Learning from experience: Three case studies of New Zealand natural disasters and engineers' responses, 1878–1953

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Abstract
This paper investigates how significant late 19th- to mid-20th century natural disasters affected the development of New Zealand engineering practice and is the platform for further study on the topic. The purpose of the research is to provide a historical overview of New Zealand's main natural hazards and risks, and the engineering practice developments associated with three selected case study natural disasters: the 1878 Clutha Great Flood, the 1931 Hawke's Bay earthquake and 1953's Tangiwai Disaster. Each case study highlights the role of a notable engineer, expanding the compiled biographical information for Harry Pasley Higginson (1838–1900), Lachlan Bain Campbell (1882–1956) and Charles William Oakey Turner (1901–1994), respectively. Where possible, their first-hand experiences, reactions and responses to the event in which they were involved are included. The case studies show natural disasters have historically been a catalyst for engineering and legislative change in New Zealand as well as increasing public understanding of the profession's role in mitigating risk.

1. Introduction

New Zealand is subjected to a range of natural hazards and risks. Its location on the boundary of the Australian and Pacific tectonic plates has given New Zealand mountainous terrain, volcanic activity and frequent earthquakes. In addition, the country is in the path of the Roaring Forties weather system. As well as being susceptible to extreme wind events, heavy rain systems are driven onto the country, condensing against mountain barriers and triggering flood events. In contrast, many areas are also prone to drought. As an island nation, the tsunami risk is another in a long list of natural hazards.

New Zealand has a history of extraordinary natural events which could be classed as "acts of God". However, New Zealanders appreciate that these are inevitable and, as such, a defining characteristic of the country. This means that alleviating the risk from floods, earthquakes, volcanic activity and other threats has challenged engineers since New Zealand's colonial history began.

Responses from engineers have been collected as part of various oral history and documentary projects undertaken in the aftermath of the 2010 and 2011 Canterbury earthquakes. This prompted the author to consider how engineers have historically been affected by similarly tragic events. This paper is the author's first step towards developing a picture of how significant historic natural events and disasters have tested engineers' problem-solving skills and influenced engineering practice in New Zealand. This paper provides an overview of some of the country's main natural hazards and three case study examples.

The first case study focuses on New Zealand's flood risk, in particular the devastating 1878 Clutha Great Flood in Otago. Over the next few years Dunedin-based consulting engineer, Harry Pasley Higginson (1838–1900), worked extensively in the area, repairing infrastructure damage and advising on engineered flood mitigation measures. The resulting preference for building suspension bridges, generally single span, is a regional engineering heritage legacy of the flood. The event also motivated river control legislation.

Arguably New Zealand's most influential natural disaster was the 1931 Hawke's Bay earthquake. This had a catastrophic effect, especially in the area's most populous town, Napier. The post-quake recovery work was directed by engineers such as Lachlan Bain Campbell (1882–1956), one of Napier's emergency Commissioners. Seismic engineering came to the fore and this event resulted in the development of New Zealand's modern Building Code.

Although not as common as major flooding or earthquake events, volcanic activity has also had calamitous results in New Zealand. The Tangiwai Disaster of 1953 was caused by a lahar originating from the North Island's Mount Ruapehu. It destroyed a railway bridge and subsequently a passenger train ploughed into the swollen Whangaehu River with significant fatalities. Charles William Oakey Turner (1901–1994) was involved in the disaster's Board of Inquiry. The event lead to greater awareness of lahar risk and has resulted in on-going mitigation measures.

The author acknowledges that there are many other events throughout New Zealand's history and engineers who could be profiled in relation to each natural hazard. This paper is an initial stage in building a portfolio of this type of information and an exercise in establishing the format it may take.

2. Flood

New Zealand's storm and heavy rain events have caused significant loss of life and considerable property damage. Shipwrecks with high casualties were a relatively common result of storms, particularly in the 19th and early 20th centuries. Heavy rain has also caused substantial landslides, like the one which caused the Ongarue railway accident (1923), killing 17 people.

However, of the New Zealand's weather-related events, severe floods are the most frequent form of natural disaster and collectively have had the biggest economic impact. [1] Table 1 details some of these events.

