Level Decisions)

Micro-level frameworks and models are the more traditional assessment tools utilised to understand the performance or the investment value of individual infrastructure assets or projects. The micro-level is crucial to understanding the infrastructure assets' performance, the investment returns (economic, social, cultural, environmental), and impacts (positive or negative) directly related to the infrastructure asset.

An example of a micro-level model developed to address a specific question or issue can be seen in a study conducted by Balkema (2002). This study looked at whether it is possible to be more sustainable in water management through improving existing centralised wastewater systems or shifting to decentralised systems. To assess this question, their research tested a multi-criteria assessment using sustainable indicators in a multi-objective optimisation framework to identify the selection of more sustainable centralised wastewater treatment systems. A key difference in this study was the explicit acknowledgement of the need to take technology into account in assessing other sustainable factors. Figure 21 shows the interaction of various sustainable variables on technology to illustrate the concept of sustainable technology that does not threaten the quantity or quality of the resources. The study notes that 'as the quantity and quality of the resources and the resilience of the environment change over time and space, the most sustainable technology solution will change accordingly'.

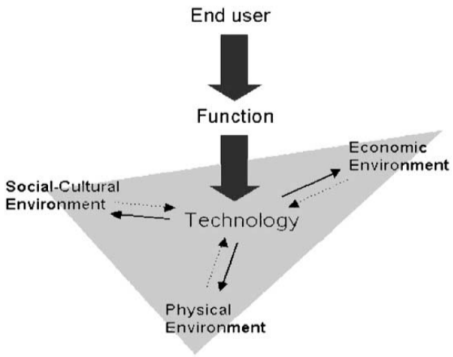


Figure 21. Technology interacting with the environment, reproduced from Balkema et al., 2002

The study looked at assessing the sustainability of wastewater treatment systems considering exergy analysis, economic analysis, life cycle assessment, and general systems analysis. The methodology proposed is set up in three phases: goal and scope definition, inventory analysis, and optimisation and results. In this work, the last phase has been identified as crucial as there is a need to integrate the different tools, weigh the different indicators and consider trade-offs (Balkema et al., 2002).

Looking at the different tools consider in this study; we can see how they interact and are being explored to enable assessments at a micro-level. The use of exergy analysis tries to identify a single simple indicator. Exergy is defined as, 'the maximum useful work which can be extracted from a system as it reversibly comes into equilibrium with its environment' (*What is exergy?*, 2019). It has been considered for its ability to try to capture sustainability into one indicator, as some economic analysis. It is noted that the use of exergy analysis creates a simple, straightforward quantifiable indicator but also creates a limiting factor as the outputs only show the efficiency of the processes but not the different environmental impacts. The use of economic analysis is also considered for the similar reason to have a single indicator and that it can be easily applied to decision making. Life cycle assessment (LCA) is used for its ability to be able to assess different environmental impacts over the assets whole lifetime (Balkema et al., 2002). An LCA generally follows four phases: defining the goal and scope of the study; compiling an environmental inventory of energy and mass inputs with environmental releases; evaluating potential impacts; and results interpretation for decision-makers to use (ISO, 2006) (Curran, 2013) (Balkema et al., 2002). Though the methodology is standardised, the framework can be open to interpretation by users leading to different results for similar assessments (Curran, 2013) and requires aggregation of a large quantity of data into a standardised environmental impact categories. This could lead to loss of granularity in the analysis; the LCA also limits itself to a restricted set of technical and environmental areas (Balkema et al., 2002). Though an LCA can be considered a systems analysis, the concept of general systems analysis generally takes a more general and abstract approach by describing a system in a mathematical manner.

Balkema (2002) states that it is essential to consider both the whole system using a multi-dimensional set of indicators to fully understand the integrated relationships and find where there may be gaps and potential solutions. This perspective helps to better understand the

systems dynamics where one dimension leading to positive changes may have negative feedback loops creating unintended consequences in other areas. The measurement and understanding of wellbeing require the use of a systems approach as wellbeing is not linear or constant, and its impact on today can be different when applied over time. If we understand the system better, we can build decision-making frameworks that better represent the levers that are adaptable to change (Favager, 2019).

Chapter 4 expanded on the literature review to further assess the gap between the macro frameworks (i.e., NZ LSF and UN SDG), which focus on policy direction and national wellbeing performance, and micro frameworks, which focused on individual asset performance or investment assessments. This additional review was completed to better understand and inform the development of a meso level performance framework and to gain a more in-depth understanding of the drivers leading to the development of existing frameworks, their intended use, desired outcomes, and interrelationships between the three levels (macro, meso, micro). Chapter 5 will utilised the research from the previous chapters to support the development of a meso level wellbeing performance monitoring framework for three-waters infrastructure assets that utilises the wellbeing's.

Chapter 5. Developing a Wellbeing Performance Monitoring Framework

5.1. Modelling the Change in Wellbeing Using a Stock and Flows Technique

Considering a systems thinking approach, decision making is influenced by societal systems that people live in (Morgan, 2006). In this respect, the New Zealand Living Standards Framework looks to understand the stock and flow interaction of the system to better understand the societal systems people live in. In the LSF, a 'capital stocks and flows' approach has been used as the basis to understand and model this system. In the LSF, stock can be defined as the quantity present at one specific time (or entities that can accumulate or deplete), and the flow variable is measured over an interval of time (about a year long time period), or flows are entities that make stocks increase or decrease. As shown in Figure 22, this framework comprises four types of capital that are integral to current and future living standards. Both create and affect the current and future sustainability of wellbeing. These four capital stocks represent the wealth of the country and interact to generate beneficial flows.

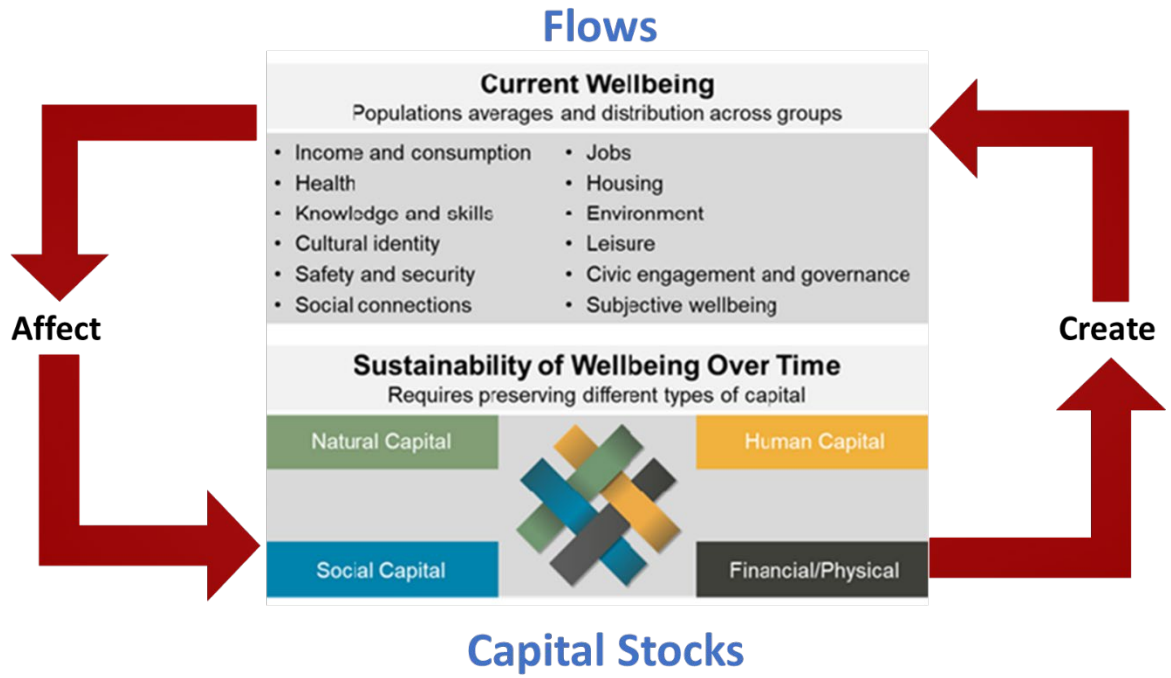


Figure 22. New Zealand Living Standards Framework Stock and Flow Interaction, adapted from King et al., 2018

By using certain capital stocks and flows, other forms of capital (and flows) may be affected (Gleisner et al., 2011). These may create a positive effect (increasing one stock of capital may lead to flows of services that benefit other forms of capital) or a negative effect (increasing one form of capital may undermine others) (Gleisner et al., 2011). The use of a dynamic, non-linear systems model that considers the entire system to include the economy, society, and nature that considers both the stocks and flows is required to help understand progress toward societal wellbeing (Costanza et al., 2016). An example of a full dynamic stock/flow model is shown in Figure 23. This model captures the underlying systems dynamic needed to assess interaction over space/time, including stock/flows and cause/effects (Costanza et al., 2016).

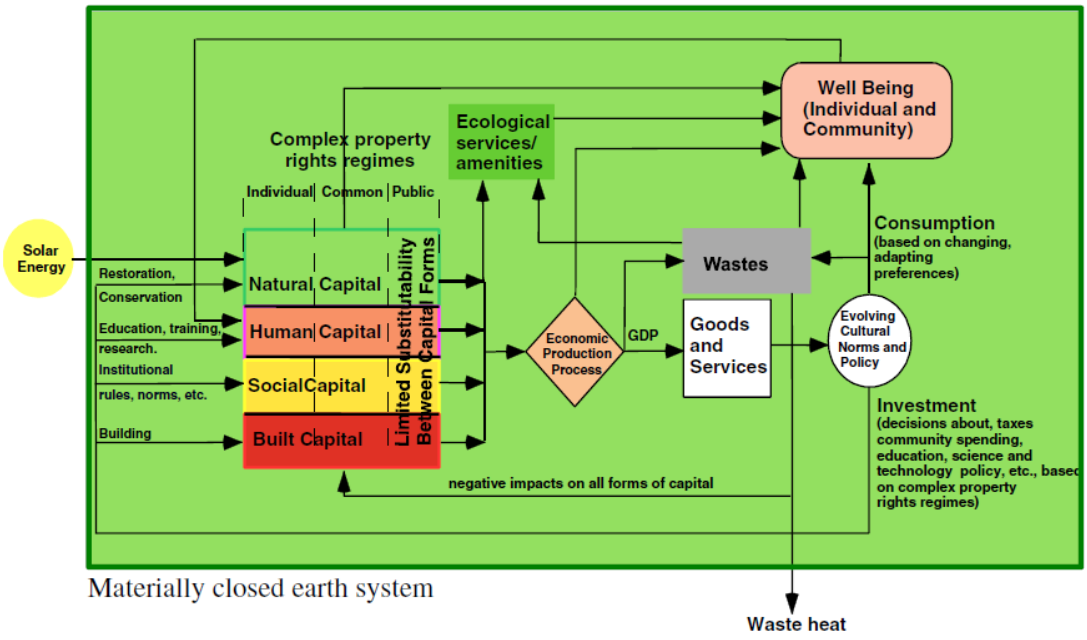


Figure 23. Example of wellbeing stock/flow model for the whole system, reproduced from Costanza et al., 2016

There has been significant econometric work looking at the interaction between two aspects at a time (King, 2018). This could be the interaction between health and income or health and life satisfaction or education and social connection. This type of work is significant for identifying the factors that contribute to different aspects of wellbeing and finding some of the connections between those different aspects (King, 2018). However, such measurement does not let us experiment with different settings nor allow us to understand their interactions. Most of the current and historical work is theoretical and only brings one or two aspects of wellbeing together, most commonly growth or income and the environment (King, 2018). The use of stock and flow in the NZ LSF also portrays how risk and resiliency are captured. Shocks to the system place pressure on the ability of a nation to either absorb the impact of the shock,

enable a fast transition out of the shock or severely impact wellbeing over a long period depending on the amount of capital stock and rate of flow (Chapter 2: Figure 10).

The use of social capital in a stock-flow model also provides some challenges as some authors have pointed out that social capital is different to other capitals as it cannot be stored or saved for the future but rather needs to be maintained or nurtured. The New Zealand Treasury does not see this being a barrier if we are clear on the definition and use of social capital, noting 'as long as we are clear about the limitations of the metaphor, the concept of social capital provides a useful way of bringing economic, sociological, psychological and political theories together to jointly explain developments in individual and societal wellbeing' (Frieling, 2018).

A model developed by King , integrates environmental, social, and economic factors, and associated externalities, as essential and complementary influences on wellbeing (Karacaoglu et al., 2019). This model includes all eleven aspects of the OECD's "How's Life?" framework of wellbeing, and is intended for implementation in a computational form for use in policy analysis (King, 2018). It is a top-down stock-and-flow model that includes a Computable General Equilibrium (CGE) model of an open economy (Karacaoglu et al., 2019). This model details the behaviours of multiple household types, businesses, production processes, international linkages, and the role of government. The model consists of sets of direct and indirect influences on wellbeing and their interactions. The direct influences of wellbeing are simply the eleven components of the OECD Better Life Index. There are a number of supporting elements required to complete the model and accommodate a variety of policy and other experiments within the model. This includes the production sector and a government sector, as well as the interactions with the rest of the world (such as migration) (Karacaoglu et al., 2019). Many of the interactions between different influences on wellbeing occur in the "flow" equations of the model. These flow equations describe how the stocks (also called capitals) in the model change from one time period to the next, typically in response to changes in the stocks that relate to other influences on wellbeing (Karacaoglu et al., 2019).

5.2. Development of a Meso Level Performance Framework for Three-waters

5.2.1 **Limitations of Current Frameworks for Infrastructure Performance Monitoring**

Infrastructure (i.e. transport, wastewater, water, energy) has been identified in studies as providing the fundamental services that contribute to human wellbeing and have over time been developed in a fragmented manner and mostly managed independently (Otto et al., 2014). The issue around the use of sustainable variables to understand infrastructures influence on intergenerational wellbeing is further compounded by the complexity sustainable variables add to an assessment. Understanding the relationship and interactions between the variables is difficult as trade-offs, influences on the variables, and stocks and flows between the wellbeing's create a dynamic that is hard to model and understand. Investment assessments and decision-making frameworks and models tend to utilise technical, financial, and environmental indicators that are easy to measure and have easily obtainable data sources. It ignores variables that are hard to show their impact or hard to show the interactions between each other, such as social and cultural outcomes (Balkema et al., 2002; Morgan, 2006; Padilla-Rivera & Güereca, 2019; Padilla-Rivera et al., 2016; Wilson, 2020). The trade-offs between sustainable variables are also hard to assess because it is more of a political process rather than a scientific process (Balkema et al., 2002). This was identified by the Netherlands Scientific Council for Government Policy when they stated, "estimating environmental risks objectively or uniformly is not scientifically possible. To translate the concept of sustainability into an operative policy concept it is, therefore, necessary to make explicit normative choices in relation to identified risks and uncertainties" (WRR, 1994). The United Nations World Commission on the Environment (The Brundtland Report) (WECD, 1987) indicated that there are boundaries to development, "not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities…sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life".

The concept of sustainable development has become more prominent in the planning, design, and construction of infrastructure, with international and national policies putting more focus on defining what sustainable development means, setting targets, and developing policies to drive infrastructure development to more sustainable outcomes. To enable sustainable

development, planning mechanisms and initial decision-making need to embrace sustainable concepts and understand the implications on wellbeing. Litman and Burwell (2006) state in their work, "Sustainability planning is to develop what preventive medicine is to health: it anticipates and manages problems rather than waiting for crises to develop. Sustainable development strives for an optimal balance between economic, social and ecological objectives". Despite a growing interest in sustainable development, utilising sustainable variables and having consideration of the wellbeing's in decision making, few studies have provided a generic framework that can be used for wastewater, water or stormwater investment decision making (Padilla-Rivera & Güereca, 2019). Even fewer studies have tried to embed the use of social and cultural indicators.

Another challenge in assessment approaches considering the wellbeing's and capitals, is effectively considering indigenous values and their ancestral water rights (T. Morgan et al., 2012). A review of international and New Zealand examples of wellbeing monitoring products conducted by the Community and Public Health department of the Canterbury District Health Board (New Zealand) indicated that there is no one consistent framework used to conceptualise or monitor wellbeing in the international or New Zealand examples reviewed; most have been commissioned by the organisation for their own purposes and use (Community and Public Health, 2017). The review also identified two main areas frameworks tended to focus on, monitoring of sustainability, or progress toward sustainability of communities and monitoring of health and wellbeing of individuals in the community (Community and Public Health, 2017). The NZ Treasury also indicates that the NZ LSF is a framework for thinking about wellbeing at a societal level and not a framework to tell decision makers how to improve wellbeing (Frieling, 2018; Ormsby, 2018). The LSF focus on the macro level through 'public social capital' (societal wellbeing) and not on 'private social capital' (individual wellbeing) (Frieling, 2018) also limits the ability to understand decision making at the meso and micro levels. The NZ LSF does utilise the concept of human capital to focus on an individual's productive wealth, generally through the education and skill level of the population (Morrissey, 2018).

5.2.2 **Management Levels for Managing Wellbeing**

When considering developing a more holistic decision-making model for infrastructure, one needs to consider wellbeing from a wider perspective. The transference of capital (natural, human, built, or social capital) is limited by the finite resources of the world and society's desire to elevate toward our ultimate end. For example, *Daly's Hierarchy of Means and Ends*

helps us to understand how the transferability of capital moves from the natural base (ultimate means), to built capital (intermediate means), to social capital (intermediate ends), and to our highest good or wellbeing (ultimate end) (Daly, 2014 ; T. K. K. B. Morgan et al., 2012). The New Zealand Living Standards Framework (LSF) builds on this concept with the use of capital stocks and flows to help understand the impact of policy decisions on well-being along with understanding the level of risk and resilience of a people and country (Chapter 2: Figure 9) (Gleisner et al., 2011). The overall objective of the Treasury's LSF is for measuring wellbeing outcomes and the capital stocks at a national or macro level. The wellbeing framework can also be used to analyse the impact of policies and support national budget decision-making. It is doubtful, though, whether the stock model would be appropriate at a meso and micro level given the scale and particular investment question at these levels.

The development of a holistic performance monitoring framework for infrastructure not only requires the understanding of the transference of capitals to obtain a 'good life,' we also need to understand the spatial relevance. The spatial relevance needs to consider the scale of the analysis and its relationship to the infrastructure decision being made. Preoccupation with aggregate notional conditions hides the local or real human scale problems that need to be considered. Not understanding the spatial relevance can hide local conditions and relevance to more specific goals and indicators (Pacione, 2003). Pacione (2003) discusses the need to understand the scale and relevance and indicates that as the quality of individual life can be assessed at various levels so society can be assessed at different geographic scales ranging from individual through to group or international, national, regional and local levels. The risk in focusing on the macro (national) level is that the aggregated view does not necessarily correlate to reflect the life concerns of the individual, and the larger unit of enquiry, the greater the potential ignorance of variations from the mean position (Pacione, 2003). Mapping at the macro level is of value to provide direction to further investigation (Pacione, 2003) and identifying policy level wellbeing settings. However, more localised indicators are required to derive benefit in understanding and making decisions at a meso (regional/network) or micro (local/individual infrastructure) scale.

An example of a macro-level policy decision making could be the overarching rules, funding, national budget planning, and reporting requirements. Whereas, at the meso level, decision making can help operational design strategy, agency policy, and for helping local government to make long term and annual planning decisions for different utilities. At the micro-level this

policy decision making can help for service delivery, and evidence-based interventions. The interaction of the three levels is shown in Figure 24.

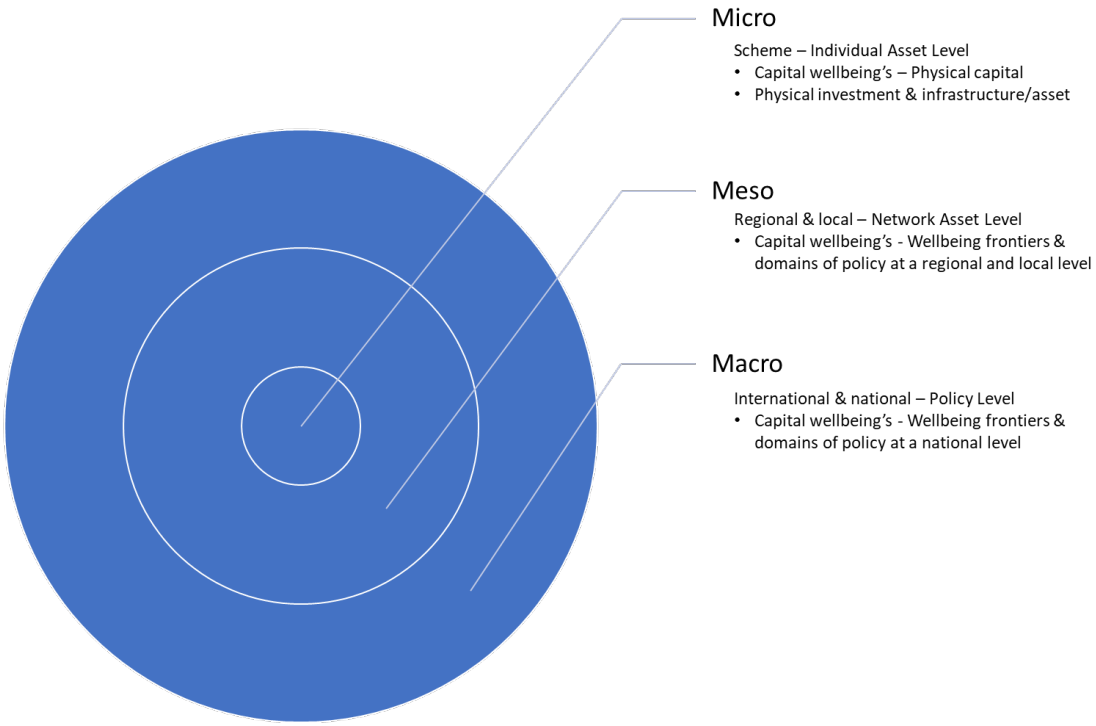


Figure 24. Macro, Meso, Micro levels for policy and infrastructure provision

5.2.3 **Building a Meso Level Infrastructure Decision-Making Framework**

Governmental frameworks such as the UN SDG, OECD's BLI, and NZ LSF focus on providing guidance around the domains of wellbeing for macro policy level decision making (Karacaoglu et al., 2019; OECD, 2011, 2017; The Treasury, 2019; UN, 2019), however, their linkages to localised infrastructure development are weak.

In developing a meso level decision-making framework, it is essential to understand how we define both wellbeing's as well as infrastructure services to start to shape a framework focused on regional/local policy direction, wellbeing outcomes, and infrastructure development. Otto et al. (2014) defined infrastructure services "as the provision of an option for activity by operating physical facilities and accompanying human systems to convert, store, and transmit flow entities." This definition is useful in understanding how we link the technical aspects of infrastructure, the services they provide, and delivery of wellbeing outcomes utilising the stock flow model such as the NZ LSF.

The NZ LSF utilises the concepts developed by (Karacaoglu et al., 2019), where the wellbeing capitals are developed within dimensions of a collective 'wellbeing frontier' containing the domains of public policy (see Figure 25). Through this model, the public policy aims to build intergenerational wellbeing through the capacity of the capitals to enhance the wellbeing frontier. The sustainability domain of the frontier links the other domains together, leading to intergenerational wellbeing (Karacaoglu et al., 2019).

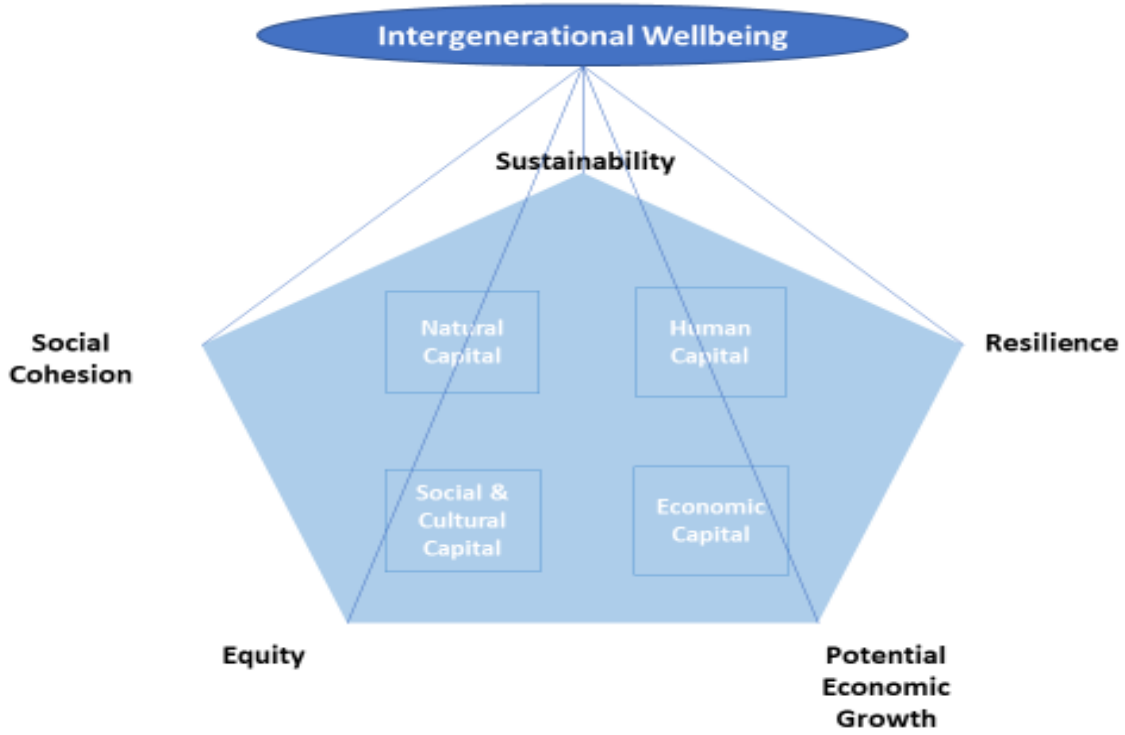


Figure 25. Wellbeing frontier, adapted from Karacaoglu et al., 2019

Karacaoglu et al. (2019) also stipulate a shift in direction from looking for optimal policy solutions to building resiliency in sustainable outcomes. This moves our thinking from a focus on identifying the perfect solutions or policy direction that balances social, environmental, and economic outcomes to one that helps nourish and build resilience to system shocks that threaten our wellbeing's and help us manage complexity and uncertainty (Karacaoglu et al., 2019) (see Figure 26).

To embed the wellbeing's into an infrastructure decision-making framework, we need a more integrated approach that allows us to link the macro, meso, and micro-interactions, and to consider the wellbeing frontier, the capitals, and the physical infrastructure and activity flow. The framework also needs to consider the growing uncertainty we are facing (i.e., climate change, technology, and growth pressures) and how we can enhance resilience.

Figure 26. Sustainability, resilience, and managing risk, adapted from Karacaoglu et al., 2019

A system-of-systems approach that considers the wellbeing frontiers, uncertainty and infrastructure, is required to model the long-term infrastructure performance over a wide range of future conditions that can take into account the interdependencies of infrastructure services and the complexity of challenges from resource availability, diversification, technology, changes in socio-economic systems, and responses to climate change pressures (Balkema et al., 2002; Otto et al., 2014). The New Zealand Treasury's work in developing the Living Standards Framework indicated the importance of thinking about multiple dimensions, specifically related to social capital, to ensure any model was dynamic enough to see how different combinations could produce different results and test optimal combinations over time (Frieling, 2018).

The systems approach for a three waters performance framework also needs to acknowledge the need to take technology into account in the assessment. Consideration of sustainability and infrastructure as illustrated in Figure 27 shows the interaction of sustainable variables on infrastructure (technology). Sustainable infrastructure that considers the interactions with its environment (physical, economic, and social-cultural) does not threaten the quantity or quality of the resources. Balkema et al. (2002) noted that through this interaction identified in Figure 27, the quantity and quality of the resources and the resilience of the environment (physical, economic, and social-cultural) change over time and space, the most sustainable technology

solution would change accordingly. This study looked at assessing the sustainability of wastewater treatment systems considering exergy analysis, economic analysis, life cycle assessment, and general systems analysis and helps to illustrate the interactions infrastructure assets (or technology as Balkema et al. (2002) indicates) role in the development of a wellbeing performance framework.

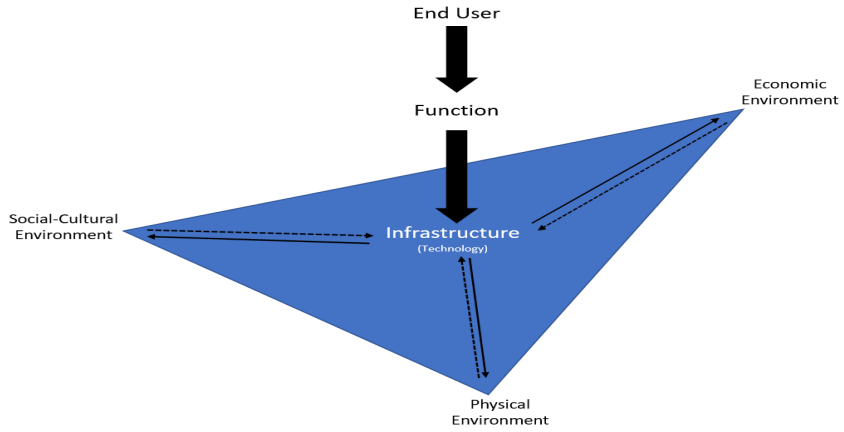


Figure 27. Infrastructure (technology) interacting with the environment, adapted from Balkema et al., 2002

5.2.4 **Proposed Meso Level Infrastructure Performance & Decision-making Framework**

A proposed novel framework has been developed for a meso level decision-making and performance model for three-waters infrastructure (drinking water, wastewater, and stormwater). The framework utilises the NZ LSF domains, UN SDG, the capitals, and integrates infrastructure (technology) (see Figure 28; refer to Table 7 for NZ LSF and UN SDG linkages). The proposed framework follows the NZ Treasury assessment of the NZ LSF and UN SDG linkages with several key differences to help clarify the links to a meso level framework focused on three-waters infrastructure. The novelty of the proposed framework in this research include:

- Separating the NZ LSF financial/physical capital into separate capitals comprising economic capital and infrastructure (or technology) capital. NZ Treasury conducted a series of discussion papers during the development of the NZ LSF financial/physical capital that alternative capital frameworks had separated the two capitals into economic and produced capitals, but the New Zealand Treasury desired to combine the two due to the links with risk and resilience (Janssen, 2018);

- Separating UN SDG 7 and SDG 9 into the infrastructure capital and retaining SDG 12 with the economic capital (this is splitting the SDG's link to the NZ LSF financial/physical capital);
- Providing links of SDG 5 and SDG 10 into the framework through the subjective wellbeing domain;
- Including SDG 17 with the civic engagement and governance domain; and
- Including SDG 6 in the health domain.

Figure 28. Meso Level Infrastructure Wellbeing Performance Framework

The layers of the framework are structured like an onion to indicate the layers from the central Wellbeing Dimension that includes the capitals (physical, natural, human, economic, and social/cultural) and the stocks comprising comprehensive wealth and the physical environment. The layer outside of the wellbeing dimension comprises the wellbeing frontiers and domains of public policy. This layer embraces the linkage of the NZ LSF domains (see Figure 29) and adds the additional UN SDG and NZ LSF Domain linkages identified above. Finally, the outer

layers signify the overarching drive toward sustainability and, ultimately, intergenerational wellbeing.

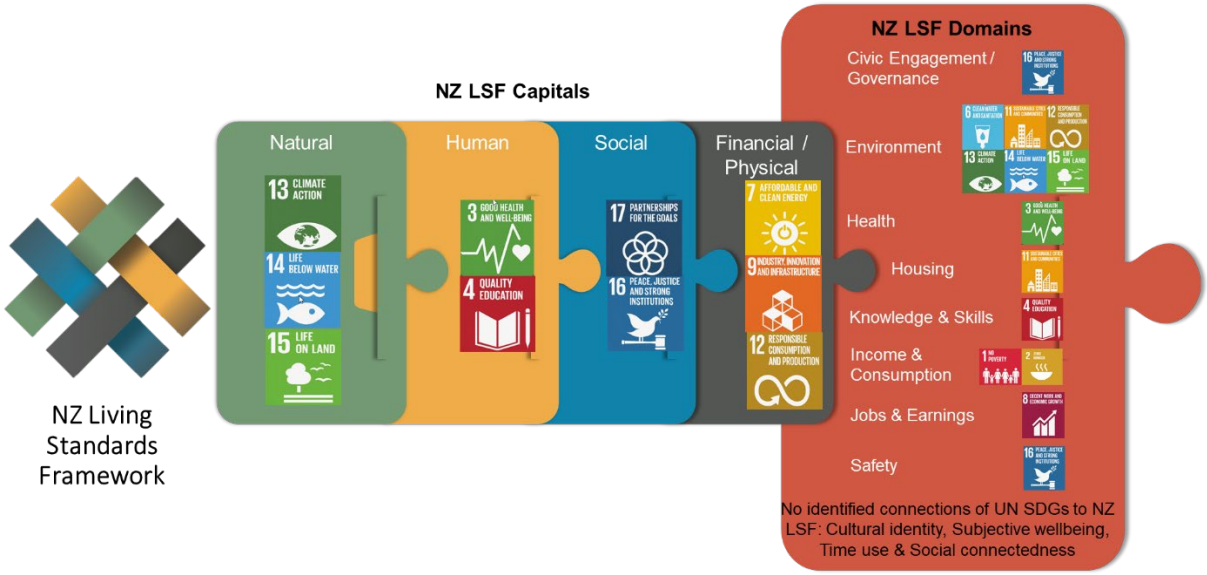


Figure 29. Linkages to NZ Living Standards and UN SDGs, adapted from Ormsby, 2018

The proposed framework graphically links the NZ LSF and UN SDGs while recognising the changes required when considering a meso level focus on three-waters infrastructure asset performance and decision making. It also portrays the interaction of the capital stocks, their flow in relation to each other, risks and resiliency of shocks on the capital stocks, and drive to Daly's ultimate end or, in this case, intergenerational wellbeing. This framework provides the foundation for the development work on the conceptual model and selection of subsequent indicators and measures. The framework will need to be further refined and tested, but it is built on the understanding that a more comprehensive approach is required to better link infrastructure development decisions to the technology or infrastructure assets used, the impact on the capitals, resiliency, regional/local policies, enhancement of resiliency and ultimately improved sustainability and intergenerational wellbeing.

