

Mātauranga Māori in geomorphology: existing frameworks, case studies and recommendations for incorporating Indigenous knowledge in Earth science

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10 **Abstract.** Mixed-method bicultural research in Aotearoa New Zealand, including the weaving of Indigenous and other knowledges, is emerging within many academic disciplines. However, *mātauranga* Māori (the knowledge, culture, values and worldview of the Indigenous peoples of Aotearoa New Zealand) and *Te Ao Māori* (the Māori world) is poorly represented within geomorphological investigations. Here, we review international efforts to include Indigenous knowledge in geologic and geomorphic studies and provide an overview of the current state of *mātauranga* Māori within research endeavours in
15 Aotearoa New Zealand. We review three theoretical frameworks (i.e., methodologies) for including *mātauranga* Māori in research projects and three models (i.e., methods) for including Māori values within research. We identify direct benefits to geomorphology and discuss how these frameworks and models can be adapted for use with Indigenous knowledge systems outside of Aotearoa New Zealand. The aim of this review is to encourage geomorphologists around the world to engage with local Indigenous peoples to develop new approaches to geomorphic research. In Aotearoa New Zealand, we hope to inspire
20 geomorphologists to embark on research journeys in genuine partnership with Māori that promote *toitū te mātauranga*—the enduring protection, promotion and respect of *mātauranga* Māori.

Keywords: geomorphology, *mātauranga* Māori, bicultural research

1 Introduction

25 Earth scientists are increasingly recognising the benefits of conducting mixed-methods bicultural research (e.g., Townsend et al., 2004; Tipa, 2009; Harmsworth et al., 2011; Crow et al., 2018; Hikuroa et al., 2018). Oral histories, lore and mythologies from Indigenous communities, explained through their respective worldviews, frequently feature stories of geomorphic or landscape change in their tribal lands (e.g., Gottesfeld et al., 1991; McMillan and Hutchinson, 2002; Hikuroa, 2017). Indigenous knowledge and oral histories have been shown to complement scientific endeavours by detailing specific natural
30 events that were otherwise poorly understood or documented by scientists (e.g., Swanson, 2008; King and Goff, 2010; Reid et

al., 2014; Nunn and Reid, 2016) and fill knowledge gaps that science cannot (Bohensky and Maru, 2011). As such, Indigenous knowledge can provide an observational starting point, or corroborative evidence, for scientific investigations.

Historically, there has been discord between the scientific and Indigenous knowledge epistemologies. The science community has traditionally considered Indigenous knowledge systems and oral histories untruthful and inaccurate (Durie, 2004). Until quite recently, anthropologists still promoted the unreliability of unwritten (i.e., oral) legends that refer to events more than 1000 years before present (Simic, 2002, as cited in Reid et al., 2014). On the other hand, Indigenous communities have frequently expressed opposition to science due to its inertia to recognise nature as something more than a controllable, testable, and exploitable medium (Smith, 1999; Hikuroa et al., 2011). While scientists are typically detached “observers” and analysers of natural systems (Cruikshank, 2012), Indigenous communities position themselves within an extended genealogy that considers nature as kin (Suzuki and Knudtson, 1992; Salmón, 2000). In Indigenous worldviews and knowledge systems, humans are active participants within natural systems (Hikuroa, 2017; Pingram et al., 2019). Tensions between Indigenous knowledge and science—particularly tensions around rigor of knowledge generation, credibility, worldview, and ability to be evaluated—have created challenges for integrating knowledge systems in the past (Mercier, 2007; Bohensky and Maru, 2011).

Until recently, the historic discord between science and Indigenous knowledge prevented the synergies that do exist between the two knowledge systems from advancing new understandings. In the past 10-15 years, an emergence of sincere, respectful and reciprocal engagement between scientific and Indigenous communities has generated multiple national and international guiding policies for genuinely transformative approaches to research (e.g., Hīkina Whakatutuki Ministry of Business, Innovation and Employment, n.d.; Ministry of Research, Science and Technology, 2007; UN General Assembly, 2007). Engagement has identified research needs and aspirations of both Indigenous communities and scientists, leading to co-creation and co-development of research projects with respective responsibilities clearly defined. In 2007, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) catalysed reconsideration and rebalancing of Indigenous peoples’ rights (Hikuroa et al., 2018). The UNDRIP formalised obligations of participating governments to support and protect Indigenous communities’ rights to maintain cultural heritage, traditional knowledge, expression of their sciences, oral traditions and technologies (UN General Assembly, 2007), and created a platform on which mixed-methods research can be formulated, discussed and carried out. To date, legal and constitutional initiatives that build upon UNDRIP policies and establish the rights of nature—the recognition that nature has legal rights (Cano Pecharroman, 2018)—have occurred in Bolivia, India, New Zealand, Australia, the United States and Ecuador (Boyd, 2017; Brierley et al., 2018; Kauffman and Martin, 2018; O’Donnell and Talbot-Jones, 2018). Though these advances and recognitions are most prevalent in the policy sphere, they are transferrable to scientific research and have, in a few cases, acted as guidelines for culturally responsible and respectful research at the interface of Indigenous knowledge and Western science.

The international geosciences community is increasingly demonstrating interest in Indigenous knowledge systems and participation with Indigenous groups (e.g., Tipa, 2009; King and Goff, 2010; Harmsworth et al., 2011; Harmsworth and Roskrige, 2014; Pardo et al., 2015; Riu-Bosoms et al., 2015; Nunn and Reid, 2016; Hikuroa, 2017; Crow et al., 2018). Indigenous knowledge has been used to define research needs in geospatial research projects (e.g., Poole and Biodiversity

65 Support Program, 1995 as cited in Pacey, 2005; Harmsworth, 1999; Alessa et al., 2011; Te Rūnanga o Ngāi Tahu, 2019), natural hazard research (Swanson, 2008; Goff et al., 2010; King and Goff, 2010; King et al., 2018), natural hazard risk reduction planning (Cronin et al., 2004; Becker et al., 2008; Walshe and Nunn, 2012; Rumbach and Foley, 2014; Hiwasaki et al., 2014; Pardo et al., 2015; Rahman et al., 2017), climate-change resilience (Cruikshank, 2001, 2012; Ford and Smit, 2004; Janif et al., 2016; Iloka, 2016), environmental management (Londono et al., 2016), soil classification (Oudwater and Martin, 70 2003; Harmsworth and Roskrige, 2014) and geomorphology/hydrology research (Londono et al., 2016; Hikuroa, 2017). Moreover, Indigenous place names commonly indicate knowledge of landscape features and geomorphology (Carter, 2005; Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; Atik and Swaffield, 2017). Thus, culturally responsible and respectful weaving of Indigenous knowledge into Earth science has the potential to corroborate, bolster and create knowledge.

This review focuses on recent efforts to include *mātauranga* Māori (Māori Indigenous knowledge, culture, values 75 and worldview) alongside geomorphology in research conducted within Aotearoa New Zealand (henceforth Aotearoa-NZ). Although Aotearoa is a Māori name for New Zealand's North Island, to reflect the nation's bi-cultural foundation it is commonly used in this context (Aotearoa-NZ) to mean all of New Zealand. This review begins with a discussion of international efforts in mixed-methods research at the interface of Indigenous knowledge and geoscience, arriving at a focus on geomorphology. We then introduce *Te Ao Māori* (the Māori world) and some Māori concepts relevant to geomorphology. 80 We discuss obligations of the New Zealand government to Māori groups (i.e. *iwi* and *hapū*, tribes and sub-tribes, which are the principal political units with whom scientists engage in Aotearoa-NZ). We present three theoretical frameworks (methodologies or general research strategies) and three value-based models (methods for answering research questions) for conducting bicultural research. We then provide case studies of model development and recommendations for implementation in geomorphology research. Finally, we provide direct examples of including Indigenous knowledge in geomorphic research 85 and discuss how the frameworks and models reviewed here can be applied outside of Aotearoa-NZ. We used archival research, review and *wānanga* (discussion) to conduct this research.

The authors assert that there is no expectation that *mātauranga* be given away by *iwi* (tribes) and *hapū* (sub-tribes) to scientists. Scientists alone cannot rebuild or revitalise *mātauranga*; that is for Māori to do (Broughton et al., 2015). We uphold that the geoscience community is primed to contribute to further invigoration of *mātauranga* by welcoming it alongside science 90 for greater understanding of Earth surface phenomena. Our intentions for this review are to encourage inclusion of Indigenous knowledge and values for guiding scientific research. We acknowledge that the *mātauranga* presented here is not our own, and that we have gained approval through the Human Ethics Committee at the University of Canterbury (Christchurch, NZ) to conduct this research. In all cases, including our own, this approval is required in order to protect the Intellectual Property of Indigenous peoples. We herein acknowledge the *mana whenua* (traditional authorities) of Aotearoa-NZ as the rightful 95 holders of *mātauranga*.

2 Overview of international research at the interface of Indigenous knowledge and geoscience

Evaluating events recorded in Indigenous peoples' oral histories with scientific investigations of landforms or processes is not a new concept. Gottesfeld et al. (1991) examined a Holocene debris flow near Hazelton, British Columbia (ca. 3500 BP, before present) and discussed how the event could be the same as a story belonging to the local Indigenous peoples, the Gitksan. In the oral history, the *Medeek* (a devastation-wreaking grizzly bear) charged down the mountain, uprooted trees and left a wide gash in the hillside. Scientists have dated the debris flow to a time when the Gitksan people occupied the area. Given that both accounts describe the same event, and with scientific dating aligning with oral history of Gitksan presence in the area, it is likely that both scientists and the oral history can contribute observations and knowledge about the event. Similarly, Eisbacher and Clague (1984) discussed Indigenous perspectives of debris flows in the European Alps, wherein the events were described as "...raging giants and infuriated dragons" that were responsible for "sudden roar[s] in the gorges and the violent eruption of rubbly debris onto fields and communities" (p. 74).

More recently, scientists have recognised the plethora of land- and seascape terms within Indigenous languages (e.g., O'Connor and Kroefges, 2008) and the wealth of information about dynamic Earth processes stored in Indigenous place names (Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; Atik and Swaffield, 2017). For example, Senft (2008) indicated that the peoples of Kaile'una Island (Papua New Guinea) have specific terms for the sea at different points along a reef barrier. *O tulupwaka* means the 'sea between the inner and outer reef'; *omata sulusulu* means 'sea that covers the outer reef'; *omata takivi* means 'sea between the drop-off of the outer reef and the deep sea'; and *o tulubwabwau* means the 'deep dark sea' (Senft, 2008). Similarly, Barrera-Bassols (2015) showed that the Purhepecha peoples of central Mexico have a geomorphic soil classification system that correlates strongly with scientific approaches to soil classification, where maps of soil distribution generated by locals using local knowledge are similar to soil maps created by scientists. Others (e.g. Payton et al., 2003; Hillyer et al., 2006) have noted similar results in other parts of the world.