Table 1: Examples of notable New Zealand floods, 1840–1950. [2]

Year	Place	Notes
1846	Te Rapa, Lake Taupo	A landslide dam was created by heavy rain which burst killing at least 60 people
1858	Hutt valley	9 people killed
1863	Otago	Approximately 100 killed in flood and snowstorm
1868	Nationwide	Flooding extensive in Canterbury and Otago. 37 people died
1878	Clutha Great Flood, Otago	Extensive and widespread damage. Death toll pf 1–2 people
1908	Manawatu-Whanganui, Wellington, Canterbury and Otago	Widespread stock loses, property and infrastructure damage
1912	Northland, Manawatu-Whanganui, Wellington	Widespread flooding. At least 1 casualty
1923	Upper South Island	Widespread property and infrastructure damage. 3 people died
1936	North Island and Marlborough	High winds and widespread flooding, landslides and washouts. Several casualties.
1936	Canterbury	Extensive damage to infrastructure
1938	Kopuawhara	Flash flood causing 21 deaths
1938	Hawke's Bay, Gisborne	Severe flooding. Esk Valley properties covered in silt and/or destroyed by flood waters and landslides
1944	Northland, Auckland, Waikato, Bay of Plenty and Tasman-Nelson	Widespread stock loses and minor property damage. Many roads were inaccessible.

2.1 Clutha Great Flood (1878)

The Clutha River/Mata-au, known as the Molyneaux River in the early colonial period, has its headwaters at Lake Wanaka and its mouth near Balclutha on the South Island's east coast. Flowing through Otago, it is the country's second longest river at 322 kilometres (km) and has the largest water volume. Its principle tributaries are the Kawarau, Manuherikia, Pomahaka, and Tuapeka Rivers.

The Otago gold rush boosted the population of Central and South Otago in the 1860s and by the 1870s there were many bridges crossing the Clutha River and its tributaries. By this time towns along the river, such as Cromwell, Alexandra, Roxburgh, Beaumont and Balclutha were, or were becoming, well-established. Residents were aware of the area's flood risk because damaging floods had occurred in 1851, 1863 and 1866. [3]

In late September 1878 the region had consistent rain and bouts of heavy rain. It had been a harsh winter and the spring snow thaw pushed river levels even higher. Therefore, the Clutha River and others in the area were in flood for several weeks, inundating large sections of Central and South Otago. The counties underwater included Bruce, Clutha, Tuapeka, Vincent and Lake County. [4]

The Clutha Great Flood is the region's largest recorded flood event. Contemporary reports provide vivid accounts of the devastation. It was noted that:

> For weeks afterwards the extensive plains…continued submerged, only the roofs of houses and tops of trees being visible above the waste of waters. For upwards of fifty miles north and south along the sea coast the shore was strewn with the spoils of the Clutha Valley consisting of bridges, punts, houses, diggers' tents, farming implements, furniture, beds and bedding, carcases of horses, sheep, cattle, pigs, and goats. [5]

The damage to property was considerable and the Public Works Department's (PWD) Engineer-in-Charge for the Middle [South] Island, William Newsham Blair (1841–1891), estimated it would cost the department over £100,000 (NZ$15 million in 2014 currency) to repair or replace government assets in the flood affected region. This information was no doubt collected by the PWD's new Resident Engineer, Edgeworth Richard Ussher (1839–1916), and other staff who inspected the region as the water receded. [6]

County engineers and consultant engineers had a significant post-flood workload too. These included Vincent County's Leslie Duncan Macgeorge

(1854–1939) and Matthew Paterson (1833–1903) for Clutha County. Tasks in the response and recovery phases of the event included: inspecting damage, co-ordinating Council's response, coming up with prioritised repair programmes, lobbying central government for support and designing and project managing the construction of infrastructure such as flood protection works and replacement road bridges. [7]

2.1.1 Harry Pasley Higginson (1838–1900)

In an obituary Higginson was said to be "a gentleman well-known all over New Zealand as an eminent engineer, who took a prominent part in connection with the public works of the colony." [8] His career began with Sir William Fairburn's (1789–1874) prestigious firm in Manchester. Higginson then exported his talents, working in various engineering roles in Russia and India.

Higginson immigrated to New Zealand in 1872, after a brief return to England where he became a Member of the Institution of Civil Engineers (M.Inst.C.E). His first role in the colony was as the South Island's Superintending Engineer for the Railways Department. [9] While in government employ he also had some consulting work and Higginson entered into private practice in mid-1878, based in Dunedin. [10]

Figure 1: Harry Pasley Higginson [*circa* 1876]. Ref: 1/2-066660-F. Alexander Turnbull Library, Wellington, New Zealand. http://natlib.govt.nz/records/23233113.