Chapter 5 utilised the research from the previous chapters to support the development of a meso level wellbeing performance monitoring framework. The development of the framework defined the macro, meso, and micro levels, the role of the wellbeing capitals, and worked through the logic of incorporating the use of infrastructure (or technology) into a meso level framework that would allow for the consideration of sustainability and intergenerational wellbeing. The novel performance framework developed showed the connection of the NZ LSF domains and capitals and the UN SDGs. The layers of the framework are structured like

an onion to indicate the layers from the central Wellbeing Dimension that includes the capitals (physical (infrastructure), natural, human, economic, and social/cultural) and the stocks comprising comprehensive wealth and the physical environment. The layer outside of the wellbeing dimension comprises the wellbeing frontiers and domains of public policy linking to the NZ LSF domains and the UN SDG. Finally, the outer layers signify the overarching drive toward sustainability and, ultimately, intergenerational wellbeing. Chapter 6 will explore potential indicators and measures through consideration of existing macro, meso, and micro models and propose a conceptual model that could be utilised to show the interaction of different indicators and measures.

Chapter 6. Performance Metrics & Indicators

6.1. Context to Performance Metrices

Monitoring, measuring, analysing and evaluating infrastructure performance is a key component of understanding how infrastructure delivers on the expected outputs and defined outcomes. Identifying appropriate indicators and measures is a crucial part of monitoring performance. Understanding the difference between an indicator and measure is an important aspect in clarifying the makeup of a performance framework. Indicators in our context are defined as wellbeing components, units, structures or processes from which conclusions on the event of interest can be deduced, while measures are the properties or substance of the indicator to which a magnitude can be assigned (Heink & Kowarik, 2010). Asset managers and decision-makers need to determine the indicators for what needs to be monitored and measured, the methods for monitoring to ensure valid results, when the monitoring shall be performed, and when the results should be analysed and evaluated (ISO, 2014c). The evaluation and reporting of this measurement need to include infrastructure asset performance. This includes financial and non-financial performance and the effectiveness of the infrastructure asset management system (ISO, 2014b, 2014c). Indicators need to improve the understanding of successful performance, identify areas of improvement, and consider the relationship and alignment between different indicators (ISO, 2014b). The ISO Standards on asset management stress the need for organisations to have processes in place to ensure systemic measurement, analysis and evaluation and that the processes in place account for (ISO, 2014b):

- ‘Setting of performance metrics and associated indicators, e.g., condition or capacity indicators;
- Confirmation of compliance with the requirements;
- Examination of historical evidence;
- The use of documented information to facilitate subsequent corrective actions and decision making.’

Defining indicators that make up the measurement and subsequent evaluation and reporting is critical as selecting sustainable solutions and outcomes will be based on the indicators selected (Balkema et al., 2002). This is further exemplified when considering indicators used in a

wellbeing framework looking at intergenerational wellbeing and infrastructure asset performance. Balkema et al. (2002) indicates in their work that, 'while economic, environmental, and social-cultural indicators give insight into the efficiency of the solution, the functional indicators determine the effectiveness of the solution'. These functional indicators, defined in this research as the 'discrete framing of outcome values and purposes through which sustainability indicators can be classified (King, 2016),' can also be considered constraints on the system (Balkema et al., 2002). The use of metrics and indicators with social and cultural variables has been identified as a key area of difficulty in many studies. Unlike economic and environmental indicators, social and cultural indicators are hard to quantify (Padilla-Rivera et al., 2016). The New Zealand Treasury's LSF work has helped overcome the difficulty of quantifying social indicators. Figure 30 shows the conceptual model of social capital indicating the connections for key inputs (determinants) and outputs (social capital elements) that drive wellbeing outcomes (Frieling, 2018).

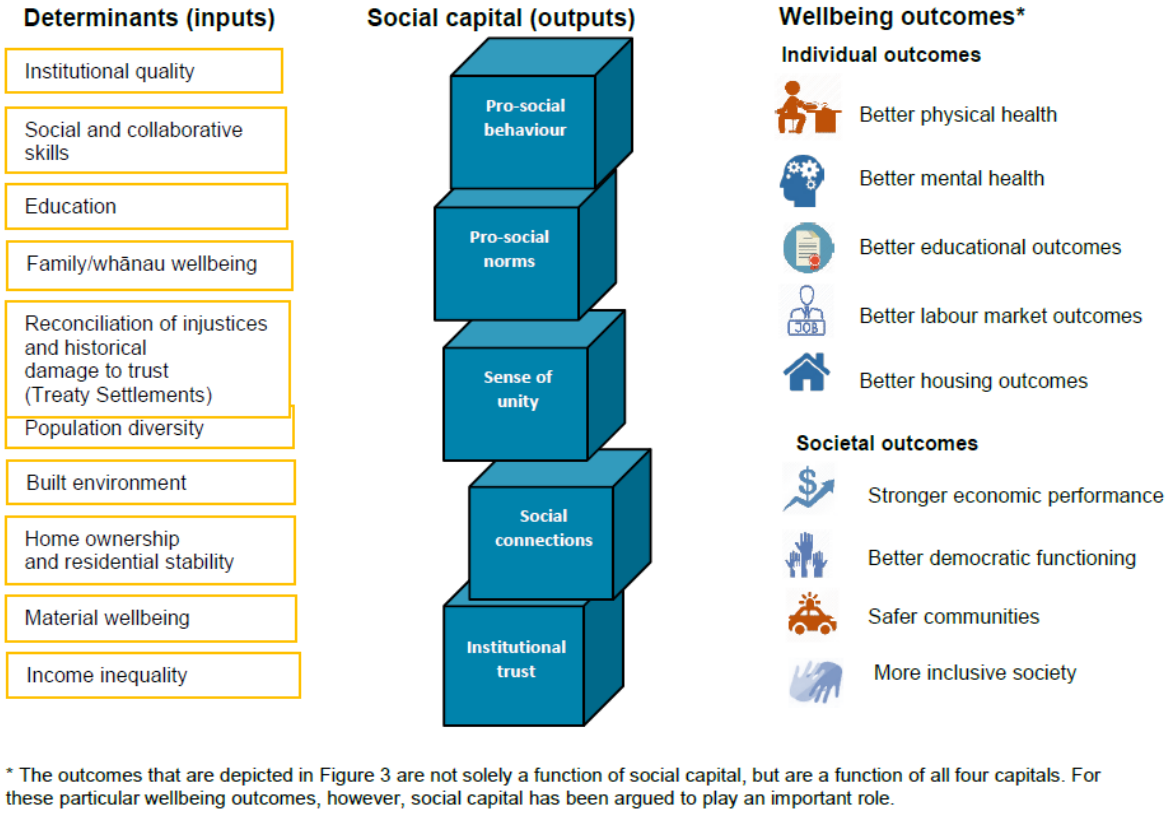


Figure 30. New Zealand LSF Conceptual Model of Social Capital, reproduced from Frieling, 2018

Assessments conducted on three waters infrastructure assets struggle to provide a comprehensive integrated assessment considering multiple complex viewpoints or interacting indicators and measures, especially regarding sustainability or assessment of wellbeing outcomes. Three-waters sustainability assessments do not provide for multiple dimensions and interactions of sustainability and usually only evaluate a single stage of the entire lifecycle (Padilla-Rivera & Güereca, 2019). The measurement of social wellbeing indicators also tend to focus on the absence of wellbeing and not the provision of wellbeing (Favager, 2019). Harmsworth (2011) reinforces this perspective in his study of scientific and cultural approaches for monitoring stream and river health. It illustrated the importance of using both monitoring approaches and indicators to show and communicate different perspectives, values, and desires and not just use indicators to show weaknesses and fallacies.

Padilla-Rivera et al. (2016) considered a methodology to assess social concerns related to wastewater treatment facilities (WWTF) and proposed 25 indicators for measuring the social performance towards more sustainable outcomes (Figure 31 and Figure 32). This work was further refined into Sustainability Evaluations of Wastewater Treatment Systems (SEWATS) model that utilised 18 indicators in a methodology considering environmental and social lifecycle assessments utilising fuzzy logic tools and lifecycle assessment (Padilla-Rivera & Güereca, 2019). To deal with the uncertainty of using social indicators in these studies Padilla-Rivera (2016) suggested analysing stakeholders at the local level and employing a scoring system to improve data assessment based on internationally accepted targets to avoid subjectivity due to ideological elements. Padilla-Rivera (2019) notes that the use of fuzzy logic in the SEWATS allows for the quantification of impressions and uncertainty as fuzzy logic can deal with the vagueness and ambiguity of human judgement. They also note that using the lifecycle assessment framework enables a robust evaluation of the entire lifecycle (material/energy used to disposal). The SEWATS metric utilises lifecycle assessments to evaluate sustainability dimensions and fuzzy logic analysis to normalise and aggregate qualitative and quantitative indicators to develop a sustainability ranking for wastewater.

This section showed the importance of identifying clear indicators and measures and their interaction within a decision making / performance framework or assessment tool. They provide some insight into the challenges and ways of tackling the complexity of integrating technical, social, economic and environmental factors but also highlight the further challenge of understanding wellbeing indicators that would focus on the quality of life and utilise subjective and objective indicators.

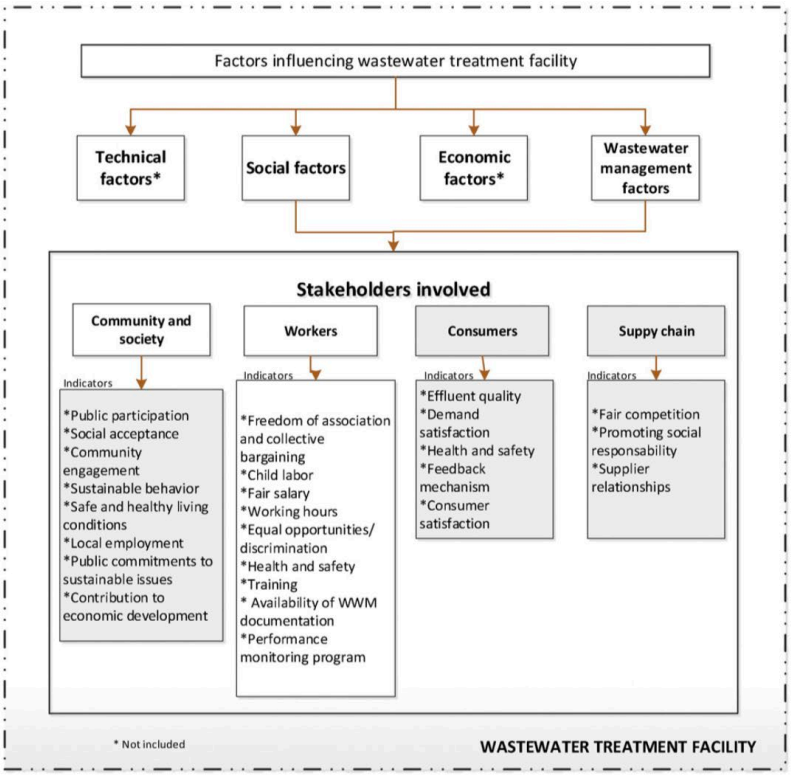


Figure 31. Wastewater Treatment Facilities – factors, stakeholders, and indicators, reproduced from Padilla-Rivera et al., 2016

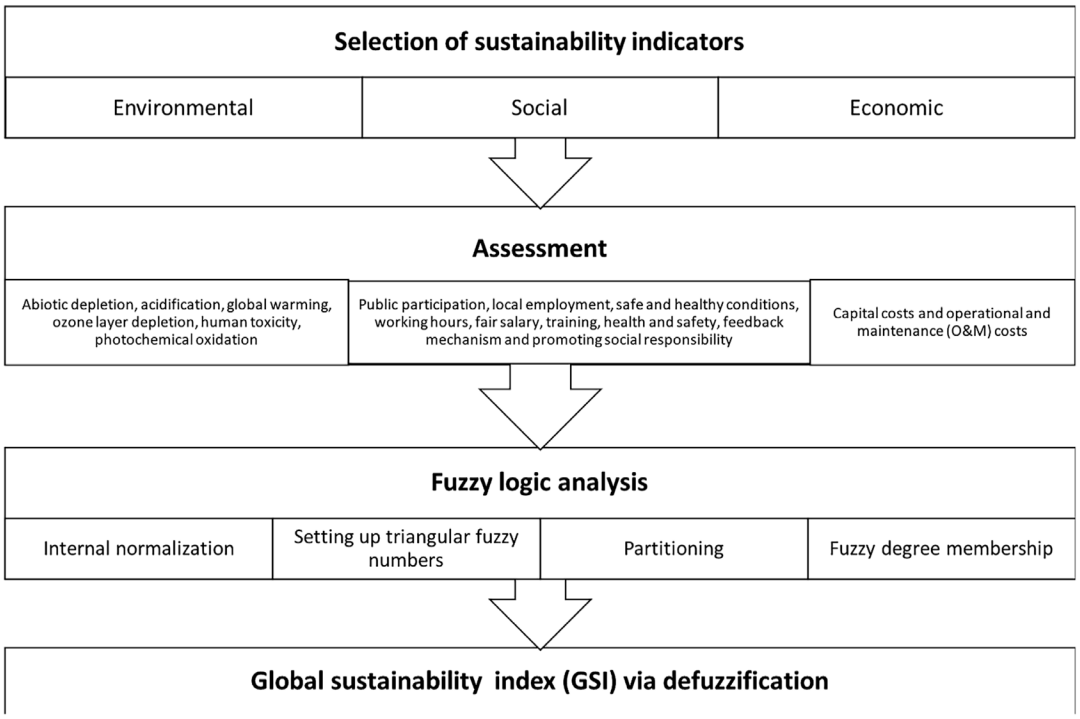


Figure 32. Sustainability Evaluations of Wastewater Treatment Systems (SEWATS), reproduced from Padilla-Rivera & Güereca, 2019

6.2. Consideration of the Quality of Life and Objective and Subjective Indicators

The quality of our environment and the impact this has on the wellbeing of human life is a modern-day concern (Pacione, 1982, 2003). Pacione (2003) considered the social geographical approach into the quality of life and urban environmental quality. The research developed a five-dimensional model for quality of life considering a social geographical perspective. A key point discussed in this work was around the 'paradox of affluence' where the importance around life quality has increased proportionally with technological progress and increases in income. The quality of life is not simply about material wealth. The growing awareness and importance of other factors, like social, political and environmental factors reflect more adequately on the society's overall health and wellbeing (Pacione, 1982). Pacione defines the meaning of the phrase, 'quality of life,' as the 'conditions of the environment in which people live, (air and water pollution, or poor housing, for example), or to some attribute of people themselves (such as health, or educational achievement)'. It is this relationship between people and their environments that is the question when trying to understand the degree to which people live in harmony or not with the environment (Pacione, 2003). The concept of 'territorial social indicators' has been developed by geographers to identify and analyse socio-spatial variations in the quality of life ranging from global to local geographic scales (Pacione, 2003). Most of the work in this area has utilised objective social indicators from primary field surveys or from analysis of secondary census-based data. This work provides insights into the extent and distribution to better understand questions like city deprivation. The use of subjective social indicators has expanded the field to help understand the liveability of a place. Pacione (2003) considered the contrast of the objective definition of urban environmental quality to urban liveability. He notes that urban liveability is not objective and is relative rather than absolute in terms of a definition and is dependent on the place, time and purpose of the assessment and the value system of the assessor. It is 'not an attribute inherent in the environment but is a behaviour-related function of the interaction of the environmental characteristics and person characteristics'. This work pulls together the thinking that it is as important to consider the environmental quality from an objective, 'on the ground', perspective as well as the environmental quality, 'in the mind', perspective (Pacione, 2003) and that aggregate national conditions hides the local situation where real individual problems occur (Pacione, 1982). This work has also been reinforced through Harmsworth (2011) where the use of both subjective cultural indicators considering Māori values and objective technical

indicators were shown, when used together, provide a more holistic view in considering environmental health of waterways as well as community health.

The scale that is being considered is another important aspect to understand, as it is possible that assessments at one level may have little correlation to another level (i.e., local, compared to national scales). Deciding on a scale will inherently compromise what is ideal from a conceptually desired perspective to what is practicable from data availability (Pacione, 1982). The five-dimensional model developed by Pacione (2003) built on the consideration of scale and considered several key conceptual and methodological issues for examining environmental quality in an urban environment, these included: choice of indicator type, indicator specificity, the scale of analysis, the 'fifth dimension' of social groups, the composition of life quality, the measurement conundrum, structural models of life quality, and theories of urban impact (see Figure 33 and Table 8).

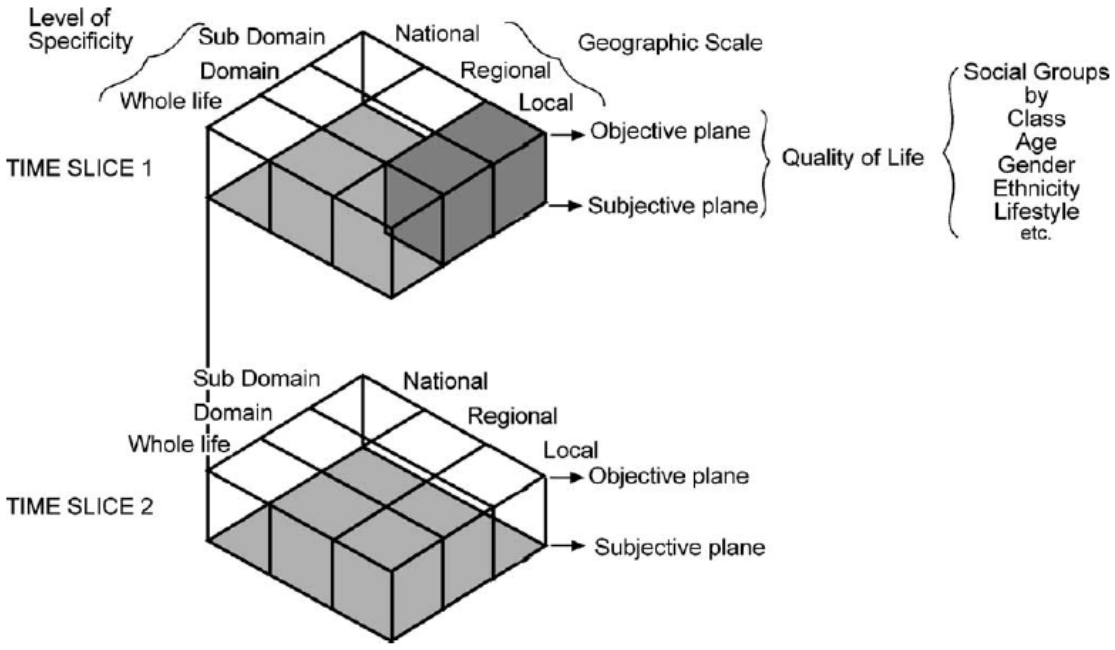


Figure 33. Five dimensional model for the quality of life research, reproduced from Pacione, 1982, 2003

Table 8. Defining indicators for urban environmental quality, adapted from Pacione (2003).

General key conceptual and methodological issues	Notes to consider
Choice of indicator/measure type	Must include two fundamental elements: internal psychological-physiological mechanisms. Understand interrelationship and distinction between objective and subjective indicators. *Understand the nature of the indicator, what type of indicator is it, i.e., measures physical, social, policy/regulations.
Indicator specificity	Classified according to their degree of specificity or generality. Pertains to the proportion of life space of an individual or group a particular indicator is relevant to.
Scale of analysis	Considers the spatial scale of reference and time, aggregated national conditions to real local human-scale. The spatial scale considers the relationship of the indicator at the national, regional, group, local, and/or individual level (i.e., macro, meso, micro).
The 'fifth dimension' of social groups	Centres on the quality of life experienced by different social groups in the urban environment. Plans of division (i.e., class, age, lifestyle, gender, and ethnicity), behaviour (public transport riders), interest (i.e. estate residents).
The composition of life quality	The fundamental aspects of society should be isolated as important components of life quality. The set of indicators chosen must be broad enough to include all the most important life concerns of the population whose wellbeing is being investigated.
The measurement conundrum	Recognition must be given to the issue that results may be influenced by (not inclusive): the selection of indicators; the method of aggregating indicators to one element; the weighting or non-weighting of indicators; and the type of measurement technique used.
Structural models of life quality	Life quality assessments must take place within a framework of a conceptual model. The simplest model indicates satisfaction with life in general is a weighted sum of satisfactions with different domains of life and in turn the domains are a weighted sum of specific satisfiers/dissatisfiers. A more complex model is Maslow hierarchy of needs model, where there are more basic needs over other needs and that until the basic needs are provided other considerations do not impact on overall satisfaction.
Theories of urban impact	Theoretical perspectives on the impact of urban environments on people. Human ecology, subcultures, environmental load, behavioural constraints, behaviour settings. These theories can be developed into a general model built around the concept of stress, as defined as 'increased wear and tear in the body as a result of attempts to cope with environmental influences'.

Pacione (2003) indicates in his research that the identification of life concerns and the determination of how people would react to them may be combined to predict people's sense of overall life quality and must take place within the framework of a conceptual model. The use of simple and complex models has been shown to provide some guidance on showing the interaction of domains for satisfaction on the assessment of the overall identification of wellbeing.

The identification of satisfaction and quality of life is connected to both individual and societal needs. Maslow (1987) identified that some needs are more fundamental than other needs and that until the basic needs are satisfied other considerations have little effect on the overall satisfaction. A simple additive approach to assess wellbeing based on the satisfaction of people will not work when considering the complexity surrounding what one person considers as a 'good life' and what a high level of wellbeing is compared to another person considers a 'good life'. Maslow's hierarchy of needs helps provide some context to the development of a structured model and a potential solution to address the issue of assessing the contribution of satisfaction domains to overall wellbeing by the use of a step-wise multiple regression analysis (Pacione, 2003). Pacione (2003) suggests that a general model based around the concept of stress, as defined as 'increased wear and tear in the body as a result of attempts to cope with environmental influences', can integrate five theories on urban impact. The stress model of urban impact (Figure 34) integrates the theories of human ecology, subcultures, environmental load, behavioural constraints, and behaviour settings (Pacione, 2003). This helps to understand the interaction of objective environmental conditions (i.e. pollution levels) and the characteristics of the individual (i.e. adaptation level or previous experience) (Pacione, 2003).

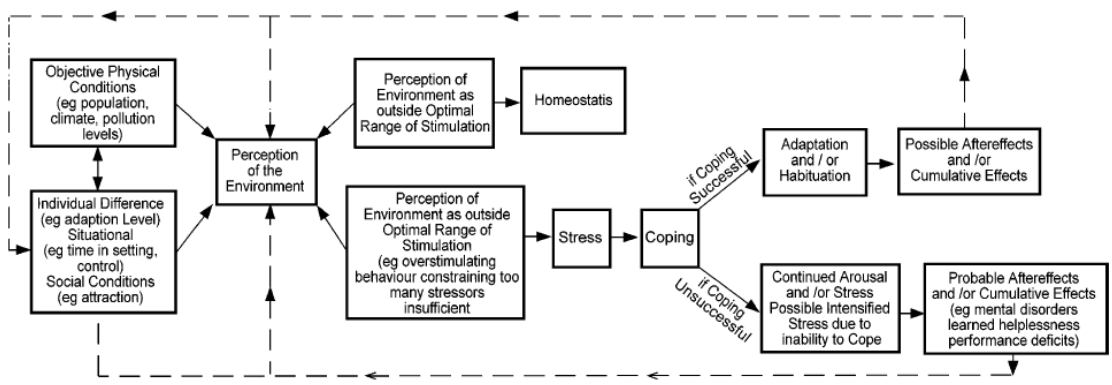


Figure 34. Stress model of urban impact, reproduced from Pacione, 2003

From an infrastructure asset perspective, we need to consider how subjective indicators utilised to understand wellbeing or quality of life would impact on a performance and decision-making framework. We also need to understand what the subjective indicators and measures will provide in helping to understand our decisions on wellbeing. In this respect, we need to understand the spatial scale (macro, meso, and micro levels) (Pacione, 2003), the level of motivational need (Hagerty, 1997b; Koltko-Rivera, 2006; Maslow, 1987), and the time scale we are looking to assess or understand (Hagerty, 1997a).

In developing a conceptual model that helps us link and test the selection of indicators and measures to a wellbeing framework Pacione's (2003) stress model and five dimensional model for the quality of life helps us to understand the linkages of spatial references like the macro, meso, and micro levels while Maslow's hierarchy of needs helps us to reference the link of motivational needs over a timescale (Hagerty, 1997a). Maslow's hierarchy of needs has been mainly used to assess how individuals develop. However, researchers have also considered how the motivational theory describes how nations develop and improve their quality of life (Hagerty, 1997a). Hagerty's (1997a) research considered Maslow's hierarchy of needs theory at a national level and if it could predict the development of quality of life in countries over time. He looked at data sets for 88 countries over 35 years with results that confirmed some parts of Maslow's theory, mainly around the time trajectories for most of the measures showing significant increase over the last 35 years, and that the sequence of actual need fulfilment is significantly correlated with Maslow's hierarchy predictions. It also showed that the mechanism of growth tends to be positive, not negative, as originally suggested by Maslow, correlated with growth in other need areas in the same year. The research noted that Maslow's theory has shortcomings when applied to a nations' quality of life as it does not consider conditions outside of the individual (i.e., environmental health, poverty in minority groups). This research shows both the usefulness of incorporating the concept of needs into a spatial indicator model looking at wellbeing, as well as limitations to areas outside of the individual.

6.3. Consideration of Micro, Meso, and Macro Scales in Performance Measurement

The concept of wellbeing is complex, multi-faceted, and any indicators used to describe wellbeing are subject to value judgements and can make the underlying issues become clouded (King et al., 2018). It is essential to consider the whole system using a multi-dimensional set of indicators to fully understand the integrated relationships and find where there may be gaps

and potential solutions (Balkema et al., 2002) and to consider the interaction of the indicators across spatial reference points of scale (Pacione, 1982, 2003), this can be viewed from three vantage points of scale, the macro, meso, and micro levels (see Figure 35). The use of the three interacting levels helps to better understand the system's dynamics where one dimension leading to positive changes may have negative feedback loops creating unintended consequences in other areas. It also helps us to understand how the indicators can be used as the levers for change and to what level these levers can be directly or indirectly attributed to the infrastructure (or the technology being considered). At the micro and partially at the meso level, indicators will have more of a direct correlation to what is being measured, they will have more direct control when used as levers for change and attribution can be seen to more directly connected as there is less complexity and the relationship between the infrastructure asset and outcome or output being measured is a direct relationship. At the macro and partially at the meso level, indicators will have less direct control and the relationship of attribution will be more difficult, this has been defined as a second order indicator. Second order indicators are proxy indicators where attribution cannot be directly connected to the macro outcome and the indicator measure is not a direct lever in controlling the infrastructure asset being assessed (see Figure 35 and Figure 38).

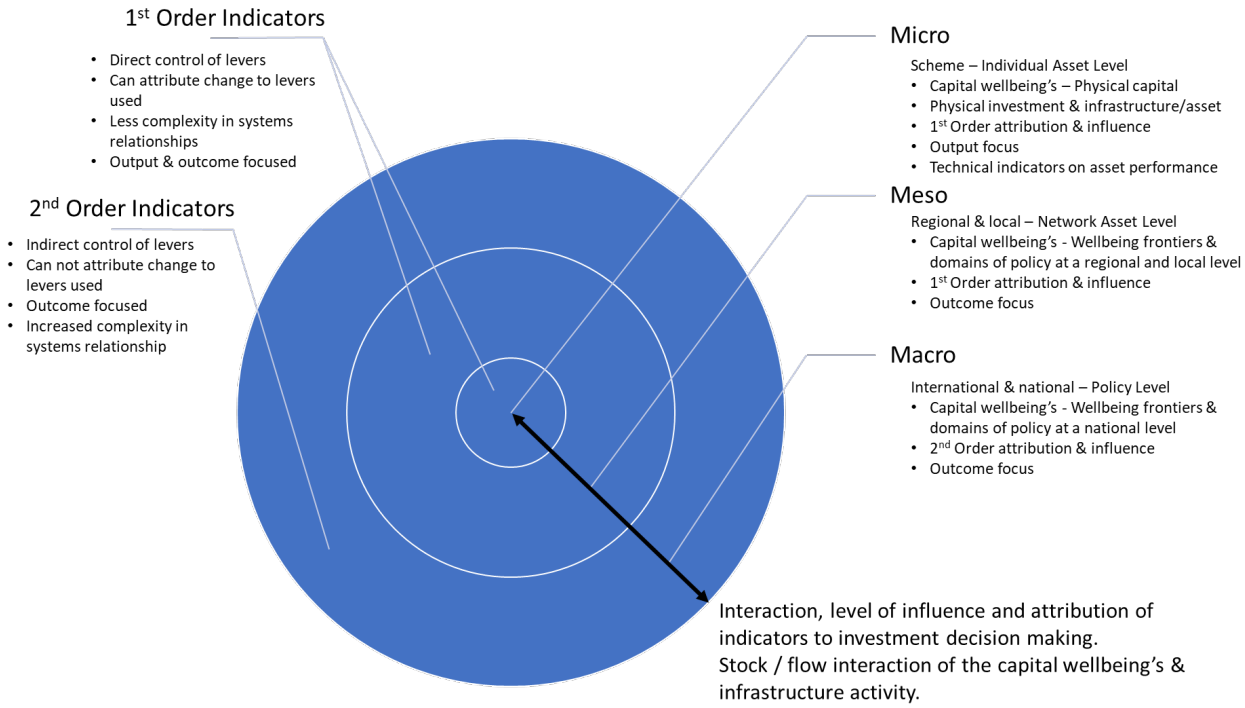


Figure 35. Micro, Meso, Macro levels and indicator order of attribution and interaction between the levels

The measurement and understanding of the wellbeing frontier also require the use of a systems approach as wellbeing is not linear or constant, and its impact on today can be different when applied over time. Defining indicators is critical as the selection of sustainable solutions and outcomes is based on the indicators selected. While sustainable indicators give insight into the efficiency, the functional indicators determine the effectiveness of the solution. The functional indicators can also be considered the constraints on the system (Balkema et al., 2002) helping set the level of stocks in the system. The selection of indicators that assess the quality of life includes two intertwined elements associated with the psychological-physiological mechanism that produces a sense of gratification and the external phenomena that engage this mechanism. The use of objective and subjective indicators provides decision makers with an appropriate way to measure societal and individual wellbeing. As such, objective indicators describe the environments within which people live and work, while subjective indicators describe how people perceive and evaluate the conditions around them (Pacione, 2003) (Prevention, 2020). There have been relatively few attempts to consider the inter-relationship between objective and subjective indicators related to understanding the quality of life or wellbeing. No single direct relationship between the two has yet to be demonstrated (Pacione, 2003).

6.4. Development of a Conceptual Indicator/Measures Model for Wellbeing Infrastructure Decision Making Framework

To practically apply the proposed novel meso infrastructure performance framework (see Chapter 5: Figure 28), a conceptual model has been developed that considers how the selected indicators and measures interact from a multi-dimensional perspective. This conceptual indicator/measure model considers the wellbeing dimension (Karacaoglu et al., 2019; OECD, 2011, 2017; The Treasury, 2019; UN, 2019), needs dimension (Hagerty, 1997b; Koltko-Rivera, 2006; Lester, 2013; Maslow, 1987), spatial dimension (Pacione, 1982, 2003), and a time dimension (Pacione, 1982, 2003). Table 9 shows the conceptual/methodological category (wellbeing, needs, spatial, and time dimensions), the definition explaining the intent of each category and the considerations for each dimension that provide the foundation for the conceptual model.

Table 9. Conceptual indicator/measure model

Conceptual / Methodological Category	Definition	Considerations
Wellbeing dimension	Identifying the broad range of fundamental aspects of society that are important components of life quality that are the most important life concerns of the population whose wellbeing is being investigated. Identifies the domains that contribute to the quality of life and the ability for people to live the lives they want to live.	• Natural capital • Social/culture capital • Human capital • Economic capital • Infrastructure (technology)
Needs dimension	Understand the interrelationship and distinction between physical and psychological indicators and how they relate to people and society. Understand the objective and subjective nature and the interrelationship. Provides the ability to understand the individual/societal level in achieving a quality life and ability of one to live the life they want to live as defined by the level of 'need'. Indicates the relative nature of the assessment in relation to developing and developed regions and the level of stress on the system (human and environmental).	• Need level: Basic needs – physiological, safety Psychological needs – belongingness, esteem Self-fulfilment needs – self-actualisation, self-transcendence • Objective vs. Subjective
Spatial dimension	Considers the relationship of the indicator at the national, regional, group, local, and/or individual scheme level	• Macro – international/national policy level • Meso – regional/local network level • Micro – group/individual asset level
Specificity level	Indicates how specific or general an indicator is and its relevance to a specific group. Helps define the proportion of life space of an individual or group a particular indicator is relevant to.	• Specific • General
Level of influence	Understand the level of influence and attribution the indicator provides to what is being measured.	• 1st order – direct control of levers can attribute directly to what is being measured and the outcome. • 2nd order – indirect control of levers, can attribute indirectly to what is being measured and the outcome. Proxy indicators.