Indigenous oral histories have also aided the international geoscience community to better understand geologic hazards. Swanson (2008) showed that native Hawai'ian oral traditions involving the volcano goddess Pele record a detailed understanding of the Kīlauea volcanic system's eruptive history over the past 400 years. The timeline of volcanic eruptions held in oral histories aligns with scientific analysis of the volcano's eruptive history indicating that oral traditions accurately recorded and described geologic events. Because of the growing recognition of oral traditions as place-based repositories of accurate geologic information, the scientific community is increasingly working with Indigenous groups to elucidate natural hazards. As a result, volcanic hazard management schemes that include elements of local Indigenous knowledge and Western science-based management have been developed in Vanuatu (Cronin et al., 2004) and Papua New Guinea (Mercer and Kelman, 2010). Indigenous knowledge and perspectives have also been used in tsunami hazard management plans in Vanuatu (Walshe and Nunn, 2012), the Pacific Northwest of the United States of America (Becker et al., 2008), Indonesia (Hiwasaki et al., 2014; Rahman et al., 2017), the Chatham Islands (Thomas, 2018), the Philippines (Hiwasaki et al., 2014), and Samoa (Rumbach and

Foley, 2014). There is even more research discussing integration of Indigenous knowledge and Western science for disaster risk reduction (e.g., Mercer et al., 2007, 2010; Kelman et al., 2012), but this is outside the scope of this review.

130 Indigenous knowledge is also being used to better understand climate-change, seasonal climate forecasts and climate-change resilience guidelines. Janif et al. (2016) reported that in Fiji, stories held by Indigenous locals of catching certain types of fish can indicate changes in sea surface temperatures. Similarly Cruikshank (2012) described stories of salmon migration (or lack thereof) held by Indigenous Alaskans that provided insight into glacial activity during the Little Ice Age (1550-1850 CE, common era). Their stories reflect that though climate change may be a global phenomenon, it has extremely local effects.

135 Nyong et al. (2007) demonstrated that local solutions to global climate change effects can bring great benefits to climate-change resilience plans. In West Africa Sahel, the ancestors of many Indigenous populations have experienced and adapted to historic climate extremes that surpassed those predicted by current International Panel for Climate Change (IPCC) models (Nyong et al., 2007). Iloka (2016) also recognised that Indigenous communities in Africa have a wealth of environmental knowledge, passed on by previous generations who endured and survived climate conditions far more extreme than current

140 predictions. Therefore, mitigation strategies developed by previous generations may have implications for future solutions.

To date, research that explicitly includes geomorphic techniques alongside Indigenous knowledge is not abundant in academic literature. Many publications have shown the potential for conducting geomorphic research with native peoples, evidenced by the large amount of studies investigating Indigenous languages for landscape, geomorphic, pedologic, hydrologic and glacial terms or classification schemes (e.g., Payton et al., 2003; Hillyer et al., 2006; O'Connor and Kroefges, 2008; Senft,

145 2008; Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; Atik and Swaffield, 2017). We recognise that geomorphic analysis with Indigenous communities could feature in studies covering ecology and biology because Indigenous peoples do not separate ecosystems from landscapes (e.g., Rainforth and Harmsworth, 2019), but there is a dearth of purely geomorphic studies that aim to weave Indigenous knowledge with science. Maxwell et al. (2020) outline methodologies for including Indigenous knowledge in marine management and Bohensky and Maru (2011) provide an extensive review of Indigenous

150 knowledge and Western science integration in the resource management field, but mention of geomorphology in these approaches is limited. To our knowledge, most work that explicitly incorporates Indigenous knowledge and values alongside geomorphic research have been conducted in Aotearoa-NZ, and are the focus of the remainder of this review.

3 Mixed-method geoscience research in contemporary Aotearoa-NZ

3.1 *Te Ao Māori* (the Māori worldview)

155 *Te Ao Māori* has, at its foundation, relationships between everything seen and unseen, human and more-than human, the natural and beyond-natural world, and in turn shapes Māori ways of doing and living (Clapcott et al., 2018). After Māori settled in Aotearoa-NZ many centuries ago (Hikuroa, 2017), distinct groups emerged (today, about 40 *iwi* and hundreds of *hapū*) that built their identity from the surrounding mountains, lakes and rivers (Ruru, 2018). These tribal identities have implications for

mātauranga-a-iwi (iwi-specific *mātauranga*), tribal ancestry, credibility and iwi-specific guardianship of tribal lands.

160 Glossaries of Māori words (Table 1) and key English terminologies used in this paper (Table 2) are provided for reference.

Table 1: Glossary of Māori terms (as used in this paper)

<i>Term</i>	<i>Phonetic Guide</i>	<i>Description</i>
Arohatanga	Ah-ror-ha-tah-nga	Care, respect, love
Atua	Ah-two-ah	Departmental gods, energies
Hapū	Hah-poo	Sub-tribe
Hine-Titama	He-neh-Tea-tah-mah	The first human, a woman
Io-Matua-Kore	Eeyore-Mah-two-ah-Ko-reh	The supreme 'first' being in Māori cosmology
Iwi	E (as in letter e)-we	Tribe
Kaitiaki/kaitiakitanga	Kay (as in kayak)-tea-ah-key/ Kay (as in kayak)-tea-ah-key-tah-nga	Guardian and the act of guardianship; principle of intergenerational sustainability and the practices to achieve it
Kete	Keh-teh	Basket
Ki Uta Ki Tai	Key Oo (as in boot)-tah Key Tie	Literally 'To Mountain To Sea', this is a Maori holistic philosophy that considers the environment in its entirety, expressing the importance of catchments extending from the mountains to the sea
Mahinga kai	Mah-he-nga kay (as in kayak)	Traditional food gathering practices and places
Mana	Mah-nah	Authority, prestige
Mana whenua	Mah-nah Feh-nu-ah	People with traditional authority over the land
Manaakitanga	Mah-nah-ah-key-tah-nga	Acts of caring for and giving
Māramatanga	Mah-rah-mah-tah-nga	Enlightenment, understanding, a phase in which knowledge can be applied
Mātauranga Māori	Mah-tow-rah-nga Mah-or-ree	Knowledge, culture, values and worldview held by Māori, the Indigenous peoples of Aotearoa New Zealand
Mātauranga-a-iwi	Mah-tow-rah-nga-ah-e-we	Iwi-specific (tribal) knowledge
Mauri	Mouw-ree	Life force, essence
Mōhiotanga	Moh-he-o-ar-tah-nga	Acknowledgement, respect, awareness of potential
Pākehā	Pah-keh-hah	Non-Māori (European descent) New Zealander
Papatuanuku	Pah-pah-two-ah-nu-ku	Earth mother (Primal parent)
Pūrākau	Puh-rah-kouh	Oral record or history, often in story form
Ranginui	Rahng-e (as in letter e)-nu-e (as in letter e)	Sky father (Primal parent)
Rūnanga	Ru-nah-nga	Tribal council or governing board
Tane	Tah-neh	God of the forests; created the first human
Taniwha	Tah-knee-fah	Supernatural creatures in Māori legends, often taking the form of a serpent or water monster
Tangata whenua	Tah-nga-tah fe-nu-ah	People of the land
Taonga	Tah-or-nga	Treasure (noun), to be treasured (verb)
Te Ao Māori	Teh Owe Mah-or-ree	Māori worldview
Te Ao Marama	Teh Owe Mah-rah-mah	The world of light, the world we inhabit
Te Kore	Teh Kor-reh	The nothingness, the potential for life
Te Po	Teh Pore	The darkness, the night
Te taiao	Teh Tie-Owe	The natural world; the environment, including people
Tikanga	Tea-kah-nga	Customary practices, values, protocols
Tino rangatiratanga	Tea-nor Rah-nga-tea-rah-tah-nga	Self-determination

Ūkaipō	U (as in cue)-kay (as in kayak)-pore	Roots
Wairuatanga	Why-rue-ah-tah-nga	Spiritual dimension
Wānanga	Wah-nah-nga	Discussion
Whakakotahitanga	Far-kah-koh-tah-he-tah-nga	Respect for differences, ability to reach consensus, participatory inclusion in decision-making
Whakapapa	Far-kah-pah-pah	Ancestral genealogy, applicable to all elements of nature
Whakataukī	Far-kah-tow-key	Story or proverb
Whānau	Far-know	Family or close kin network
Whānaungatanga	Far-know-nga-tah-nga	Family connections

Table 2: Glossary of English terms (as used in this paper)

Cultural association	The cultural uses and values associated with a landscape
Framework	Theoretical guides to research; methodology
Geomorphic rights	Rights of a river with the status of legal personhood, understood from a geomorphic perspective
Indigenous knowledge	Knowledge generated by Indigenous peoples using Indigenous methods and usually including values, culture and worldview
Knowledge	Intellectual capital generated over time and carried through a range of channels including stories, songs, philosophies and teachings
Method	Acts by which research is conducted or specific research tool
Methodology	Philosophical approach to research or general research strategy
Model	Actionable guides to research; method
Science	The pursuit of knowledge according to the scientific method, and all of the knowledge generated using that method
Treaty of Waitangi	Aotearoa New Zealand’s founding document; an agreement in Māori and English, made between Māori chiefs and the British Crown
Value	Guiding principles that support or enable acceptable actions

3.1.1 Whakapapa and tikanga (validity through ancestry)

165 *Whakapapa* (ancestry) is the Māori way of understanding the world through genealogies (Forster, 2019). It links people to flora, fauna, mountains, rivers, oceans and lakes through an understanding that all of nature descended from the *atua* (Māori gods) (Fig. 1; Harmsworth and Awatere, 2013). *Whakapapa* informs *tikanga* (cultural protocols and habits), which in turn informs how one should conduct their life (Graham, 2009).