Professionally this was a timely and shrewd move because within months the Clutha Great Flood occurred and Higginson's services were in high demand. Over the next six months, Higginson was engaged on many reports for various local River Boards and Councils about mitigating future flood risk. [11]

Higginson was also on the 1880 Commission of Enquiry into the significant flood damage around Balclutha, alongside Blair and Charles Napier Bell (1835–1906). In addition to PWD works completed after the event and those being planned, the Commission recommended constructing two storage reservoirs in the Upper Taieri Basin, alterations to existing stopbanks and removal of others, raising railway embankments, and creating floodgates in all culverts. [12] Of course, recommendations are not directives and it seems not much was done about the extra initiatives. [13]

Meanwhile, after focusing on post-flood work for several years, from 1882–1886 Higginson was the Chief Engineer for the Manawatu and Wellington Railway. Higginson retired from his subsequent position as the Engineer and Manager of the Wellington Gasworks in 1898. [14]

2.1.2 Engineering practice legacy

All but four of the road bridges between Balclutha and the Central Otago lakes were destroyed by the Great Flood, so designing bridges likely to withstand future floods became an important consideration. [15] Higginson and others recommended raising the height of replacement bridges and that scour protection be standard for bridges with piers. Higginson put this into practice with his replacement road bridge at Balclutha (1880–81). [16]

During this period, Higginson also designed the Kawarau Gorge Suspension Bridge, which was one of many local road suspension bridges constructed in the aftermath of the Great Flood. Because of the fast flowing rivers, there were many suspension bridges in the region prior to the flood. However, some multiple span truss and arch bridges, like that at Roxburgh, were also replaced with suspension bridges because limiting mid-river piers was seen as a relatively inexpensive way of mitigating flood caused failure. [17] A large proportion of these late 1870s and 1880s Central Otago suspension bridges remain. They characterise the region, are an enduring engineering heritage legacy of the Clutha Great Flood and indicate that the post-flood approach to bridge building was valid.

On a national level, the Clutha Great Flood would have been a motivating factor in creating the *River Boards Act 1884*. Similar to the *Roads Boards Act 1882*, the *River Boards Act* repealed 20 individual acts relating to different areas around New Zealand and provided rates taking and other powers to the Boards specifically for the purposes of river maintenance and flood protection. [18]

Many Boards had their own specialist engineer or at least engaged project consultants. However, the legislation was not entirely successful because of the piecemeal approach the river districts created. It was only after the 1938 Esk Valley flood in Hawke's Bay that legislation was passed which placed entire river systems in the control of catchment boards. [19]

3. Earthquake

The risk to life from flooding was particularly significant in mid- to late- 19th century New Zealand. However, in the early 20th century earthquakes claimed this dubious honour mostly due to the 1931 Hawke's Bay earthquake. On average New Zealand has one 4–4.9 magnitude earthquake per day and a 7–7.9 magnitude event every two and a half years. Earthquakes cluster along fault lines but are felt all over New Zealand. [20] Table 2 highlights some significant, large earthquakes dating from the beginning of New Zealand's colonisation until the mid-20th century.

Table 2: Examples of notable New Zealand earthquakes, 1840–1950. [21]

Year	Place	Notes
1843	Whanganui	Estimated magnitude 7.5. 2 people died
1848	Marlborough	Magnitude 7.5. The largest aftershock was magnitude 6.1 and 3 people died
1855	Wairarapa	Magnitude 8.2. Widespread property damage in central Wellington. 7 people died.
1863	Hawke's Bay	Magnitude 7.5
1868	Cape Farewell	Magnitude 7.5
1888	North Canterbury	Magnitude 7.3
1893	Nelson	Magnitude 6.9
1901	Cheviot	Magnitude 6.9. 1 death
1914	East Cape	Magnitude 6.8. 1 death
1929	Arthur's Pass	Magnitude 7.1
1929	Murchison	Magnitude 7.8. 17 people died
1931	Hawke's Bay	Magnitude 7.8. 256 people died. The largest aftershock was magnitude 7.2
1934	Pahiatua	Magnitude 7.6. 1 death
1942	Wairarapa	Magnitude 7.2. The largest aftershock was magnitude 7.0. 1 death. Widespread damage in Wellington

3.1 Hawke's Bay earthquake (1931)

Earnest European settlement of Hawke's Bay, in the North Island's east, began in the early 1850s with runholders occupying large tracts of land for sheep farming. This was followed by the Government establishing towns around the region. By 1931 the population in Hawke's Bay's main city, Napier, was over 16,000.