Time dimension	Historical (background/context/setting the scene), current day, predictive future state and/or desired future state (to look backwards and inform what needs to be done in the present day and what levers need to be pulled)	• Historical
		• Current day
		• Future
		  • Projection
		  • Target

To show the multi-dimensional interactions the model is structured on an x, y, z axes with the wellbeing dimension on the x-axis, spatial dimension on the y axis, and needs dimension on the z-axis (see Figure 36).

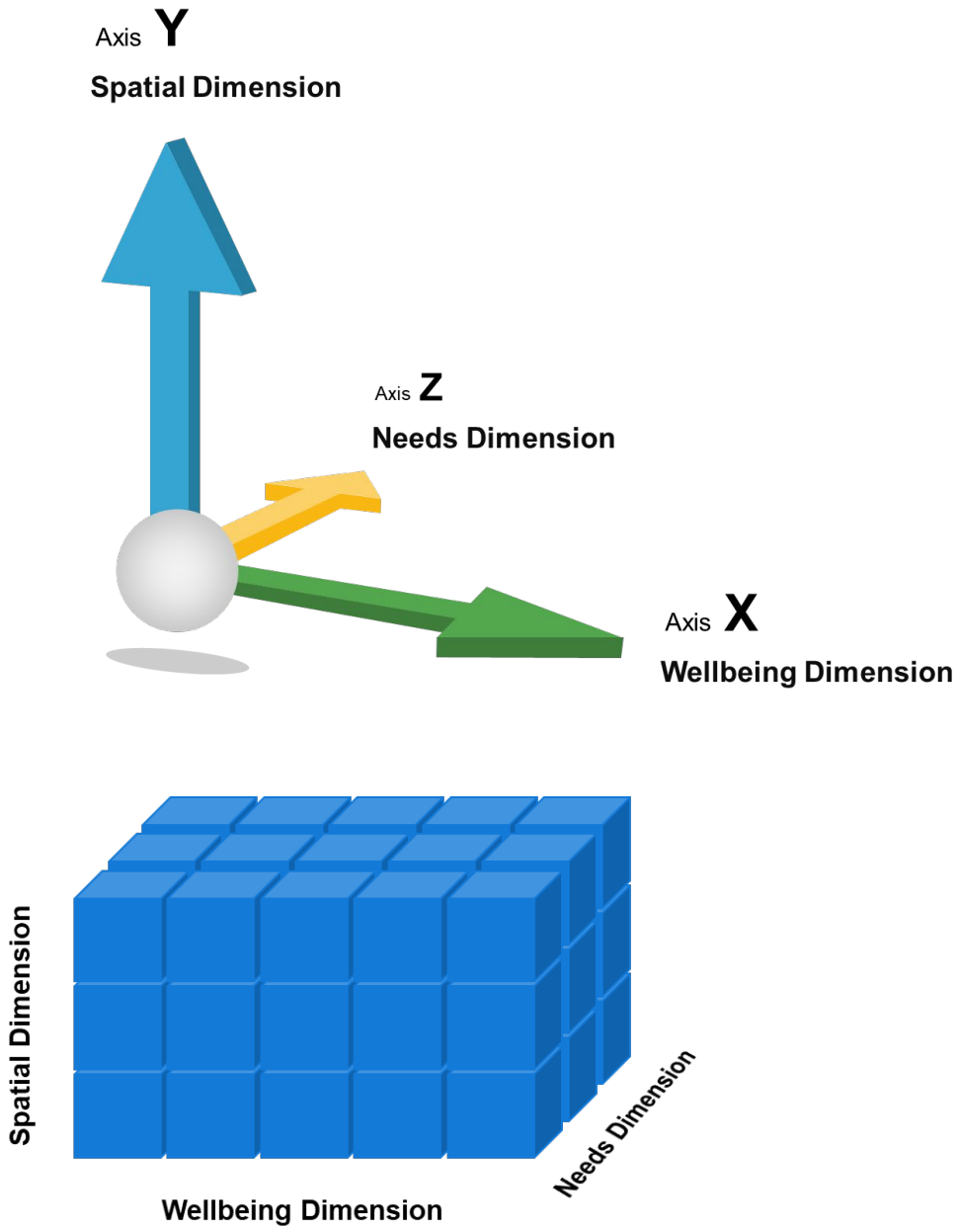


Figure 36. Indicator / Measure Conceptual Model (x, y, z axis)

The introduction of the time dimension is considered through taking 'slices' of the conceptual models x, y, z dimensions over the defined period. The time periods can be defined as historical, current day, or future projections or targets (see Figure 37). It is noted that a 'slice' in time is a static point defined by when the indicators are measured and reported, these being either actuals from historical or current data sources or desired future projections or desired targets.

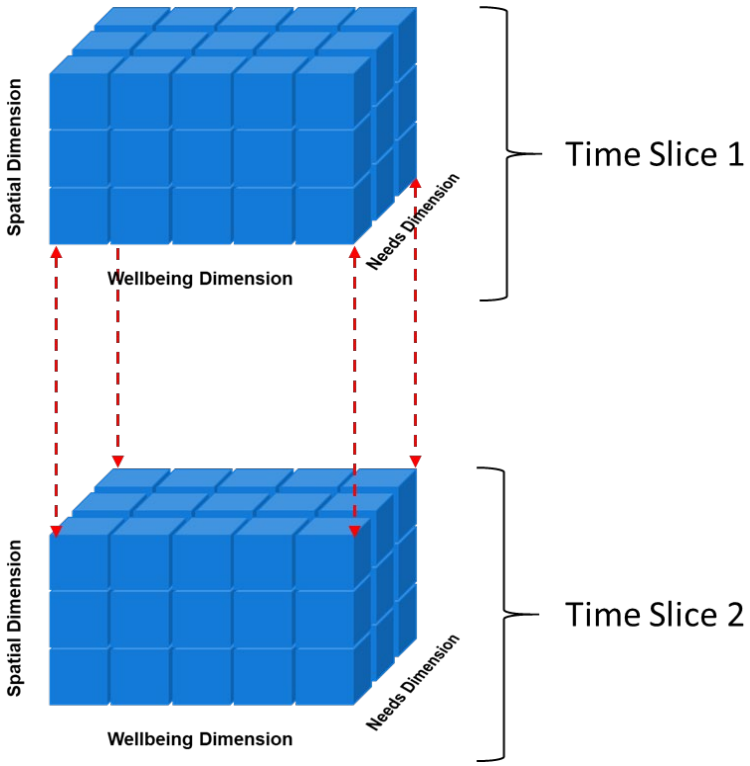


Figure 37. Indicator / Measure Conceptual Model with time dimension interaction

Each dimension on the x, y, z axis has multiple considerations that provide further clarity around the indicator's interaction and impact on the conceptual model. The spatial dimension is structured to show the interaction of the indicator/measures level of influence and attribution from micro, meso, to macro interactions. This dimension also shows how specific or general an indicator/measure is and its relevance to a specific group across the micro, meso, or macro levels and the level of influence it has (1st or 2nd order).

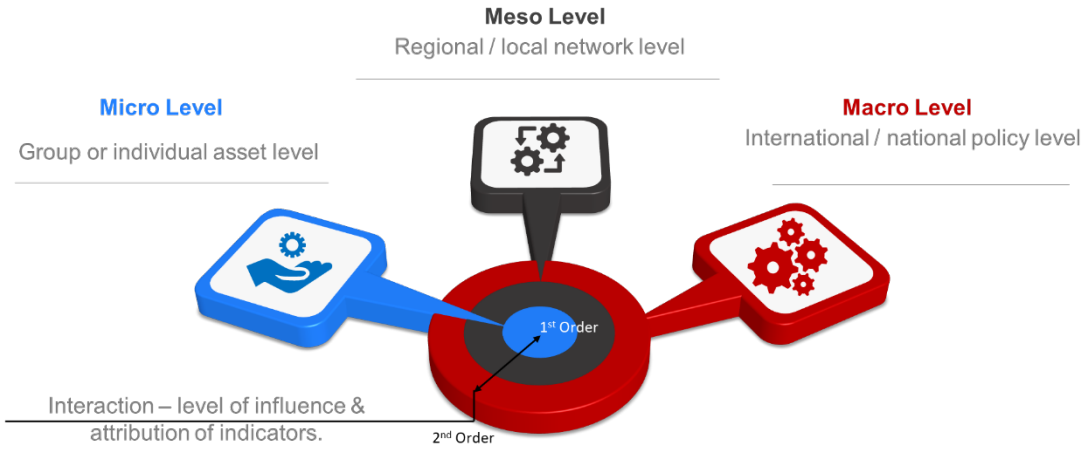


Figure 38. Spatial scale interactions - micro, meso, macro

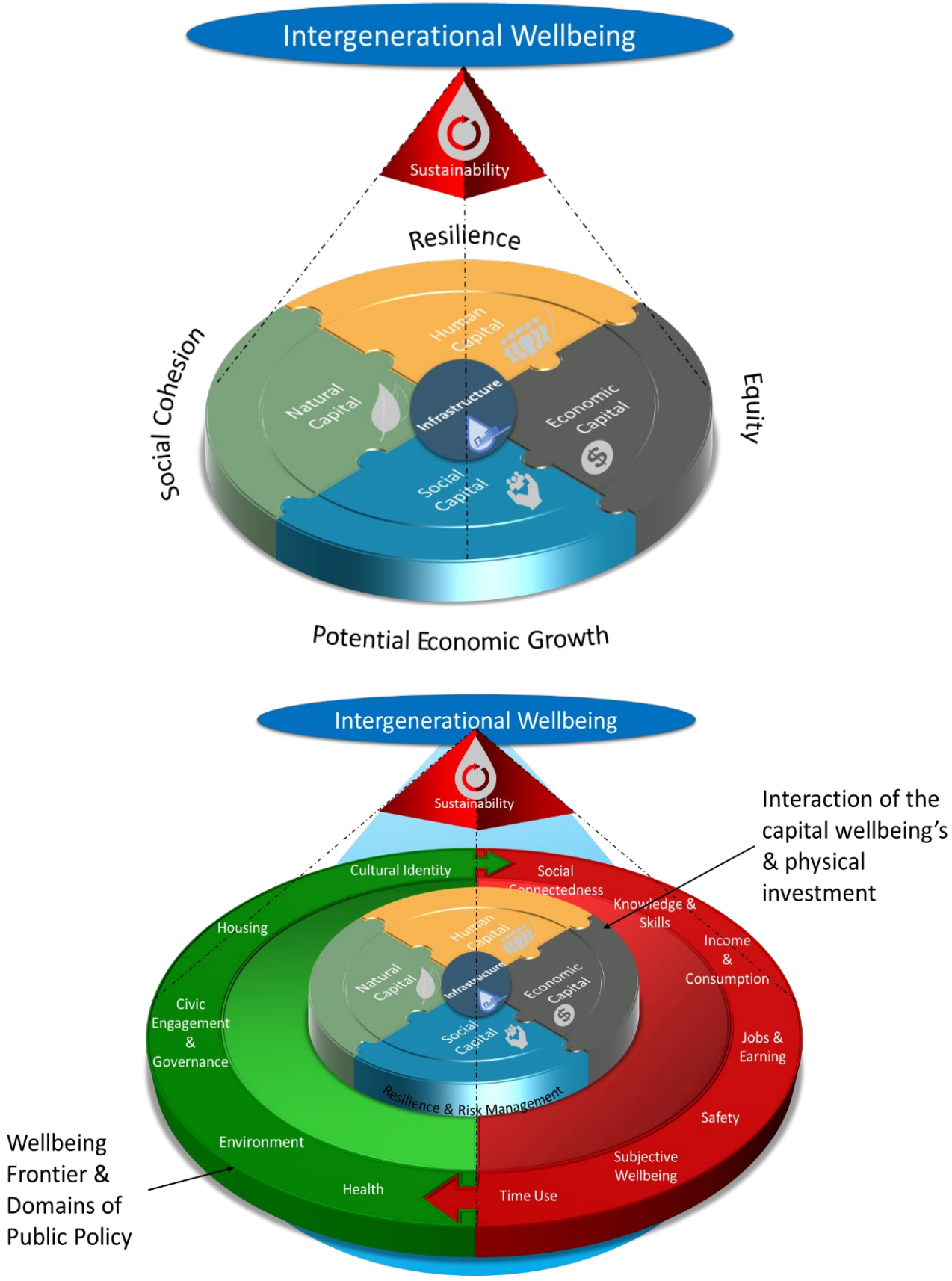


Figure 39. Meso Level Infrastructure Wellbeing Performance and Decision-Making Framework Connectivity

The wellbeing dimension is structured to consider the aspects developed through the meso level decision-making framework (Chapter 5: Figure 28 and Figure 39) through the use of the natural, social/cultural, human, and economic capitals, while incorporating an infrastructure element that ties into the specific decision making requirements of the model (infrastructure).

The needs dimension considers the quality of life and motivational need based on Maslow's Hierarchy of Needs (Chapter 2: Figure 7 and Figure 40) and the sustainable and equitable transference of capital as described by Daly's Means and Ends hierarchy (Costanza et al., 2016; Daly, 2014 ; T. Morgan et al., 2012). The social connections between individuals and society help promote a sense of connection and belonging, supporting social mechanisms that promote physical and mental wellbeing. These social connections are relevant to the development of public policy and the quality of an individual's life within a society. Macro level, policy, frameworks consider social and cultural indicators to understand the risks and opportunities of policy decisions (Frieling, 2018). The meso conceptual model also needs to consider the interaction at the macro level but focuses on the regional/network policy interactions that are related to and influence or impact on the micro-level infrastructure assets outputs. A meso level framework focused on three-waters infrastructure performance, and decision making needs to consider the social/cultural connections between individuals as well as the connections between the built, infrastructure assets, economic and natural environment. The needs dimension incorporates a structure that helps show the interrelationship between more objective indicators based on physical measurements to more subjective indicators mainly based around psychological aspects. This dimension helps to understand and define what is meant by a 'quality life' from obtaining basic needs where measures are more objective (i.e., clean drinkable water) and more easily obtained to satisfying higher level psychological and self-fulfilment needs where measures tend to be more subjective (i.e. satisfaction with water access and fulfilment of cultural values). The needs dimension also helps us understand the relationship between the 'ultimate end' of wellbeing (an equitable, sustainable, and high quality life), 'intermediate means' (efficient allocation and fair distribution; political, economic, and technology), and 'ultimate means' (staying within our boundaries of the natural environment) (Costanza et al., 2016) (see Figure 41).

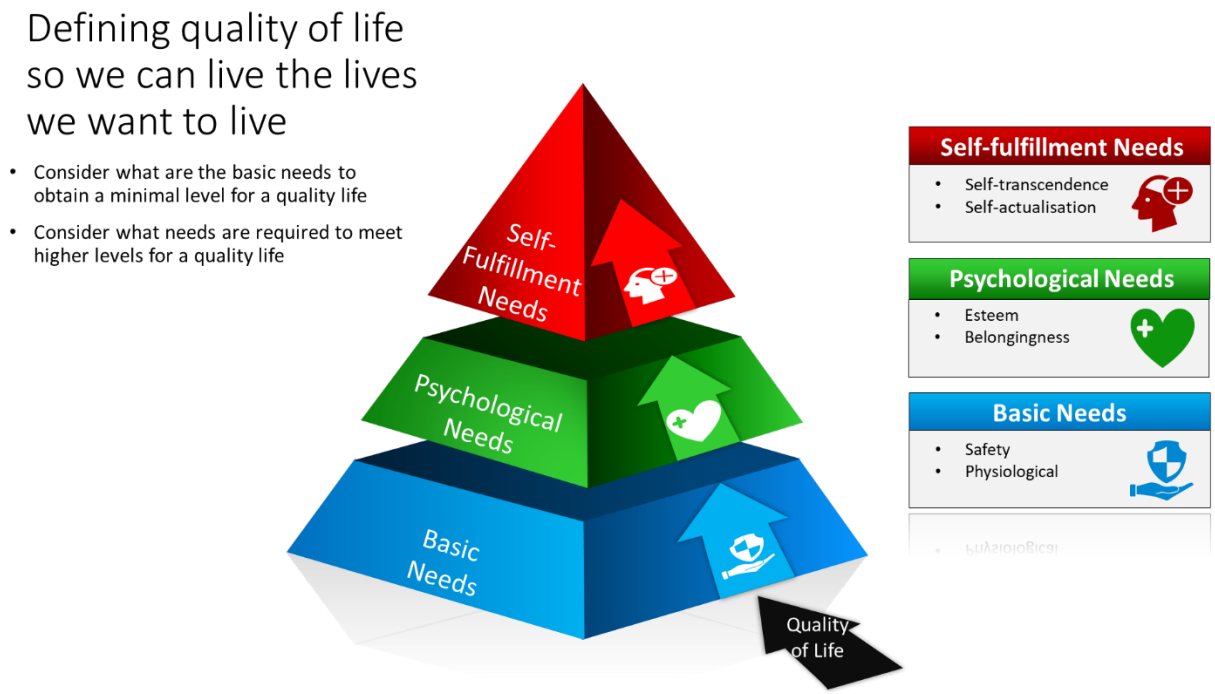


Figure 40. Needs Dimension and Quality of Life, adapted from Maslow, 1987

Figure 41. Means and Ends spectrum showing the three elements of sustainable wellbeing, reproduced from Costanza et al., 2016

Chapter 6 researched potential indicators and measures through consideration of existing macro, meso, and micro models. The chapter looked at the value of objective and subjective indicators and consideration of how these could be applied to a meso level wellbeing performance framework. The research in this area of exploration led to the need to develop a conceptual model that could be utilised to show the interaction of different indicators and measures on the wellbeing capitals in the novel wellbeing performance framework. Research

into the use of objective and subjective measures on the quality-of-life led to pulling in aspects of social geography. Pacione's (1982, 2003) work in developing a five dimensional model for the quality of life helped to guide the development of a conceptual model that incorporated the concepts explored in the thesis. The conceptual model developed identified four dimensions: 1. Wellbeing Dimension, 2. Needs Dimension, 3. Spatial Dimension, 4. Time Dimension. The three main dimensions being the wellbeing, needs, and spatial dimensions were developed into a cube model that was able to show the multi-dimensional interactions. While the time dimension enables the conceptual model to show the current and intergenerational performance through time slices or snap shots through identified time intervals. These intervals can show actual performance and identify desired targets or the proposed future state. The conceptual model developed helped to show the interrelationships between the three dimensions and to better understand how proposed indicators and measures could inform and influence infrastructure decisions and performance from a wellbeing perspective. Chapter 7 will expand on the research in Chapter 6 through identifying potential indicators and measures that can be utilised in the performance framework and conceptual model as well as develop a filtering process for indicator / measure selection and testing.

Chapter 7. Indicator Selection

7.1. Subjective and objective indicator examples

The identification of indicators is critical to provide decision makers with a holistic understanding of how effective investment in three-waters infrastructure is. Pacione (2003) emphasised that public and private decision makers must develop direct channels of communication to link scientific findings to policy objectives and that we need to embrace a multi-disciplinary approach to fully understand urban environmental quality and human wellbeing. The New Zealand Treasury work on developing indicators to measure wellbeing notes that appropriate measures of capitals depends on the desired coverage, purpose of the analysis, and data availability (Janssen, 2018). The conceptual model developed embraces the breadth of wellbeing dimensions and allows for indicators to be selected and tested to provide a holistic view of infrastructure wellbeing performance and impact of decision making and attainment of future targets for wellbeing.

The selection of indicators and measures in a three-waters framework need to consider all the dimensions of wellbeing (natural, social/cultural, human, economic) as well as functional indicators and measures associated directly with the infrastructure asset being considered. The NZ Treasury work on selecting indicators for the NZ LSF noted the challenge of the capitals being heterogeneous and that indicators could measure current or future wellbeing outcomes, they also noted that there was 'significant potential' for the same indicators to be able to provide for both describing the current wellbeing and allowing for monitoring wellbeing over time (Janssen, 2018).

Further research was conducted to better understand the types of indicators selected by different researchers looking at different types of frameworks for decision making or assessment of performance. Table 10 describes the different sustainable indicators Balkema (2002) identified in their research. The dimensions they used to categorise the indicators show an example where: functional, economic, environmental, and social/cultural (including institutional requirements, acceptance, expertise, stimulation of sustainable behaviour) were used. Balkema (2002) concluded their study with a key statement leaving the door wide open for future research, 'Although several researchers name decisive indicators, none of them gives a clear analysis of the trade-offs made, as such there is still limited insight as to which systems are most sustainable in different situations' (the use of 'systems' here indicates wastewater

treatment systems). Harmsworth (2011) considered the role of cultural and scientific monitoring of river health by assessing 25 sites, finding a correlation between the results from the two approaches (scientific and cultural). This research suggests that cultural indicators could be used in a similar manner to objective indicators to set environmental benchmarks (using a scientific approach). The study found that both objective scientific and subjective cultural indicators can be regarded as complimentary, reflecting two different knowledge systems (Harmsworth et al., 2011). Harmsworth's (2011) study considered Māori worldviews and incorporated the Māori value system in the study noting iwi/hapu goals to 'maintain the mauri of rivers and enhance the relationship and connection between iwi/hapu and place; maintain and enhance the customary use of resources in the catchment and revitalise matauranga Māori of cultural resource; improve access; maintain, protect and enhance the diversity and condition of cultural resources/taonga; and maintain and enhance Māori wellbeing.' Table 11 and Table 12 show the indicators used by Harmsworth (2011) and are an example of indicator selection and use, organised by cultural relevance, in this case, Māori Atua (ancestor with continuing influence or deity (Moorfield, 2021)) domains. The cultural indicators selected contained qualitative and subjective measures that were collected on observations from in-depth cultural and environmental experience and knowledge by local communities. These indicators allowed the study to understand both the health of the waterway as well as the health of the community. The results from the study showed that the indicators provided a holistic assessment of river health, identifying issues, and defining problems but noted the high reliance of training monitoring and collection personnel to ensure consistency and accuracy over the long term. In contrast the objective technical indicators were more robust as they could use methods and tools that were well tested and peer reviewed (Harmsworth et al., 2011). The two studies reinforce the need to consider both subjective and objective indicators that consider the range of capital wellbeing's as well as technical indicators to understand the health of the entire system. The use of different approaches provides indicators that can benchmark different perspectives, values, standards, regulations, limits, and guidelines as well as provide a better understanding for decision makers balancing conflicting pressures and resource limitations (both physical and societal) (Harmsworth et al., 2011).

Table 10. An overview of indicators used in the literature to compare wastewater treatment systems, reproduced from Balkema, 2002

An overview of indicators used in the literature to compare wastewater treatment systems

	Az	Be[a]	Bu	D	Em[a]	E	F	H	I	J	L	M	N	O	Ø[a]
Economical indicators															
Costs				C		S	P	S		E		S			E
Labour								S							
Environmental indicators															
Accumulation	P								T						
Biodiversity/land fertility	P			100		S	P							P	
Dissication														Cn	
Export of problems in time and space										T	S				P
Extraction	P														
Integration in natural cycles						S								P	
Land area required/space				1				S				S			
Odour/noise/insects/visual															
Optimal resource utilisation/reuse	P					S	P		St	S			P	P	
Water			S	1000		S	P	S	St		S			Cn	
Nutrients		V	S			S	P	S	St		S			Cn	
Energy		V	S	100	V	S	P	S			S	S		Cn	V
Raw materials		V		10	V	S	P	S						Cn	
Pathogen removal/health			S	1000		S	P	S							
Pollution prevention			S			S	P						P	P	
Emissions															
BOD/COD		V		1000	V	S		S			S	S			V
Nutrients		V		100		S		S			S	S			V
Heavy metals				1000	V	S		S							
Others		V			V	S		S							
Sludge/waste production		V		1000	V	S					S	S			V
Use of chemicals		V		10		S					S	S			
Technical indicators															
Durability			S			S									
Ease of construction/low tech													P		
Endure shock loads/seasonal effects								S						Cn	
Flexibility/adaptability			S			S		S							
Maintenance														Cn	
Reliability/security						S	P								
Small scale/onsite/local solution			S							Te			P		
Social–cultural indicators															
Awareness/participation						S		S		S					
Competence/information requirements						S	P								
Cultural acceptance						S		S							
Institutional requirements						S	P								
Local development			S												
Responsibility							P								

Source: Az—Azar, Holmberg, and Lindgren (1996), Be—Bengtsson et al. (1997), Bu—Butler and Parkinson (1997), D—DTO (1994), Em—Emmerson et al. (1995), E—ETC (1996), F—Finnson and Peters (1996), H—Hellström, Jeppsson, and Kärrman (2000), I—Icke and Aalderink (1997), J—Jacobs, de Knegt, Koedood, and Karst (1996), L—Lundin et al. (1999), M—Mels et al. (1999), N—Niemczynowicz (1994), O—Otterpohl et al. (1997), Ø—Ødegaard (1995).

Note: The numbers in the table indicate the used weighting factors, the abbreviations refer to the terms used in the publications; C—costs, Cn—concerns, E—environmental efficiency, P—principles for sustainability, S—sustainability indicator/factor/criterion, St—steering variables, T—target, Te—technical paradigm, V—variables in the LCA input-output table.

[a] LCA study.

Table 11. Cultural monitoring assessment framework with key indicators organised into Atua domains, reproduced from Harmsworth et al., 2011

Atua domains	
Ranginui (sky father, immeasurable universe)	Key indicators
Tangaroa (sea, coast, waterways)	Riverbank condition*[1]
	Sediment on riverbed*[1]
	Water clarity*[1]
	Water flow*[1]
	Water quality*[1]
	Shape and form of river*[1]
	Insect life (method, no. & species)
	Fish (method, no. & species)
Tāne mahuta (forests, birds, animals)	Riparian vegetation*[1]
	Catchment vegetation*[1]
	Bird life (method, no. & species)
	Ngahere/taonga (no. & species)
	Pest plants/animals (no. & species)
Haumia tiketike (wild foods)	Mahinga kai (no. & species)
	Traditional mahinga kai site*[2]
Rongomatāne (crops, peace, harvested resources)	Contemporary mahinga kai site*[2]
	Rongōa (no. & species)
Tūmatauenga (human made/human activities and conflicts/war)	Use of river*[1]
	Use of river margins*[1]
	Access to river*[2]
	Cultural site (descriptive)
Tāwhirimātea (air, wind)	Smell of river*[1]
	Weather*
Ora—Overall health	Feeling in puku*
Papatuānuku (earth mother, planet earth)	

*Indicators are assigned a score from 1 to 5. Scores are averaged to calculate a Cultural Stream Health Measure[1] and Mahinga kai score[2].

Table 12. Complementary monitoring approaches in the study of river and stream health, reproduced from Harmsworth et al., 2011

Monitoring approach	Skill requirements	Examples
Māori knowledge or culturally based		
Cultural impact assessment; iwi monitoring of cultural-heritage sites; iwi monitoring of contaminated sites; cultural health index; Māori wetland, ngahere and estuarine indicators; culturally based environmental indicators	Require in-depth Māori knowledge and understanding of particular environments and issues; understanding of Māori values, goals, and aspirations; good for problem definition	Māori values; cultural sites, mahinga kai, pā, kainga; cultural history; taonga lists; te mauri; uses and preparation of taonga; land management, development issues; cultural information systems; culturally based assessments of river and stream health; coastal survey and monitoring of marine environments
Community–scientific based		
Stream Health Monitoring and Assessment Kit; Waterway Self Assessment Form; community based environmental performance indicators; amateur surveys	Require moderate levels of technical input and skill but scientifically robust and part-value based; cost effective, relatively simple and short duration; good for problem definition.	Stream and river condition; community based indicators; community values; community coastal surveys; non technical assessments; school monitoring programmes
Professionally based		
Scientific or technical assessments; river and stream water quality monitoring methods; coastal survey and monitoring; archaeological survey; scientific environmental indicators; laboratory analysis	Require higher levels of technical input and skill, robust sampling strategies, analysis and interpretation; may be expensive and/or time-consuming; good for providing insight to solutions	Water/sediment quality; biological sampling including fish, macroinvertebrates, macrophytes, riparian vegetation, ecosystem processes; bacterial counts, pathogens; geographic information systems; satellite imagery; hydrology; groundwater survey; archaeological survey

As discussed in this research, the use of social and cultural indicators tends to be less well understood and harder to identify, especially when considering indigenous cultures. Harmsworth et al. (2016) work to improve understanding and use of co-governance, co-management, and co-planning around freshwater management tools and frameworks identified some management variable examples to maintain and/or enhance Māori cultural values; these can be seen in Table 13. A key element of this is the indication of using the Cultural Health Index (CHI) for freshwater bodies (Zealand, 2021). The CHI is a New Zealand wide tool that measures aspects of cultural importance to Māori regarding the freshwater environment, capturing the cultural health status of a waterway based on indigenous knowledge from the local area. The CHI score is made up of 'site status, mahinga kai (customary food gathering) status, and cultural water quality' (see Figure 42) for an example of the reporting from the CHI website) (Zealand, 2021).

Table 13. Māori cultural values linked to performance measures/tools and management variables (an example, reproduced from Harmsworth et al., 2016

Values	Objectives	Performance measures/tools	Management variables (examples)
Kaitiakitanga Mauri Mahinga kai	Set limits to restore the mauri of freshwater, cultural resources, mahinga kai areas (define standards/limits/bottom lines to support life-supporting capacity/ecological integrity for taonga spp. and habitats)	Monitoring such as Cultural Health Index and mauri assessment; identify change/trends in the state or mauri Abundance/condition of cultural resources, taonga spp., mahinga kai	Minimum flows Nutrient management/reduction Water clarity and sediment loads Habitat extent and condition Groundwater-surface water Connectivity Pathogens (e.g., *E. coli*) levels Stock exclusion Catchment management-land use

The Mauri Model embraces the use of wellbeing metrics and links them to mauri and the physical dimensions that represent the four wellbeing's. Morgan (2006) identified metrics for each of the wellbeing dimensions for social (community), economic (whanau/family unit), environmental (ecosystem), and cultural (hapū / clan group). These can be seen in Table 14. The metrics have been identified to represent the connective nature of the overall system through space, time, and connection of the people and earth. The overarching theme for each wellbeing dimension in the Mauri Model are (Morgan, 2006):

- **Social (community) –** 'The community at large includes non-Māori, Māori from other regions and the Tāngata Whenua. The community well-being dimension includes their general health and safety and includes the ability to accommodate future community needs such as land and water resources to satisfy housing demand or the creation of employment opportunities.'

- **Economic (whanau/family unit) –** 'Economic well-being is assessed in terms of the impact upon the mauri of the whanau (family unit). The family unit is chosen because it is ultimately at this level that economic decisions impact upon people.'

- **Environmental (ecosystem) –** 'Tāngata Whenua believe that the physical and spiritual integrity of the ecosystem is reflected by its mauri and the state of the environment. This includes all land, air, flora, fauna, and water.'

- **Cultural (hapū / clan group) –** 'The well-being of a particular environment, in particular the qualities of water within a catchment and how well managed it is, impacts on the identity, standing and authority of the hapū in a variety of ways. These include reinforcing the ability to continue in a guardianship role, the prestige associated with caring for visitors; maintenance of the hapū knowledge base through active reinforcement; the effective dissemination of knowledge to successive generations; and the integrity of all of these practices.'

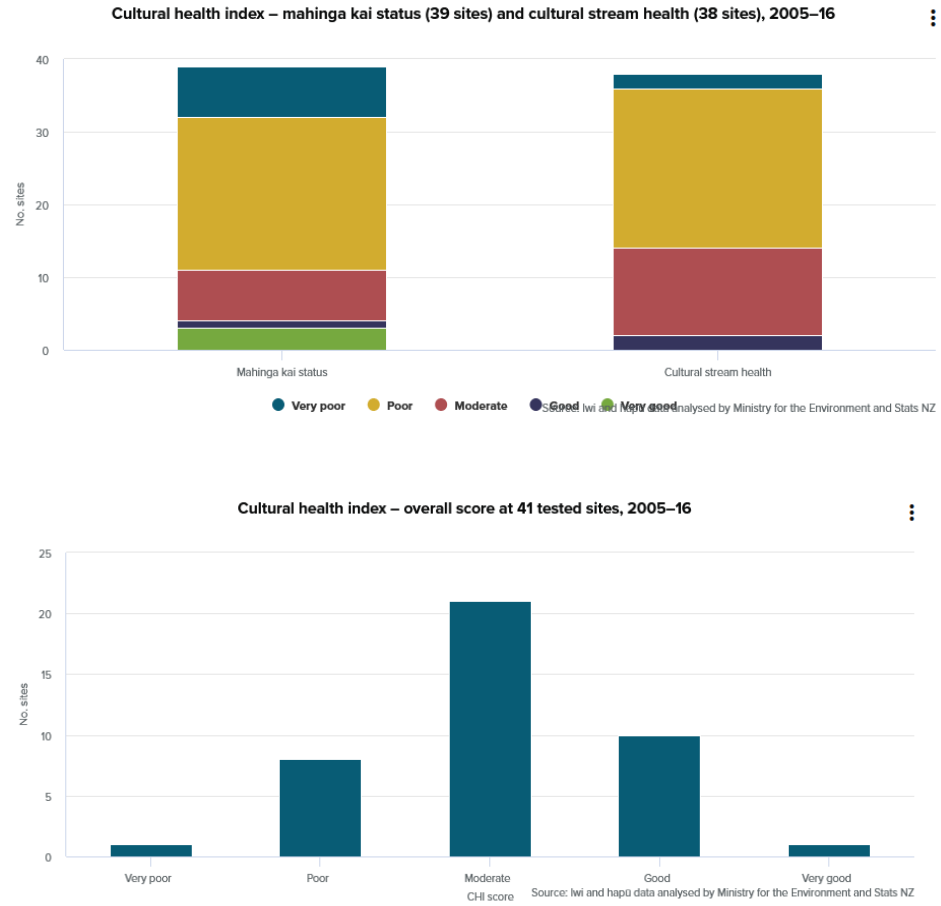


Figure 42. Cultural Health Index – reporting examples (2005-2016), reproduced from Zealand, 2021

The Mauri Model initially considers performance indicators independently from stakeholder bias and then introduces bias as part of the sensitivity analysis on the raw results (T. Morgan et al., 2012).