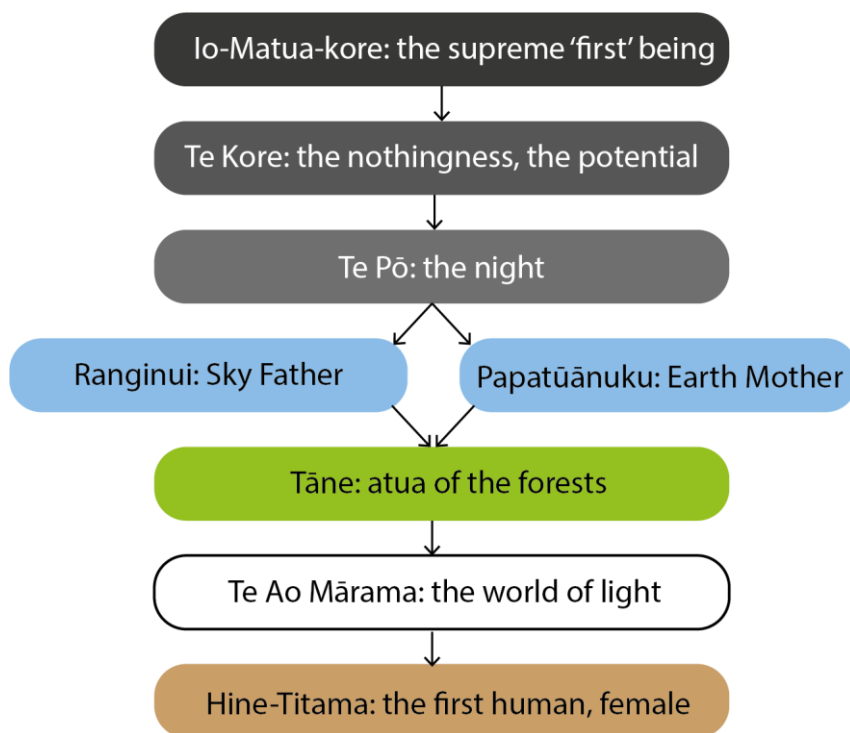


Figure 1. The pedigree of mankind in *Te Ao Māori*. Modified from Graham, 2009.

Whakapapa is at the core of Indigenous Māori knowledge generation (Graham, 2009). *Whakapapa* legitimates Māori epistemologies within research and fosters credibility by establishing connections between researchers and research objectives, and by guiding research questions based on *tikanga* (Graham, 2009). By understanding that all things—both physical and metaphysical—are connected through genealogy (Hikuroa, 2017), it can be understood that *whakapapa* is a structured methodology for creating *mātauranga* (Royal, 1998). The relationships within *whakapapa* inform histories, stories, and interactions, which can be analysed in a Māori-centred way to create new knowledge (Fig. 2).

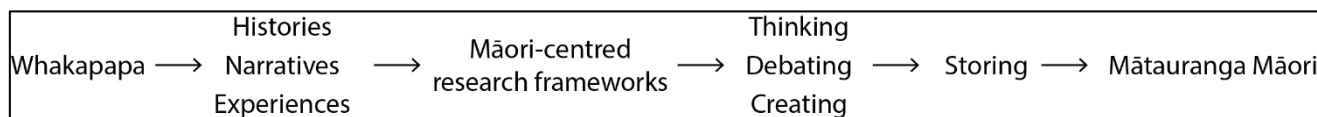


Figure 2. Generation of Māori knowledge. Modified from Graham, 2009.

3.1.2 *Mātauranga* Māori (Māori knowledge)

Mātauranga Māori is a detailed and dynamic way of knowing that has its *ūkaipō* (roots) in Māori ancestry (Paul-Burke et al., 2018). *Mātauranga* is a *taonga* (treasure) that is lived, practiced, tested, updated and that grows and develops as it is passed

from generation to generation. Based on Polynesian origins (Clapcott et al., 2018), Māori have been developing their *mātauranga* since their arrival to Aotearoa-NZ some 800-1000 years ago (Broughton et al., 2015). *Mātauranga* is not only
180 knowledge, but is also a method of expressing knowledge through language, cultural practices, values, principles and ethics (Hikuroa, 2017; Paul-Burke et al., 2018). *Mātauranga taiao* (Māori environmental knowledge) is both traditional and contemporary and reflects the totality of Māori interactions with the environment during their occupation of Aotearoa-NZ (King et al., 2007).

Mātauranga-a-iwi provides local, place-based knowledge for an *iwi*'s tribal area. This knowledge can provide
185 intimate understandings of landscape dynamics and change through time. *Mātauranga-a-iwi* is informed directly by *whakapapa* (ancestry) because local landscape features are seen as kin through genealogical ties (Wilkinson and Macfarlane, in press; Ruru, 2018). The aim is to live with the environment in an intergenerationally sustainable way in which the landscape and its resources are respected as elders. Interacting with specific landscape feature has generated and developed *mātauranga-a-iwi* and continues to refine local Indigenous knowledge.

190 3.1.3 Kaitiakitanga (well-being of people and environment)

In *Te Ao Māori*, *mana whenua* (traditional authorities) are the *kaitiaki* (guardians) of their lands, waters, and physical and cultural environments. *Kaitiakitanga* (guardianship) is a responsibility to maintain the well-being of people and environment. Contemporary *kaitiakitanga* can be understood as implementation of *mātauranga*-informed decisions and management (Clapcott et al., 2018; Paul-Burke et al., 2018). It can also be understood as the responsibility to guide research priorities in
195 the interest of the environment and the landscape. For example, studies that consider water quality and establish baseline minimums for flow (e.g., Tipa, 2009b; Crow et al., 2018; Hikuroa et al., 2018) are expressions of *kaitiakitanga* in modern research and management.

3.2 Obligations of the Aotearoa New Zealand government to Māori through the Treaty of Waitangi

The founding document of the modern state of Aotearoa-NZ is the Treaty of Waitangi (Hudson and Russell, 2009). The Treaty
200 represents the establishment of a formal relationship between the British Crown and Māori, in which Māori are legal partners of the Crown. Two versions of the Treaty exist: one in *te reo* Māori (Māori language) and one in English. The *te reo* Māori text was signed in Waitangi on 6 February 1840 by more than 40 Māori chiefs and was then circulated to other Māori communities around the country (Anderson et al., 2015). Not all chiefs signed the Treaty, but it did receive more than 500 Māori signatures. The Treaty established that Māori *taonga* (treasures), including *mātauranga*, would be protected and that
205 Māori had the right to participate as active citizens of Aotearoa-NZ. To Māori, the status of the Treaty remains as strong and relevant today as it did in 1840; however, the applicability of the Treaty within modern Aotearoa-NZ has changed (Durie et al. 1989; Hudson and Russel, 2009).

In 1988, the Royal Commission on Social Policy made a gesture to establish interpretations of the Treaty that would be applicable in modern Aotearoa-NZ society (Durie, 1994; Hudson and Russel, 2009). These interpretations have been further

210 refined (Waitangi Tribunal, 2016) and are known as the Principles of the Treaty. The Principles of the Treaty, developed by the Waitangi Tribunal, intend to ensure that interactions between Māori and Crown entities—including research interactions—are ethical and within the stipulations of the Treaty. Select resource-specific principles (Brierley et al., 2018) indicate that the right to establish the spiritual and cultural significance of certain landscape features and resources remains with *mana whenua* (traditional authorities) (Harmsworth et al., 2016).

215 **3.2.1 The Treaty in practice**

The Principles of the Treaty mandates that scientific investigations must consider the applicability and appropriateness of including Māori in research projects. Moreover, the Principles of the Treaty reflects the *te reo* Māori (Māori language) version of the Treaty, which refers to depths of knowledge and implicitly includes science within the construct of *mātauranga*. Several research projects conducted within Aotearoa-NZ over the past few years exemplify the Treaty in practice. Harmsworth et al.
220 (2016) outline Aotearoa-NZ legislative frameworks that apply the Treaty of Waitangi to modern research endeavours. Here, we discuss two major advances in culturally responsive legislation.

3.2.1.1 Te Manahuna Aoraki Project

The Department of Conservation (DOC) is Aotearoa-NZ’s government agency for conservation of national heritage, both natural and historic. DOC has a strict consultation procedure for engaging with *iwi* (tribes), *hapū* (sub-tribes) and *whānau*
225 (family groups). The consultation process is meant to uphold DOC’s status as a Treaty partner and employs the principles of partnership, protection, redress and reconciliation, and informed decision making (Department of Conservation, n.d.).

A modern and on-going example of the DOC consultation process with *iwi* is through *Te Manahuna Aoraki* Project. The players in this project are DOC, the NEXT foundation, Te Rūnanga o Waihao, Te Rūnanga o Moeraki, Te Rūnanga o Arowhenua, and others (Te Manahuna Aoraki Project, 2018). The *iwi* are official partners, which elevates their status from
230 stakeholder to decision-maker (Jo McLean, in Booth et al., 2019). The consultation process is not easy, however, as not all players will have the same priorities. For *iwi*, spiritual values of the *Te Manahuna* (the Mackenzie basin) are held as a priority to be conserved, which may be challenging to communicate to their partners (Jo McLean, in Booth et al., 2019). However, both *Pākehā* (European New Zealanders) and Māori parties recognise *Te Manahuna* as a place of vitality, which can enable mutual respect for partners and the landscape.

235 The consultation process is still in its early stages (Jo McLean, in Booth et al., 2019), but the purpose is to make a transformational shift in the way that organisations come together to deliver outcomes (Suzette van Aswegen, in Booth et al., 2019). Though this project is for conservation and management, there are many lessons that can be transferred to geomorphic research. Early consultation, legitimate partnership with *iwi*, sustained discussions and fair consideration of all key players’ views are essential for a successful project that involves Māori and non-Māori researchers.

In 2017, the Whanganui River on the North Island of Aotearoa-NZ gained the status of legal personhood. *Te Awa Tupua* was declared as “an indivisible and living whole from the mountains to the sea, incorporating the Whanganui River and all of its physical and metaphysical elements” (Te Awa Tupua [Whanganui River Claims Settlement] Act, section 13(b), 2017). Granting a river system personhood rights reflects a Māori approach to river system interaction and understanding. After *Te Awa Tupua* was legally recognised, Brierley et al. (2018) defined the geomorphic implications of the act. The authors posited that the river now has the following geomorphic “rights” (Brierley et al., 2018, p.4):

1. “A right to flowing water, and associated spatial and temporal variability in hydrologic and hydraulic regime.
2. A right to convey sediment, adjusting the balance of erosional and depositional processes in any given reach, and how these reaches fit together at the catchment scale, as materials are transported from “source to sink.”
- 250 3. A right to be diverse, reflecting geographic and historical controls upon the inherent geodiversity (i.e., heterogeneity and/or homogeneity) of a river reach.
4. A right to adjust, shaped by mutual interactions between flow, sediment, riparian vegetation, wood, ecosystem engineers, and groundwater that set the dynamic habitat mosaic of river systems.
5. A right to evolve, set by responses to disturbance events and changes to boundary conditions that influence the trajectory of geomorphic adjustment of a river.
- 255 6. A right to operate at the catchment scale, as connectivity relations determine how changes to one part of a river system impact elsewhere in the catchment, and at the coastal interface, over what timeframe.
7. A right to be healthy, operating as a living river that maintains its integrity, vigour, and vitality, maximizing its resilience to impacts of disturbance.”