A magnitude 7.8 earthquake struck the morning of 3 February and a fire subsequently added to the destruction in central Napier. While building collapse was a significant contributor to the death toll, water supply failure also resulted in an uncontrolled fire sweeping through the business district. [22] In Napier 161 people died as a result and the province's death toll was 256, making the event New Zealand's deadliest natural disaster on record. [23]

Engineers offered assistance from around New Zealand in the immediate aftermath. For example, the Engineer-in-Chief, Frederick Furkert (1876–1949), and others from PWD head office arrived in Hawke's Bay within days to start directing vital road repairs, the programme of demolishing and clearing buildings and mobilising a labour force of over 500 people to carry it out. [24]

The earthquake pushed up land, in some places by one to two metres, causing significant damage to water and waste water infrastructure and also the electricity supply to pumps. Within weeks, Wanganui City Engineer, John Stanley Longton Deem (1895–1933) was on hand to oversee the works and Wellington City Council's Engineer, George Hart (1870?–1948), designed a new sewerage system for Napier South by the end of March. [25]

3.1.1 Lachlan Bain Campbell (1882–1956)

Campbell was a PWD Inspecting Engineer flown to Hawke's Bay within hours of the earthquake and, along with magistrate John Saxon Barton (1875–1961), was soon appointed one of Napier's earthquake recovery Commissioners. [26]

Born in Waiapu, Campbell studied at Canterbury College before becoming a Public Works Department engineering cadet in 1901. His early focus on the North Island Main Trunk's (NIMT) construction lead to similar work around the North Island. He was a foundation member of the New Zealand Society of Civil Engineers in 1914 (he was the Auckland Branch President in 1927) and was also M.Inst.C.E. During World War One, Campbell was awarded the Military Cross. [27]

Immediately prior to the war, Campbell had been Napier's PWD Resident Engineer. After his war service Campbell travelled and then came back to New Zealand to continue progressing through the PWD's ranks. He soon became District Engineer in Dunedin and then Auckland in 1924. Following the career progression of his predecessor, Alfred James Baker (1881–1943), he was promoted to Inspecting Engineer in late 1928. [28] It was in this capacity he first became involved in Hawke's Bay earthquake response work. Within days he was made the PWD's temporary controlling officer in Hastings, Hawke's Bay's second largest city, in charge of the demolition of dangerous buildings. [29]

The lack of co-ordinated national disaster management was immediately highlighted after the earthquake and legislation was quickly pushed through Parliament to compensate. Passed in April, the *Hawke's Bay Earthquake Act 1931* formed the Hawke's Bay Adjustment Court and Rehabilitation Committee which basically held the Government purse-strings. The Act also ratified Barton and Campbell's appointments as Napier's Commissioners and the emergency powers they had been given by the Municipal Council to effectively manage the city's recovery and reconstruction. [30]

Campbell stated that "what was needed [in Napier] was a broad outlook and not a confusing mass of detail." Indeed, this seems to have been his mandate – to have the overview of infrastructure and other building required and to co-ordinate the city's rebuild as speedily and cost effectively as possible. [31]

Campbell was engaged in Napier for over two years and his work which "Napier in a large measure owes much" was appreciated and praised. [32] Campbell was soon appointed Secretary of the Marine Department, remaining in the position until he retired in 1944. [33]

Figure 2: Foundation members of the New Zealand Society of Civil Engineers, 1954 (detail). From left to right: Hugh Vickerman, Lachlan Bain Campbell and Henry Featherston Toogood. [34] Image courtesy of IPENZ.

3.1.2 Engineering practice legacy

Seismic design was already a focus for the PWD in the wake of the 1929 Murchison earthquake and current best practice was a feature of Napier's Chief Post Office. [35] Completed in 1930, this building was one of only a few central Napier buildings to survive the earthquake, but was gutted by the fire. The PWD had a wide reach and the Hawke's Bay earthquake affirmed the validity of considering seismic resistance in building design. After the event, the PWD developed its own publically available building standards for implementation on all its projects. [36]

Within weeks of the earthquake, a Building Regulations Committee was established. The committee, chaired by Canterbury College School of Engineering's Professor John Ernest Lelliot Cull (1879–1943), was set up to develop guidelines for the rebuild based on evidence from the disaster, which it seems likely Campbell would have been involved in collecting. The majority of the committee were engineers, including senior consultant and council engineers from Auckland, Wellington and Christchurch and PWD Designing Engineer, William Langston Newnham (1888–1974). [37] This recognised the engineering profession's important role and expertise in building design above that of architects. The committee's recommendations became the forerunner of New Zealand's modern building codes, something the committee advocated for, which was first realised in 1936 with the *Model Building By-Law*. [38]

4. Volcanic eruption

Most of New Zealand's modern volcanic activity has been focused in the North Island's Central Plateau. However, other places, including the country's largest city, Auckland, are potentially vulnerable. With the exception of the 1886 Mount Tarawera eruption, much of New Zealand's volcanic activity since European colonisation began has been spectacular but caused little property damage or loss of life. Excluding White Island, the volcanoes in Table 3 are all located in the Central Plateau.