Table 14. Mauri Model Wellbeing Dimension Metrics, adapted from Morgan, 2006

Mauri Model Wellbeing Dimension	Metric
Social (community)	Threats to public health Loss of life Public safety Public recreational access Amenity value of public space Includes measures as mitigation
Economic (whanau/family unit)	Metrics need to understand the impact on the family unit as a measure of the direct personal effect as a result of a choice or action. This is usually measured in terms of economic impact experience as a direct fee (i.e., taxation). This impacts on a family to allocate financial resources on other items like food, heating, or housing. The economic wellbeing in this dimension tends to be best understood by engineering/asset managers when considering technical solutions and choices.
Environmental (ecosystem)	Threats to or loss of air quality and quantity Water quality and quantity Native species diversity (flora and fauna) Land quality and quantity Measures or outcomes as mitigation Consumption of energy Consumption of water Renewable and non-renewable materials Emissions to the air, water and land Intergenerational equity – the state of the environment as it is passed onto future generations is more important to this dimension.
Cultural (hapū / clan group)	Metrics for cultural wellbeing depend on the metrics for environmental wellbeing but with specific attention to the maintenance of hapū practices and relevance to intergenerational wellbeing.

The Wai Ora Cultural Monitoring Framework developed nine attributes (tohu – sign or symbols) as indicators that were of interest to Iwi (Wilson, 2020). These tohu were tested through a subgroup of the New Zealand Environmental Protection Authority that consisted of Government and Iwi representation, to establish if they could be used in a cultural monitoring framework (Wilson, 2020). The nine tohu or attributes are (Wilson, 2020):

- Vegetation
- Water
- Soil
- Air
- Animals
- Sacred places
- Metaphysical attributes
- Special places
- Urban impact

Combined results of the attributes provide a grade that gives direction to the individual tahu's wellbeing ('i.e., animals relates to all living creatures within the catchment; water relates to the water quality as well as access to water, kai (food) gathering capabilities and invasive pest species'). Characteristics of the attributes are dependent on the 'geographical region, history of the awa, present capacity of the marae to kuia and kaumatua, and living knowledge' (Wilson, 2020). This research provides a good basis for helping to select indicators and measures that align to social and cultural wellbeing's that are important to Māori and New Zealand specific values.

A review of well-being monitoring frameworks conducted by the Canterbury District Health Board (New Zealand) was considered to explore indicator selection further. They identified a range of wellbeing indicators being used in different monitoring regimes, these included (Community and Public Health, 2017):

- Income / personal finances / economic standard of living
- Jobs / economy / paid work
- Health status
- Education / knowledge / skills

- Civic engagement
- Environmental quality / natural environment
- Social connections / community / belonging / engagement / social capital
- Life satisfaction / personal wellbeing / quality of life
- Safety / crime / violence
- Housing
- Equalities / gap between rich and poor
- Transport / public transport
- Arts and culture
- Sport and recreation
- Ageing
- Youth / children
- Food security
- Time use / work-life balance
- Built environment / sense of place
- Cultural identity

The range of indicators identified falls into common groupings across the different monitoring regimes considered in the review. Each has more focus on a specific area of interest depending on the organisation, i.e., sustainability-focused monitoring contained more environmental indicators while those focused on health care included more health-related indicators. Canterbury's review noted that indicators tended to be developed by expert groups with some consultation with communities, the indicator groups chosen were conceptually sound, able to be disaggregated, and contained data that was readily available from official sources; very few utilised original data (Community and Public Health, 2017). The UN particularly stresses upon the need for Sustainable Development Goal indicators to be disaggregated. It proposes disaggregation through sex, age, race, ethnicity, migratory status, disability, and geographic location where relevant (UN, 2020). The Sustainable Development Goals were agreed in the UN 2030 Agenda for Sustainable Development (Desa, 2016) where 17 goals, 169 targets, and over 300 indicators have been agreed to by member nations (Costanza et al., 2016; Desa, 2016). The SDGs have been noted to be a major improvement over the original Millennium

Development Goals that focused more on developing countries only. Appendix A (Table 27) shows the UN SDGs and the identified indicators for each SDG.

In 2019 the New Zealand Government launched the first wellbeing budget (Government, 2019b) utilising the New Zealand Living Standards Framework. The Government indicated the desire to embed wellbeing into policy decision making and noted that this would be an ongoing process with changes to legislation, reporting, and working with the public sector toward a new way of working. The release of the Wellbeing Budget further progressed the New Zealand Treasury's development of the Living Standards Framework that builds on 30 years of New Zealand and international research (in particular drawing from the OECD analysis of wider indicators of well-being (Morrissey & Hawkins, 2018)) to develop a framework for intergenerational wellbeing impacts of policies and proposals. The New Zealand Treasury released the Living Standards Framework Dashboard that provided a range of wellbeing indicators (see Table 15) and analysis to inform the 2019 budget (Frieling & Warren, 2018; Government, 2019b; Janssen, 2018; Morrissey, 2018; van Zyl & Au, 2018). Coupled to the LSF dashboard, Statistics New Zealand has indicated that the Indicators Aotearoa New Zealand (IANZ) will be able to report against the UN SDG's with good alignment to the NZ LSF indicators (Ormsby, 2018). Treasury noted that no single set of indicators can capture all that matters to New Zealanders. The dashboard enabled one perspective on how the Government could measure the nation's wellbeing. These indicators can be seen in Table 15 (Government, 2019b). The indicators were developed to provide a macro-level assessment of wellbeing performance and cover the current quality of life (domains of wellbeing) and indicators of future intergenerational wellbeing (capitals) that are relevant to New Zealand. They were selected based on an inclusive process that included Māori co-design, public consultation, and peer review. The technical criteria for indicator selection aligned to the UN SDG criteria and included the need to be relevant to the underlying phenomenon, sensitive to change, statistically sound, able to be disaggregated, intelligible, and consistent (Morrissey & Hawkins, 2018).

Table 15. New Zealand Treasury Living Standards Framework Indicators, reproduced from NZ Government, 2019b and Stats Zealand, 2020

Indicators of New Zealand's current quality of life (Domains of wellbeing)			
Civic engagement and governance • Voter turnout • Trust in government institutions • Perceived corruption	**Cultural identity** • Te reo Māori speakers • Ability to express identity	**Environment** • Air quality • Access to the natural environment • Water quality (swimmability) • Perceived environmental quality	**Health** • Healthy life expectancy • Health status • Mental health • Suicide rate
Housing • Household crowding • Housing cost • Housing quality	**Income and consumption** • Disposable income • Financial wellbeing • Consumption	**Jobs and earnings** • Unemployment rate • Employment rate • Hourly earnings	**Knowledge and skills** • Educational attainment (tertiary) • Educational attainment (upper secondary) • Cognitive skills at age 15
Safety and security • Intentional homicide rate • Domestic violence • Workplace accident rate • Feeling safe	**Social connections** • Social network support • Loneliness • Discrimination • Māori connection to marae	**Subjective wellbeing** • General life satisfaction • Sense of purpose in one's life	**Time use** • Leisure and personal care • Paid work • Unpaid work
Indicators of New Zealand's sustainable and intergenerational wellbeing (Capitals)			
Financial and physical capital • Total net fixed assets • Net intangible fixed assets • Household net worth • Multifactor productivity growth • Net international investment position • Total Crown net worth	**Human capital** • Educational attainment (tertiary) • Educational attainment (upper secondary) • Expected educational attainment • Non-communicable diseases • Cognitive skills at age 15 • Life expectancy	**Natural capital** • Natural hazard regulation • Climate regulation • Sustainable food production • Drinking water • Biodiversity and genetic resources • Waste management	**Social capital** • Trust held in others • Perceived corruption • Discrimination • Trust in government institutions • Sense of belonging

The conceptual model is designed to show the interrelationships between the three dimensions and to better understand how indicators and measures inform and influence infrastructure decisions and performance from a wellbeing perspective. The conceptual model utilises the concepts identified above and incorporates them into a cube model to show the multi-dimensional interactions (Figure 43). The literature review of indicator and measures utilised

in different research was considered in the development of the conceptual model to show the multiple views considered and to identify how the various wellbeing indicators interact through the defined dimensions.

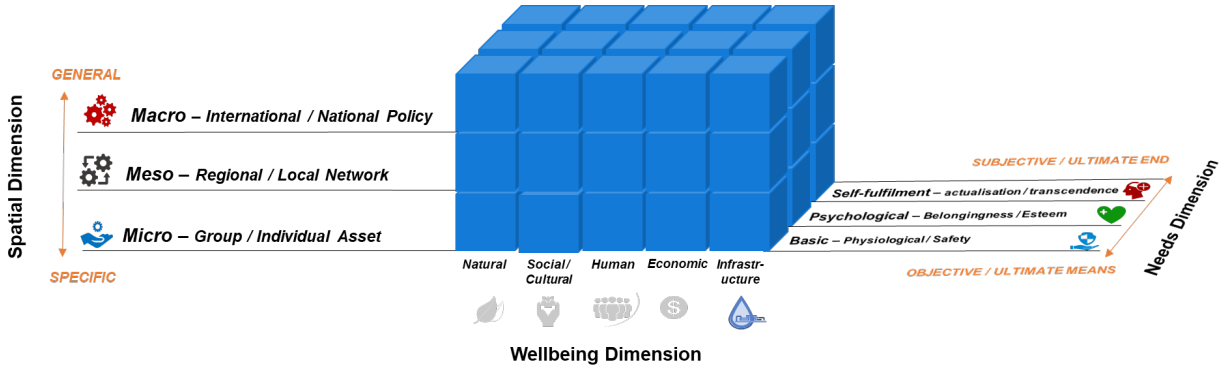


Figure 43. Conceptual Model showing breakdown of spatial, needs and wellbeing dimensions.

The time element of the conceptual model is shown in Figure 44 with 'time slices' indicating the current performance or state and desired future performance or state (time slice 1). An intermediary assessment of performance is shown to show progress toward the desired future performance (time slice 2). Intermediary assessments can be taken as often as required to identify how interventions and decision making are impacting on the overall wellbeing performance. A final assessment is taken to show the obtainment of the desired future performance or state (time slice 3), noting that continued assessment is still required beyond this point to identify if any deterioration of performance is occurring or if over performance is occurring.

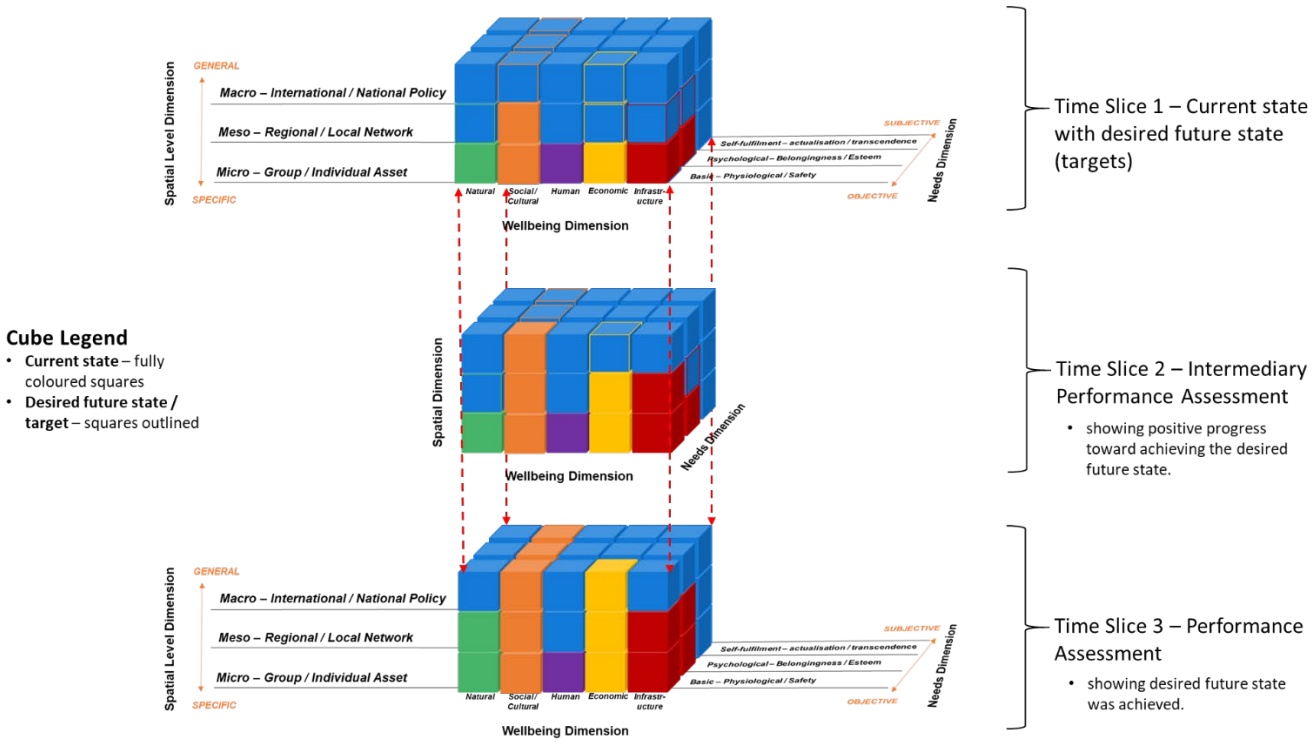


Figure 44. Meso conceptual model time dimension example

The literature reviewed in this section helped to better understand the rationale behind the development of the wellbeing performance conceptual model and will help to provide guidance on the selection of the candidate indicators and measures.

7.2. Selection and Filtering of Candidate Indicators

The review of potential indicators and measures shows the multitude of indicators used to assess the performance of specific systems (i.e., UN SDGs, NZ LSF, and infrastructure asset). Indicators range from a focus on macro (Desa, 2016; Government, 2019b; OECD, 2011, 2017, 2019; UN, 2020) to micro (Balkema et al., 2002) level assessments with a notable gap of systems designed specifically for meso level indicators. To filter and select indicators the Meso Level Infrastructure Wellbeing Performance Framework (Chapter 5: Figure 28 and Figure 39) and Conceptual Indicator/Measure Model (Figure 43 and Figure 44) were utilised to develop a filtering process to select indicators to test the framework and conceptual model. The process developed (Figure 45) utilises the Meso Level Infrastructure Wellbeing Performance Framework to structure the indicators into the wellbeing dimensions and provides macro level linkages to the wellbeing frontiers and domains of public policy utilising the NZ LSF and UN SDG's (stage 1, see sections 1 to 6). The next step (stage 2) in the filtering process was to identify indicators relevant to three-waters decision making (see section 7 for indicator

selection background). Indicators from the NZ LSF and UN SDGs were identified as well as more traditional indicators for assessing three-waters infrastructure performance and investment. The indicators selected at this stage of the filtering process were selected to provide a range of measurement with 1st and 2nd order attribution over the defined wellbeing dimensions that are both associated with three-waters infrastructure investment and performance as well as how they would help to understand performance against wellbeing frontiers and domains (defined by the Meso Level Infrastructure Wellbeing Performance Framework). The next stage, stage 3, was to validate the data availability and fitness for intended purpose this was completed by conducting a case study with two organisations (Chapter 8). In this stage the relevance of each measure with available data was tested across the spatial and needs dimensions to ensure the indicators are providing an appropriate cross section against the Conceptual Model. The last stage (stage 4) was to identify the fitness and gaps from the case study and is covered in Chapter 9, the discussion section. This filtering process provides an initial indication of the design validity of the novel performance framework and conceptual model and will require further work to verify the voracity of the design work and ability to develop the framework and conceptual model into a working performance and potential decision making model.

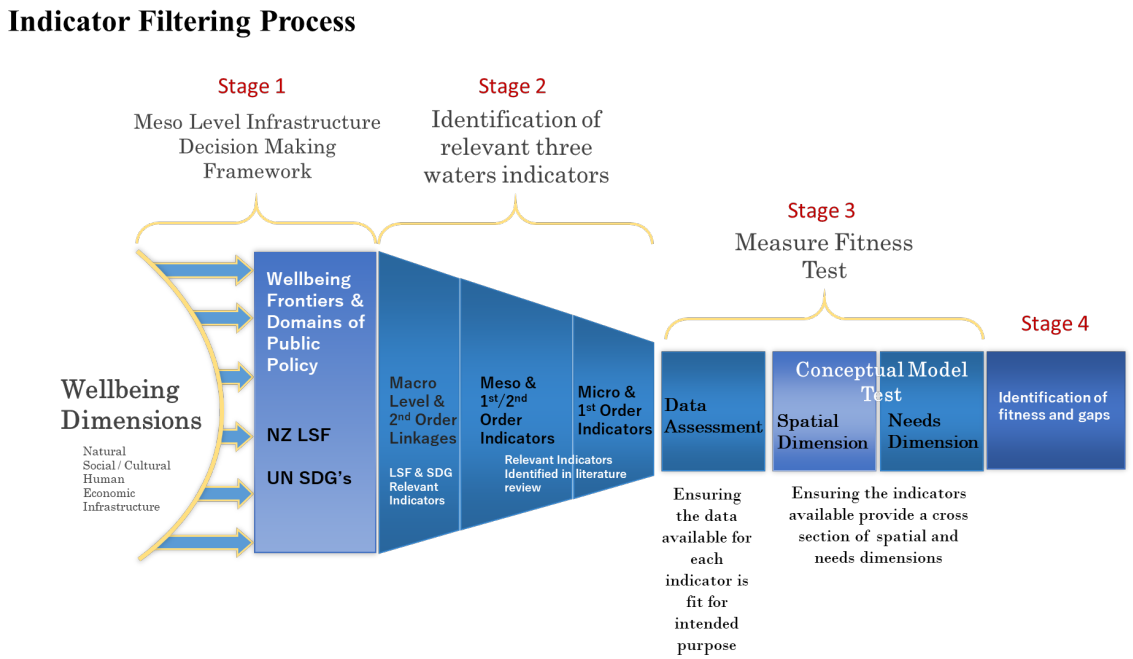


Figure 45. Indicator filtering and selection process

7.3. Review of potential indicators

An initial review of indicators was completed to identify potential indicators that could be utilised to test the meso level framework and conceptual model (stage 2) (see Section 7). To help refine the selection of indicators, the UN Sustainable Development Goals and New Zealand Living Standards Framework indicators were used as an initial filter and to allow for the alignment with the developed framework. The goals, domains and indicators from the UN SDG and NZ LSF frameworks were assessed (Chapter 5: Figure 28 and Figure 29) and linkages were developed and identified between the macro-level policy framework (NZ LSF) and international goals and targets (UN SDG).

A review of the UN Sustainable Development Goals and the associated goals and targets for each SDG was completed to identify the SDGs, Goals/Targets, and indicators that would be relevant in linking macro level indicators to a meso level three-waters infrastructure performance framework. As the SDGs are designed to show progress toward the UNs international goals and targets for sustainable development, their focus is on providing an understanding of performance at a macro level and have a 2nd order connection to the meso level decision making framework. The UN SDGs provide a good initial macro link covering the key aspects of the 17 sustainable development goals; however, the breadth and range of the 169 targets and over 300 indicators (Desa, 2016; UN, 2020) provide diluted guidance at a meso level due to the political complexity around the development of the SDG's (Costanza et al., 2016). The relevant UN SDG goals, targets and associated indicators for this research are identified in Appendix B, Table 28.

The selection process of identifying relevant UN SDG goals, targets and indicators was supported through the linkages the New Zealand Treasury identified and the research and development work completed in the formation of the novel framework and conceptual model. This was further supported through utilising the research by Costanza (2016), where they worked to relate the UN SDG's to overall measures of wellbeing. In this work, Costanza argues the need to have a dynamic systems approach that can embrace both a dashboard approach and aggregate indicators. Costanza utilised Daly's Means and Ends hierarchy (Chapter 6: Figure 41 and Figure 46) to categorise the UN SDG's (see Table 16) (Costanza et al., 2016). Costanza identified three basic approaches to aggregate indicators of wellbeing with the UN SDG's, these included:

1. Consumption, production, and wealth-based indicators (i.e., GDP);

2. Aggregation of all of the SDG indicators into a unit-less index (i.e., weighted indexes like the OECD Better Life Index);

3. Contributions to subjective wellbeing (i.e. regression model with all indicators as the independent variables and some existing approximation of wellbeing as the dependent variable, World Happiness Report) (Costanza et al., 2016).

Costanza (2016) proposes a hybrid approach utilising parts of the three basic approaches they suggest with each covering contributions to wellbeing from an economic, societal, and environmental/natural perspective. This work maps the 17 UN SDGs to the hybrid approach and Daly's Means and Ends (Chapter 6: Figure 41). It has helped to provide a filter and test the alignment of the UN SDG targets and indicators to the meso level wellbeing performance framework and conceptual indicator/measures model.

Appendix B, Table 28 and Appendix C provide the comprehensive table showing the wellbeing capitals and infrastructure alignment to the NZ LSF and relevant UN SDGs.

Table 16. UN SDGs aligned to Daly's Means to Ends hierarchy, reproduced from Robert Costanza, 2016

Efficient allocation: building a living economy	
Goal 7.	Ensure access to affordable, reliable, sustainable, and modern energy for all
Goal 8.	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9.	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 11.	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12.	Ensure sustainable consumption and production patterns
Fair distribution: protecting capabilities for flourishing	
Goal 1.	End poverty in all its forms everywhere
Goal 2.	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3.	Ensure healthy lives and promote well-being for all at all ages
Goal 4.	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all
Goal 5.	Achieve gender equality and empower all women and girls
Goal 10.	Reduce inequality within and among countries
Goal 16.	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17.	Strengthen the means of implementation and revitalize the global partnership for sustainable development
Sustainable scale: staying within planetary boundaries	
Goal 6.	Ensure availability and sustainable management of water and sanitation for all
Goal 13.	Take urgent action to combat climate change and its impacts *
Goal 14.	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15.	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

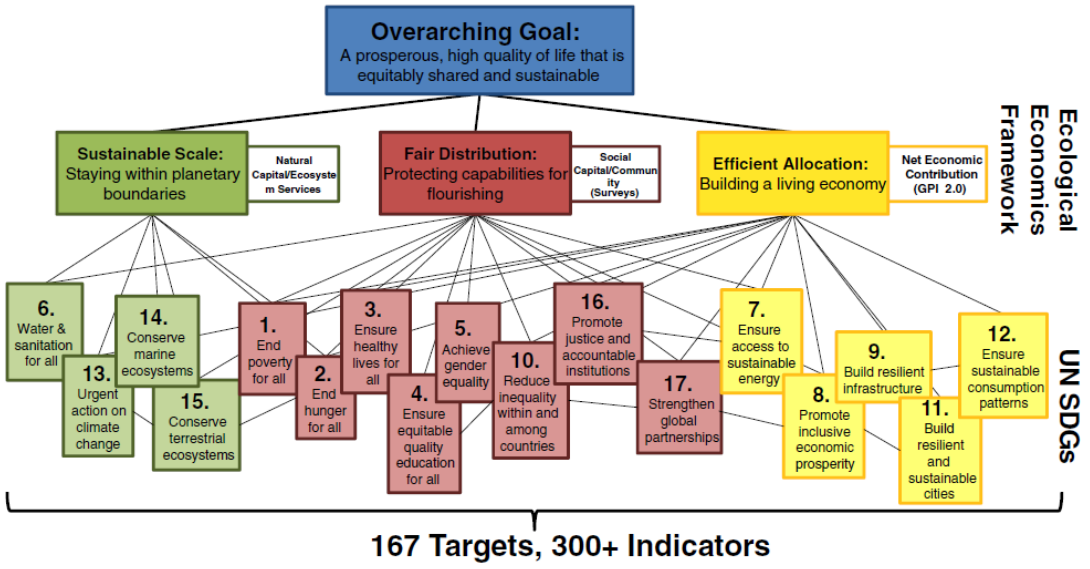


Fig. 2. The relationship of the 17 UN Sustainable Development Goals (SDGs) to each other, to the framework of ecological economics, and to the overarching goal of a sustainable, equitable and prosperous system of humans embedded in the rest of nature.

Figure 46. Mapping 17 UN SDG's to an ecological economics framework based on Daly's Means and End's, reproduced from Costanza et al., 2016

7.4. Indicator selection for use and testing of the conceptual model

A list of indicators has been identified for use in the meso level conceptual model (see Table 17 and Appendix C & D for detailed connections). The indicators have been aligned to the performance frameworks capitals, NZ LSF domains, and UN SDG's. The identification of potential candidate indicators helped define the interaction between the levels in the framework and conceptual model. The development work was utilised to test the level the indicators would be most appropriately utilised for (first or second order). The first order indicators provide direct control of levers, can attribute the change to levers used, and are output and outcome-focused; these indicators tend to be directly related to the infrastructure. The second-order indicators have indirect control of levers, cannot fully attribute the change to the levers used, and are outcome-focused; these indicators tend to be more focused on policy setting.

Table 17. Meso level framework assessment of candidate indicators and alignment to NZ LSF and UN SDG; the table summarises the detailed development in Appendix C and D (Balkema et al., 2002; Community and Public Health, 2017; Costanza et al., 2016; Harmsworth et al., 2011; Ministry for the Environment & Stats NZ, 2017; Ministry of Health, 2018 ; T. Morgan et al., 2012; Morgan, 2006; Morrissey, 2018; OECD, 2001; Padilla-Rivera & Güereca, 2019; Padilla-Rivera et al., 2016; Tipa & Teirney, 2006; Water New Zealand, 2017; World Economic Forum, 2017; World Health Organisation, 2012)

Capital Wellbeing's	NZ LSF Domains	UN SDG's	Indicators (potential)
Natural	Environment		Environmental quality (pollution), Biodiversity, Natural resource depletion, Land use impacts, Ecosystem vulnerability, Conservation, resilience (climate adaptation), Ability to support mahinga kai species, access to safe water/land
Social / Cultural	Cultural Identity	None	Indigenous rights, Cultural acceptance, Satisfaction with access to natural environment and access to 3 waters
	Civic Engagement & Governance		Institutional trust, Participation / engagement, Satisfaction with decision making
	Social Connectedness	None	Belongingness, Migration, Resilience, Whanau (family) wellbeing, access to suitable recreational grade monitored fresh/coastal swimming sites
	Time Use	None	Generational relevancy
Human	Health		Life expectancy, Food availability , Infections / disease, access to compliant drinking water, access to wastewater services, illness due to water borne infections, notifications of non-compliance
	Housing		Affordability, Availability
	Knowledge & Skills		Training, Availability / ease of access, qualification levels
	Safety		Crime, Safety, Corruption , Resilience
	Subjective wellbeing		Life satisfaction, Time availability, Poverty, Satisfaction, Inequality, Subjective satisfaction of water, wastewater, and storm water services
Economic	Income & Consumption		GDP (National/Regional), Export / Import, Wealth
	Jobs & Earnings		Employment- availability/growth/diversity , Unemployment, Cost of labor, Earnings, House ownership, Organisational balance statement (debt & investment levels, Productivity, Job satisfaction, Strain/stress, mean equalized household disposable income & household income
Infrastructure (Technology)	Not Applicable		Lifecycle / asset preservation, capacity, resilience, affordability, adaptability/flexibility, emissions, Net present value, cost benefit, operating ratio (annual operating revenues to annual operating expenses)

Table 17 was developed to show how the four capitals from the macro wellbeing frontier connect to the meso level. Indicators were identified through a search of international and New Zealand based literature (as identified in earlier chapters) to identify potential indicators that would help to understand the impacts on the system and test the development of a meso level conceptual model. During indicator selection, the OECD (OECD, 2001), NZ Treasury (Morrissey, 2018), and World Economic Forum (World Economic Forum, 2017) were the main sources for indicators related to human and social capital. In addition, the work developed by the New Zealand Ministry for the Environment was mainly considered in the development of indicators for the cultural and environmental health of streams and waterways (Ministry for the Environment & Stats NZ, 2017; Tipa & Teirney, 2006). Potential indicators of consumer perceptions of water was also included (Water New Zealand, 2017). Finally, the work completed by the New Zealand Ministry of Health (Ministry of Health, 2018) and World Health Organisation (World Health Organisation, 2012) helped to identify potential indicators related to water and human health. Morgan (2006; 2012) and Harmsworth (2016; 2011) work on Māori cultural values was also utilised to support and test the selection of indicators and measures. With regard to sustainability, indicators developed for micro-level infrastructure investment models were considered (Balkema et al., 2002; Padilla-Rivera & Güereca, 2019; Padilla-Rivera et al., 2016). Overall, indicators identified are a mix of qualitative/quantitative and objective/subjective measures and have been developed to better understand the system dynamics when looking at the interrelationships between the macro, meso, and micro levels.

Chapter 7 identified potential indicators, measures and developed a filtering process. The research into indicators and measures utilised in other frameworks identified 28 indicators and 168 measures to test for potential use in the novel wellbeing performance framework and conceptual model. A filtering process was developed that utilised the novel wellbeing performance framework and conceptual model to select indicators and structure the indicators into the wellbeing dimensions. This initial alignment work provided macro level linkages to the wellbeing frontiers and domains of public policy utilising the NZ LSF and UN SDG's (stage 1, see chapters 1 to 6). The next step (stage 2) in the filtering process identified indicators relevant to three-waters decision making (see chapter 7 for indicator selection background). Indicators from the NZ LSF, UN SDGs were identified as well as more traditional indicators for assessing three-waters infrastructure performance and investment. The indicators selected at this stage of the filtering process were selected to provide a range of measurement with 1st and 2nd order attribution over the defined wellbeing dimensions that are both associated with

three-waters infrastructure investment and performance as well as how they would help to understand performance against wellbeing frontiers and domains.

Chapter 8 provides a case study to test the initial development work of the conceptual model. This initial work will allow for the future development and integration of the macro analysis model with micro level influences on the meso level. This in turn will help to understand the level of resilience in the system through the stock and flow interaction and the influence and attribution of the indicators on decision making for today and the future.

Chapter 8. Case Study -Testing the Framework and Conceptual Model Indicators and Measures

8.1. Development of the measure fitness test

To test the conceptual model and performance framework two data sources were identified, one at a national level (Stats NZ) and one at a regional level (Waikato Regional Council). The intent of this test was to provide an initial review of the fitness of the data available for the identified measures for each indicator. The fitness of the data is defined as data that is fit for the intended purpose, is accessible and relevant to the identified conceptual model and indicator/measure identified. The fitness for the intended purpose is the 'extent to which the information resource is of appropriate quality for the situation in which it is to be used' (Klobas, 1995).

The case study completed the third stage of the filter process, testing the fitness of the data through a data assessment and testing the available measures against the conceptual model (stage 3; Figure 47). This fitness test provides an indication if the measures selected will support the initial validity of the conceptual model and provide a basis for further research for the development of a mathematical model to support the performance framework and conceptual model. This final stage (stage 4) will also identify gaps that will need to be explored and addressed in any further research, Chapter 9: Discussion covers this stage.

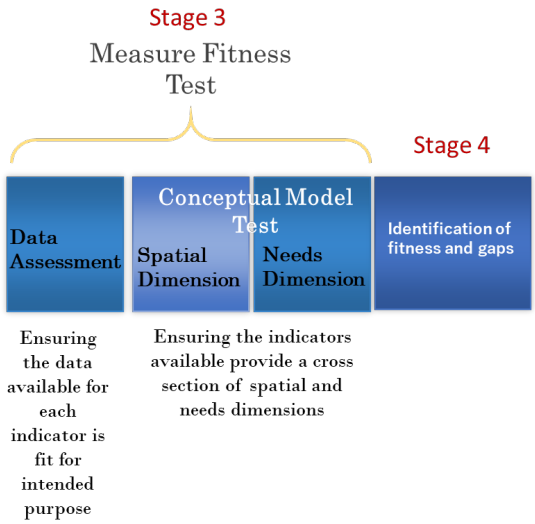


Figure 47 Stage 3 and 4 of indicator filtering process.

The data assessment was completed through the collection of information from two sources as an initial test, Stats NZ and Waikato Regional Council were asked to complete a data collection questionnaire. The data collection questionnaire listed each of the indicators and associated measures against each of the wellbeing capitals, asking the agencies to identify whether they collected the data or not and what type of data they held for the measure (if they collected it). For each of the wellbeing capitals in the performance framework (natural, social-cultural, human, economic, infrastructure) a series of questions were asked, an example of the form and questions is shown in Table 18 below.

Once the two organisations completed the form, a data assessment was completed to assess the fitness for intended purpose. This was completed utilising a data information use model that considers data quality and data accessibility (Klobas, 1995). The information model was adapted for use (see Figure 48) in this research to test the fitness of the indicators and measures for their intended use in the meso level infrastructure wellbeing performance framework and conceptual model.