260 Brierley et al. (2018) state that the river has the right to be a river, the right to flow freely and transport sediment from the mountains to the sea. The river has a right to be a living system (Salmond et al., 2019). Brierley et al. (2018) argue that *Te Awa Tupua* was a milestone achievement in river management and geomorphologic research because river scientists created research questions that reflected both societal and environmental values. This act has implications for future legal interactions concerning *mātauranga* Māori, Māori worldview, science, landscape research priorities and conservation efforts (Ruru, 2018; 265 Geddis and Ruru, 2019).

3.3 Woven spaces—the interface of *mātauranga* Māori and science

3.3.1 The relationship between *mātauranga* and science

Like with many Indigenous knowledge systems, *mātauranga* Māori has historically been ‘systematically dismissed and erased... as being worthless’ (Waitangi Tribunal 1999, as cited in Broughton et al., 2015). However, when expressed in a way to which Western scientists can relate, it is clear that Māori generated some of their knowledge in ways consistent with the scientific method (Cunningham, 2000; Hikuroa, 2017). Over the past decade, select Māori researchers in the physical sciences (e.g., King et al., 2007; Tipa, 2009; Harmsworth et al., 2016; Hikuroa, 2017; Hikuroa et al., 2018; Paul-Burke et al., 2018) have made strides for advancing *mātauranga* alongside Western science. These researchers have promoted the *mana* (authority) of *mātauranga* and advocated for its place in national research through their own research endeavours. As a result of the efforts of these researchers, as well as others in different fields (e.g., Durie, 2004; Smith, 2012; Macfarlane et al., 2015), the Aotearoa-NZ government now requires an acknowledgement and consideration of research relevance to Māori in many major grant and funding applications, such as the *Hikina Whakatutuki* Ministry of Business Innovation and Employment’s Endeavour Fund, National Science Challenges and *Te Punaha Hihiko*: Vision Mātauranga Capability Fund (Hikina Whakatutuki Ministry of Business, Innovation and Employment, n.d.). Notably, in 2011, the Vision Mātauranga policy statement was incorporated into the Statements of Core Purpose of Crown Research Institutes (CRIs), which requires CRIs to enable the potential for innovative research with Māori.

Perhaps the major difference between Indigenous knowledge (here, *mātauranga*) and science is perception of objectivity. In a scientific worldview, objectivity is essential for making unbiased observations to test hypotheses (Moller, 2009; Crawford, 2009). Facts and values are separated (Hikuroa, 2017). In a Māori worldview, humans sit within natural systems, along with all other components. There is no separation between values and facts. The reciprocity between values and facts may be considered another major difference between *mātauranga* generation and Western knowledge generation. However, because Māori values are both traditional and contemporary, Māori perspectives have the potential to contribute to innovative research approaches in which knowledge is co-created considering both Māori and Western values. Rather than contesting relative validities, Durie (2004) and Peet (2006) demonstrate that work at the interface can be a space for inventiveness and inspiration.

3.3.1.1 Indigenous values

Māori values can, in part, be understood as the means by which Māori make sense of and understand their environment (Marsden, 1989 as cited in Harmsworth and Awatere, 2013). Examples of these values include *tikanga* (cultural protocols), *whakapapa* (genealogy), *tino rangatiratanga* (self-determination), *mana whenua* (traditional authorities), *whanaungatanga* (family connections), *kaitiakitanga* (guardianship), *manaakitanga* (acts of care), *whakakotahitanga* (respect for differences), *arohatanga* (love, care) and *wairuatanga* (spirituality). Māori values directly inform *mātauranga* (knowledge), and *mātauranga* informs Māori values (Harmsworth and Awatere, 2013).

3.3.2 Identifying mutual research needs and benefits

In 2007, the Aotearoa-NZ government outlined a goal for research at the interface of Western science and *mātauranga* Māori in their Vision Mātauranga statement: *To unlock the innovation potential of Māori knowledge, resources and people to assist New Zealanders to create a better future* (Ministry of Research, Science and Technology, 2007). One of the four Vision Mātauranga research themes is *Taiao*: Achieving Environmental Sustainability through *Iwi* and *Hapū* Relationships with Land and Sea. This theme explores *iwi* (tribe) and *hapū* (sub-tribe) relationships with land and seascapes, and encourages Māori involvement in research relating to the sustainability of these environments. This official document is a tool for researchers considering different projects and their applicability to Māori. Though Vision Mātauranga does not explicitly outline how to conduct research at the interface (Macfarlane and Macfarlane, 2018), it establishes the context for bicultural approaches to research.

Iwi management plans (IMPs) and *iwi* environmental management plans (IEMPs) are official documents that can be used to define *iwi*-identified research needs. Extensive work has been completed to highlight the utility of IMPs as guides and frameworks for engagement with Māori (Saunders, 2017). IMPs provide clear, official documentation of *iwi* values and interests that can be considered in research (Waikato Regional Council, 2019). Many IMPs and IEMPs discuss *iwi* goals for minimum river flows and flood hazards (e.g., Tipa et al., 2014), which are specifically relevant to geomorphologists. Some plans have sections with specific goals for rivers (e.g., Waikato-Tainui Te Kauhanganui Incorporated, 2013) or catchments (e.g., Te Rūnanga o Kaikōura et al., 2005; Jolly and Ngā Papatipu Rūnanga Working Group, 2013). Most IMPs are focused on improving the *mauri* (life force, vitality) of landscapes.

IMPs provide the opportunity for *mātauranga* Māori to be included in planning and research projects as a knowledge system parallel to Western science (Saunders, 2017). In addition to outlining key values and interests, IMPs provide specific guidance to researchers and planners on how each *iwi* (tribe) proposes consultation and engagement activities might proceed.

3.3.3 Potential challenges and risks of conducting research at the cultural interface

It is essential to note that there may be circumstances when it is inappropriate to draw upon both Western science and *mātauranga* Māori (Mercier, 2007). Mika and Stewart (2017) in fact advocate that perhaps it is better to maintain a binary research sphere all together, wherein Western and Māori approaches are kept separate. There may be situations when one explanation (i.e. Indigenous) for an event does not align with another explanation (i.e. Western). For example, research concerning oral histories of meteor impact craters in Australia indicate that it is possible that events recorded in oral histories cannot be correlated with physical scientific evidence (e.g., Hamacher and Norris, 2010) or that some landscapes do not have associated oral histories (e.g., Hamacher and Goldsmith, 2013). In cases such as these, it is essential to maintain mutual respect by not using one method to prove the other method wrong (Durie, 2004). Accordingly, science and *mātauranga* should not be used to disprove each other (Hikuroa et al., 2011; Hikuroa, 2017). It becomes the researcher’s responsibility to determine which approach provides the stronger supporting evidence, but not by dismissing one knowledge base over the other due to

330 inconsistencies or discrepancies. If done appropriately, it is possible for the two approaches to strengthen one another and provide better outcomes for all involved (Durie, 2007). These could be opportunities to explore the richness and contingency of oral traditions separate from scientifically-determined landscape events. Equally, oral traditions could be the only record of something that was perishable in the geomorphological/geological record. In cases where scientific findings and Indigenous knowledge do align, the supporting evidence is purely stronger.

335 A Māori worldview accepts that there can be more than one explanation for an event or landform. The concept of contested knowledges and opposing viewpoints between Indigenous communities was an accepted part of life (Smith, 1999). This led to creating an environment of tolerance, mutual respect and reciprocity between Indigenous communities. Multiple ideas or explanations for an event is also common in the field of geomorphology, where landscape formation can be explored through multiple working hypotheses via the principle of equifinality. While conducting research at the interface poses many
340 challenges, it reveals similarities such as these and presents opportunities to generate corroborative evidence for events and landforms.

4. Frameworks and models for incorporating *mātauranga* Māori alongside geomorphic research

Extensive work has been done by Māori researchers to develop frameworks and models for including Māori knowledge, values and *tikanga* (cultural protocols) in research. Smith (1992) established and promoted ways for non-Māori researchers to engage
345 with Māori and maintain a standard of cultural responsibility. Smith (2012) later described *kaupapa* Māori research, or research by Māori for Māori, and detailed appropriate ways for Māori to lead their own research aspirations. The methodologies proposed by Smith (1992, 2012) can be thought of as frameworks: guiding principles according to which researchers define research questions, select tools and approaches to address questions, and plan analyses (Harding, 1987; Smith, 2012).

Harmsworth et al. (2016) and Rainforth and Harmsworth (2019) discuss models for integrating Māori values into
350 environmental research. The models can be thought of as methods: actions or procedures by which a researcher addresses core research questions and collects data (Smith, 2012). The models reviewed by Harmsworth et al. (2016) and Rainforth and Harmsworth (2019) are Indigenous approaches to research, which include Indigenous values and protocols (Smith, 2012). Indigenous approaches to research are commonly structured as models or decision support tools (Morgan, 2006) that empower Indigenous values alongside Western practices (Hikuroa et al., 2018). Harmsworth et al. (2016) and Rainforth and Harmsworth
355 (2019) indicate that a strong effort to include *mātauranga* Māori has been made in ecological and environmental assessments, but reveal a dearth of studies that weave *mātauranga* Māori with geomorphic research.

This section introduces three theoretical frameworks (i.e. methodologies) for including or considering *mātauranga* Māori in geomorphic research. The frameworks discussed here have been previously analysed in the health and education contexts (e.g., Macfarlane et al., 2015; Macfarlane and Macfarlane, 2018). We discuss how each theoretical framework could
360 be transferrable to geomorphic research. Keeping in mind that *mātauranga* and values cannot always be separated, we then introduce three models (i.e. methods) for including Māori values within science conducted according to Western practices and

highlight how each model could be used in geomorphic research. A critical assessment of the frameworks and models is provided in section 5, and a discussion of how these frameworks and models can be applied outside of Aotearoa-NZ is provided in section 6.

365 **4.1 Theoretical frameworks for including *mātauranga* Māori in geomorphic research**

The following theoretical frameworks are guiding methodologies for including *mātauranga* Māori in research projects. The three frameworks reviewed here have been discussed by Macfarlane and Macfarlane (2018), but here we also discuss their applicability to geomorphology. Although these frameworks were developed and promoted by researchers seeking better outcomes in the health and education sphere, we do not believe they are necessarily only applicable to those spaces.

370 **4.1.1 *He Poutama Whakamana (mirror-images of knowledge and understanding)***

The *He Poutama Whakamana* framework draws directly from principles that reflect the intent of the Ministry of Research, Science and Technology’s 2007 Vision Mātauranga policy (Macfarlane and Macfarlane, 2018). *He Poutama Whakamana* alludes to mirror-imaged panels—*Poutama Tukutuku*—that are typically present in traditional Māori meeting houses (Fig. 3). These *Poutama Tukutuku* represent a journey of growth and learning in order to metaphorically climb up to where knowledge and understanding are achieved.