Table 3: Examples of notable New Zealand volcanic activity, 1840–1950. White Island had fairly low level but continuous eruptions during this period, which have only intensified in the last 40 years.

Year	Mountain	Notes
1861	Mount Ruapehu	Eruption and lahar in Whangaehu River
1868	Mount Tongariro	Forms the upper Te Maari crater
1870	Mount Ngāuruhoe	Culmination of 30 years of frequent eruptions. Lava flows
1886	Mount Tarawera	153 people died
1889	Mount Ruapehu	Eruption and lahar
1895	Mount Ruapehu	Eruption and lahar
1896–97	Mount Tongariro	50 millimetres of ash falls locally and spreads as far as Napier
1903	Mount Ruapehu	Eruption and lahar
1914	White Island	11 people killed in debris avalanche
1925	Mount Ruapehu	Eruption and lahar

1945	Mount Ruapehu	A series of explosive eruptions with lava and ash and rock fall. In 1953 a lahar from the undermined Crater Lake caused the Tangiwai Disaster
1948-49	Mount Ngāuruhoe	Small lava flow, 6 km high ash cloud

New Zealand's volcanic activity causes different threats, from ash clouds, avalanches, lava flows and domes, pyroclastic flows and tsunamis. Lahars are another aspect of volcanic activity – fast flowing volcanic mudflows of ash and rock often generating from a crater lake and/or melting snow and ice. [39] The density and speed of lahars mean they are especially destructive and people caught in them are unlikely to survive. Lahars are also notoriously difficult to channel or control.

4.1 Tangiwai Disaster (1953)

Mount Ruapehu is New Zealand's largest active volcano as well as an important part of a World Heritage Site and a centre for leisure activities such as skiing and climbing. At 2797 m high this stratovolcano (composite peak volcano) is the North Island's tallest peak. Crater Lake dominates the summit. The capacity of this lake is approximately 8 million cubic metres of acid water. [40]

There are several rivers with their headwaters on Mount Ruapehu, including the Whangaehu River. The river's name, meaning large body of muddy or turbid water in Māori, is suggestive of its history of lahars. [41]

Eruption events in 1945–46 emptied Crater Lake and by December 1953 the re-filled lake was considerably higher than its pre-1945 levels because eruption material had raised the sides. The 1940s activity also altered a water outlet cave Ice crevassing through the ash barrier is thought to have undermined the cave, causing its collapse and sending copious amounts of water down the Whangaehu River and taking old volcanic ash, pieces of glacier ice and gorge boulders with it. Some "vibrations" were detected by a nearby seismograph at the Chateau Tongariro hotel preceding the lahar, so experts did not rule out the possibility that volcanic or earthquake activity hastened the cave's collapse on 24 December.

The resulting lahar destroyed the rail bridge at Tangiwai, between Waiouru and Ohakune. New Zealand Railways speed and operating procedures were all being followed, but unfortunately the timing of the Wellington to Auckland Express Train meant the locomotive and front carriages plunged off of the failed Whangaehu River Bridge despite application of the emergency brake. The Tangiwai Disaster is New Zealand's worst railway disaster with a death toll of 151. The nearby road bridge was also destroyed but no casualties resulted.

The steel plate girder bridge with mass concrete abutments and piers was an original NIMT structure, constructed in 1906. There were no construction files to indicate whether the river's lahar risk was a design consideration, especially in regard to pier foundation depth, because these and other government records were destroyed in the July 1952 Hope Gibbons Building fire, Wellington. [42]

4.1.1 Charles William Oakey Turner (1901–1994)

Turner was Ministry of Works (MoW) Engineer-in-Chief from 1951–1962. Born and educated in Britain, Turner began his career in New Zealand in the PWD's national Design Office as an Assistant Engineer in 1926. While in this position he was sent to Napier to assist the Commissioners with the 1931 Hawke's Bay earthquake recovery. After completing study fellowships in the United States of America, Turner became Chief Designing Engineer in 1937 and then Chief Inspecting Engineer. Turner was also the State Hydro Electric Department's Chief Civil Engineer, 1946–47, before being transferred back to MoW. [43]

Figure 3: Chief executive officers of the State Hydro-electric Department, 1946 (detail). From left to right: AE Davenport, CWO Turner and S Roberts. [44] Image courtesy of IPENZ.