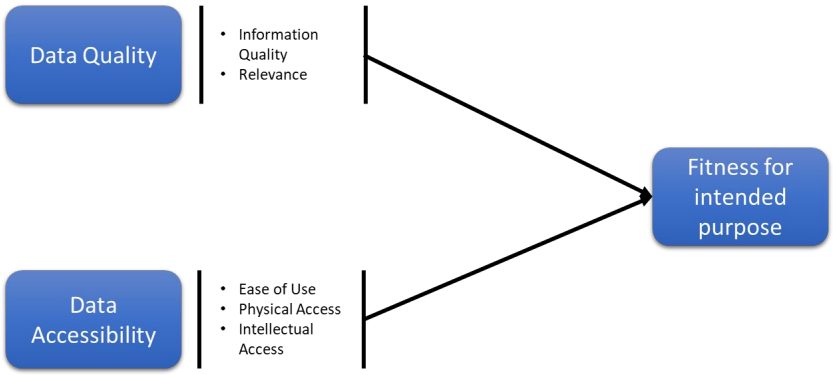


Figure 48. Data information model used to test the data fitness, adapted from Klobas, 1995

Data quality was assessed considering the information quality as assessed by the organisation it was obtained from, this focused on the type of information and not a technical data quality assessment (technical data quality will need to be assessed in future research). The data quality assessment also consider the relevance to the measure, an assessment of whether the data type and information recorded is relevant to the intended use (Klobas, 1995). Data accessibility was assessed by considering the ease of use (is it collected and easily accessible from an organisation), aspects of physical access to the data (can it be obtained in a way that makes it usable, i.e. spreadsheet, API) and the intellectual access (will a user be able to understand and use the data) (Klobas, 1995). The questionnaire provided to the organisations had a series of

questions designed to test the data quality and accessibility, see Table 18. The assessment was completed providing a one to five rating to each associated measure where the organisations indicted data was available. The rating of one (1) indicated a low fitness level to a five (5) indicating a high level of fitness.

Table 18. Conceptual Model Measure Testing Data Collection Questions Sent to Stats NZ and Waikato Regional Council

Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework	Wellbeing Indicators (selected to trial with conceptual framework) Measure
Questionnaire Questions	**Data Assessment Model Link**
Do you record the data?	Accessibility
If "No", Can you suggest the name of organisation who records this data?	Accessibility
Unit of measurement Type of access (ease, spreadsheet, API etc)	Data Quality
Ethics concerns	Accessibility
Public / Private	Accessibility
Is data linked to any specific Māori elements? (Spiritual (whakapapa), physical, etc) - Te mana atewi (spirit of the water)	Accessibility
Data quality & completeness	Data Quality
Data type	Data Quality
From Date to To Date of data record	Data Quality
Frequency of data recording	Data Quality
Data available for individual City/District Council?	Accessibility
Who controls	Accessibility
Key Person	General Information (removed from thesis data due to privacy requirements)
Contact Details	General Information (removed from thesis data due to privacy requirements)

The conceptual model was then utilised to test the available data identified by the two organisations for their fitness in how the data contributed to the spatial, needs, and wellbeing dimensions of the conceptual model. A summary of the fitness assessment is show in Figure 49.

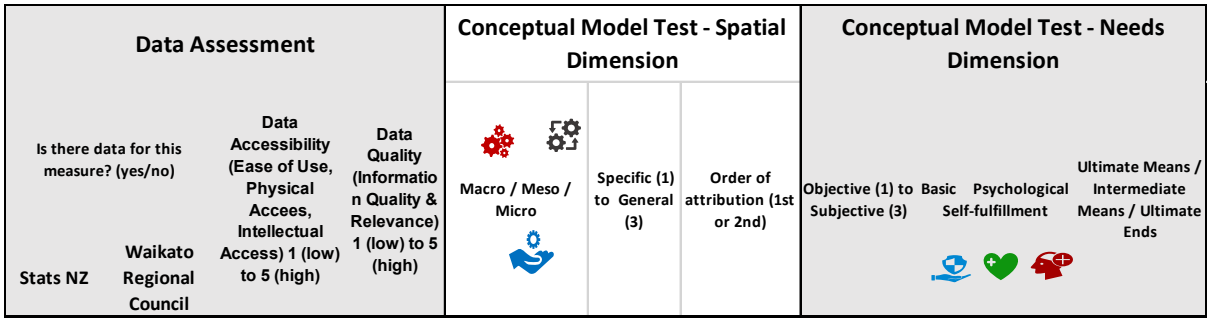


Figure 49. Fitness assessment criteria for assessment of measures against questionnaire responses

8.2. Testing the measures fitness with Stats NZ and Waikato Regional Council

Contact was made with Stats NZ, and Waikato Regional Council to obtain data from two key levels: national (Stats NZ) and regional (Waikato Regional Council). The initial request to Stats NZ and the Waikato Regional Council was to have the organisations complete the questionnaire form to answer the questions and provide the available data. Through engagement with the two organisations the request to obtain the actual data was removed, substantially reducing the resources and time required by the organisations. This change still allowed for the completion of the designed testing of the measures for the thesis as the focus for this initial research was to test the fitness of the measures for the intended use against the conceptual model and not to analyse the data itself. This will also allow future research to be more focused with data requests.

The individual responses were consolidated into an assessment table (see Table 19) and each measure was initially assessed where data was available from Stats NZ or Waikato Regional Council. If data was available, the measure was then assessed for fitness based on the criteria previously identified. General observations from the data fitness assessment and observations from Table 19 are provided in Chapter 9. Chapter 9, Discussion of Findings also provides a summary of the outcomes from the case study in relation to the design of the performance framework and conceptual model and identifies gaps for further research.

Chapter 8 continued the filtering process developed in chapter 7. This step (stage 3) validated the data availability and fitness for intended purpose by conducting a case study with two organisations, Stats NZ and the Waikato Regional Council. The data collection questionnaire provided to the two organisations listed each of the indicators and associated measures against each of the wellbeing capitals, asking the organisations to identify whether they collected the

data or not and what type of data they held for the measure (if they collected it). In this stage the relevance of each measure with available data was tested across the spatial and needs dimensions of the conceptual model to ensure the indicators provided an appropriate cross section against the conceptual model. This was completed utilising an adapted data information use model to test the fitness of the indicators and measures for their intended use in the meso level infrastructure wellbeing performance framework and conceptual model. Chapter 9 will discuss the findings from the case study with general observations, identification of gaps, and future research.

Table 19. Indicator and Measure Fitness Assessment Utilising Stats NZ and Waikato Regional Council Questionnaire Responses

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension			
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic Psychological Self-fulfillment	Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Natural Capital	Environmental quality (pollution)	Satisfaction with Water quality –pollution exceedance	No	No									
		Proportion of bodies of water with good ambient water quality	No	Yes	2	4	Meso	1	1st	1	Basic	Ultimate Means	aspects of water quality. You could test your threshold
		Number of posted no fishing/collection days in water bodies (due to contaimination)	No	No									
		Number of posted no swim days in water bodies (due to contaimination)	No	No									green algae data for some recreational waters
		Water quality - exceedance of consent conditions	No	Yes	1	4	Meso	1	1st	1	Basic	Intermediate Means	and assessed. But across thousands of consents across
	Biodiversity	Satisfaction with condition and management of waterways (in point of biodiversity)	No	No									
		State of the lakes, rivers, harbours, and coastlines (In point of biodiversity)	No	Yes	2	4	Meso	1	1st	1	Basic	Intermediate Means	macrioinvertebrates are monitored, stream fish, coastal
	Natural resource depletion	Percentage of treated water leakage in the network	No	No									
		Change in water-use efficiency over time	No	No									
		Suitability for Recreational Grade for monitored freshwater swimming sites	No	Yes	4	4	Meso	1	1st	1	Psychological	Intermediate Means	
		Suitability for Recreational Grade for monitored coastal swimming sites	No	Yes	3	4	Meso	1	1st	1	Psychological	Intermediate Means	green algae data for some recreational waters
	Land use impacts	Land use or land cover in the wider catchment that can be seen from the site being assessed	No	No									WRC: Not sure what you're after
		Percentage of wastewater consent exceedance	No	Yes	2	4	Meso	1	2nd	1	Psychological	Intermediate Means	after. we do monitor compliance
		Water quality - exceedance of consent conditions	No	Yes	2	4	Meso	1	1st	1	Psychological	Intermediate Means	WRC: compliance assessed
	Ecosystem vulnerability	Change in the extent of water-related ecosystems over time (overtime / climate / shock events)	No	No									
	Conservation	Proportion of wastewater safely treated	No	No									
		Proportion of drinking water used to availability	No	No									WRC: not sure what you're after
		Percentage of treated water leakage in the network	No	No									
	Resilience (climate adaptation)	Salt intrusion in drinking water supply	No	No									
		Risk of impact from hazards (environment / people)	No	Yes	4	3	Macro	3	2nd	2	Psychological	Intermediate Means	WRC: some hazards are mapped
	Ability to support mahinga kai species (native food species)	Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species)	No	Yes	4	3	Meso	1	2nd	1	Basic	Ultimate Means	WRC: we monitor fish in rivers at certaain sites
		Comparison between the species present today and the traditional mahinga kai sourced from the site	No	No									
	Access to safe water/land	Households with access to bacteriological (E-coli) compliant drinking water	No	No									
		Household with access to protozoal compliant drinking water	No	No									
		Household with chemical compliant drinking-water	No	No									
		Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	No	No									
		Households with access to fluoridated drinking water	No	No									
		Proportion of population using safely managed drinking water services	No	No									
		Satisfaction with access to natural environment	No	No									
		Satisfaction with access to 3 waters services	No	No									
		Access to safe water for recreation and food gathering	No	No									
		Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household	No	No									
		Suitability for Recreational Grade for monitored coastal swimming sites	No	Yes	4	4	Meso	1	1st	1	Psychological	Intermediate Means	WRC: bacterial indicators monitored

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension			
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic Psychological Self-fulfillment	Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Social / Cultural Capital	Indigenous rights	Involvement of Maori in decision making	Yes	No	5	4	Macro	2	2nd	1	Psychological	Intermediate Means	
		Proportion of local administrative units with established and operational policies and procedures for participation of local	No	No									
		Importance of being engaged in Maori culture	Yes	No	5	4	Macro	2	2nd	2	Self-fulfillment	Ultimate Ends	
	Cultural acceptance	Site significance to tangata whenua (i.e. tradional/non-traditional)	No	No									
		Assessment of tangata whenua would return to the site in future as they did in the past or not	No	No									
		Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to	No	Yes	4	3	Meso	1	2nd	1	Basic	Ultimate Means	
		Comparison between the species present today and the traditional mahinga kai sourced from the site	No	No									
		Land use or land cover in the wider catchment that can be seen from the site being assessed	No	Yes	4	3	Meso	1	2nd	1	Basic	Ultimate Means	
	Satisfaction with access to natural environment and access to three waters	Satisfaction with access to natural environment	No	Yes	3*	4	Meso	2	2nd	3	Psychological	Intermediate Means	
		Satisfaction with smell of water	No	No									
		Satisfaction with access to 3 water network	No	No									
		Access to safe water for recreation and food gathering	No	No									
		Is the vegetation (indigenous or exotic) that is visible along the margins (100 m either side) of the waterway.	No	Yes	4	3	Meso	1	2nd	1	Psychological	Intermediate Means	
		Is the extent the margins of a stream are being used (heavy use of the margins can impact on stream health)	No	Yes	4	3	Meso	1	2nd	1	Psychological	Intermediate Means	
		The state of the riverbed can be assessed by the amount of sediment that has built up	No	Yes	4	3	Meso	1	2nd	1	Psychological	Intermediate Means	
		River channel shape that has been modified by work in the channel or other similar types of activities such as gravel	No	No									
		Rate flow in river and flow-related habitat variety that can impact on river health	No	Yes	4	3	Meso	1	2nd	2	Psychological	Intermediate Means	
		Should water clarity be low the stream might be carrying sediment or some form of effluent that can impact on stream	No	No									
		Water quality (or satisfaction with water quality or feeling in puku (gut) about the site is poor/excellent)	No	No									
		Quality of life	No	Yes	2*	3*	Meso	3	2nd	3	Self-fulfillment	Ultimate Ends	
		Suitability for Recreational Grade for monitored coastal swimming sites	No	Yes	4	4	Meso	1	1st	1	Psychological	Intermediate Means	
	Institutional trust	Local and Central government reputation survey	No	Yes	2*	3*	Macro	3	2nd	3	Psychological	Intermediate Means	
	Participation / engagment	Percentage of population participating in elections	No	Yes	2*	3*	Macro	3	2nd	1	Psychological	Intermediate Means	
		Satisfaction with decision making	No	Yes	2*	3*	Meso	3	2nd	3	Self-fulfillment	Ultimate Ends	
		Percentage of population participating in decision making (feedback/engagment)	No	No									
	Belongingness	Whanau (family) wellbeing	Yes	No	4	4	Macro	3	2nd	3	Self-fulfillment	Ultimate Ends	
		Migration	Yes	No	4	2	Macro	2	2nd	1	Psychological	Intermediate Means	
	Generational relevancy	Financial treatment shows intergenerational contributions are provided for (i.e. depreciation is collected, debt funding use, rate/taxes)	No	No									
		Involvement of Maori to look after someone who was disabled or ill	Yes	No	4	2	Macro	2	2nd	2	Basic	Ultimate Means	
		Time availability	Yes	No	4	1	Macro	2	2nd	3	Self-fulfillment	Ultimate Ends	

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension			
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic Psychological Self-fulfillment	Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Human Capital	Life expectancy	Self-rated health	No	No									
		Life expectancy	Yes	No	4	4	Macro	1	2nd	1	Basic	Ultimate Means	
	Infections / disease/Mental health/change in physical health	Hazardous drinking	No	No									
		Acute medical admission	No	No									
		Notifications of campylobacteriosis, cryptosporidiosis and giardiasis	No	No									
		Notification of Diarrhoea with untreated water	No	No									
		Notifications of campylobacteriosis, cryptosporidiosis and giardiasis with untreated water as a risk factor	No	No									
		disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease	No	No									
		Percentage of children who are caries-free, by fluoridation status	No	No									
		Mean number of decayed, missing or filled teeth of children, by fluoridation status	No	No									
		Impact of waterborne disease on mental health of Maori and non-Maori (Aotearoa/NZ)	No	No									
		and risk) in weeks to months after extreme events (e.g flooding, landslides, storm surges, drought) on health of	No	No									
		Ross river virus) and impact of such disease on Maori and non Maori	No	No									
		flooding, storm surges, drought etc.) on physical health of Maori and non-Maori	No	No									
		persons attributed to disasters (e.g. flooding) per 100 000 population	No	No									
		Increase/decrease or proportion of Maori aged 15-24 years who smoke regularly	Yes	No	4	2	Macro	2	2nd	2	Psychological	Intermediate Means	
		% of hospitalized for serious injury from self-harm for Maori (males) aged 15-24 years.	No	No									
		% of Maori adults reported having very good health	No	No									
		circulatory system diseases (including heart disease and stroke)	No	No									
		Maori under 75 years to die from circulatory system diseases	No	No									
		% of Maori admitted to hospital for mental disorder	No	No									
		Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe water, sanitation, and hygiene for all (WASH) services)	No	No									
	Access to compliant drinking water	Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household	No	No									
		Households with access to bacteriological (E-coli) compliant drinking water	No	No									
		Household with access to protozoal compliant drinking water	No	No									
		Household with chemical compliant drinking-water	No	No									
		Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	No	No									
		Households with access to fluoridated drinking water	No	No									
		Proportion of population using safely managed drinking water services	No	No									
	Access to wastewater services	Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household	No	No									
	Illness due to water borne infections	Notifications of campylobacteriosis, cryptosporidiosis and giardiasis	No	No									
		Notification of Diarrhoea with untreated water	No	No									
		Notifications of campylobacteriosis, cryptosporidiosis and giardiasis with untreated water as a risk factor	No	No									
		disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease	No	No									
		Unmet need for primary health care	No	No									

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension				
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic Psychological Self-fulfillment		Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Human Capital	Household	House hold affordability	No	No										
		Hoousehold availability	No	No										
		% of Maori living in the deprived decile areas	Yes	No	4	4	Macro	1	2nd	2	Basic		Ultimate Means	
		Depervation index	Yes	No	4	4	Macro	1	2nd	2	Basic		Ultimate Means	
	Training (qualification level)	Extent to which global citizenship education and education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in: (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment	No	No										
		Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies	No	No										
		% of households who believe education is important	No	No										
		Highest qualification for those aged 15 years and over	Yes	No	4	3	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		School leavers' achievement of NCEA level 2 or higher	Yes	No	4	3	Macro	1	2nd	2	Psychological		Intermediate Means	
		Year-1 entrant's previous participation in ECE	No	No										
		The number of adults aged 25 to 64 holding at least an upper secondary degree over the population of the same age	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		The proportion of adults aged 25–64 years with educational attainment of at least a Bachelor's degree or higher qualification	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		% of Maori adults aged 18 years and over had at least a level 2 certificate	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
	Safety	Crime rate	No	No										
		Perception of safety	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Curruption	No	No										
		% of households who feels safe at work	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Physical health risk factors associated with jobs (Tiring and painful position, carrying ro moving heavy loads, Exposed to vibrations from hand tools or machinery, Exposure to high noise, Exposure to high or low temperature)	No	No										
	Life satisfaction	Quality of life	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Emotional wellbeing	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Migration due to good quality of life	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Self-reported stress	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Sense of purpose	Yes	No	4	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Percentage of people who have friends or relatives to rely on in case of need	Yes	No	4	2	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Satisfaction with the opportunities to participate in council decision making	Yes	No	3	4	Macro	1	2nd	2	Self-fulfillment		Ultimate Ends	
		Satisfaction that the Council is making decisions in the best interest of the City	No	No										
		Satisfaction with the quality of drinking water	No	No										
		Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)	No	No										
		Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)	No	No										
		Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)	No	No										

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension				
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic Self-fulfillment	Psychological	Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Economic Capital	Wealth	GDP (National)	Yes	No	5	3	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		GDP (Regional)	Yes	No	5	5	Meso	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Regional Exports / Imports	Yes	No	5	5	Meso	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Regional wealth	Yes	No	5	5	Meso	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Productivity	Yes	No	5	4	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Disposable income	Yes	No	5	4	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Poverty level	No	No										
		Food availability	No	No										
		Organisatinal balance statement (debt & investment levels)	No	No										
		Mean equivalised household disposable income	Yes	No	5	4	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Household net adjusted disposable income per capita	Yes	No	5	4	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		% of Maori adults postpone or put off visits to the doctor, due to low income	No	No										
		telecommunications (landline/internet/no mobile phone/ no telecommunications) due to low income	No	No										
		Satisfaction with income meeting everyday needs	No	No										
		Median(or average) hourly earnings of a household	Yes	No	5	3	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Low household income	Yes	No	5	3	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
	Employment - availability/growth/diversity/job satisfaction	Employment rate	Yes	No	5	4	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Labour force participation rate	Yes	No	5	5	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Unemployment rate	Yes	No	5	5	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Underemployment rate	Yes	No	5	5	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Cost of labour	Yes	No	5	5	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Earning inequality	Yes	No	5	5	Macro	1	2nd	1	Self-fulfillment		Ultimate Ends	
		Job satisfaction	Yes	No	5	5	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		work autonomy and learning opportunities (can choose or change the order of tasks, can choose or change methods of work, job involves learing new things-employer provided training or on-the-job training	Yes	No	5	5	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		Workplace relationships	Yes	No	5	3	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		Feel “at home” at work and have very good friends at work	No	No										
		Job strain	Yes	No	5	4	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		Time pressure at work	Yes	No	5	4	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		Difficulty to take an hour or two off during working hours for personal or family matters	Yes	No	5	4	Macro	3	2nd	3	Self-fulfillment		Ultimate Ends	
		Work at very high speed and to tight deadlines	No	No										

Fitness Assessment - Wellbeing Conceptual Model Indicator Assessment for Meso Level Performance Framework & Conceptual Model			Data Assessment				Conceptual Model Test - Spatial Dimension			Conceptual Model Test - Needs Dimension				
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Is there data for this measure? (yes/no) Stats NZ	Waikato Regional Council	Data Accessibility (Ease of Use, Physical Accees, Intellectual Access) 1 (low) to 5 (high)	Data Quality (Information Quality & Relevance) 1 (low) to 5 (high)	Macro / Meso / Micro	Specific (1) to General (3)	Order of attribution (1st or 2nd)	Objective (1) to Subjective (3)	Basic	Psychological Self-fulfillment	Ultimate Means / Intermediate Means / Ultimate Ends	Comments
Infrastructure (technology)	Lifecycle / asset preservation	Asset capacity	No	No										Stats NZ or WRC do not collect or publish any of this data
		Demand	No	No										Stats NZ or WRC do not collect or publish any of this data
		Backlog - pipes that are beyond condition/performance level that they should be	No	No										Stats NZ or WRC do not collect or publish any of this data
		Resilience	No	No										Stats NZ or WRC do not collect or publish any of this data
		Affordability	No	No										Stats NZ or WRC do not collect or publish any of this data
		Net asset value & future value over time	No	No										Stats NZ or WRC do not collect or publish any of this data
		Emissions	No	No										Stats NZ or WRC do not collect or publish any of this data
		Net present value	No	No										Stats NZ or WRC do not collect or publish any of this data
		Cost benefit	No	No										Stats NZ or WRC do not collect or publish any of this data
		Operating ratio (annual operating revenues to annual operating expenses)	No	No										Stats NZ or WRC do not collect or publish any of this data

Chapter 9. Discussion of Findings

The fitness assessment completed with the Stats NZ and Waikato Regional Council questionnaire provided an initial indication that a wide range of data sets are available to test the performance framework and conceptual model. The range of data identified in the case study indicates that the data available has the potential to provide an appropriate range of indicators and measures covering the natural, social-cultural, human, and economic capitals but there is a lack of available data for infrastructure. The lack of infrastructure data pertains to the level of data collection conducted by Stats NZ and the Waikato Regional Council as both organisations do not collect information on three water infrastructure assets leaving this to District or City Councils and private owners to collect and manage this information. The assessment also identified complimentary collection of data with Stats NZ and Waikato Regional Council collecting different information, with no cross over of data indicated that was available on any measure.

A total of 28 indicators and 168 measures were identified in the initial development work, through the questionnaire response there is data available for 22 indicators and 68 measures (Table 20). The data fitness overall is considered good through the assessment but is lacking in the number of 1st order, meso and micro level measures that can be attributed directly to three waters infrastructure. This is most likely occurring due to the lack of feedback from a data source that owns the asset, i.e., District or City Council. The other areas of missing data or poor data coverage for indicators was in the human capital wellbeing indicator, 'infections/disease/mental health/change in physical health' and general three waters satisfaction measures (see Table 19).

A review of the indicators and measures that did not have available data in the case study was completed, identifying an additional six indicators and 43 measures that require further research to identify data fitness and testing (see Table 21). Potential alternate data sources have been identified in Table 21 by the author and Appendix E by case study respondents.

The fitness assessment was designed to provide an initial test of the performance framework using the conceptual model. The fitness assessment criteria utilised (Chapter 8: Figure 49 and Table 19) was assessed through the lens of the conceptual models intended use and focused on the data's availability, measure relevance, and how the measure data would potentially work if used in the conceptual model. An example of the intended use of the indicators and measures

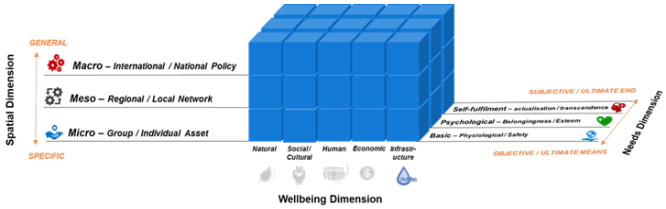
is shown in Figure 50. This example shows how the indicators and measures could help to inform and understand the performance of three waters infrastructure on each of the capitals, where the current performance is identified with each capital indicating the overall spatial and needs dimension performance as a slice in time. In this example three slices of time are used to show the current performance (Time Slice 1: Current state with desired future targets), intermediary performance assessment (Time Slice 2), and the final state (Time Slice 3: Final state (target); showing obtaining the identified target performance, noting continued assessment of performance will be required to ensure performance continues to meet desired expectations).

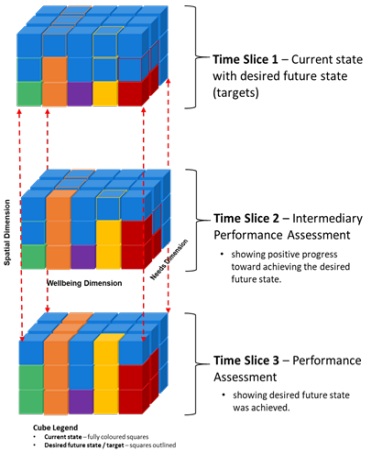
Table 20. List of indicators and measures with identified data sources from case study (in green)

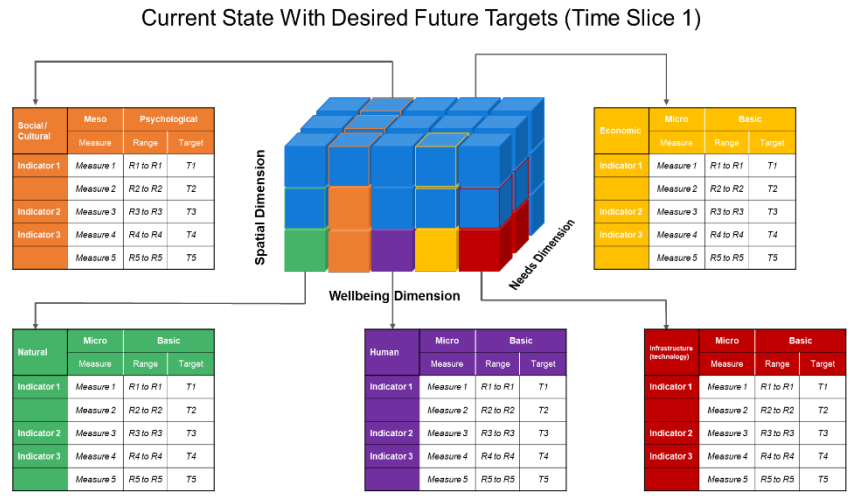
Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures
Natural Capital	Environmental quality (pollution)	Proportion of bodies of water with good ambient water quality
		Water quality - exceedance of consent conditions
	Biodiversity	State of the lakes, rivers, harbours, and coastlines (In point of biodiversity)
	Natural resource depletion	Suitability for Recreational Grade for monitored freshwater swimming sites
		Suitability for Recreational Grade for monitored coastal swimming sites
	Land use impacts	Percentage of wastewater consent exceedance
		Water quality - exceedance of consent conditions
	Resilience (climate adaptation)	Risk of impact from hazards (environment / people)
	Ability to support mahinga kai species (native food species)	Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species)
	Access to safe water/land	Suitability for Recreational Grade for monitored coastal swimming sites
Social / Cultural Capital	Indigenous rights	Involvement of Maori in decision making
		Importance of being engaged in Maori culture
	Cultural acceptance	Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species)
		Land use or land cover in the wider catchment that can be seen from the site being assessed
	Satisfaction with access to natural environment and access to three waters	Satisfaction with access to natural environment
		Is the vegetation (indigenous or exotic) that is visible along the margins (100 m either side) of the waterway.
		Is the extent the margins of a stream are being used (heavy use of the margins can impact on stream health)
		The state of the riverbed can be assessed by the amount of sediment that has built up
		Rate flow in river and flow-related habitat variety that can impact on river health
		Quality of life
		Suitability for Recreational Grade for monitored coastal swimming sites
	Institutional trust	Local and Central government reputation survey
	Participation / engagment	Percentage of population participating in elections
		Satisfaction with decision making
	Belongingness	Whanau (family) wellbeing
		Migration
	Generational relevancy	Involvement of Maori to look after someone who was disabled or ill
		Time availability
Human Capital	Life expectancy	Life expectancy
	Infections / disease/Mental health/change in physical health	Increase/decrease or proportion of Maori aged 15-24 years who smoke regularly
	Household	% of Maori living in the deprived decile areas
		Depervation index
	Training (qualification level)	Highest qualification for those aged 15 years and over
		School leavers' achievement of NCEA level 2 or higher
		The number of adults aged 25 to 64 holding at least an upper secondary degree over the population of the same age
		The proportion of adults aged 25–64 years with educational attainment of at least a Bachelor's degree or higher qualification
		% of Maori adults aged 18 years and over had at least a level 2 certificate
	Safety	Perception of safety
		% of households who feels safe at work
	Life satisfaction	Quality of life
		Emotional wellbeing
		Migration due to good quality of life
		Self-reported stress
		Sense of purpose
		Percentage of people who have friends or relatives to rely on in case of need
		Satisfaction with the opportunities to participate in council decision making
Economic Capital	Wealth	GDP (National)
		GDP (Regional)
		Regional Exports / Imports
		Regional wealth
		Productivity
		Disposable income
		Mean equivalised household disposable income
		Household net adjusted disposable income per capita
		Median(or average) hourly earnings of a household
		Low household income
	Employment - availability/growth/diversity/job satisfaction	Employment rate
		Labour force participation rate
		Unemployment rate
		Underemployment rate
		Cost of labour
		Earning inequality
		Job satisfaction
		work autonomy and learning opportunities (can choose or change the order of tasks, can choose or change methods of work, job involves learing new things-employer provided training or on-the-job training
		Workplace relationships
		Job strain
		Time pressure at work
		Difficulty to take an hour or two off during working hours for personal or family matters

Table 21. List of indicators and measure gaps that did not have data available from case study, the list indicates proposed indicators and measures (in orange) that would add value in obtaining data for future research

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Discussion
Natural Capital	Environmental quality (pollution)	Satisfaction with Water quality –pollution exceedance	Look to obtain data from local Council
	Biodiversity	Satisfaction with condition and management of waterways (in point of biodiversity)	Identify data source and availability
	Natural resource depletion	Percentage of treated water leakage in the network	Look to obtain data from local Council
		Change in water-use efficiency over time	Look to obtain data from local Council
	Land use impacts	Land use or land cover in the wider catchment that can be seen from the site being assessed	Identify data source and availability
	Ecosystem vulnerability	Change in the extent of water-related ecosystems over time (overtime / climate / shock events)	Identify data source and availability
	Conservation	Proportion of wastewater safely treated	Look to obtain data from local Council
		Proportion of drinking water used to availability	Look to obtain data from local Council
		Percentage of treated water leakage in the network	Look to obtain data from local Council
	Resilience (climate adaptation)	Salt intrusion in drinking water supply	Look to obtain data from local Council
	Access to safe water/land	Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	Look to obtain data from local Council or other source
		Proportion of population using safely managed drinking water services	Look to obtain data from local Council or other source
		Satisfaction with access to 3 waters services	Look to obtain data from local Council
Social-Cultural Capital	Cultural acceptance	Site significance to tangata whenua (i.e. tradional/non-traditional)	Identify data source and availability
	Satisfaction with access to natural environment and access to three waters	Satisfaction with access to 3 water network	Look to obtain data from local Council
		Access to safe water for recreation and food gathering	Look to obtain data from local Council
Human Capital	Infections / disease/Mental health/change in physical health	Notifications of campylobacteriosis, cryptosporidiosis and giardiasis	sources
		Notification of Diarrhoea with untreated water	sources
		Notification of vector-borne disease (mosquito-borne disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease	Look to obtain from district health sources
		Immediate trauma and indirect impacts (chronic diseases and risk) in weeks to months after extreme events (e.g flooding, landslides, storm surges, drought) on health of Maori and non-Maori (e.g. from pre-existing conditions, mental health)	Look to obtain from district health sources
		Number of deaths, missing persons and directly affected persons attributed to disasters (e.g. flooding) per 100 000 population	Look to obtain from district health sources
		Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe water, sanitation, and hygiene for all (WASH) services)	Look to obtain from district health sources
	Access to compliant drinking water	Households with access to bacteriological (E-coli) compliant drinking water	Look to obtain data from local Council
		Household with access to protozoal compliant drinking water	Look to obtain data from local Council
		Household with chemical compliant drinking-water	Look to obtain data from local Council
		Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	Look to obtain data from local Council
		Households with access to fluoridated drinking water	Look to obtain data from local Council
	Access to wastewater services	Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household	Look to obtain data from local Council
	Illness due to water borne infections		Remove Indicator - repetative measures to 'Infections / disease/Mental health/change in physical health' indicator. No additional measure required.
	Household	House hold affordability	Identify data source and availability
		Household availability	Identify data source and availability
	Safety	Crime rate	Identify data source and availability
	Life satisfaction	Satisfaction with the quality of drinking water	Look to obtain data from local Council
		Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)	Look to obtain data from local Council
Infrastructure (technology)	Lifecycle / asset preservation	Asset capacity	Look to obtain data from local Council
		Demand	Look to obtain data from local Council
		Backlog - pipes that are beyond condition/performance level that they should be	Look to obtain data from local Council
		Resilience	Look to obtain data from local Council
		Affordability	Look to obtain data from local Council
		Net asset value & future value over time	Look to obtain data from local Council
		Emissions	Look to obtain data from local Council
		Net present value	Look to obtain data from local Council
		Cost benefit	Look to obtain data from local Council
		Operating ratio (annual operating revenues to annual operating expenses)	Look to obtain data from local Council







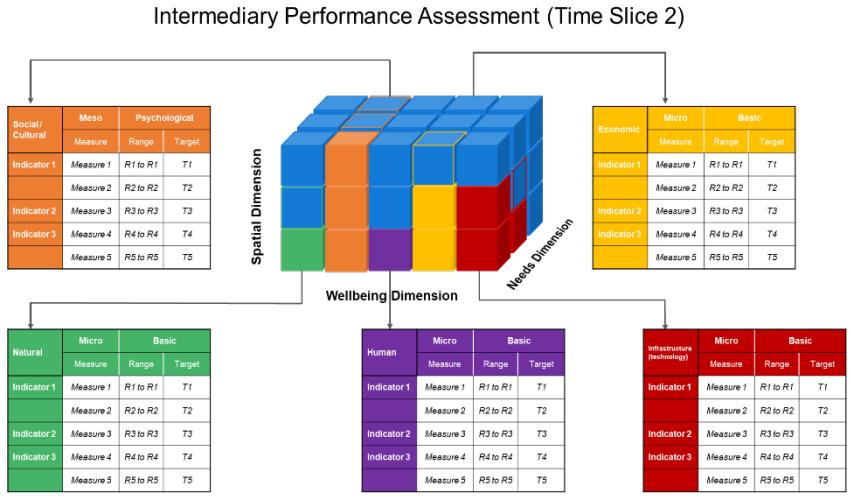


Figure 50. Example of utilisation of indicators and measures in the conceptual model

The case study responses to the questionnaire and fitness assessment (Table 19) were reviewed to identify key observations from the fitness assessment and in reference to the intended future use of the conceptual model (Figure 50). These observations, gaps, and identification of further research requirements are summarised in Table 22, Table 23, Table 24, Table 25, and Table 26.