Macfarlane and Macfarlane (2018) propose that this is a good framework for including Māori phenomena (e.g., individuals, culturally significant landscapes, values) into research. There are three main steps of the framework: *mōhiotanga* (acknowledgement, respect), *mātauranga* (knowledge, understanding) and *māramatanga* (integration, application). Each of the three steps individually and uniquely addresses four principles from Vision Mātauranga: *kaitiakitanga* (guardianship), *mātauranga* (knowledge), *tikanga* (customary protocols) and *rangatiratanga* (self-determination). These four principles reappear in each of the three steps, with different implications in each iteration (Fig. 3a). *He Poutama Whakamana* follows a *kaupapa* Māori research approach. *Kaupapa* Māori, described in depth by Smith (2012), can be understood as research that is “culturally safe” and that takes place within a Māori worldview (Irwin, 1994 as cited in Smith, 2012). There is space for non-Indigenous researchers within a *kaupapa* Māori approach (Bishop, 1994 as cited in Smith, 2012).

385 The mirror-imaged panel symbolism of *Poutama Tukutuku* presents a metaphorical space for the scientific method
to operate alongside the *kaupapa* Māori theme (Fig. 3b). Both themes can maintain their individual integrity and are
strengthened during each level of the framework by “check-ins” that ensure the Vision Mātauranga principles are being
reflected in both themes. Adequately addressing Vision Mātauranga principles in both themes has the potential to ultimately
produce co-created knowledge (Fig. 3c). This approach also has the potential to emphasize the differences between the two
390 approaches (e.g., Mercier, 2007), which may in its own right lead to better understandings and outcomes. *He Poutama*
Whakamana is suitable for geomorphic research because it is open-ended and not specialised for any one field of research. It

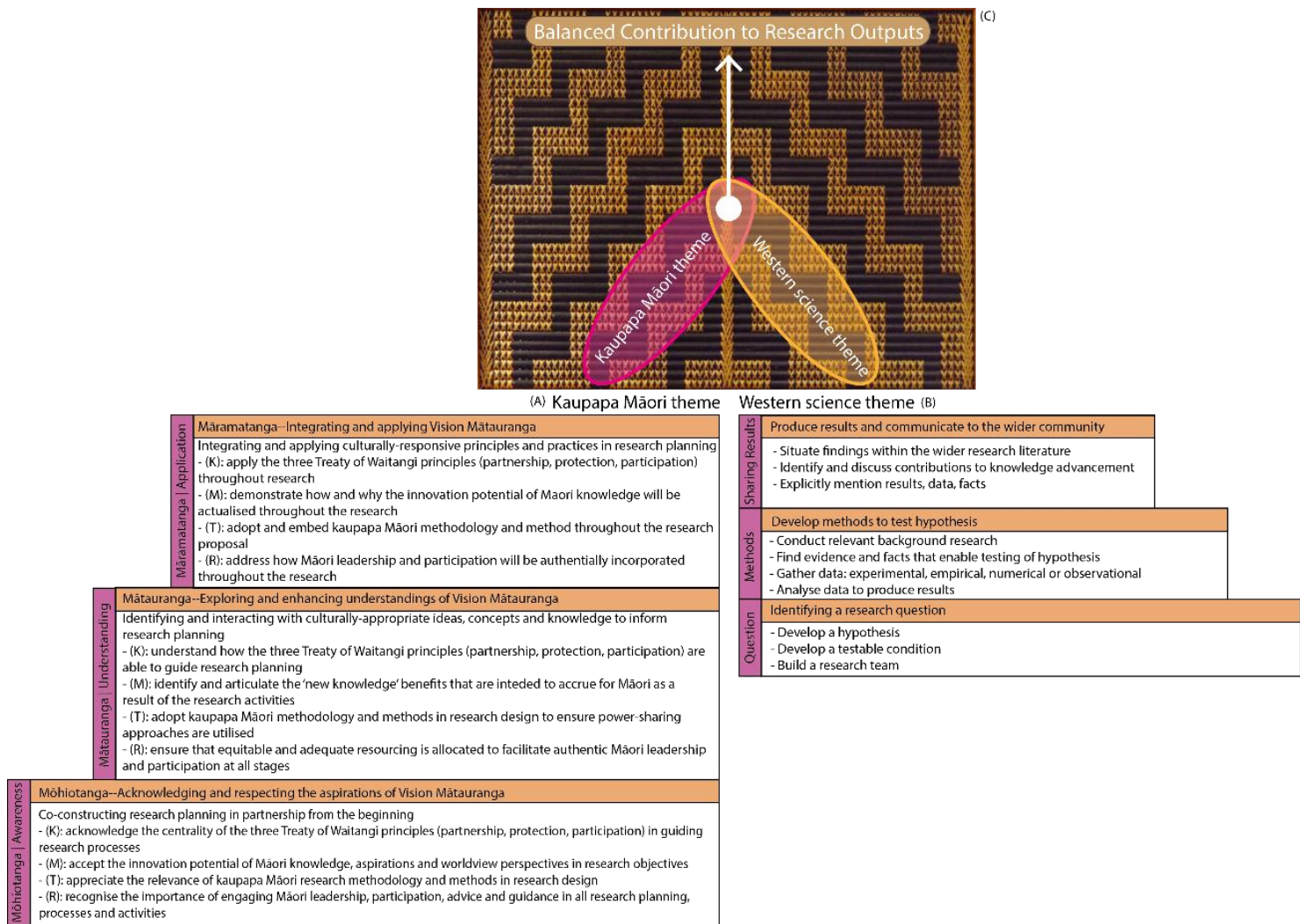


Figure 3. A) The *He Poutama Whakamana* framework (Macfarlane and Macfarlane, 2018) mirrored by B) the scientific method theory on the opposite side of the *Poutama Tukutuku*. C) represents upwards growth towards co-creation of knowledge.

welcomes research conducted under the guidance of the Treaty of Waitangi, and as long as each step of the framework is addressed, the research will potentially be culturally responsible and safe.

4.1.2 IBRLA (initiation, benefits, representation, legitimization, accountability)

395 The IBRLA framework is an open-ended research framework that aims to ensure that Māori thinking and voice are included
in research involving Māori (Bishop, 1996; Macfarlane and Macfarlane, 2018). It features a series of accountability questions
within each component of the framework (Table 3). These questions are meant to guide researchers and help ensure that Māori
knowledge is being included throughout the research project. These questions, such as “How did Māori participate in the
conceptualisation and initiation process?” or “How will Māori thinking and knowledge be represented at all research phases?”
400 hold researchers responsible for ensuring that Māori involvement and contribution is not only included but prioritised in the

Table 3: The IBRLA framework. *Adapted from Macfarlane and Macfarlane, 2018.*

	Principle	Accountability Questions
I	Initiation	• Who conceptualised and initiated this research project? • How did Māori participate in the conceptualisation and initiation process? • How was the agreement to proceed with the research achieved?
B	Benefits	• How will the research (process and outcomes) accrue benefits for Māori? • How has information been shared with Māori about the intended benefits? • How will these benefits be determined and measured—and by whom?
R	Representation	• Whose ideas will be represented in the methodology, design and approach? • How will Māori thinking and knowledge be represented at all research phases? • How will this be monitored so that ongoing agreement/partnership is maintained?
L	Legitimation	• Who will legitimate the analysis and interpretation of information/research data? • How will Māori understandings be legitimately represented? • How will this be structured so that research fidelity is achieved/protected?
A	Accountability	• Who is accountable to whom—and in what ways? • How will on-going and mutual accountability be built into the research process? • How will this be monitored and evaluated to ensure safety for all stakeholders?

research. Principles of the Treaty of Waitangi—partnership, participation and protection—feature throughout the IBRLA framework. In this framework, the accountability questions help ensure that *mātauranga* Māori is respected and upheld throughout the research process.

405 Just as the scientific method often encourages revisiting hypotheses, the IBRLA framework encourages researcher reflection during the concept design stage (similar to hypothesis formation and method development) through to the end of the research. The intent of IBRLA is to produce collaborative research stories (Bishop, 1996). This framework can provide a sense of researcher security when including Māori knowledge, while maintaining the integrity of the scientific method.

4.1.3 He Awa Whiria (a braided rivers approach)

The *He Awa Whiria* framework is based on the imagery of braided river systems (iconic landscape features throughout Aotearoa-NZ) and traditional woven baskets (Fig. 4). A research project designed under the *He Awa Whiria* framework has 410 two streams, one representing Western science and the other representing Māori knowledge. Like a braided river, the streams may diverge, converge, and meander, but ultimately, they both flow in the same direction and towards the same goal. The streams are accompanied by the metaphor of knowledge *kete* (baskets), which is inspired by the Māori *whakataukī* (saying/proverb) “*nā tō rourou, nā taku rourou, ka ora ai te iwi*” (“with your food basket and my food basket, the people will 415 thrive”). These symbols represent the weaving of Western science and Indigenous knowledge through a Māori worldview, in which the integrity and sovereignty of each is respected.

Throughout the duration of a research project, the streams may wane or grow in strength, change directions, or even die out in places, as do the channels in a braided river. Both streams have the same objective, which is to provide balanced contributions to research outcomes. It is accepted that the streams may spend more time apart than together (Macfarlane and 420 Macfarlane, 2018). It is the researcher’s role to manage how and when the two streams must converge, and when it is appropriate for them to diverge. It is the also researcher’s responsibility to make the moments of convergence times of learning. Ultimately, when research conclusions are drawn, they must represent co-creation of knowledge using both streams.

The *He Awa Whiria* methodology allows for flexibility within a research project. It recognises the benefits of both the Western science paradigm and *kaupapa* Māori principles and allows the research team to determine their own checks and 425 balances. It provides grounds for *mātauranga* Māori input to guide and focus the Western science analysis. Wilkinson and Macfarlane (in press) demonstrate that the *He Awa Whiria* framework can be applied to geomorphic studies by allowing the two knowledge streams to operate both independently and collaboratively. The *He Awa Whiria* methodology supports a culturally responsible and responsive approach to research and allows for variable approaches to research depending on the specific topic (Macfarlane et al., 2015; Macfarlane and Macfarlane, 2018). Methodological adaptability is essential for 430 conducting research with Māori, because different Māori groups will have different values, priorities and interests when it comes to pursuing research questions.