Turner was involved in the inquiry into the Tangiwai Disaster because of his senior position within the MoW. The inquiry indicated a 1925 lahar mystified the Acting District Engineer who could not account for the flooding since there had been no rain for a fortnight. That event caused considerable scouring, especially around pier 4. In 1944 further flood scour was filled with stone, and then in 1946 eight five-ton concrete blocks were positioned at pier 4 as protective works. [45]

When questioned about the apparent insufficient response in 1925, Turner stated: "It is very difficult for me to get myself away from the present situation." Based on the information available to the 1925 engineer Turner thought he would have acted similarly; repairing damage promptly and making some enquiries about the lack of rainfall, but not being “unduly perturbed about it”. [46]

Despite no significant mitigation steps being taken, the 1925 lahar drew PWD/MoW attention to the potential vulnerabilities of the Whangaehu River road and rail bridges. The MoW seems to have been wary of Mount Ruapehu’s volcanic activity particularly during and after the mid-1940s eruptions. The Crater Lake’s levels were monitored regularly and a senior engineer was sent to the mountain to make measurements and observations in early 1953. Therefore, Turner was able to estimate that on the night of 24 December the lake dropped over 6 m in two and a half hours which is indicative of the force of the lahar. About 340,000 cubic metres of water is thought to have gushed out of the lake. [47]

Turner retired in 1962. During his tenure as Engineer-in-Chief he was in charge of projects such as the Wairekei Geo-thermal power development, as well as the Cook Strait power cable, among many others. In retirement he consulted on projects, including Manapouri Power Station. [48]

4.1.2 Engineering practice legacy

It was noted in the Board of Inquiry Report that lahar was a term more frequently used by geologists than civil engineers. However, as a result of the Tangiwai Disaster there was wider understanding of this type of natural hazard among engineers and the public in general. [49]

Until 1957 a temporary rail bridge was service at Tangiwai. Obviously, lahar risk was considered in the design of replacement Pratt truss bridge with reinforced concrete cylinder piers. The Railways Department also undertook works on other local bridges in the wake of this event, such as the Mangaturuturu Viaduct further north. [50] There have been at least 13 Mount Ruapehu lahar episodes since 1945, so this is an ongoing aspect of state highway and NIMT management in the region. [51]

The Board of Inquiry recommended bridge failure warning devices be installed on all railway bridges crossing rivers and stream from Mount Ruapehu between Waiouru and National Park. Road bridges were not included in this. There does not seem to have been technology available at the time to create an especially reliable warning system. [52]

Half a century later, such a system was possible and the East Ruapehu Lahar Alarm Warning System was installed by the Department of Conservation (DoC) in 2001–02. It consists of a series of sensors and acoustic flow monitors, whose data feeds back to the base at Tokaanu Power Station and is distributed to various stakeholder agencies through pagers, telephone and Internet. Accepting that not all the risk from lahar can be mitigated, the early alarm system is designed to alert agencies such as the local councils, Police, DoC, electricity, rail and road infrastructure agencies, activating their emergency and evacuation procedures. These include the halting of NIMT trains and road traffic in the area. [53]

5. Conclusion

The case studies show that following significant natural disasters, engineers have taken centre stage and public understanding has increased about the specialist role they have in reducing risks from natural hazards. This has been useful in the aftermath of disasters because it gives an informal mandate for public spending on mitigating future risk, even decades later, as with the East Ruapehu Lahar Alarm Warning System. In some cases, natural disasters, such as the Clutha Great Flood and the 1931 Hawke’s Bay earthquake, have been the impetus for creating or refining the regulatory framework various engineering fields operate within.

The case studies all highlight senior engineers and there is scope for providing more specifics, especially their personal, not just professional, reactions. An interesting direction for this type of research could also be to identify younger engineers and to trace whether the natural disaster they were involved in was a formative occurrence affecting their career path and specialisation. Likewise, replicating this case study exercise and surveying other significant natural events may provide a better picture of whether we are cumulatively learning from our natural disaster experiences in a lasting and meaningful way or may end up repeating past mistakes.

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