Table 22. Fitness assessment observations from case study responses – Natural Capital

Natural	Observations from case study fitness assessment
Wellbeing Dimension	*The coverage of indicators and measures with data sources identified through the case study are limited and will require further refinement with additional data sourced for measures related to specific three waters infrastructure assets and higher order measures for the needs dimension of the conceptual model.*
Spatial Dimension	*The measures identified:* • *Provide good coverage at the meso and macro level;* • *Provide data sources that are specific with only one general data set (being hazards mapping); and* • *Provide a mix of 1st and 2nd order attribution to the indicators and capital.*
Needs Dimension	*The measures identified:* • *Provide objective data, except for the hazards mapping;* • *Cover basic and physiological needs with no measure identified to provide for at the self-fulfillment level; and* • *Cover ultimate and intermediate means with no measure identified to provide for at the ultimate ends level.*
Data Assessment	• *The data available was from the Waikato Regional Council with no data available from Stats NZ.* • *The data accessibility ranges from quantitative and easily accessible data (i.e., water quality) too hard to access and process data (i.e., decades of consent monitoring reports).* • *Regional Council data is site specific and does not cover all areas equally.* • *Data relevance was good though most data identified by the Regional Council would be hard to collate and process.* • *Data related to measures specific to infrastructure assets was not obtainable from the case study sources.* • *Data for most measures is site specific and not generalised over the entire region.*
Gaps & Further Research Requirements	• *There is a gap for measures providing coverage at the higher needs level, self-fulfillment and ultimate ends. Identification of measures at this level is required to cover the full range in the conceptual model.* • *Data sources for some measures indicate potential difficulty in collating and analysing (i.e., consent monitoring information). Refinement or removal of these measures may be required as the data may not be easily processed and analysed.* • *Data completeness and technical quality will need to be assessed.* • *Measures with data at the micro level will be required to provide direct linkages (at the 1st order attribution) to the three waters infrastructure, these relate to assessing the impacts of specific three waters infrastructure assets.* • *Future modelling of three waters infrastructure may require pre-assessment of impact or areas of significance to identify specific areas to obtain data from. This is due to the Regional Council data being site specific and not covering the entire region.* • *Obtaining additional data for measures identified in Table 21 will be required.*

Table 23. Fitness assessment observations from case study responses – Social / Cultural Capital

Social / Cultural	Observations from case study fitness assessment
Wellbeing Dimension	*The coverage of indicators and measures with data sources identified through the case study for this wellbeing covers all levels of the needs and spatial dimensions providing adequate coverage for assessment in this wellbeing dimension. There are no micro level measures identified, though the nature of this wellbeing with the social/cultural focus makes micro and 1st order connections more difficult.*
Spatial Dimension	*The measures identified:* • *Provide good coverage at the meso and macro level;* • *Provide data sources that are both specific and general; and* • *Focus on 2nd order attribution to the indicators and capital, with only one measure identified as 1st order attribution (Suitability for Recreational Grade for monitored coastal swimming sites).*
Needs Dimension	*The measures identified:* • *Provide a mix of objective and subjective data;* • *Cover all needs levels from Basic, Intermediate, to Self-fulfillment; and* • *Cover ultimate and intermediate means and ultimate ends level.*
Data Assessment	• *The data available was from both Stats NZ and Waikato Regional Council.* • *The data accessibility ranges from easily accessible data in spreadsheets and processed data to unknown data types and access (responses did not provide this information).* • *Data completeness from Regional Council indicated most data, though available, was incomplete.* • *Data relevance was good though most data identified will need to be verified.*
Gaps & Further Research Requirements	• *Three additional measures around site significance to Tangata Whenua, satisfaction with access to three waters network, and access to safe water for recreation and food gathering would add benefit to this wellbeing but would not be critical if data is not obtainable (Table 21).* • *Data completeness and technical quality will need to be assessed.* • *Follow up of data access is required to verify accessibility.* • *Further explore micro level and 1st order measures and data sources for direction attribution to three waters infrastructure.*

Table 24. Fitness assessment observations from case study responses – Human Capital

Human	Observations from case study fitness assessment
Wellbeing Dimension	*The coverage of indicators and measures with data sources identified through the case study provide a good range for the spatial and needs dimensions of the conceptual model with a focus on the self-fulfillment and ultimate ends. Measures are also focused on a 2nd order attribution and provide good coverage of the quality of life, emotional wellbeing, and stress and sense of purpose. This provides the human capital a good coverage at the self-fulfillment and ultimate ends level in the needs dimension. Micro level and 1st order measures for three waters infrastructure access will be required as well as meso level measures for health will be required.*
Spatial Dimension	*The measures identified:* • *Provide good coverage at the macro level with no identified measures at the meso or micro level;* • *Provide data sources that are specific with most information obtained through census collection; and* • *Focus on 2nd order attribution to the indicators and capital with no 1st order attribution noted.*
Needs Dimension	*The measures identified:* • *Lean toward more subjective data;* • *Cover all needs levels from Basic, Intermediate, to Self-fulfillment, with the primary focus being at the self-fulfillment level; and* • *Cover ultimate and intermediate means and ultimate ends level, with a focus on ultimate ends.*
Data Assessment	• *The data available was from Stats NZ with no data available from Waikato Regional Council.* • *The data accessibility is good with Stats NZ being able to provide information from Census data, excel spreadsheets, web access, and customised data sets.* • *Data relevance was good.*
Gaps & Further Research Requirements	• *Data completeness and technical quality will need to be assessed.* • *Obtaining additional data for measures identified in Table 21 will be required. These measures are primarily focused on infections, disease, and physical health (potentially obtained from District Health Boards) and household access to three waters services (potentially obtained from City of District Councils).* • *Assessment of micro and 1st order connections will be required.*

Table 25. Fitness assessment observations from case study responses – Economic Capital

Economic	Observations from case study fitness assessment
Wellbeing Dimension	*The coverage of indicators and measures with data sources identified through the case study provide a good range for the spatial and needs dimensions of the conceptual model with a focus on the self-fulfillment and ultimate ends. Measures are also focused on a 2nd order attribution and provide good coverage of both specific/objective economic data at the national and regional level and general/subjective data for measures like job satisfaction, relationships, and strain. This provides the economic capital a good coverage at the self-fulfillment and ultimate ends level in the needs dimension.*
Spatial Dimension	*The measures identified:* • *Provide good coverage at the macro level with some regional data sources for meso level;* • *Provide data sources that are both specific (i.e., GDP, income, earnings) and general (i.e., job satisfaction); and* • *Focus on 2nd order attribution to the indicators and capital.*
Needs Dimension	*The measures identified:* • *Provide a mix of objective and subjective data;* • *Cover only the Self-fulfillment; and* • *Cover only the ultimate ends level.*
Data Assessment	• *The data available was from Stats NZ with no data available from Waikato Regional Council.* • *The data accessibility is good with Stats NZ being able to provide information through spreadsheets and databases.* • *Data relevance was very good.*
Gaps & Further Research Requirements	• *Data completeness and technical quality will need to be assessed.* • *Assessment of regional data sources will be required.* • *No further measures or data sources will be required.*

Table 26. Fitness assessment observations from case study responses – Infrastructure Capital

Infrastructure (technology)	Observations from case study fitness assessment
Wellbeing Dimension	*The coverage of indicators and measures with data sources identified through the case study indicates no data available from Stats NZ or Waikato Regional Council. Identification of sources for the data will be required, it is noted that this type of data collection is completed by infrastructure asset owners, such as City or District Councils.*
Spatial Dimension	*Not able to assess in this research due to two participating organisations not collecting data for this capital.*
Needs Dimension	*Not able to assess in this research due to two participating organisations not collecting data for this capital.*
Data Assessment	*Not able to assess in this research due to two participating organisations not collecting data for this capital.*
Gaps & Further Research Requirements	• *Identify suitable provider for data in this capital, i.e., City or District Councils.* • *Obtain data for measures identified in Table 21 will be required.* • *Data completeness and technical quality will need to be assessed.*

Chapter 9 discussed the findings from the case study completed in chapter 8. This chapter completed the last stage (stage 4) of the filtering process and provided observations, identified the fitness and gaps from the case study. This stage of the filtering process provided an initial indication of the design validity of the performance framework and conceptual model with the case study indicating that data is available for 22 indicators and 68 measures of the total 28 indicators, and 168 measures identified in the initial development work. The data fitness overall was considered good but had a gap in the number of 1st order, meso and micro level measures that can be attributed directly to three waters infrastructure assets. This is most likely occurring due to the lack of feedback from a data source that owns the asset, i.e., District or City Council. The other areas of missing data or poor data coverage for indicators was in the human capital wellbeing indicator, 'infections / disease / mental health / change in physical health' and general three waters satisfaction measures. A review of the indicators and measures that did not have available data in the case study identified an additional six indicators and 43 measures that require further research to identify data fitness and testing. The outputs from the case study were reviewed to identify key observations from the fitness assessment and in reference to the intended future use of the conceptual model (Figure 50). These observations, gaps, and identification of further research requirements are summarised in Table 22, Table 23, Table 24, Table 25, and Table 26 in chapter 9.

Chapter 10. Summary and Recommendations

10.1. Overview

Water infrastructure is under stress around the world with potable drinking water, stormwater, and wastewater management services impacting on our communities' health and wellbeing. The issues we are experiencing in water infrastructure investment originates from an infrastructure asset (physical base), infrastructure decision making (holistic investment analysis), and the ability to comprehensively analyse and query information (data type and quantity). This thesis focused on understanding the problem of a lack of a holistic investment decision making model considering social, environmental, economic, and infrastructure variables leading to investment decisions that are unable to deliver sustainable intergenerational wellbeing in three waters infrastructure.

The research presents a novel holistic performance monitoring framework and a conceptual model for three waters infrastructure (drinking water, wastewater, & stormwater); giving due consideration to the New Zealand Treasury Living Standards Framework (NZ LSF) and the United Nations Sustainable Development Goals (UN SDG). The performance framework and conceptual model developed for three waters infrastructure considered the social, cultural, environmental, economic, and infrastructure variables as well as intergenerational wellbeing and sustainability.

The research will help decision-makers better understand the impact of their decisions on intergenerational wellbeing and help address the pressures that are leading to the identified problem statement. To achieve this, the objectives were to:

- Integrate with the New Zealand Living Standards Framework and United Nations Sustainable Development Goals (macro-level);
- Demonstrate the development of a three-waters wellbeing performance framework and conceptual model that could be adopted at a regional, district, or city council level (Meso level);
- Identify initial potential indicators and measures that could be used to understand the performance of the wellbeing three-waters framework;

- Explore the availability of data and fitness of the data for the performance framework utilising a sample taken from Statistics New Zealand and the Waikato region; and
- Identify future development potential, which includes finding the impact of investment in three-waters on the community's wellbeing and conducting a performance analysis.

10.2. Developed Framework

The research identified a range of frameworks focused on different decision-making levels from the high level (macro), intermediate level (meso), and individual level (micro). A gap was identified in the performance and decision-making investment frameworks, with most frameworks working at the micro (individual asset or scheme) level or macro-level (international or national), and not a meso level (regional / local or network). Also, the literature review identified a gap between the macro frameworks, which focused more on policy direction and national wellbeing performance, and micro-level, which focused on individual asset performance or investment assessment. A further assessment of the gap between the macro frameworks (i.e., NZ LSF and UN SDG), which focus on policy direction and national wellbeing performance, and micro frameworks, which focused on individual asset performance or investment assessments was completed to better understand the development of a meso level performance framework and to gain a more in-depth understanding of the drivers leading to the development of existing frameworks, their intended use, desired outcomes, and interrelationships between the three levels (macro, meso, micro). This research was used to help better understand the identified problem and the key elements required to develop a meso level framework that utilises the wellbeing's in three-waters infrastructure assets.

The development of the framework defined the macro, meso, and micro levels, the role of the wellbeing capitals, worked through the logic of incorporating the use of infrastructure (or technology) into a meso level performance framework that would allow for the consideration of sustainability and intergenerational wellbeing. The novel performance framework developed showed the connection of the NZ LSF domains and capitals and the UN SDGs. The layers of the framework are structured like an onion to indicate the layers from the central Wellbeing Dimension that includes the capitals (physical (infrastructure), natural, human, economic, and social/cultural) and the stocks comprising comprehensive wealth and the physical environment. The layer outside of the wellbeing dimension comprises the wellbeing

frontiers and domains of public policy linking to the NZ LSF domains and the UN SDG. Finally, the outer layers signify the overarching drive toward sustainability and, ultimately, intergenerational wellbeing.

Following the development of the performance framework a conceptual model was developed to help understand the interactions between indicators and measures used in the framework. The conceptual model incorporated four dimensions: 1. Wellbeing Dimension, 2. Needs Dimension, 3. Spatial Dimension, 4. Time Dimension. The three main dimensions being the wellbeing, needs, and spatial dimensions were developed into a cube model that was able to show the multi-dimensional interactions. While the time dimension enables the conceptual model to show the current and intergenerational performance through time slices or snap shots through identified time intervals. These intervals can show actual performance and identify desired targets or the proposed future state. The conceptual model developed helped to show the interrelationships between the three dimensions and to better understand how the proposed indicators and measures could inform and influence infrastructure decisions and performance from a wellbeing perspective.

10.3. Findings from Validation

A validation process was undertaken to assess the data availability and fitness for the intended purpose by conducting a case study with two organisations, Stats NZ and the Waikato Regional Council. The data collection questionnaire provided to the two organisations listed each of the indicators and associated measures against each of the wellbeing capitals, asking the organisations to identify whether they collected the data or not and what type of data they held for the measure (if they collected it). In this stage, the relevance of each measure with available data was tested across the spatial and needs dimensions to ensure the indicators provided an appropriate cross-section against the conceptual model. This was completed utilising an adapted data information use model to test the fitness of the indicators and measures for their intended use in the meso level infrastructure wellbeing performance framework and conceptual model. A filtering process was developed and used to provide an initial indication of the design validity of the performance framework and conceptual model. The case study indicated that data is available for 22 indicators and 68 measures of the total 28 indicators and 168 measures identified in the initial development work. The data fitness overall was considered good but had a gap in the number of 1st order, meso and micro level measures that can be attributed directly to three waters infrastructure. This is most likely occurring due to the lack of feedback

from a data source that owns the asset, i.e., District or City Council. The other areas of missing data or poor data coverage for indicators was in the human capital wellbeing indicator, 'infections/disease/mental health/change in physical health' and general three waters satisfaction measures. A review of the indicators and measures that did not have available data in the case study identified an additional six indicators and 43 measures that require further research to identify data fitness and testing. The outputs from the case study were reviewed to identify key observations from the fitness assessment and in reference to the intended future use of the conceptual model. These observations, gaps, and identification of further research requirements are summarised in Table 22, Table 23, Table 24, Table 25, and Table 26 in Chapter 9.

10.4. Recommendations and Further Research Needs

Significant work has been undertaken by organisations to develop macro-level wellbeing frameworks that support policy setting at the national level. The development of a novel meso level wellbeing performance framework and a suite of indicators that will integrate with macro and micro levels will provide a valuable resource for decision-makers when considering performance and investments in the three waters infrastructure. This study has identified the value of utilising a framework like the NZ LSF and how it could be integrated with the UN SDGs for use at a meso (regional/local) level to understand the most appropriate three waters infrastructure solution and the impact on intergenerational wellbeing. This initial work has successfully developed a wellbeing performance framework and conceptual model. The initial work has also identified the potential usefulness of the framework and conceptual model for use by three waters infrastructure asset managers and owners in assessing wellbeing performance and investment decisions. Further research is required to develop a supporting mathematical model, obtain further data with 1st order attribution at the micro (individual asset) level and health indicators, test the technical quality of the data available, and further develop the framework and conceptual model.

This is only the first step in the development journey, with further work required to explore the concepts and better define the interactions, systems dynamics, modelling, and indicators that can be utilised to understand the current and future state of wellbeing. It is also recommended that further research is completed to adapt the framework and conceptual model for use with other infrastructure assets.

References

Abdallah, S., Thompson, S., Michaelson, J., Marks, N., & Steuer, N. (2009). The Happy Planet Index 2.0: Why Good Lives Don't have to Cost the Earth.

Alejandro Padilla-Rivera, L. P. G. (2019). A proposal metric for sustainability evaluations of wastewater treatment systems (SEWATA). *Ecological Indicators*, *103*, 22-23.

Alexander Otto, J. W. H., Adrian J. Hickford, Robert J. Nicholls, David Alderson, Stuart Barr, and Martino Tran. (2016). A Quantified System-of-Systems Modeling Framework for Robust National Infrastructure Planning. *IEEE Systems Journal*, *10*(2), 385-396.

Amadi-Echendu, J. E., Willett, R., Brown, K., Hope, T., Lee, J., Mathew, J., . . . Yang, B.-S. (2010). What Is Engineering Asset Management? In *Definitions, Concepts and Scope of Engineering Asset Management* (pp. 3-16). Springer London. https://doi.org/10.1007/978-1-84996-178-3_1

Balkema, A. J., Preisig, H. A., Otterpohl, R., & Lambert, F. J. (2002). Indicators for the Sustainability Assessment of Wastewater Treatment Systems. *Urban water*, *4*(2), 153-161.

Beeching, A., Georgieva, A., & Sloggett, J. (2020). Responsible Investment and Central Bank Asset Management. In *Asset Management at Central Banks and Monetary Authorities* (pp. 439-457). Springer International Publishing. https://doi.org/10.1007/978-3-030-43457-1_26

Community and Public Health, C. D. H. B. (2017). *Summary of Rapid Review of International and New Zealand Examples of Wellbeing Monitoring Products*.

Costanza, R., Daly, L., Fioramonti, L., Giovannini, E., & Kubiszewsk, I. (2016). Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals. *Ecological Economics*, *130*, 350-355. (26 July 2016)

Curran, M. A. (2013). Life Cycle Assessment: a review of the methodology and its application to sustainability. *Current Opinion in Chemical Engineering*, *2*, 273-277.

Daly, H. (2014). *An Economics Fit for Purpose in a Finite World*. Center for the advancement of the steady state economy. Retrieved 2 October 2014 from https://steadystate.org/an-economics-fit-for-purpose-in-a-finite-world/

Daly, H. (2014). *An Economics for Purpose in a Finite World Centre for the Advancement of the Steady State Economy* https://steadystate.org/an-economics-fit-for-purpose-in-a-finite-world/

Desa, U. (2016). Transforming our World: The 2030 Agenda for Sustainable Development.

DPMC. (2003). *Sustainable Development for New Zealand*. Wellington, New Zealand

Dr Anita King, D. G. H. a. N. M. (2018). *Wellbeing Frameworks for the Treasury*. Retrieved from http://www.treasury.govt.nz/publications/research- policy/dp/2018/18-01

Favager, C. (2019, 28 May 2019). Reflections on frameworks of wellbeing. https://blog.deloitte.co.nz/articles/reflections-on-frameworks-of-wellbeing/

Felce, D., & Perry, J. (1995). Quality of life: Its definition and measurement. *Research in Developmental Disabilities*, *16*(1), 51-74. https://doi.org/10.1016/0891-4222(94)00028-8

Franco, M. P. V. (2018). Searching for a Scientific Paradigm in Ecological Economics: The History of Ecological Economic Thought, 1880s–1930s. *Ecological Economics*, *153*, 195-203.

Frieling, M. (2018). *The Start of a Conversation on the Value of New Zealand's Social Capital* (Living Standards Series: Discussion Paper 18/04, Issue. http://www.treasury.govt.nz/publications/researchpolicy/

Frieling, M., & Warren, K. (2018). *Resilience and Future Wellbeing - The start of a conversation on improving risk management and resilience of the Living Standards Capitals* (Living Standards Series: Discussion Paper 18/05, Issue. https://treasury.govt.nz/publications/dp/dp-18-05

Gebre, S. L., Cattrysse, D., & Van Orshoven, J. (2021). Multi-Criteria Decision-Making Methods to Address Water Allocation Problems: A Systematic Review. *Water*, *13*(2), 125. https://doi.org/10.3390/w13020125

Girol Karacaoglu, J. B. K., Anita King. (2019). *Intergenerational Wellbeing and Public Policy - An Integrated Environmental, Social, and Economic Framework*. Springer.

Gleisner, B., Llewellyn-Fowler, M., & McAlister, F. (2011). *Working Towards Higher Living Standards for New Zealanders*. New Zealand Treasury paper.

Local Government Act 2002 (3 Sept 2007), (2007).

Local Government Act 2002 (5 Dec 2012), (2012).

Government, N. (2018). *The Treasury Approach to the Living Standards Framework*. Retrieved from http://www.treasury.govt.nz/publications/research-policy/tp/approach-to-lsf

Local Government Act 2002 (14 May 2019), (2019a).

Government, N. (2019b). *The Wellbeing Budget*. Retrieved from budget.govt.nz/budget/2019/ wellbeing

Treaty of Waitangi Act 1975, (1975). https://legislation.govt.nz/act/public/1975/0114/latest/DLM435368.html#DLM435834

Resource Management Act 1991, (2020). https://legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

Gustafsson, P. F. a. S. (2017). Moving from high-level words to local action — governance for urban sustainability in municipalities. *Current Opinion in Environmental Sustainability*, *26-27*, 129-133.

Hagerty, M. R. (1997a). *Social Indicators Research*, *46*(3), 249-271. https://doi.org/10.1023/a:1006921107298

Hagerty, M. R. (1997b). Testing Maslow's Hierarchy of Needs: National Quality-of-Life Across Time. *Social Indicators Research*, *46*(3), 249-271. https://doi.org/10.1023/a:1006921107298

Harmsworth, G. *The role of Māori values in Low-impact Urban Design and Development (LIUDD)*.

Harmsworth, G., Awatere, S., & Robb, M. (2016). Indigenous Māori values and perspectives to inform freshwater management in Aotearoa-New Zealand. *Ecology and Society*, *21*(4).

Harmsworth, G., Young, R., Walker, D., Clapcott, J., & James, T. (2011). Linkages between cultural and scientific indicators of river and stream health. *New Zealand Journal of Marine and Freshwater Research*, *45*(3), 423-436.

Heink, U., & Kowarik, I. (2010). What are indicators? On the definition of indicators in ecology and environmental planning. *Ecological Indicators*, *10*(3), 584-593. https://doi.org/10.1016/j.ecolind.2009.09.009

IPWEA. (2015). *International Infrastructure Management Manual* (L. Roberts, Ed. Vol. 5.0).

ISO. (2006). ISO 14044: Environmental management — Life cycle assessment — Requirements and guidelines. In *ISO 14044:2006(E)*. Geneva: International Organisation for Standardization.

ISO. (2014a). ISO 5500:2014(E) - Asset management - Overview, principles and terminology. In *International Standard*. Switzerland.
ISO. (2014b). ISO 5502:2014(E) Asset management - Management systems - Guidelines for the application of ISO 5501. In. Switzerland: International Organization for Standardization.
ISO. (2014c). ISO 55001:2014(E) Asset management - Management systems - Requirements. In *International Standard*. Switzerland: International Organization for Standardization.
Janssen, J. (2018). *The Start of a Conversation on the Value of New Zealand's Financial/Physical Capital* (Living Standards Series: Discussion Paper 18/07, Issue. https://treasury.govt.nz/publications/dp/dp-18-07
Karacaoglu, G., Krawczyk, J. B., & King, A. (2019). *Intergenerational Wellbeing and Public Policy: An Intgrated Environmental, Social, and Economic Framework* Springer Singapore.
King, A. (2018). *Living Standards Analysis Model: The First Prototype* (New_Zealand_Treasury, Ed.).
King, A., Huseynli, G., & MacGibbon, N. (2018). *Wellbeing Frameworks for the Treasury*. Retrieved from http://www.treasury.govt.nz/publications/research- policy/dp/2018/18-01
King, A., Huseynli, G., & MacGibbon, N. (2018). *Wellbeing Frameworks for the Treasury*. New Zealand Treasury.
King, L. O. (2016). Functional sustainability indicators. *Ecological Indicators*, *66*, 121-131. https://doi.org/10.1016/j.ecolind.2016.01.027
Klobas, J. E. (1995). Beyond information quality: fitness for purpose and electronic information resource use. *Journal of Information Science*, *21*(2), 95-114. https://doi.org/10.1177/016555159502100204
Koltko-Rivera, M. E. (2006). Rediscovering the Later Version of Maslow's Hierarchy of Needs: Self-Transcendence and Opportunities for Theory, Research, and Unification. *Review of General Psychology*, *10*(4), 302-317. https://doi.org/10.1037/1089-2680.10.4.302
Kraay, A. (2018). *Methodology for a World Bank Human Capital Index*. The World Bank.
Larson, A. W. K. L. (2012). Water, People, and Sustainability—A Systems Framework for Analyzing and Assessing Water Governance Regimes. *Water Resource Management*, *26*, 3153-3171.
Lester, D. (2013). Measuring Maslow's Hierarchy of Needs. *Psychological Reports*, *113*(1), 15-17. https://doi.org/10.2466/02.20.pr0.113x16z1
Lima, E. S., Mcmahon, P., & Costa, A. P. C. S. (2021). Establishing the relationship between asset management and business performance. *International Journal of Production Economics*, *232*, 107937. https://doi.org/10.1016/j.ijpe.2020.107937
Litman, T., & Burwell, D. (2006). Issues in sustainable transportation. *International Journal of Global Environmental Issues*, *6*(4), 331-347.
Lombardi, R., Schimperna, F., Smarra, M., & Sorrentino, M. (2021). Accounting for infrastructure assets in the public sector: The state of the art in academic research and international standards setting. *Public Money & Management*, *41*(3), 203-212. https://doi.org/10.1080/09540962.2020.1840761
Maslow, A. H. (1987). *Motivation and personality* (3rd ed. / rev. by Robert Frager ... [et al.].. ed.). New York : Harper and Row c1987.
McLeod, S. (2020). *Maslow's Hierarchy of Needs*. Simply Psychology. https://www.simplypsychology.org/maslow.html

McMeeking, S., Kahi, H., & Kururangi, G. (2019). *He Ara Waiora - Background Paper on the development and content of He Ara Waiora*.
Merriam-Webster. (2021). Dictionary. In https://www.merriam-webster.com/
Ministry for the Environment & Stats NZ. (2017). *NZ Environmental Reporting Series: Our Fresh Water 2017*. NZ Goverment.
Ministry of Health. (2018). *Annual Report on Drinking-Water Quality 2016-2017* NZ Government
Moorfield, J. C. (2021). *Māori Dictionary*. https://Māoridictionary.co.nz
Morgan, T. K. K. B. (2006). Decision-support tools and the indigenous paradigm. *Engineering Sustainability*, *159*(ES4), 169-177.
Morgan, T. K. K. B., Sardelic, D. N., & Waretini, A. F. (2012). The Three Gorges Project: How Sustainable? *Journal of Hydrology*, *460*, 1-12.
Morrissey, S. (2018). *The Start of a Conversation on the Value of New Zealand's Human Capital* (Living Standards Series: Discussion Paper 18/02, Issue. www.treasury.govt.nz/publications/research-policy/dp/2018/18-02
Morrissey, S., & Hawkins, E. (2018, 27 November). *Wellbeing indicators and policy frameworks in New Zealand*
OECD. (2001). *The Wellbeing of Nations: The Role of Human and Social Capital*. OECD Paris.
OECD. (2011). How's Life? Measuring Well-being. *OECD Paris*.
OECD. (2017). *Better Life Index*. http://www.oecdbetterlifeindex.org/#/11111111111
OECD. (2019). *Measuring well-being and progress*. Paris Retrieved from www.oecd.org/statistics/better-life-initiative.htm
Opher, T., & Friedler, E. (2016). Comparative LCA of decentralized wastewater treatment alternatives for non-potable urban reuse. *Journal of Environmental Management*, *182*, 464-476.
Ormsby, J. (2018). *The Relationship between the Living Standards Framework and the Sustainable Development Goals* (Living Standards Series: Discussion Paper 18/06, Issue. https://treasury.govt.nz/publications/dp/dp-18-06
Otto, A., Hall, J. W., Hickford, A. J., Nicholls, R. J., Alderson, D., Barr, S., & Tran, M. (2014). A Quantified System-of-Systems Modeling Framework for Robust National Infrastructure Planning. *IEEE Systems Journal*, *10*(2), 385-396.
Pacione, M. (1982). The Use of Objective and Subjective Measures of Life Quality in Human Geography. *Progress in Human Geography*, *6*(4), 495-514. https://doi.org/10.1177/030913258200600402
Pacione, M. (2003). Urban environmental quality and human wellbeing—a social geographical perspective. *Landscape and Urban Planning*, *65*(1-2), 19-30. https://doi.org/10.1016/s0169-2046(02)00234-7
Padilla-Rivera, A., & Guereca, L. P. (2019). A proposal metric for sustainability evaluations of wastewater treatment systems (SEWATA). *Ecological Indicators*, *103*, 22-23.
Padilla-Rivera, A., Morgan-Sagastume, J. M., Noyola, A., & Guereca, L. P. (2016). Addressing Social Aspects Associated with Wastewater Treatment Facilities. *Environmental Impact Assessment Review*, *57*, 101 - 113.
Parida, A. (2012). Asset Performance Assessment. In *Asset Management* (pp. 101-113). Springer Netherlands. https://doi.org/10.1007/978-94-007-2724-3_7
Prevention, C. f. D. C. a. (2020). *Well-being Concepts*. https://www.cdc.gov/hrqol/wellbeing.htm
PRI. (2021). *About the Principles for Responsible Investment*. https://www.unpri.org/pri/about-the-pri

Rena, J., & Liang, H. (2017). Multi-criteria group decision-making based sustainability measurement of wastewater treatment processes. *Environmental Impact Assessment Review*, *65*, 91-99.
Roy, B., & Vincke, P. (1981). Multicriteria analysis: survey and new directions. *European Journal of Operational Research*, *8*(3), 207-218. https://doi.org/10.1016/0377-2217(81)90168-5
Scaria, D., Brandt, M. L., Kim, E., & Lindeman, B. (2020). What Is Wellbeing? In *Success in Academic Surgery* (pp. 3-10). Springer International Publishing. https://doi.org/10.1007/978-3-030-29470-0_1
Seppälä, J., Basson, L., & Norris, G. A. (2001). Decision Analysis Frameworks for Life-Cycle Impact Assessment. *Journal of Industrial Ecology*, *5*(4), 45-68. https://doi.org/10.1162/10881980160084033
The Treasury. (2019). The Wellbeing Budget. *New Zealand Treasury*.
Tipa, G., & Teirney, L. D. (2006). *A Cultural Health Index for Streams and Waterways: a Tool for Nationwide Use*. Ministry for the Environment Wellington.
Treasury. (2018). *Living Standard Framwork: Background and Future work*. New Zealand Treasury.
Treasury, N. Z. (2021). *Living Standards Framework - Dashboard*. https://lsfdashboard.treasury.govt.nz/wellbeing/
Ul-Haq, M. (1990). *UNDP Human Development Report 1990: Concept and Measurement of Human Development* (O. U. press, Ed.). Oxford University press.
UN. (2015). *TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT*. Retrieved from sustainabledevelopment.un.org
UN. (2019). *The Future is Now: Science for Achieving Sustainable Developement*. United Nations Department of Economic and Social Affairs.
UN. (2020). *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development* (A/RES/71/313, Issue. U. Nations.
van Zyl, S., & Au, J. (2018). *The Start of a Conversation on the Value of New Zealand's Natural Capital* (Living Standards Series: Discussion Paper 18/03, Issue. http://www.treasury.govt.nz/publications/research-policy/dp/2018/18-03
W.E.C.D. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. New York: United Nations
Wang, M., Sweetapple, C., Fu, G., Farmani, R., & Butler, D. (2017). A framework to support decision making in the selection of sustainable drainage system design alternatives. *Journal of Environmental Management*, *201*, 145-152.
Water New Zealand. (2017). *New Zealand Water Consumer Survey 2017*. Water New Zealand.
What is exergy? (2019). Energy Economics. https://exergyeconomics.wordpress.com/exergy-economics-101/what-is-exergy/
Wilson, P. (2020). *Wai Ora Cultural Monitoring Framework - A Māori Innovation Towards Sustainability* Water New Zealand, Hamilton.
World Economic Forum. (2017). *The Global Human Capital Report 2017: Preparing People for Future of Work*.
World Health Organisation. (2012). *Health Indicators of Sustainable Water*. World Health Organisation.
WRR. (1994). *Sustained Risks:a Lasting Phenomenon*. Netherlands Scientific Council for Government Policy.https://english.wrr.nl/publications/reports/1994/06/07/sustained-risks-a-lasting-phenomenon
Zealand, S. N. (2020). *Aligning with Living Standards Framework*. https://wellbeingindicators.stats.govt.nz/en/aligning-with-living-standards-framework/

Zealand, S. N. (2021). *Cultural Health Index for Freshwater Bodies*. New Zealand Government. https://www.stats.govt.nz/indicators/cultural-health-index-for-freshwater-bodies

Zietsman, J., Rilett, L. R., & Kim, S.-J. (2006). Transportation corridor decision-making with multi-attribute utility theory. *International Journal of Management and Decision Making*, *7*(2/3), 254-266.