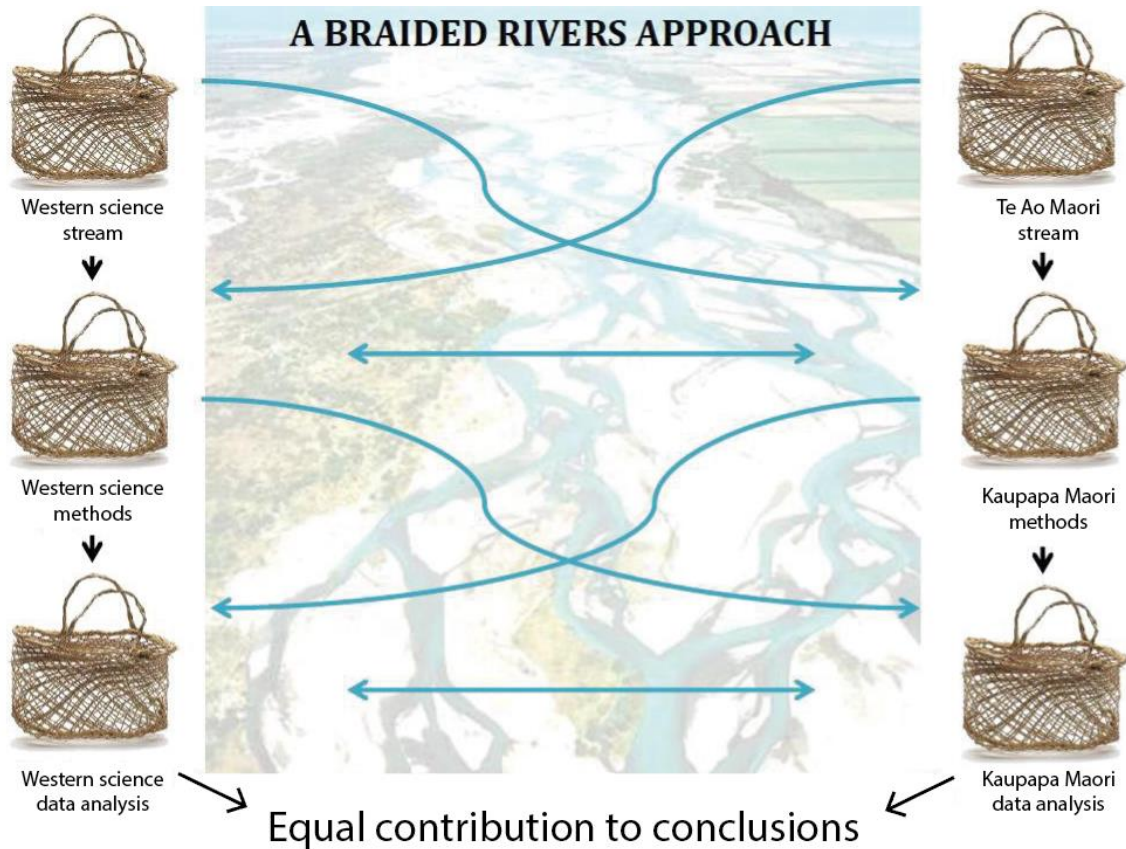


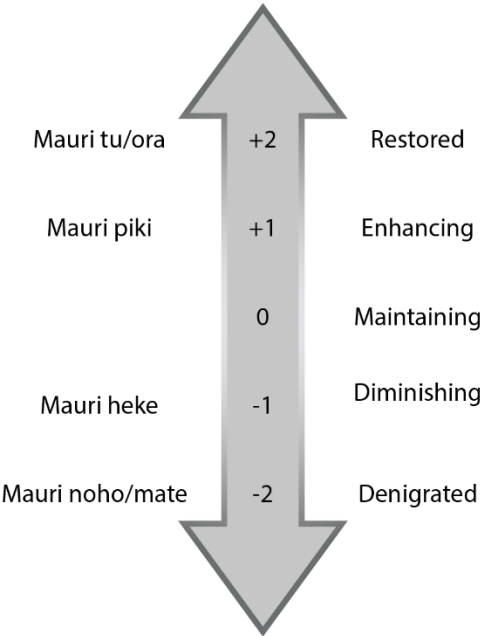
Figure 4. The *He Awa Whiria* framework. The blue lines represent knowledge exchange and development as the two streams converge and re-converge throughout the research programme. *Modified from Macfarlane et al., 2015.*

4.2 Models for including Māori values in geomorphic research

The following models are step-by-step methods for explicitly including Māori values into scientific research. Many of these models were originally designed to assist with environmental decision-making and management. These models can be
 435 incorporated into the knowledge-inclusion frameworks above, creating research projects with nested frameworks (methodologies) and models (methods).

4.2.1 *Mauri Model*

The *Mauri Model* was developed as a tool for creating sustainable solutions for environmental decision-making in Aotearoa-NZ (Morgan, 2006; Faauí et al., 2017). It is grounded in the Māori concept of *mauri*, which can be best understood as an
440 ethereal bond that links all elements of the natural world, the binding force between the physical and the metaphysical, the life-supporting capacity of soil and water. The *Mauri Model* is a decision-making model and provides a template for the explicit inclusion of Indigenous values with Western knowledge (Morgan, 2006). The aim of the *Mauri Model* is to define the degree of sustainability of proposed projects or activities by assessing the impact of an action on the *mauri* of an area (Hikuroa et al., 2011). The model considers a wide range of environmental, cultural, social, and economic indicators for use in analysis.
445 Each indicator receives a value from a scale of -2 to +2, with -2 being *mauri noho/mate* (denigrated), -1 being *mauri heke* (diminishing), 0 being maintaining, 1 being *mauri piki* (enhancing) and 2 being *mauri tu/ora* (restored) (Fig. 5). The *Mauri Model* can work independently of science but is most effective when science is integrated into the analysis.



**Figure 5. “Mauri Meter” (Morgan, 2006);
Infographic of the valuing system in the *Mauri*
Model. Modified from Hikuroa et al., 2011.**

To complete the assessment, each indicator is listed in a table and the integer values of each indicator are summed to determine the impact on the area of interest's *mauri*. This method could be appealing to researchers or project managers working in bicultural spaces because it combines stakeholder interests with Indigenous values in a semi-quantitative model (Morgan and Fa'au, 2018).

Morgan (2006) originally developed the *Mauri Model* to create a tool that could be utilised to include Māori input on water management issues in Aotearoa-NZ. It has since been used nationally and internationally to conduct environmental assessments in post-disaster maritime settings (Faau et al., 2017), in geothermal development areas (Hikuroa et al., 2010) in areas of high anthropogenic modification (Hikuroa et al., 2018) and in dam impact studies (Morgan et al., 2012). Hikuroa et al. (2018) provide an extensive list of studies that have utilised the *Mauri Model* both within and beyond Aotearoa-NZ.

4.2.1.1 Transferability to geomorphology (*Mauri model*)

Although the *Mauri Model* was designed as an assessment for the impact of human activities on an area, the ideas of denigrated and diminishing, or enhanced and restoring landscapes can be transferred to geomorphology research. For example, in 2016 an M_w 7.8 earthquake struck the Kaikōura region on the South Island of Aotearoa-NZ (Hamling et al., 2017). The earthquake caused over 20,000 landslides that delivered mass amounts of sediment to river catchments (Massey et al., 2018). Fine sediment has been carried to the sea and has smothered and suffocated tidal to intertidal shallow-marine ecosystems (Schiel et al., 2019). High sedimentation coupled with coastal uplift has caused the biogeomorphology of the region to change dramatically following the earthquake (Schiel et al., 2019). The ongoing stability of marine species has the potential to indicate sedimentation rates and the effect that the geomorphology of the area has on marine populations. In a study of *Te Awa o te Atua* (Tarawera River), Hikuroa et al. (2018) show that sedimentation is a contributing factor in the *Mauri Model* assessment. Therefore, we hypothesise that the *Mauri Model* could be applied to research investigating the effects of a natural geologic or geomorphic event (rather than a specifically human-induced act) on an ecosystem or landscape.

4.2.2 Cultural Flow Preference Study

The Cultural Flow Preference Study (CFPS) model was developed as a tool for Māori to assess their ability to engage in cultural practices within catchments at certain river flow levels (Tipa and Nelson, 2012) and to engage with freshwater resource management decisions (Crow et al., 2018). The CFPS model falls under the process of Cultural Opportunity Mapping, Assessments and Responses (COMAR), which are integrated processes that empower *mana whenua* (traditional authorities) to engage in freshwater studies and management (Tipa and Nelson, 2008).

475 As the CFPS is heavily site-specific, it demonstrates the benefits that *iwi* (tribe) and *hapū* (sub-tribe) knowledge and values can bring to modern river management and scientific endeavours (Tipa, 2009b; Crow et al., 2018). The CFPS model accounts for variations in cultural values between *whānau* (family groupings), *hapū* and *iwi* by providing a method that can be transferred and applied for different studies. The first step of a CFPS is to identify the *tangata whenua* team (Māori or Indigenous participants), who act as the leading experts for a specific river or area, and determine the cultural values held by that team. After the *tangata whenua* team has been formed, a series of steps are followed in order to create a CFPS (Fig. 6). The ultimate aim of a CFPS is to link cultural values to variations in river flow, and to determine how cultural values change depending on the flow of the river.

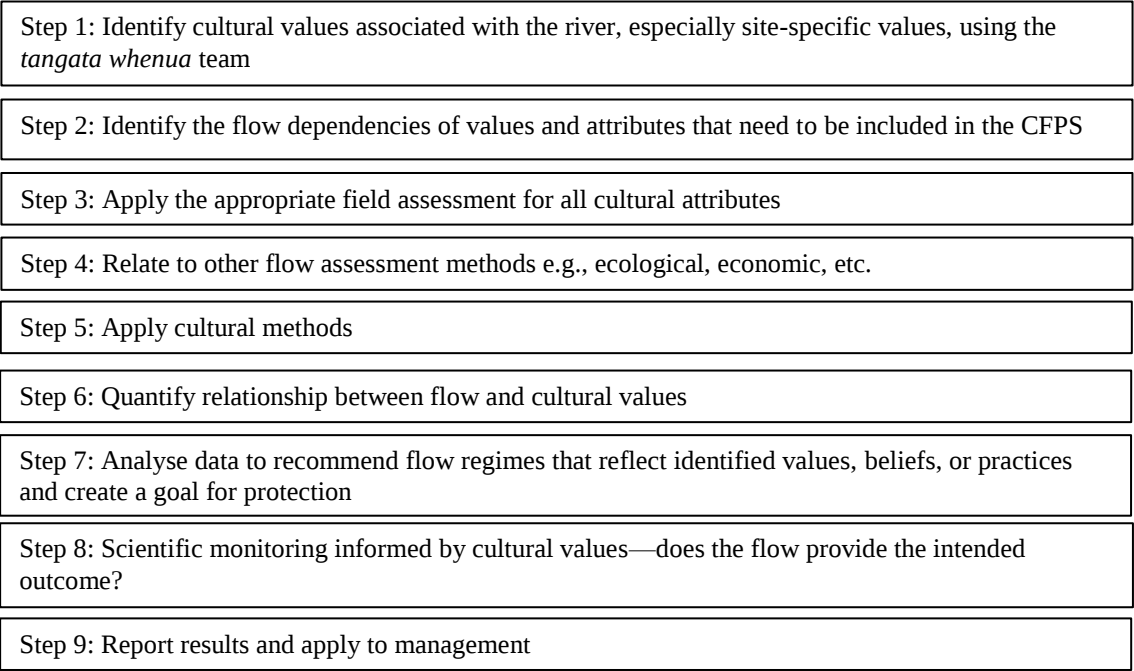


Figure 6. Steps to complete a CFPS. Modified from Crow et al., 2018.