Appendix A: UN Sustainable Development Goals

Table 27. UN Sustainable Development Goals and associated indicators (UN, 2020)

UN Sustainable Development Goal	Indicators
Goal 1. End poverty in all its forms everywhere	Proportion of the population living below the international poverty line by sex, age, employment status and geographic location (urban/rural)
	Proportion of population living below the national poverty line, by sex and age
	Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions
	Proportion of population covered by social protection floors/systems, by sex, distinguishing children, unemployed persons, older persons, persons with disabilities, pregnant women, new-borns, work-injury victims and the poor and the vulnerable
	Proportion of population living in households with access to basic services
	Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure
	Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
	Direct economic loss attributed to disasters in relation to global gross domestic product (GDP)
	Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
	Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
	Total official development assistance grants from all donors that focus on poverty reduction as a share of the recipient country's gross national income
	Proportion of total government spending on essential services (education, health and social protection)
	Pro-poor public social spending
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Prevalence of undernourishment
	Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
	Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age
	Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)
	Prevalence of anaemia in women aged 15 to 49 years, by pregnancy status (percentage)
	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size
	Average income of small-scale food producers, by sex and indigenous status
	Proportion of agricultural area under productive and sustainable agriculture
	Number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities
	Proportion of local breeds classified as being at risk of extinction
	The agriculture orientation index for government expenditures
	Total official flows (official development assistance plus other official flows) to the agriculture sector
	Agricultural export subsidies

	Indicator of food price anomalies
Goal 3. Ensure healthy lives and promote well-being for all at all ages	Maternal mortality ratio
	Proportion of births attended by skilled health personnel
	Under-5 mortality rate
	Neonatal mortality rate
	Number of new HIV infections per 1,000 uninfected population, by sex, age and key populations
	Tuberculosis incidence per 100,000 population
	Malaria incidence per 1,000 population
	Hepatitis B incidence per 100,000 population
	Number of people requiring interventions against neglected tropical diseases
	Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease
	Suicide mortality rate
	Coverage of treatment interventions (pharmacological, psychosocial and rehabilitation and aftercare services) for substance use disorders
	Alcohol per capita consumption (aged 15 years and older) within a calendar year in litres of pure alcohol
	Death rate due to road traffic injuries
	Proportion of women of reproductive age (aged 15–49 years) who have their need for family planning satisfied with modern methods
	Adolescent birth rate (aged 10–14 years; aged 15–19 years) per 1,000 women in that age group
	Coverage of essential health services
	Proportion of population with large household expenditures on health as a share of total household expenditure or income
	Mortality rate attributed to household and ambient air pollution
	Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)
	Mortality rate attributed to unintentional poisoning
	Age-standardized prevalence of current tobacco use among persons aged 15 years and older
	Proportion of the target population covered by all vaccines included in their national programme
	Total net official development assistance to medical research and basic health sectors
	Proportion of health facilities that have a core set of relevant essential medicines available and affordable on a sustainable basis
	Health worker density and distribution
	International Health Regulations (IHR) capacity and health emergency preparedness
	Percentage of bloodstream infections due to selected antimicrobial-resistant organisms
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Proportion of children and young people (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex
	Completion rate (primary education, lower secondary education, upper secondary education)
	Proportion of children aged 24-59 months who are developmentally on track in health, learning and psychosocial well-being, by sex

	Participation rate in organized learning (one year before the official primary entry age), by sex
	Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex
	Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill
	Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as disability status, indigenous peoples and conflict-affected, as data become available) for all education indicators on this list that can be disaggregated
	Proportion of population in a given age group achieving at least a fixed level of proficiency in functional (a) literacy and (b) numeracy skills, by sex
	Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
	Proportion of schools offering basic services, by type of service
	Volume of official development assistance flows for scholarships by sector and type of study
	Proportion of teachers with the minimum required qualifications, by education level
Goal 5. Achieve gender equality and empower all women and girls	Whether or not legal frameworks are in place to promote, enforce and monitor equality and non-discrimination on the basis of sex
	Proportion of ever-partnered women and girls aged 15 years and older subjected to physical, sexual or psychological violence by a current or former intimate partner in the previous 12 months, by form of violence and by age
	Proportion of women and girls aged 15 years and older subjected to sexual violence by persons other than an intimate partner in the previous 12 months, by age and place of occurrence
	Proportion of women aged 20–24 years who were married or in a union before age 15 and before age 18
	Proportion of girls and women aged 15–49 years who have undergone female genital mutilation/cutting, by age
	Proportion of time spent on unpaid domestic and care work, by sex, age and location
	Proportion of seats held by women in (a) national parliaments and (b) local governments
	Proportion of women in managerial positions
	Proportion of women aged 15–49 years who make their own informed decisions regarding sexual relations, contraceptive use and reproductive health care
	Number of countries with laws and regulations that guarantee full and equal access to women and men aged 15 years and older to sexual and reproductive health care, information and education
	(a) Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure
	Proportion of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control
	Proportion of individuals who own a mobile telephone, by sex
	Proportion of countries with systems to track and make public allocations for gender equality and women's empowerment
Goal 6. Ensure availability and sustainable management of water and sanitation for all	Proportion of population using safely managed drinking water services

	Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water
	Proportion of domestic and industrial wastewater flows safely treated
	Proportion of bodies of water with good ambient water quality
	Change in water-use efficiency over time
	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
	Degree of integrated water resources management
	Proportion of transboundary basin area with an operational arrangement for water cooperation
	Change in the extent of water-related ecosystems over time
	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan
	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	Proportion of population with access to electricity
	Proportion of population with primary reliance on clean fuels and technology
	Renewable energy share in the total final energy consumption
	Energy intensity measured in terms of primary energy and GDP
	International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
	Installed renewable energy-generating capacity in developing countries (in watts per capita)
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Annual growth rate of real GDP per capita
	Annual growth rate of real GDP per employed person
	Proportion of informal employment in total employment, by sector and sex
	Material footprint, material footprint per capita, and material footprint per GDP
	Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
	Average hourly earnings of employees, by sex, age, occupation and persons with disabilities
	Unemployment rate, by sex, age and persons with disabilities
	Proportion of youth (aged 15–24 years) not in education, employment or training
	Proportion and number of children aged 5–17 years engaged in child labour, by sex and age
	Fatal and non-fatal occupational injuries per 100,000 workers, by sex and migrant status
	Level of national compliance with labour rights (freedom of association and collective bargaining) based on International Labour Organization (ILO) textual sources and national legislation, by sex and migrant status
	Tourism direct GDP as a proportion of total GDP and in growth rate
	(a) Number of commercial bank branches per 100,000 adults and (b) number of automated teller machines (ATMs) per 100,000 adults

	Proportion of adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider
	Aid for Trade commitments and disbursements
	Existence of a developed and operationalized national strategy for youth employment, as a distinct strategy or as part of a national employment strategy
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Proportion of the rural population who live within 2 km of an all-season road
	Passenger and freight volumes, by mode of transport
	Manufacturing value added as a proportion of GDP and per capita
	Manufacturing employment as a proportion of total employment
	Proportion of small-scale industries in total industry value added
	Proportion of small-scale industries with a loan or line of credit
	CO2 emission per unit of value added
	Research and development expenditure as a proportion of GDP
	Researchers (in full-time equivalent) per million inhabitants
	Total official international support (official development assistance plus other official flows) to infrastructure
	Proportion of medium and high-tech industry value added in total value added
	Proportion of population covered by a mobile network, by technology
Goal 10. Reduce inequality within and among countries	Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population
	Proportion of people living below 50 per cent of median income, by sex, age and persons with disabilities
	Proportion of population reporting having personally felt discriminated against or harassed in the previous 12 months on the basis of a ground of discrimination prohibited under international human rights law
	Labour share of GDP
	Redistributive impact of fiscal policy
	Financial Soundness Indicators
	Proportion of members and voting rights of developing countries in international organizations
	Recruitment cost borne by employee as a proportion of monthly income earned in country of destination
	Number of countries with migration policies that facilitate orderly, safe, regular and responsible migration and mobility of people
	Number of people who died or disappeared in the process of migration towards an international destination
	Proportion of the population who are refugees, by country of origin
	Proportion of tariff lines applied to imports from least developed countries and developing countries with zero-tariff
	Total resource flows for development, by recipient and donor countries and type of flow (e.g., official development assistance, foreign direct investment and other flows)
	Remittance costs as a proportion of the amount remitted
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable	Proportion of urban population living in slums, informal settlements or inadequate housing
	Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities

	Ratio of land consumption rate to population growth rate
	Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
	Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)
	Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
	Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters
	Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities
	Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)
	Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities
	Proportion of persons victim of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months
	Number of countries that have national urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space
	Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
	Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
Goal 12. Ensure sustainable consumption and production patterns	Number of countries developing, adopting or implementing policy instruments aimed at supporting the shift to sustainable consumption and production
	Material footprint, material footprint per capita, and material footprint per GDP
	Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
	(a) Food loss index and (b) food waste index
	Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement
	(a) Hazardous waste generated per capita; and (b) proportion of hazardous waste treated, by type of treatment
	National recycling rate, tons of material recycled
	Number of companies publishing sustainability reports
	Degree of sustainable public procurement policies and action plan implementation
	Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
	Installed renewable energy-generating capacity in developing countries (in watts per capita)
	Implementation of standard accounting tools to monitor the economic and environmental aspects of tourism sustainability
	Amount of fossil-fuel subsidies per unit of GDP (production and consumption)

Goal 13. Take urgent action to combat climate change and its impacts	Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
	Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
	Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
	Number of countries with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications
	Total greenhouse gas emissions per year
	Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
	Amounts provided and mobilized in United States dollars per year in relation to the continued existing collective mobilization goal of the $100 billion commitment through to 2025
	Number of least developed countries and small island developing States with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	(a) Index of coastal eutrophication; and (b) plastic debris density
	Number of countries using ecosystem-based approaches to managing marine areas
	Average marine acidity (pH) measured at agreed suite of representative sampling stations
	Proportion of fish stocks within biologically sustainable levels
	Coverage of protected areas in relation to marine areas
	Degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
	Sustainable fisheries as a proportion of GDP in small island developing States, least developed countries and all countries
	Proportion of total research budget allocated to research in the field of marine technology
	Degree of application of a legal/regulatory/ policy/institutional framework which recognizes and protects access rights for small-scale fisheries
	Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the United Nations Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Forest area as a proportion of total land area

	Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
	Progress towards sustainable forest management
	Proportion of land that is degraded over total land area
	Coverage by protected areas of important sites for mountain biodiversity
	Mountain Green Cover Index
	Red List Index
	Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits
	Proportion of traded wildlife that was poached or illicitly trafficked
	Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species
	(a) Number of countries that have established national targets in accordance with or similar to Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011–2020 in their national biodiversity strategy and action plans and the progress reported towards these targets; and (b) integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental-Economic Accounting
	(a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments
	(a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments
	Proportion of traded wildlife that was poached or illicitly trafficked
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Number of victims of intentional homicide per 100,000 population, by sex and age
	Conflict-related deaths per 100,000 population, by sex, age and cause
	Proportion of population subjected to (a) physical violence, (b) psychological violence and (c) sexual violence in the previous 12 months
	Proportion of population that feel safe walking alone around the area they live
	Proportion of children aged 1–17 years who experienced any physical punishment and/or psychological aggression by caregivers in the past month
	Number of victims of human trafficking per 100,000 population, by sex, age and form of exploitation
	Proportion of young women and men aged 18–29 years who experienced sexual violence by age 18
	Proportion of victims of violence in the previous 12 months who reported their victimization to competent authorities or other officially recognized conflict resolution mechanisms
	Unsentenced detainees as a proportion of overall prison population
	Proportion of the population who have experienced a dispute in the past two years and who accessed a formal or informal dispute resolution mechanism, by type of mechanism
	Total value of inward and outward illicit financial flows (in current United States dollars)
	Proportion of seized, found or surrendered arms whose illicit origin or context has been traced or established by a competent authority in line with international instruments

	Proportion of persons who had at least one contact with a public official and who paid a bribe to a public official, or were asked for a bribe by those public officials, during the previous 12 months
	Proportion of businesses that had at least one contact with a public official and that paid a bribe to a public official, or were asked for a bribe by those public officials during the previous 12 months
	Primary government expenditures as a proportion of original approved budget, by sector (or by budget codes or similar)
	Proportion of population satisfied with their last experience of public services
	Proportions of positions in national and local institutions, including (a) the legislatures; (b) the public service; and (c) the judiciary, compared to national distributions, by sex, age, persons with disabilities and population groups
	Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group
	Proportion of members and voting rights of developing countries in international organizations
	Proportion of children under 5 years of age whose births have been registered with a civil authority, by age
	Number of verified cases of killing, kidnapping, enforced disappearance, arbitrary detention and torture of journalists, associated media personnel, trade unionists and human rights advocates in the previous 12 months
	Number of countries that adopt and implement constitutional, statutory and/or policy guarantees for public access to information
	Existence of independent national human rights institutions in compliance with the Paris Principles
	Proportion of population reporting having personally felt discriminated against or harassed in the previous 12 months on the basis of a ground of discrimination prohibited under international human rights law
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Total government revenue as a proportion of GDP, by source
	Proportion of domestic budget funded by domestic taxes
	Net official development assistance, total and to least developed countries, as a proportion of the Organization for Economic Cooperation and Development (OECD) Development Assistance Committee donors' gross national income (GNI)
	Foreign direct investment, official development assistance and South-South cooperation as a proportion of gross national income
	Volume of remittances (in United States dollars) as a proportion of total GDP
	Debt service as a proportion of exports of goods and services
	Number of countries that adopt and implement investment promotion regimes for developing countries, including the least developed countries
	Fixed Internet broadband subscriptions per 100 inhabitants, by speed
	Total amount of funding for developing countries to promote the development, transfer, dissemination and diffusion of environmentally sound technologies
	Proportion of individuals using the Internet
	Dollar value of financial and technical assistance (including through North-South, South-South and triangular cooperation) committed to developing countries
	Worldwide weighted tariff-average
	Developing countries' and least developed countries' share of global exports
	Weighted average tariffs faced by developing countries, least developed countries and small island developing States

	Macroeconomic Dashboard
	Number of countries with mechanisms in place to enhance policy coherence of sustainable development
	Extent of use of country-owned results frameworks and planning tools by providers of development cooperation
	Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the Sustainable Development Goals
	Amount in United States dollars committed to public-private partnerships for infrastructure
	Statistical capacity indicator for Sustainable Development Goal monitoring
	Number of countries that have national statistical legislation that complies with the Fundamental Principles of Official Statistics
	Number of countries with a national statistical plan that is fully funded and under implementation, by source of funding
	Dollar value of all resources made available to strengthen statistical capacity in developing countries
	Proportion of countries that (a) have conducted at least one population and housing census in the last 10 years; and (b) have achieved 100 per cent birth registration and 80 per cent death registration

Appendix B: UN Sustainable Development Goals and Indicators Used in The Three Waters Meso Level Infrastructure Performance Framework

Table 28. Relevant SDG goals, targets, and indicators used in the three waters meso level infrastructure performance framework (UN, 2020)

UN Sustainable Development Goal	Goals and targets	Indicators
Goal 1. End poverty in all its forms everywhere	1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	1.4.1 Proportion of population living in households with access to basic services 1.4.2 Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2.1.1 Prevalence of undernourishment 2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
	2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	2.3.1 Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size 2.3.2 Average income of small-scale food producers, by sex and indigenous status
	2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme	2.4.1 Proportion of agricultural area under productive and sustainable agriculture

	weather, drought, flooding and other disasters and that progressively improve land and soil quality	
	2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities 2.5.2 Proportion of local breeds classified as being at risk of extinction
	2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular, least developed countries	2.a.1 The agriculture orientation index for government expenditures 2.a.2 Total official flows (official development assistance plus other official flows) to the agriculture sector
Goal 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services) 3.9.3 Mortality rate attributed to unintentional poisoning
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	4.3.1 Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex
	4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	4.4.1 Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill
	4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the	4.5.1 Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as

	vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	disability status, indigenous peoples and conflict-affected, as data become available) for all education indicators on this list that can be disaggregated
	4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	4.7.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
Goal 5. Achieve gender equality and empower all women and girls	5.1 End all forms of discrimination against all women and girls everywhere	5.1.1 Whether or not legal frameworks are in place to promote, enforce and monitor equality and non-discrimination on the basis of sex
	5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life	5.5.1 Proportion of seats held by women in (a) national parliaments and (b) local governments 5.5.2 Proportion of women in managerial positions
Goal 6. Ensure availability and sustainable management of water and sanitation for all	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1 Proportion of population using safely managed drinking water services
	6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water
	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and	6.3.1 Proportion of domestic and industrial wastewater flows safely treated 6.3.2 Proportion of bodies of water with good ambient water quality

	substantially increasing recycling and safe reuse globally	
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
	6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1 Degree of integrated water resources management 6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation
	6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1 Change in the extent of water-related ecosystems over time
	6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan
	6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption
	7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1 Energy intensity measured in terms of primary energy and GDP

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	8.1.1 Annual growth rate of real GDP per capita
	8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	8.2.1 Annual growth rate of real GDP per employed person
	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	8.4.1 Material footprint, material footprint per capita, and material footprint per GDP 8.4.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
	8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	8.5.1 Average hourly earnings of employees, by sex, age, occupation and persons with disabilities 8.5.2 Unemployment rate, by sex, age and persons with disabilities
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	No linked indicators. Indicators for SDG are focused on road and freight volumes and not appropriate for three-waters.
	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	9.4.1 CO2 emission per unit of value added

Goal 10. Reduce inequality within and among countries	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average	10.1.1 Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population
	10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	10.2.1 Proportion of people living below 50 per cent of median income, by sex, age and persons with disabilities
	10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality	10.4.1 Labour share of GDP
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing
	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	11.3.1 Ratio of land consumption rate to population growth rate 11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
	11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage	11.4.1 Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)
	11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	11.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population 11.5.2 Direct economic loss in relation to global GDP, damage to critical infrastructure and number

		of disruptions to basic services, attributed to disasters
	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	No linked indicators. Indicators for SDG are focused on solid waste and air quality and not appropriate for three-waters.
	11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	11.a.1 Number of countries that have national urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space
	11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels	11.b.1 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
Goal 12. Ensure sustainable consumption and production patterns	12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	12.1.1 Number of countries developing, adopting or implementing policy instruments aimed at supporting the shift to sustainable consumption and production
	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1 Material footprint, material footprint per capita, and material footprint per GDP 12.2.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP

	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1 National recycling rate, tons of material recycled
	12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	12.6.1 Number of companies publishing sustainability reports
	12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	12.7.1 Degree of sustainable public procurement policies and action plan implementation
	12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
	12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	12.b.1 Implementation of standard accounting tools to monitor the economic and environmental aspects of tourism sustainability
Goal 13. Take urgent action to combat climate change and its impacts	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population 13.1.2 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
	13.3 Improve education, awareness-raising and human and institutional capacity on climate change	13.3.1 Extent to which (i) global citizenship education and (ii) education for sustainable

	mitigation, adaptation, impact reduction and early warning	development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	14.1.1 (a) Index of coastal eutrophication; and (b) plastic debris density
	14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	14.2.1 Number of countries using ecosystem-based approaches to managing marine areas
	14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1 Proportion of land that is degraded over a total land area
	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of	15.5.1 Red List Index

	biodiversity and, by 2020, protect and prevent the extinction of threatened species	
	15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	15.8.1 Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species
	15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1 (a) Number of countries that have established national targets in accordance with or similar to Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011–2020 in their national biodiversity strategy and action plans and the progress reported towards these targets; and (b) integration of biodiversity into national accounting and reporting systems, defined as the implementation of the System of Environmental-Economic Accounting
	15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1 (a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	16.6 Develop effective, accountable and transparent institutions at all levels	16.6.1 Primary government expenditures as a proportion of the original approved budget, by sector (or by budget codes or similar) 16.6.2 Proportion of population satisfied with their last experience of public services

	16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels	16.7.1 Proportions of positions in national and local institutions, including (a) the legislatures; (b) the public service; and (c) the judiciary, compared to national distributions, by sex, age, persons with disabilities and population groups 16.7.2 Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	17.6.1 Fixed Internet broadband subscriptions per 100 inhabitants, by speed
	17.14 Enhance policy coherence for sustainable development	17.14.1 Number of countries with mechanisms in place to enhance policy coherence of sustainable development
	17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries	17.16.1 Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the Sustainable Development Goals
	17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	17.17.1 Amount in United States dollars committed to public-private partnerships for infrastructure

Appendix C: Performance Framework Alignment with NZ LSF and UN SDGs

Reference notes: 1: (Ormsby, 2018), 2: (The Treasury, 2019), 3: (Government, 2019b), 4: (UN, 2020)

Meso Performance Framework Wellbeing's	Wellbeing frontier & policy domains (meso & 2nd order framework connections to NZ LSF and UN SDGs)							
	New Zealand Living Standards Framework					United Nations Sustainable Development Goals		
	NZ LSF Capitals[1,2,3]	NZ LSF Capitals Indicators (Indicators of NZ's sustainable and intergenerational wellbeing)[1,2,3]	NZ LSF Domains of Wellbeing (indicators of New Zealand's Current quality of life)[1,2,3]	NZ LSF Domains of Wellbeing Indicators[1,2,3]	UN SDGs[4]	UN SDG[4]	UN SDG Goals & Targets[4]	UN SDG Indicators[4]
Infrastructure (technology)	Financial and Physical Capital	Total Crown net worth	Physical	Total net fixed assets	9, 7	Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	No linked indicators. Indicators for SDG are focused on road and freight volumes and not appropriate for three waters.
				Net intangible fixed assets			9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	9.4.1 CO2 emission per unit of value added
				Household net worth		Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption
				Multifactor productivity frowth			7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1 Energy intensity measured in terms of primary energy and GDP
				Net international investment position				
				Total Crown net worth				

Meso Performance Framework Wellbeing's	Wellbeing frontier & policy domains (meso & 2nd order framework connections to NZ LSF and UN SDGs)								
	New Zealand Living Standards Framework				United Nations Sustainable Development Goals				
	NZ LSF Capitals[1,2,3]	NZ LSF Capitals Indicators (Indicators of NZ's sustainable and intergeneration al wellbeing)[1,2,3]	NZ LSF Domains of Wellbeing (Indicators of New Zealand's Current quality of life)[1,2,3]	NZ LSF Domains of Wellbeing Indicators[1,2,3]	UN SDGs[4]	UN SDG[4]	UN SDG Goals & Targets[4]	UN SDG Indicators[4]
Natural Capital	Natural Capital	Natural hazard regulation	Environment	Air quality	6, 11, 12, 13, 14, 15	Goal 6. Ensure availability and sustainable management of water and sanitation for all	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1 Proportion of population using safely managed drinking water services
							6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water
							6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of domestic and industrial wastewater flows safely treated
								6.3.2 Proportion of bodies of water with good ambient water quality
							6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time
								6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
							6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1 Degree of integrated water resources management
								6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation
							6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1 Change in the extent of water-related ecosystems over time
							6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan
							6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management
		Climate regulation		Access to the natural environment		Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing
							11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	11.3.1 Ratio of land consumption rate to population growth rate
								11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
							11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage	11.4.1 Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)
							11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	11.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
								11.5.2 Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters
							11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	No linked indicators. Indicators for SDG are focused on solid waste and air quality and not appropriate for three waters.
							11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	11.a.1 Number of countries that have national urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space
							11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels	11.b.1 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
								11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
		Sustainable food production				Goal 12. Ensure sustainable consumption and production patterns	12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	12.1.1 Number of countries developing, adopting or implementing policy instruments aimed at supporting the shift to sustainable consumption and production
							12.2 By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1 Material footprint, material footprint per capita, and material footprint per GDP
								12.2.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
							12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1 National recycling rate, tons of material recycled
							12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	12.6.1 Number of companies publishing sustainability reports
							12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	12.7.1 Degree of sustainable public procurement policies and action plan implementation
							12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
							12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	12.b.1 Implementation of standard accounting tools to monitor the economic and environmental aspects of tourism sustainability
		Drinking water		Water quality (swimability)		Goal 13. Take urgent action to combat climate change and its impacts	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
								13.1.2 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
								13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
							13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
						Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	14.1.1 (a) Index of coastal eutrophication; and (b) plastic debris density
							14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	14.2.1 Number of countries using ecosystem-based approaches to managing marine areas
							14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations
		Biodiversity and genetic resources		Percieved environmental quality		Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
							15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1 Proportion of land that is degraded over total land area
							15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1 Red List Index
							15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	15.8.1 Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species
		Waste management					15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1 (a) Number of countries that have established national targets in accordance with or similar to Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011–2020 in their national biodiversity strategy and action plans and the progress reported towards these targets; and (b) integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental-Economic Accounting
							15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1 (a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments

Meso Performance Framework Wellbeing's	Wellbeing frontier & policy domains (meso & 2nd order framework connections to NZ LSF and UN SDGs)							
	New Zealand Living Standards Framework				United Nations Sustainable Development Goals			
	NZ LSF Capitals[1,2,3]	NZ LSF Capitals Indicators (Indicators of NZ's sustainable and intergenerational wellbeing)[1,2,3]	NZ LSF Domains of Wellbeing (indicators of New Zealand's Current quality of life)[1,2,3]	NZ LSF Domains of Wellbeing Indicators[1,2,3]	UN SDGs[4]	UN SDG[4]	UN SDG Goals & Targets[4]	UN SDG Indicators[4]
Social / Cultural Capital	Social Capital	Trust held in others Perceived corruption	Cultural Identity	Te reo Maori speakers Ability to express identity	6	Goal 6. Ensure availability and sustainable management of water and sanitation for all	6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management
		Discrimination	Civic Engagement & Governance	Voter turnout	6, 16, 17	Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	16.6 Develop effective, accountable and transparent institutions at all levels	16.6.1 Primary government expenditures as a proportion of original approved budget, by sector (or by budget codes or similar)
				Trust in government institutions				16.6.2 Proportion of population satisfied with their last experience of public services
				Perceived corruption			16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels	16.7.1 Proportions of positions in national and local institutions, including (a) the legislatures; (b) the public service; and (c) the judiciary, compared to national distributions, by sex, age, persons with disabilities and population groups 16.7.2 Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group
		Trust in government institutions				Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	17.6.1 Fixed Internet broadband subscriptions per 100 inhabitants, by speed
							17.14 Enhance policy coherence for sustainable development	17.14.1 Number of countries with mechanisms in place to enhance policy coherence of sustainable development
							17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries	17.16.1 Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the Sustainable Development Goals
							17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	17.17.1 Amount in United States dollars committed to public-private partnerships for infrastructure
		Sense of belonging	Social Connectedness	Social network support Loneliness Discrimination Maori connection to marae	None			
			Time Use	Leisure and personal care Paid work Unpaid work	None			

Meso Performance Framework Wellbeing's	Wellbeing frontier & policy domains (meso & 2nd order framework connections to NZ LSF and UN SDGs)							
	New Zealand Living Standards Framework					United Nations Sustainable Development Goals		
	NZ LSF Capitals[1,2,3]	NZ LSF Capitals Indicators (Indicators of NZ's sustainable and intergenerational wellbeing)[1,2,3]	NZ LSF Domains of Wellbeing (indicators of New Zealand's Current quality of life)[1,2,3]	NZ LSF Domains of Wellbeing Indicators[1,2,3]	UN SDGs[4]	UN SDG[4]	UN SDG Goals & Targets[4]	UN SDG Indicators[4]
Human Capital	Human Capital	Educational attainment (tertiary)	Health	Healthy life expectancy	3, 6	Goal 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services) 3.9.3 Mortality rate attributed to unintentional poisoning
						Goal 6. Ensure availability and sustainable management of water and sanitation for all	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1 Proportion of population using safely managed drinking water services
				Health status			6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water
							6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of domestic and industrial wastewater flows safely treated
				Mental health				6.3.2 Proportion of bodies of water with good ambient water quality
							6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time
								6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
							6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1 Degree of integrated water resources management
								6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation
				Suicide rate			6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1 Change in the extent of water-related ecosystems over time
		Educational attainment (upper secondary)					6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan
							6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management
				Household crowding			11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing
		Expected educational attainment					11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	11.3.1 Ratio of land consumption rate to population growth rate
								11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
							11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage	11.4.1 Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)
				Housing cost			11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	11.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
			Housing		11	Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable		11.5.2 Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters
							11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	No linked indicators. Indicators for SDG are focused on solid waste and air quality and not appropriate for three waters.
							11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	11.a.1 Number of countries that have national urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space
		Non-communicable diseases		Housing quality			11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels	11.b.1 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
								11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
			Knowledge & Skills	Educational attainment (tertiary)	4	Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	4.3.1 Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex
				Educational attainment (upper secodary)			4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	4.4.1 Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill
							4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	4.5.1 Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as disability status, indigenous peoples and conflict-affected, as data become available) for all education indicators on this list that can be disaggregated
				Cognitive skills at age 15			4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	4.7.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
		Cognitive skills at age 15						
			Safety & security	Intential homicide rate	16	Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	16.6 Develop effective, accountable and transparent institutions at all levels	16.6.1 Primary government expenditures as a proportion of original approved budget, by sector (or by budget codes or similar)
				Domestic violence				16.6.2 Proportion of population satisfied with their last experience of public services
				Workplace accident rate			16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels	16.7.1 Proportions of positions in national and local institutions, including (a) the legislatures; (b) the public service; and (c) the judiciary, compared to national distributions, by sex, age, persons with disabilities and population groups
				Feeling safe				16.7.2 Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group
		Life expectancy		General life satisfaction				
			Subjective wellbeing			Goal 10. Reduce inequality within and among countries	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average	10.1.1 Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population
				Sense of purpose in one's life	10, 5		10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	10.2.1 Proportion of people living below 50 per cent of median income, by sex, age and persons with disabilities
							10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality	10.4.1 Labour share of GDP
						Goal 5. Achieve gender equality and empower all women and girls	5.1 End all forms of discrimination against all women and girls everywhere	5.1.1 Whether or not legal frameworks are in place to promote, enforce and monitor equality and non-discrimination on the basis of sex
							5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life	5.5.1 Proportion of seats held by women in (a) national parliaments and (b) local governments
								5.5.2 Proportion of women in managerial positions

Meso Performance Framework Wellbeing's	Wellbeing frontier & policy domains (meso & 2nd order framework connections to NZ LSF and UN SDGs)							
	New Zealand Living Standards Framework					United Nations Sustainable Development Goals		
	NZ LSF Capitals[1,2,3]	NZ LSF Capitals Indicators (Indicators of NZ's sustainable and intergeneration al wellbeing)[1,2,3]	NZ LSF Domains of Wellbeing (indicators of New Zealand's Current quality of life)[1,2,3]	NZ LSF Domains of Wellbeing Indicators[1,2,3]	UN SDGs[4]	UN SDG[4]	UN SDG Goals & Targets[4]	UN SDG Indicators[4]
Economic Capital	Financial and Physical Capital	Total net fixed assets	Income & Consumption	Disposable income	1, 2	Goal 1. End poverty in all its forms everywhere	1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	1.4.1 Proportion of population living in households with access to basic services
								1.4.2 Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure
						Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2.1.1 Prevalence of undernourishment
								2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
							2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	2.3.1 Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size
								2.3.2 Average income of small-scale food producers, by sex and indigenous status
				Financial wellbeing			2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	2.4.1 Proportion of agricultural area under productive and sustainable agriculture
							2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities
								2.5.2 Proportion of local breeds classified as being at risk of extinction
				Consumption			2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	2.a.1 The agriculture orientation index for government expenditures
								2.a.2 Total official flows (official development assistance plus other official flows) to the agriculture sector
		Net intangible fixed assets	Jobs & Earnings	Unemployment rate	8	Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	8.1.1 Annual growth rate of real GDP per capita
		Household net worth		Employment rate			8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	8.2.1 Annual growth rate of real GDP per employed person
		Multifactor productivity growth		Hourly earnings			8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	8.4.1 Material footprint, material footprint per capita, and material footprint per GDP
								8.4.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
		Net international investment position					8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	8.5.1 Average hourly earnings of employees, by sex, age, occupation and persons with disabilities

Appendix D: Candidate Indicators and Measures Alignment with Meso Level Infrastructure Wellbeing Performance Framework

Meso Performance Framework Wellbeing's	Candidate Conceptual Model Indicators & Measures		
	Indicators (selected to trial with conceptual framework)	**NZ LSF Capital/Domain Indicators & UN SDG Target/Indicator Connection**	**Measures (selected from literature review)**
Economic Capital	**Wealth**	**SDG1: 1.4-1.4.1 SDG2: 2.1-2.1.1, 2.1.2 & 2.3-2.3.1, 2.3.2 & 2.4 SDG8: 8.1-8.1.1 & 8.2-8.2.1 & 8.4-8.4.1,8.4.2 LSF Capitals: Total Net Fixed Assets, Net Factor Productivity Growth, Net Tangible Fixed Assets, Net International Investment Position LSF Domains: Income & Consumption- Disposable income, Financial wellbeing, Consumption**	GDP (National) GDP (Regional) Regional Exports / Imports Regional wealth Productivity Disposable income Poverty level Food availability Organisatinal balance statement (debt & investment levels) Mean equivalised household disposable income Household net adjusted disposable income per capita % of Maori adults postpone or put off visits to the doctor, due to low income % of Maori households living without utilizing telecommunications (landline/internet/no mobile phone/ no telecommunications) due to low income Satisfaction with income meeting everyday needs Median(or average) hourly earnings of a household Low household income
	Employment - availability/growth/diversity/job satisfaction	**SDG8: 8.5-8.5.1 & 8.5.2 LSF Domains: Jobs & Earnings- Unemployment rate, Employment rate, Hourly earnings**	Employment rate Labour force participation rate Unemployment rate Underemployment rate Cost of labour Earning inequality Job satisfaction work autonomy and learning opportunities (can choose or change the order of tasks, can choose or change methods of work, job involves learing new things-employer provided training or on-the-job training Workplace relationships Feel "at home" at work and have very good friends at work Job strain Time pressure at work Difficulty to take an hour or two off during working hours for personal or family matters Work at very high speed and to tight deadlines
Infrastructure (technology)	**Lifecycle / asset preservation**	**SDG9: 9.1 & 9.4-9.4.1 SDG7: 7.2-7.2.1 & 7.3-7.3.1 LSF Capitals: Total Crown Net Worth LSF Domains: Physical- Total net fixed assets, Net intanbible assets**	Asset capacity Demand Backlog - pipes that are beyond condition/performance level that they should be Resilience Affordability Net asset value & future value over time Emissions Net present value Cost benefit Operating ratio (annual operating revenues to annual operating expenses)