4.2.2.1 Transferability to geomorphology (CFPS)

CFPSs are applicable to geomorphic studies, specifically fluvial geomorphology. Tipa and Nelson (2012) demonstrate the utility of applying a CFPS in a study concerning the Kakaunui Catchment, South Island Aotearoa-NZ. During this process, they followed the CFPS method to: 1) identify their *tangata whenua* team (Te Rūnanga o Moeraki); 2) have the *tangata whenua* team define their cultural association with the river; 3) conduct a participatory mapping exercise to identify how the local *iwi* (tribe) valued the river, what hydrological characteristics the local *iwi* believed to be essential to protect those values, how current and historic hydrologic and geomorphic characteristics differ, and how the current flow rates affect cultural values and

490 uses; 4) identify and analyse *tangata whenua*-identified flow issues; and 5) calculate minimum flows that would satisfy cultural
flow preferences. Through this method, Tipa and Nelson (2012) concluded that the current minimum flow in the Kakaunui
Catchment (250 L/s) is likely too low to maintain Te Rūnanga o Moeraki's values within the catchment. This study allowed
geomorphic, hydraulic, ecologic and cultural values to be considered in tandem. Identified *tangata whenua* values helped drive
the research intentions and resulted in an outcome that could have application in future management of the Kakaunui
495 catchment.

4.2.3 Sustainability Assessment Method

The Sustainability Assessment Method (SAM) is another environmental monitoring tool for assessing freshwater catchment
health that can be used to include Māori values alongside more traditional monitoring assessments (Tipa, 2009b). The SAM
explicitly includes social, cultural, economic and environmental values. This multi-dimensional assessment is laid-out in a
500 step-by-step guide that enables researchers to document cultural values and associations with river catchments alongside
scientific monitoring techniques (Fig. 7). The cultural dimension of this model focuses strongly on water quality and typically
uses *mahinga kai* (traditional food gathering practices and places) as the most important indicator of the health of waterways.

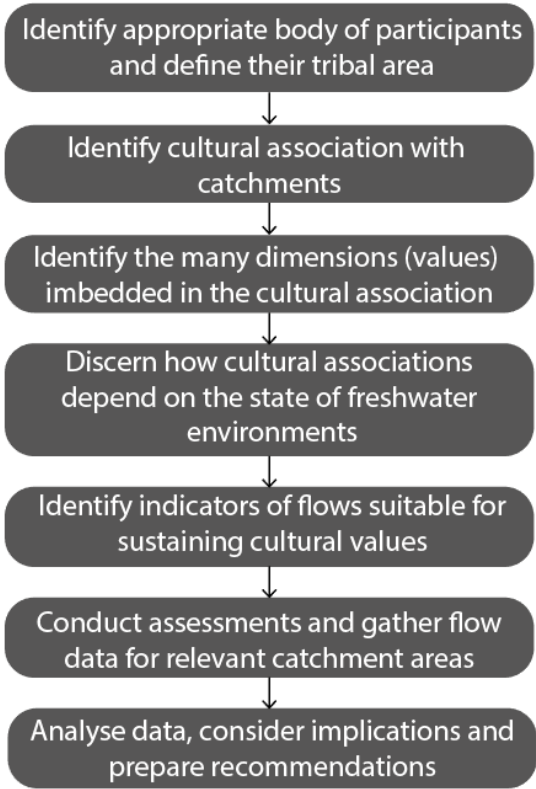


Figure 7. Steps in a SAM. Modified from Tipa, 2009.

The SAM follows a similar trajectory as other research frameworks involving Māori. The first step is to identify the appropriate group of *tangata whenua* participants, document their cultural relationships with a catchment, and ultimately determine baseline water quality and quantity standards compliant with Māori preferences. Tipa (2009) suggests that this model can be used as an alternative to strictly Western-style freshwater assessments, but it is possible that this model could be included alongside a Western-style analysis to build a more comprehensive assessment. Māori involvement is required, and the final step—analyse data, evaluate implications, prepare strategies and recommendations—should include both Māori and Western interpretations of the results.

4.2.3.1 Transferability to geomorphology (SAM)

In 2005, the SAM was adapted for use in an assessment of New Zealand river catchments from Māori perspectives (Tipa 2007 as cited in Tipa, 2009). Lists of Māori values, beliefs and practices associated with three river catchments in the South Island of Aotearoa-NZ were accumulated from analyses of contemporary writings and historical accounts. From the lists, tables were constructed to describe all concepts that portrayed a value, belief or practice that surfaced from the initial analyses. Using the SAM allowed Māori concepts to be organised in a way that each element could be examined separately, in the context of each individual river. Beauty, *mahinga kai*, water quality and *Ki Uta Ki Tai* (from the mountains to the sea) are a few examples of the many identified by *tangata whenua* as important values within these catchments (Tipa, 2009). The result of this exercise was to show that the SAM could give resource managers the opportunity to consider cultural values alongside westernised resource management priorities. The SAM promotes a tool for policy makers that incorporates a place-based approach, allowing for more specialised outcomes.

As indicated by Tipa (2009), it would be possible to also include geomorphic values alongside a SAM analysis. Recalling Brierly et al.’s (2018) geomorphic rights of the river, the SAM would enable river geomorphologists and managers to apply equitable consideration to both Indigenous and scientific values in river management strategies or research projects. The requirement would be that the team includes members who are experts—either individually or collectively—in both *mātauranga* and scientific techniques. That way, geomorphic values can be considered alongside the cultural values proposed by the *tangata whenua* team. This sort of approach could yield better river management outcomes for both Māori and non-Māori.

5. Embarking on the bicultural research journey

The frameworks and models reviewed here do, ideally, require Māori guidance and Māori participation on the research team. In many cases, it may be appropriate to select a theoretical framework to guide research methodologies and, if appropriate, apply a value-based model within the research framework to act as a guide for the project’s methods. This section provides an analysis of the presented theoretical knowledge frameworks and the value-based models, offers recommendations for

geomorphic subdisciplines, and provides information about how researchers can identify research questions using Māori priorities.

535 **5.1 Framework recommendations for subdisciplines**

The theoretical research frameworks (e.g. *He Poutama Whakamana*, IBRLA, *He Awa Whiria*) are methodologies for weaving Māori worldview and knowledge into or alongside many research disciplines, including geomorphology. These frameworks support and promote Māori knowledge and ensure that *mātauranga* is prioritised throughout the research process. They do not preclude researchers from using the scientific method to produce knowledge, but they do require that researchers also use a
540 *kaupapa* Māori approach to co-create knowledge with Māori.

It may be best to select theoretical frameworks based on the distribution of Māori to non-Māori researchers involved in the research project. The *He Poutama Whakamana* and IBRLA models may be most appropriate for research teams where the research team has a majority of non-Māori leadership, because they are not strictly expressed through a Māori worldview. These frameworks are rooted in Aotearoa-NZ governmental policy—the Treaty of Waitangi and Vision Mātauranga—and
545 provide explicit checks and balances for researchers. Researcher reflection is a major element of these frameworks. The *He Awa Whiria* framework may be suitable for research teams comprising any ratio of Māori to non-Māori leaders. Because the two research streams converge, diverge, and act dynamically for the entirety of the project (Macfarlane et al., 2015), it may be possible for one stream to have a larger sub-leadership team than the other. This framework specifically allows for *mātauranga* Māori to focus the Western science stream. This balance will vary from project to project, but a project will successfully adhere
550 to this framework as long as the interactions that do occur between the two streams foster learning and new knowledge generation (Macfarlane and Macfarlane, 2018).

So, which framework might a glaciologist, or a fluvial geomorphologist, or a pedologist, choose to ensure that they include Māori knowledge in their research? Selecting the right framework will stem from conversations with the appropriate *iwi* groups or Māori researchers early in the research process, and it will depend on the expertise of the research team. There
555 is a common theme throughout frameworks and models that the first step is to identify the appropriate group of Māori participants, or *tangata whenua*, to act as the leading experts for their tribal areas. Once these individuals are identified, framework selection can happen cooperatively between scientists and *tangata whenua*. Each of the frameworks discussed here allow flexibility within the project and allow *kaupapa* Māori principles to excel alongside the scientific method. We therefore propose that framework selection must be done on a case-by-case basis, and the correct framework for any given research
560 endeavour will be the one that suits all parties.

5.2 Model application to include Indigenous values

Explicitly including Māori values in research can be achieved by nesting value-based models (e.g., *Mauri Model*, CFPS, SAM) within the aforementioned theoretical frameworks. When value-based models are nested in Māori-focused theoretical frameworks, the interconnectedness between values and knowledge becomes apparent.

565 The models are useful tools to assist non-Māori researchers in including Māori knowledge by way of Māori values. Value-based models are an adequate way to follow step-by-step processes (similar to research processes produced according to the scientific method) that address Māori ways of knowing and living. The *Mauri* Model, CFPS, and SAM allow for explicit inclusion of *iwi*-identified cultural, environmental, and research values in geomorphic investigations. Model selection, like framework selection, will depend on the research questions at hand and must be done on a case-by-case basis as a joint decision
570 between the Māori community from whom the *mātauranga* is sourced. Regardless of how Māori knowledge is included, it is ideal to have a Māori researcher on the project leadership team to minimise risk of cultural misrepresentation or appropriation of knowledge.

5.3 Guiding resources for initiating projects in Aotearoa-NZ

As previously discussed, many *iwi* (tribes) and *hapū* (sub-tribes) in Aotearoa-NZ have published *iwi* management plans or *iwi*
575 environmental management plans that can outline research priorities for scientists (Saunders, 2017). Many IMPs contain information specifically relevant to geomorphologists. For example, most IMPs discuss *iwi* goals for minimum river flows and mitigating flood hazards (e.g., Tipa et al., 2014). Other *iwi* environmental management plans have sections with specific goals for rivers (e.g., Waikato-Tainui Te Kauhanganui Incorporated, 2013) or catchments (e.g., Te Rūnanga o Kaikōura et al., 2005; Jolly and Ngā Papatipu Rūnanga Working Group, 2013). Most IMPs focus on improving the *mauri* (life force, vitality)
580 of landscapes over which the authoring organisation (typically a *rūnanga*, tribal council) possesses *kaitiakitanga* (guardianship). Researchers can use information outlined in IMPs and IEMPs to identify the appropriate research leadership team and select the appropriate research framework.

Research funding guidelines for projects that aim to include *mātauranga* Māori alongside Western science can be found through Aotearoa-NZ's Ministry of Research, Science and Technology. Specifically, the Ministry of Business,
585 Innovation and Education (MBIE) operates Te Punaha Hihiko, the Vision Mātauranga Capability Fund, which provides guidelines for research projects in its application process (Ministry of Research, Science and Technology, 2007). The Marsden Fund, through the Royal Society of New Zealand, also provides for how proposals should include consideration of Māori involvement in research (Royal Society Te Apārangi, n.d.).

Many universities and research organisations have *iwi* engagement and support teams. These teams are excellent
590 resources for gaining guidance on identifying the best *tangata whenua* team for research needs, and how to appropriately engage with *iwi* or *hapū*. In Aotearoa-NZ, the universities and CRIs, in particular, have excellent resources for connecting researchers with Māori. We recommend early and, ideally, regular interaction with these resource groups. It is worth noting that an argument exists to make Māori representation on research project teams mandatory, but ultimately, forcing Māori involvement runs the risk of perpetuating colonizing practices. Instead, we maintain that the Māori community should decide
595 how much—or how little—they wish to contribute to research projects. Engagement and support teams will be able to advise on this subject.

6. Lessons for the international geomorphology community

Indigenous knowledge around the globe is a valid source of information because it has endured for generations, keeping populations alive and securing their livelihoods. Moreover, Indigenous knowledge has been shown to be accurate and precise (Hikuroa, 2017). In this section, we outline some direct benefits of including Indigenous knowledge in geomorphic research, discuss how the frameworks detailed in this review can be adapted for use outside of Aotearoa-NZ, and discuss how Indigenous knowledge and geomorphic research can and are working together to inform sustainability policy and legislation.

6.1 Direct benefits to geomorphology

A clear benefit to geomorphology is the temporal extension of observations of geomorphic events into pre-history. The 400-year volcanic record discussed by Swanson (2008) and the cycles of flood and channel avulsion evaluated by Hikuroa (2017) indicate that Indigenous knowledge can bolster scientifically-investigated geomorphic histories. King and Goff (2006) further demonstrated that Māori oral histories frequently discuss multiple geomorphic phenomena happening in tandem or as cascading events. Recognition of the interconnectedness of landscape processes is a common theme in many Indigenous societies (Riggs, 2005) and this recognition has resulted in a way of life that responds to, interacts with and learns from concurrent or cascading suites of local landscape processes.

Another key benefit of including Indigenous knowledge in geomorphic endeavours is the opportunity to co-create new approaches to research that build holistic and more complete understandings of landscape processes. Contemporary Indigenous knowledge and narratives can provide signposts for initiating and conducting geomorphic research by indicating geographic areas or research questions that are of interest to Indigenous groups. The concept of ‘ethnogeomorphology’ (Wilcock and Brierley, 2012; Wilcock et al., 2013) draws upon modern Indigenous knowledge and relationships with landscapes to guide geomorphic research questions and methodologies. The dynamic and adaptive nature of Indigenous knowledge generation (Berkes, 2009) has the potential to influence adaptive research methods, which in turn have the potential to generate robust data collection with information from a variety of sources.

A prime example of how adaptive research methods incorporating Indigenous knowledge can provide significant contributions to geomorphic research is the New Zealand Palaeotsunami Database. The database aims to catalogue all tsunamis that occurred prior to written historical records and uses three types of evidence to identify palaeotsunami events: sedimentary/artefactual (“primary”), geomorphic (“secondary”) and anthropological/*pūrākau* (“cultural”) (Goff, 2008; New Zealand Palaeotsunami Database, 2017). The cultural information allowed the database compilers to better constrain the age of palaeotsunami events by dating archaeological sites that were associated with the cultural information (Goff, 2008). A typical prehistoric Māori response to big waves was to abandon coastal settlements and move to higher elevations (Goff and Chagué-Goff, 2015). Cultural knowledge of the locations of abandoned sites allowed researchers to conduct archaeological investigations and date the time at which such sites had been occupied, thus providing a well-constrained date for the tsunami event. Māori *pūrākau* (oral histories/stories) often provide even more detailed information (McFadgen and Goff, 2007). Stories

of *taniwha* (supernatural creatures in Māori mythology) may indicate big wave events that wreaked havoc on coastal communities, causing changes in settlement and local geomorphology (King and Goff, 2010; Goff and Chagué-Goff, 2015). Currently, cultural information is included for 14% of recorded tsunami events in the database, most of which have come from *pūrākau* (New Zealand Palaeotsunami Database, 2017). The cultural information, alongside geomorphic and sedimentary information, provide key data for the generation of a robust and comprehensive palaeotsunami database for Aotearoa New Zealand (Goff et al., 2010).

6.2 International application of Aotearoa-NZ bicultural research frameworks and models

Indigenous communities around the world share many fundamental principles, including their interconnectedness with and inseparability from nature (Salmón, 2000; Wambrauw and Morgan, 2016). Cultural values, such as environmental stewardship and sustainability, are also common Indigenous values that guide ways of living and ways of knowing. Common values among Indigenous cultures enable and encourage transferability of established frameworks outside of the place where they have been developed. The three theoretical frameworks discussed in this review—*He Poutama Whakamana*, IBRLA and *He Awa Whiria*—can potentially be applied outside of Aotearoa-NZ due to their flexible nature and adaptability for different research groups and purposes. Likewise, the value-based models—the *Mauri* Model, the CFPS and SAM—can be modified to incorporate Indigenous values and priorities outside of the Aotearoa-NZ context, because the models are specified with Indigenous groups on a case-by-case basis. Indigenous groups anywhere can identify which values they consider essential for the frameworks and models.

The *Mauri* Model, developed in Aotearoa-NZ, has been successfully applied in Papua, Indonesia to evaluate the potential effects of a new agricultural development scheme in the Merauke regency in the lowlands of Papua (Wambrauw and Morgan, 2014, 2016). Due to its ability to incorporate Indigenous and Western values, the *Mauri* Model was deemed an appropriate tool to assess the potential environmental and cultural impacts of the development scheme. The first step to successfully applying the model was to understand the new context in which it would be used. After confirming the *Mauri* Model would be appropriate, stakeholders for the project were selected, which included the Malind Anim Indigenous peoples. The *Mauri* Model was adjusted to have a minimum value of -3 and a maximum value of +3 (rather than -2 and +2, respectively), based on local values and requirements. The results from using the *Mauri* Model indicated that the cultural values associated with the site would be denigrated if the development scheme proceeded. The *Mauri* Model provided semi-quantitative evidence that the development scheme would have serious negative impacts on the Malind Anim.

It is challenging to review the applicability of Aotearoa-NZ frameworks and models to international geomorphic research because, to our knowledge, there are extremely few studies that explicitly use the tools to conduct geomorphic research outside of Aotearoa-NZ. However, we believe that there is great potential for these frameworks and models to be adapted outside of Aotearoa-NZ, or for these tools to act as inspiration for the generation of new frameworks and models for use with Indigenous groups in other parts of the world. The case of using the *Mauri* Model in Papua indicates that this model is transferrable, which suggests that the others could be as well. If the models are adapted appropriately and in accordance with

local Indigenous communities’ values and desires, we see no encumbrance to using these models in international geomorphic research.

6.3 Benefits of Indigenous knowledge and geomorphology to society

665 There is a growing understanding that long-term sustainability on Earth is not achievable with monodisciplinary or reductionist scientific approaches (Pingram et al., 2019). Increasingly, geomorphology and Earth surface science are playing stronger roles in modern society and policy, guiding legislative action towards a more sustainable future. Sustainability is also at the core of many Indigenous cultures, which has enabled Indigenous knowledge and ways of life to persist for generations. We propose that both Indigenous concepts and values and Westernised understandings of landscape processes have the potential to generate significant changes in the way people interact with the Earth’s surface. More so, if these two streams of knowledge work together from the onset of a research project, there is the possibility of making discoveries that could not be made by either approach alone.

Landmark policy achievements that consider both scientific and Indigenous concepts emphasise the human and non-human elements of landscapes (Brierley et al., 2018; Aho, 2019; Pingram et al., 2019). These policies prioritise sustainability by acknowledging the integrity of both geomorphic science and Indigenous knowledge. These policies include legal personhood for rivers and the legal rights of nature (Brierley et al., 2018; O’Donnell and Talbot-Jones, 2018; Eckstein et al., 2019). Policies such as these provide opportunities for geomorphologists and Indigenous communities to act as advocates for the landscape, which is a relatively novel approach to sustainable landscape management and interaction within Westernised societies.

680 **7. Conclusions and recommendations to geomorphologists**

Incorporating Indigenous knowledge with Western science has the potential to bring mutual benefits to scientists, Indigenous communities and governments. This review highlighted theoretical frameworks for including *mātauranga* Māori and Māori value-based models into geomorphic research in Aotearoa-NZ. Each of the theoretical frameworks (*He Poutama Whakamana*, IBRLA and *He Awa Whiria*) and value-based models (the *Mauri* Model, Cultural Flow Preference Study and the Sustainability Assessment Model) provide different benefits to scientists and Māori. The most appropriate framework selection for projects will occur on a case-by-case basis with Māori involvement. Though this review mostly focused on the Aotearoa-NZ context, these frameworks are all capable of being applied in bicultural research contexts across the globe, so long as they accurately reflect the values and knowledge of the local Indigenous peoples. We encourage geomorphologists interested in working with Indigenous communities to consult with Indigenous peoples engagement support teams or Indigenous studies departments at their local research institutes. Additionally, in Aotearoa-NZ, we encourage researchers embarking on geomorphic research to consult *iwi* management plans and national funding guidelines for assistance in identifying potential research avenues that may

include *mātauranga*. The potential for including these tools in geomorphic research is promising, particularly where such work overlaps with *iwi* aspirations.

695 We hope this review encourages and inspires geomorphologists to explore landscapes in Aotearoa-NZ and the world through a bicultural lens, one that includes both Indigenous knowledge and modern scientific techniques to acknowledge and respect the uniqueness of the world's landscapes. Using the approaches reviewed here have high potential to yield better outcomes, as drawing from both knowledge systems will realise new understandings and solutions that neither body of knowledge could reach in isolation.

8. Author contribution statement

700 Wilkinson and Hikuroa developed the original ideas and organisation of this review. Macfarlane provided translations for Māori terminology and developed ideas for theoretical framework analysis. Hughes contributed concepts that also improved framework and model analysis. Wilkinson prepared the manuscript with contributions from all co-authors.

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