Meso Performance Framework Wellbeing's	Candidate Conceptual Model Indicators & Measures		
	Indicators (selected to trial with conceptual framework)	**NZ LSF Capital/Domain Indicators & UN SDG Target/Indicator Connection**	**Measures (selected from literature review)**
Natural Capital	**Environmental quality (pollution)**	**SDG6: 6.1-6.1.1, 6.3-6.3.1 & 6.3.2, SDG11: 11.6 LSF Capitals: Drinking Water, LSF Domains: Environment - Water Quality (swimability), Percieved Environmental Quality**	Satisfaction with Water quality –pollution exceedance Proportion of bodies of water with good ambient water quality Number of posted no fishing/collection days in water bodies (due to contaimination) Number of posted no swim days in water bodies (due to contaimination) Water quality - exceedance of consent conditions
	Biodiversity	**SDG6: 6.6-6.6.1 LSF Capitals: Natural hazard regulation, Climate regulation, Biodiversity and genetic resources LSF Domains: Environment - Water quality (swimability), Percieved Environmental Quality**	Satisfaction with condition and management of waterways (in point of biodiversity) State of the lakes, rivers, harbours, and coastlines (In point of biodiversity)
	Natural resource depletion	**SDG6: 6.a-6.a.1, 6.4-6.4.1,6.4.2; 6.5-6.5.1,6.5.2, 6.6 SDG11: 11.b SDG12 12.1-12.1.1, 12.2-12.2.1, 12.2.2, LSF Capitals: Natural hazard regulation, Climate regulation LSF Domains: Environment - Water quality (swimability)**	Percentage of treated water leakage in the network Change in water-use efficiency over time Suitability for Recreational Grade for monitored freshwater swimming sites Suitability for Recreational Grade for monitored coastal swimming sites Management of water demand (aquafers, ect.)
	Land use impacts	**SDG6: 6.b-6.b.1, SDG11: 11.3, 11.4, 11.5-11.5.1, 11.5.2, 11.a LSF Capitals: Natural hazard regulation, Climate regulation LSF Domains: Environment -Water quality (swimability), Access to the natural environment**	Land use or land cover in the wider catchment that can be seen from the site being assessed Percentage of wastewater consent exceedance Water quality - exceedance of consent conditions
	Ecosystem vulnerability	**SDG14: 14.1, SDG15: 15.1, 15.3-15.3.1, 15.5, 15.8, 15.9, 15.a LSF Capitals: Biodiversity & Genetic Resources LSF Domains: Environment**	Change in the extent of water-related ecosystems over time (overtime / climate / shock events)
	Conservation	**SDG12: 12.5, SDG14: 14.1, 14.2, SDG15: 15.1, 15.5, 15.9 LSF Capitals: Drinking Water LSF Domains: Environment**	Proportion of wastewater safely treated Proportion of drinking water used to availability Percentage of treated water leakage in the network
	Resilience (climate adaptation)	**SDG11: 11.b, SDG13: 13.1 LSF Capitals: Drinking Water, Climate Regulation LSF Domains: Environment**	Salt intrusion in drinking water supply Risk of impact from hazards (environment / people)
	Ability to support mahinga kai species (native food species)	**LSF Capitals: Sustainable Food Production LSF Domains: Environment**	Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species) Comparison between the species present today and the traditional mahinga kai sourced from the site
	Access to safe water/land	**SDG6: 6.1, 6.2, 6.3, 6.a , 6.bSDG11: 11.1, 11.5, 11.6, 11.a LSF Capitals: Drinking Water, LSF Domains: Environment - Access to Natural Environment, Water Quality (swimability), Percieved Environmental Quality**	Households with access to bacteriological (E-coli) compliant drinking water Household with access to protozoal compliant drinking water Household with chemical compliant drinking-water Population with fully compliant drinking-water (bacteriological, protozoal, chemical) Households with access to fluoridated drinking water Proportion of population using safely managed drinking water services Satisfaction with access to natural environment Satisfaction with access to 3 waters services Access to safe water for recreation and food gathering Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household Suitability for Recreational Grade for monitored coastal swimming sites
Social / Cultural Capital	**Indigenous rights**	**LSF Domains: Cultural Identity- Te reo Maori Speakers, Ability to express identity; Social Connectedness - Social network support, Maori connection to marea**	Involvement of Maori in decision making Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management Importance of being engaged in Maori culture
	Cultural acceptance	**LSF Domains: Cultural Identity- Te reo Maori Speakers, Ability to express identity; Social Connectedness - Social network support, Maori connection to marea**	Site significance to tangata whenua (i.e. tradional/non-traditional) Assessment of tangata whenua would return to the site in future as they did in the past or not Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species) Comparison between the species present today and the traditional mahinga kai sourced from the site Land use or land cover in the wider catchment that can be seen from the site being assessed
	Satisfaction with access to natural environment and access to three waters	**SDG16: 16.6-16.6.2 SDG17 LSF Capitals: Sense of Belonging LSF Domains: Cultural Identity- Ability to express identity**	Satisfaction with access to natural environment Satisfaction with smell of water Satisfaction with access to 3 water network Access to safe water for recreation and food gathering Is the vegetation (indigenous or exotic) that is visible along the margins (100 m either side) of the waterway. Is the extent the margins of a stream are being used (heavy use of the margins can impact on stream health) The state of the riverbed can be assessed by the amount of sediment that has built up River channel shape that has been modified by work in the channel or other similar types of activities such as gravel abstraction. Rate flow in river and flow-related habitat variety that can impact on river health Should water clarity be low the stream might be carrying sediment or some form of effluent that can impact on stream health Water quality (or satisfaction with water quality or feeling in puku (gut) about the site is poor/excellent) Quality of life Suitability for Recreational Grade for monitored coastal swimming sites
	Institutional trust	**SDG16: 16.7-16.6.1, 16.7.2 LSF Capitals: Trust Held In Others, Percieved Curruption, Discrimination, Trust In Government Institutions Domains: Civic Engagement & Governance - Trust in government institutions**	Local and Central government reputation survey
	Participation / engagment	**SDG6: 6.b-6.b.1, SDG16: 16.7-16.7.2 SDG17: 17.14, 17.16, 17.17 LSF Capitals: Trust Held In Others, Percieved Curruption, Discrimination, Trust In Government Institutions LSF Domains: Civic Engagement & Governance - Trust in government institutions**	Percentage of population participating in elections Satisfaction with decision making Percentage of population participating in decision making (feedback/engagment)
	Belongingness	**LSF Capitals: Sense of Belonging LSF Domains: Social Connectedness- Social network support, loneliness, discrimination**	Whanau (family) wellbeing Migration
	Generational relevancy	**SDG17: 17.17 LSF Sense of Belonging LSF Domains: Time Use- Leisure and personal care**	Financial treatment shows intergenerational contributions are provided for (i.e. depreciation is collected, debt funding use, rate/taxes) Involvement of Maori to look after someone who was disabled or ill Time availability

Meso Performance Framework Wellbeing's	Candidate Conceptual Model Indicators & Measures		
	Indicators (selected to trial with conceptual framework)	NZ LSF Capital/Domain Indicators & UN SDG Target/Indicator Connection	Measures (selected from literature review)
Human Capital	Life expectancy	SDG3: 3.9-3.9.2 LSF Capitals: Life Expectancy LSF Domains: Health-Healthy life expectancy	Self-rated health Life expectancy
	Food availability		Infant mortality rate (UN)
	Infections / disease/Mental health/change in physical health	SDG6: 6.1-6.1.1 & 6.1.2, 6.2-6.2.1 LSF Capitals: Noncomunicable dieseses LSF Domains: Health- Health status, Mental health	Hazardous drinking Acute medical admission Notifications of campylobacteriosis, cryptosporidiosis and giardiasis Notification of Diarrhoea with untreated water Notifications of campylobacteriosis, cryptosporidiosis and giardiasis with untreated water as a risk factor Notification of vector-borne disease (mosquito-borne disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease Percentage of children who are caries-free, by fluoridation status Mean number of decayed, missing or filled teeth of children, by fluoridation status Impact of waterborne disease on mental health of Maori and non-Maori (Aotearoa/NZ) Immediate trauma and indirect impacts (chronic diseases and risk) in weeks to months after extreme events (e.g flooding, landslides, storm surges, drought) on health of Maori and non-Maori (e.g. from pre-existing conditions, mental health) Vector-borne disease (mosquito-borne disease, e.g. dengue, Ross river virus) and impact of such disease on Maori and non-Maori Impact of Increase and decrease on outdoor time (due to flooding, storm surges, drought etc.) on physical health of Maori and non-Maori Number of deaths, missing persons and directly affected persons attributed to disasters (e.g. flooding) per 100 000 population Increase/decrease or proportion of Maori aged 15-24 years who smoke regularly % of hospitalized for serious injury from self-harm for Maori (males) aged 15-24 years. % of Maori adults reported having very good health Maori adults aged 25 years and over to be hospitalized for circulatory system diseases (including heart disease and stroke) Maori under 75 years to die from circulatory system diseases % of Maori admitted to hospital for mental disorder Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe water, sanitation, and hygiene for all (WASH) services)
	Access to compliant drinking water	SDG6: 6.1-6.1.1 & 6.1.2, 6.2-6.2.1 LSF Capitals: Noncomunicable dieseses LSF Domains: Health- Health status	Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household Households with access to bacteriological (E-coli) compliant drinking water Household with access to protozoal compliant drinking water Household with chemical compliant drinking-water Population with fully compliant drinking-water (bacteriological, protozoal, chemical) Households with access to fluoridated drinking water Proportion of population using safely managed drinking water services
	Access to wastewater services	SDG6: 6.3-6.3.1, 6.3.2 LSF Capitals: Noncomunicable dieseses LSF Domains: Health- Health status	Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household
	Illness due to water borne infections	SDG6: 6.1-6.1.1 & 6.1.2, 6.2-6.2.1 LSF Capitals: Noncomunicable dieseses LSF Domains: Health- Health status	Notifications of campylobacteriosis, cryptosporidiosis and giardiasis Notification of Diarrhoea with untreated water Notifications of campylobacteriosis, cryptosporidiosis and giardiasis with untreated water as a risk factor Notification of vector-borne disease (mosquito-borne disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease Unmet need for primary health care
	Household	SDG11: 11.1-11.1.1 LSF Domains: Housing- Household crowding, Housing cost, Housing quality	House hold affordability Hoousehold availability % of Maori living in the deprived decile areas Deprivation index
	Training (qualification level)	SDG4: 4.3, 4.4, 4.7 LSF Capitals: Expected Educational Attainment, Educational Attainment (secondary), Educational Attainment (tertiary) LSF Domains: Knowledge & Skills- Educational attainment (tertiary), Educational attainment (upper secondary)	Extent to which global citizenship education and education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in: (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies % of households who believe education is important Highest qualification for those aged 15 years and over School leavers' achievement of NCEA level 2 or higher Year-1 entrant's previous participation in ECE The number of adults aged 25 to 64 holding at least an upper secondary degree over the population of the same age The proportion of adults aged 25–64 years with educational attainment of at least a Bachelor's degree or higher qualification % of Maori adults aged 18 years and over had at least a level 2 certificate
	Safety	SDG16 LSF Domains: Safety & Security- Workplace accident rate, Feeling safe	Availability / ease of access Crime rate Perception of safety Curruption % of households who feels safe at work Physical health risk factors associated with jobs (Tiring and painful position, carrying ro moving heavy loads, Exposed to vibrations from hand tools or machinery, Exposure to high noise, Exposure to high or low temperature)
	Life satisfaction	SDG5 SDG6 SDG10 SDG16 LSF Domains: Subjective Wellbeing- General life satisfaction, Sense of purpose in one's life	Quality of life Emotional wellbeing Migration due to good quality of life Self-reported stress Sense of purpose Percentage of people who have friends or relatives to rely on in case of need Satisfaction with the opportunities to participate in council decision making Satisfaction that the Council is making decisions in the best interest of the City Satisfaction with the quality of drinking water Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure) Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure) Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)

Appendix E: Case Study Stats NZ & Waikato Regional Council Response Data (additional questions not covered in main body of thesis)

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Data Type	Type of access (ease, spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Maori elements? (spiritual (whakapapa), physical, etc) - Te mana atewi (spirit of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/District Council?	Who controls
Natural Capital	Environmental quality (pollution)	Satisfaction with Water quality –pollution exceedance		Spreadsheet	https://www.legislation.govt.nz/act/public/1	Public act	http://www.environmentguide.org.nz/issues/biodiversity/	No quality metadata found	Ministry for the Environment	2015 - 2021	annual	No	MFE
		Proportion of bodies of water with good ambient water quality		Spreadsheet	https://www.legislation.govt.nz/act/public/1	Public act	https://www.legislation.govt.nz/all/results.aspx?search=		Ministry for the Environment	2016 - 2021	annual	No	MFE
		Number of posted no fishing/collection days in water bodies (due to contaimination)			**Above Acts of Parliament would**	Public act	**Above Acts of Parliament would**		District/city council		when necessary		
		Number of posted no swim days in water bodies (due to contaimination)							District/city council		when necessary		LAWA
		Water quality - exceedance of consent conditions							District/city council		when necessary		Various councils
	Biodiversity	Satisfaction with condition and management of waterways (in point of biodiversity)	Policy documents	Documents		Public			https://www.landcareresearch.co.nz/discover-our-research/biodiversity/				
		State of the lakes, rivers, harbours, and coastlines (In point of biodiversity)	Policy documents	Documents		Public			https://www.landcareresearch.co.nz/discover-our-research/biodiversity/		annual		
	Natural resource depletion	Percentage of treated water leakage in the network							Regional Councils various (see Public Private column)				Various councils
		Change in water-use efficiency over time							Regional Councils various				Various councils
		Suitability for Recreational Grade for monitored freshwater swimming sites							Regional Councils various				
		Suitability for Recreational Grade for monitored coastal swimming sites	Number	Interactive tool					https://www.lawa.org.nz/explore-data/swimming/	Annual	Seasonal	District Coucil	Land Air Water Aotearoa
	Land use impacts	Land use or land cover in the wider catchment that can be seen from the site being assessed				https://www.horizons.govt.nz/managing-natural-resources/land			LINZ https://www.linz.govt.nz/land/maps				
		Percentage of wastewater consent exceedance				https://www.nrc.govt.nz/resource-library-archive/environmental-monitoring-archive/?state=of-the-https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-			Regional Councils various				Various councils
		Water quality - exceedance of consent conditions							Regional Councils various				Various councils
	Ecosystem vulnerability	Change in the extent of water-related ecosystems over time (overtime / climate / shock events)							Regional Councils various				
	Conservation	Proportion of wastewater safely treated							https://www.watemz.org.nz/WWTPInventory		regular	District Coucil	Water NZ
		Proportion of drinking water used to availability							https://www.watemz.org.nz/WWTPInventory		regular	District Coucil	Water NZ
		Percentage of treated water leakage in the network							https://www.watemz.org.nz/WWTPInventory		regular	District Coucil	Water NZ
	Resilience (climate adaptation)	Salt intrusion in drinking water supply											NIWA and National Rural Fire Authority
	Ability to support mahinga kai species (native food species)	Risk of impact from hazards (environment / people)											Te Tiaki Mahinga Kai and various councils
		Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support mahinga kai species)											
		Comparison between the species present today and the traditional mahinga kai sourced from the site											Te Tiaki Mahinga Kai and various councils
	Access to safe water/land	Households with access to bacteriological (E-coli) compliant drinking water	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Household with access to protozoal compliant drinking water	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Household with chemical compliant drinking-water	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Households with access to fluoridated drinking water	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Proportion of population using safely managed drinking water services	Various	interactive tool					https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Annual	Water Quality (instantatlas.com)	Massey Univerisity
		Satisfaction with access to natural environment	Various						Some local council websites				
		Satisfaction with access to 3 waters services	Various						Some local council websites				
		Access to safe water for recreation and food gathering	Various						https://www.ehinz.ac.nz/indicators/water/drinking-water-quality/access-to-		Seasonal	Water Quality (instantatlas.com)	Land Air Water Aotearoa
		Proportion of population that has access to a sustainable safe water supply and hygienic sanitation in the household											EHINZ
		Suitability for Recreational Grade for monitored coastal swimming sites		Map					https://www.lawa.org.nz/explore-data/swimming/		Seasonal	Water Quality (instantatlas.com)	Land Air Water Aotearoa

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Data Type	Type of access (ease, spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Moari elements? (spiritual (whakapap), physical, etc) - Te mana atewi (spirit of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/District Council?	Who controls
Social / Cultural Capital	Indigenous rights	Involvement of Maori in decision making	Graphs, Count		As at election	Stats NZ, Electorial Commission	https://www.stats.govt.nz /topics/citizen-						
		Proportion of local administrative units with established and operational policies and procedures for participation of local					https://www.dia.govt.nz/T hree-Waters-Reform-						
		Importance of being engaged in Maori culture	Reports, CSV, Customised tables		5 yearly	Stats NZ	Dr Golda Verona	Dean Ogilvie	Dean Ogilvie				
	Cultural acceptance	Site significance to tangata whenua (i.e. tradional/non-traditional)				Various councils	https://www.waikatoregio n.govt.nz/community/your-						
		Assessment of tangata whenua would return to the site in future as they did in the past or not				Various Iwi							
		Identification of mahinga kai species present at the site (the productivity of a site includes the ability of the waterway to support	presence absence	NZ Freshwater Fish Database	no	Various councils / Public	https://www.mahingakai.o rg.nz/ // no	incomplete, variable quality		NIWA			
		Comparison between the species present today and the traditional mahinga kai sourced from the site				Various councils	https://ourlandandwater.n z/research-						
		Land use or land cover in the wider catchment that can be seen from the site being assessed	land cover	shapefile	no	Various councils / Public	https://ourlandandwater.n z/research-	complete, snapshot in time	polygons	landcare for LCDB or WRC for WISE Land use layer			
	Satisfaction with access to natural environment and access to three waters	Satisfaction with access to natural environment					https://www.waikatoregio n.govt.nz/community/abo						WRC
		Satisfaction with smell of water				Various Councils, Water NZ, LAWA, MFE,	https://www.waikatoregio n.govt.nz/community/abo						
		Satisfaction with access to 3 water network				Various Councils, Water NZ, LAWA, MFE, DIA, Three Waters	https://www.waikatoregio n.govt.nz/community/abo						
		Access to safe water for recreation and food gathering				Various councils, LAWA	https://www.lawa.org.nz/e xplore-data/swimming/						
		Is the vegetation (indigenous or exotic) that is visible along the margins (100 m either side) of the waterway.	%cover	spreadsheet	no	Various councils, Ministry of Primary Industries, River organisations,	https://www.mpi.govt.nz/a griculture/farm-	incomplete	%	WRC			
		Is the extent the margins of a stream are being used (heavy use of the margins can impact on stream health)	%cover	spreadsheet	no	Various councils, Ministry of Primary Industries, River organisations,	https://www.mpi.govt.nz/a griculture/farm-	incomplete	%	WRC			
		The state of the riverbed can be assessed by the amount of sediment that has built up	%cover	spreadsheet	no	Ministy for the Environment, NIWA // Public	https://niwa.co.nz/our- science/freshwater/tools/	incomplete	%	WRC			
		River channel shape that has been modified by work in the channel or other similar types of activities such as gravel abstraction.				Various Councils, Ministry for the Environment; NIWA,	https://environment.govt.n z/publications/predicting-						
		Rate flow in river and flow-related habitat variety that can impact on river health	m3/s	API	no	Various Councils, Ministry for the Environment; NIWA // Public	https://niwa.co.nz/ // no	incomplete	time series	WRC			
		Should water clarity be low the stream might be carrying sediment or some form of effluent that can impact on stream health				Various Councils, Ministry for the Environment;	https://www.waikatoregio n.govt.nz/environment/nat						
		Water quality (or satisfaction with water quality or feeling in puku (gut) about the site is poor/excellent)				Various councils, LAWA	https://www.lawa.org.nz/; https://www.waikatoregio						
		Quality of life				Quality of Life Project	http://www.qualityoflifepro ject.govt.nz/survey.htm	QoL survey every two years, WPI	WRC	Beat Huser			
		Suitability for Recreational Grade for monitored coastal swimming sites	various	LAWA	no	LAWA, various councils // Public	https://www.lawa.org.nz/e xplore-data/swimming/ //	incomplete	spot samples	WRC			
	Institutional trust	Local and Central government reputation survey				Local government NZ, Various Councils	https://www.lgnz.co.nz/a ssets/Uploads/d3464622		WRC	Ruth Buckingham			
	Participation / engagment	Percentage of population participating in elections						Waikato Progress Indicators	WRC	Beat Huser			
		Satisfaction with decision making				Various councils	https://www.southwaikato .govt.nz/repository/librarie	Waikato Progress Indicators	WRC	Beat Huser			
		Percentage of population participating in decision making (feedback/engagment)				Electorial Commission	Electoral Commission https://elections.nz/about						
	Belongingness	Whanau (family) wellbeing	Reports, CSV, Customised tables		Quaterly	Stats NZ Wellbeing	https://www.stats.govt.nz /information-	Sophie Flynn	04 931 4833				
		Migration	Reports, Graphs, CSV, Customised tables		Monthly, 5 yearly	Stats NZ Census and ITM	https://www.stats.govt.nz /indicators/international-						
	Generational relevancy	Financial treatment shows intergenerational contributions are provided for (i.e. depreciation is collected, debt funding use, rate/taxes)											
		Involvement of Maori to look after someone who was disabled or ill	Customised tables		5 yearly	Stats NZ Census Unpaid activities	https://figure.nz/chart/N8 uQNabDrmalsRDe;						
		Time availability			No longer collected	Stats NZ Time use survey	https://www.stats.govt.nz /services/customised-						

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Data Type	Type of access (e.g., spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Maori elements? (spiritual (whakapapa), physical, etc) - To make sense of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/Dirtrict Council?	Who controls
Human Capital	Life expectancy	Self-rated health					MOH and MSD						
		Life expectancy	Life tables in Excel format	From 2006 we released data for	Every five years, Statistics NZ also	yes		Kim Dunstan					
		Hazardous drinking	NZ Health Survey		annual		MOH		data.enquiries@health.govt.nz				
		Acute medical admission	needs further investigation				DHBs						
		Notifications of campylobacteriosis, cryptosporidiosis and giardiasis	website				ESR Institute of Environmental Science and Research						
		Notification of Diarrhoea with untreated water	website				ESR Institute of Environmental Science and Research						
		Notifications of campylobacteriosis, cryptosporidiosis and giardiasis with untreated water as a risk factor	website				ESR Institute of Environmental Science and Research						
		disease, e.g. dengue, Ross river virus or tick-borne) and non-vector borne zoonotic disease	website				ESR Institute of Environmental Science and Research						
		Percentage of children who are caries-free, by fluoridation status	Excel				MOH: https://www.health.govt.nz						
		Mean number of decayed, missing or filled teeth of children, by fluoridation status	Excel				MOH: https://www.health.govt.nz						
		Impact of water borne disease on mental health of Maori and non-Maori (Aotearoa NZ)	n/a	n/a	n/a	n/a	n/a						
	Infections / disease/Mental health/change in physical health	and risk) in weeks to months after extreme events (e.g flooding, landslides, storm surges, drought) on health of	needs further investigation		n/a	n/a	n/a						
		dengue, Ross river virus) and impact of such disease on Maori and non-Maori	needs further investigation		n/a	n/a	ESR Institute of Environmental Science and Research						
		flooding, storm surges, drought etc.) on physical health of Maori and non-Maori	needs further investigation	n/a	n/a	n/a							
		persons attributed to disasters (e.g. flooding) per 100 000 population	needs further investigation		n/a	n/a	Civil Defence, NZ Police, Fire and						
		Increase/decrease or proportion of Maori aged 15-24 years who smoke regularly	Census data available										
		% of hospitalized for serious injury from self-harm for Maori (males) aged 15-24 years.											
		% of Maori adults reported having very good health	NZ Health Survey										
		circulatory system disease (including heart disease and stroke)	MOH or DHB data										
		Maori under 75 years to die from circulatory system disease	MOH or DHB data										
		% of Maori admitted to hospital for mental disorder	MOH or DHB data										
		Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe water, sanitation, and hygiene for all (WASH) services)	Needs further investigation	n/a									
	Access to compliant drinking water	Proportion of population that have access to sustainable safe water supply and hygienic sanitation in the household	website				ESR Institute of Environmental Science and Research						
		Households with access to bacteriological (E-coli) compliant drinking water	website				ESR Institute of Environmental Science and Research						
		Household with access to protozoal compliant drinking water	website				ESR Institute of Environmental Science and Research						
		Household with chemical compliant drinking-water	website				ESR Institute of Environmental Science and Research						
		Population with fully compliant drinking-water (bacteriological, protozoal, chemical)	website				ESR Institute of Environmental Science and Research						
		Households with access to fluoridated drinking water	website				ESR Institute of Environmental Science and Research						

Wellbeing's	Measures	Data Type	Type of access (ease, spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Maori elements? (spiritual (whakapap), physical, etc) - Te mana atewi (spirit of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/District Council?	Who controls
Human Capital	House hold affordability	Needs further investigation				Ministry of Housing and Urban Development						
	Hoousehold availability	Needs further investigation				Ministry of Housing and Urban Development -						
	% of Maori living in the deprived decile areas	Custom data	2013 and 2018	5-yearly								
	Depervation index	Custom data	2013 and 2018	5-yearly								
	Extent to which global citizenship education and education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in: (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment	needs further investigation										
	Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies	needs further investigation										
	% of households who believe education is important	needs further investigation										
	Highest qualification for those aged 15 years and over	Census data on NZ.Stat		5-yearly								
	School leavers' achievement of NCEA level 2 or higher	Census data on NZ.Stat		5-yearly								
	Year-1 entrant's previous participation in ECE	needs further investigation				Ministry of Education						
	The number of adults aged 25 to 64 holding at least an upper secondary degree over the population of the same age	Census data on NZ.Stat										
	The proportion of adults aged 25–64 years with educational attainment of at least a Bachelor's degree or higher qualification	Census data on NZ.Stat										
	% of Maori adults aged 18 years and over had at least a level 2 certificate	Census data on NZ.Stat										
	Crime rate	Police website crime tool				https://www.police.govt.nz/about-						
	Perception of safety	NZGSS		2-yearly								
	Curruption					https://www.transparency.org/en/countries/new-						
	% of households who feels safe at work	NZGSS		2-yearly								
	Physical health risk factors associated with jobs (Tiring and painful position, carrying ro moving heavy loads, Exposed to vibrations from hand tools or machinery, Exposure to high noise, Exposure to high or low temperature)	needs further investigation				Worksafe NZ						
	Quality of life	NZGSS		2-yearly		some data on stats.govt.nz website						
	Emotional wellbeing	NZGSS		2-yearly		some data on stats.govt.nz website						
	Migration due to good quality of life	NZGSS		2-yearly		some data on stats.govt.nz website						
	Self-reported stress	NZGSS		2-yearly		some data on stats.govt.nz website						
	Sense of purpose	NZGSS		2-yearly		some data on stats.govt.nz website						
	Percentage of people who have friends or relatives to rely on in case of need	NZGSS		2-yearly		some data on stats.govt.nz website						
	Satisfaction with the opportunities to participate in council decision making					local councils						
	Satisfaction that the Council is making decisions in the best interest of the City					local councils						
	Satisfaction with the quality of drinking water					local councils						
	Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)					local councils						
	Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)					local councils						
	Satisfaction with the quality of wastewater and water supply infrastructure and services (i.e satisfaction with council infrastructure)											

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Data Type	Type of access (ease, spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Moari elements? (spiritual (whakapapa), physical, etc) - Te mana atewi (spirit of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/District Council?	Who controls
Economic Capital	Wealth	GDP (National)	Spreadsheets / Database					Quarterly release and Infoshare tables	Infoshare time series available from 1988 onwards up to 2021	Quarterly	No	Stats NZ	National Accounts
		GDP (Regional)	Spreadsheets / Database					Release and Infoshare Tables	Infoshare time series available from 1988 onwards up to 2022	Annual	Regional only	Stats NZ	National Accounts
		Regional Exports / Imports	Spreadsheets / Database					Overseas Trade Data, broken down by HS codes and by NZ Port	NZ.Stat tables - 2000 - 2020 (By NZ port)	Monthly - Overseas Trade Data	No	Stats NZ (data collected from Customs NZ as well)	Overseas Trade Team
		Regional wealth	Spreadsheets / Database					Regional GDP / Regional Income data from the Census	Infoshare tables - 2000 - 2020 / Or Census NZ.Stat tables	Annual	No	Stats NZ	National Accounts
		Productivity	Spreadsheets / Database					Productivity Stats	Table available from 1978 - 2020	Annual	No	Stats NZ	National Accounts
		Disposable income	Spreadsheets					Household income and housing-cost statistics	From HES - 2008 onwards (HES run every two years)	Annual	No	Stats NZ	Income and Poverty
		Poverty level						We only have Child poverty Stats available from 2018	2018 - current	Annual	No	Stats NZ	Work, Wealth and Wellbeing
		Food availability											
		Organisatinal balance statement (debt & investment levels)											
		Mean equivalised household disposable income	Spreadsheets					Household income and housing-cost statistics	From HES - 2008 onwards (HES run every two years)	Annual	No	Stats NZ	Income and Poverty
		Household net adjusted disposable income per capita	Spreadsheets					Household income and housing-cost statistics	From HES - 2008 onwards (HES run every two years)	Annual	No	Stats NZ	Income and Poverty
		% of Maori adults postpone or put off visits to the doctor, due to low income											
		% of Maori households living without utilizing telecommunications (landline/internet/no mobile phone/ no telecommunications) due to low income											
		Satisfaction with income meeting everyday needs											
		Median(or average) hourly earnings of a household	Spreadsheets / Database					NZ.Stat tables	1998 - current	Annual	No		
		Low household income	Spreadsheets / Database					Household income and housing-cost statistics / CENSUS	1998 - current / 1996 - current (Census)	Annual / Census every 5 years	Some grouped income data from Census is available	Stats NZ	Income and Poverty
	Employment - availability/growth/diversity/job satisfaction	Employment rate	Spreadsheets / Database					Household Labour Force Survey	1988 to current	Quarterly	No / Some city level data is available from Census only	Stats NZ	Labour Markets
		Labour force participation rate	Spreadsheets / Database					Household Labour Force Survey	1988 to current	Quarterly	No / Some city level data is available from Census only	Stats NZ	Labour Markets
		Unemployment rate	Spreadsheets / Database					Household Labour Force Survey	1988 to current	Quarterly	No / Some city level data is available from Census only	Stats NZ	Labour Markets
		Underemployment rate	Spreadsheets / Database					Household Labour Force Survey	1988 to current	Quarterly	No / Some city level data is available from Census only	Stats NZ	Labour Markets
		Cost of labour	Spreadsheets / Database					Household Labour Force Survey / Quarterly Employment Survey	1988 to current	Quarterly	No	Stats NZ	Labour Markets
		Earning inequality	Spreadsheets					Household Labour Force Survey / Quarterly Employment Survey	1988 to current	Quarterly	No / Some city level data is available from Census only	Stats NZ	Labour Markets
		Job satisfaction	Spreadsheets					Survey of Working Life & Wellbeing Statistics	2008, 2012, 2018	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets
		work autonomy and learning opportunities (can choose or change the order of tasks, can choose or change methods of work, job involves learing new things-employer provided training or on-the-job training	Spreadsheets					Survey of Working Life & Wellbeing Statistics	2008, 2012, 2019	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets / Wellbeing and Housing
		Workplace relationships	Spreadsheets					Survey of Working Life & Wellbeing Statistics	2008, 2012, 2020	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets / Wellbeing and Housing
		Feel "at home" at work and have very good friends at work											
		Job strain	Spreadsheets					Survey of Working Life / Wellbeing statistics	2008, 2012, 2020	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets / Wellbeing and Housing
		Time pressure at work	Spreadsheets					Survey of Working Life / Wellbeing statistics	2008, 2012, 2021	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets / Wellbeing and Housing
		Difficulty to take an hour or two off during working hours for personal or family matters	Spreadsheets					Survey of Working Life / Wellbeing statistics	2008, 2012, 2022	SoWL Every 3-4 years / Wellbeing is run every 2 years - but had been incorporated into the HLFS during COVID	No	Stats NZ	Labour Markets / Wellbeing and Housing
		Work at very high speed and to tight deadlines											

Wellbeing's	Indicators (selected to trial with conceptual framework)	Measures	Data Type	Type of access (ease, spreadsheet, API etc)	Ethics concerns	Public / Private	Is data linked to any specific Moari elements? (spiritual (whakapap), physical, etc) - Te mana atewi (spirit of the water)	Data quality & completeness	Data type	From Date to To Date of data record	Frequency of data recording	Data available for individual City/District Council?	Who controls
Infrastructure (technology)	Lifecycle / asset preservation	Asset capacity Demand Backlog - pipes that are beyond condition/performance level that they should be Resilience Affordability Net asset value & future value over time Emissions Net present value Cost benefit Operating ratio (annual operating revenues to annual operating expenses)											