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Submarine Cable Protection and the Environment

An Update from the ICPC, Written by Marine Environmental Adviser, Dr Mike Clare

How subsea cables were affected by the most explosive volcanic eruption ever recorded.

SUBMARINE CABLE PROTECTION AND THE ENVIRONMENT

An Update from the ICPC, Written by the Marine Environmental Adviser (MEA)

PUBLISHER

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EDITOR'S CORNER

Throughout human history, people have always faced natural hazards in various forms. From flooding to storm surges, to earthquakes, tsunamis, landslides, wildfires, and volcanic eruptions. According to published estimates, about 9% of the world's population (about 500 million people) live within the potential exposure range of a volcano that has been active within recorded history. Much higher population levels live within the other hazards listed.

Submarine cable infrastructure, by its very nature, cross through areas susceptible to these hazards, and as long as people live within reach of these hazards, the digital and power infrastructure serving these populations will be at risk of damage. As a result, mitigating these risks is a cable protection issue that the ICPC is committed to understanding and providing leadership and guidance in order to enhance future resilience worldwide. It is for that reason that when the Hunga Tonga-Hunga Ha'apai volcano erupted in 2022, the ICPC and the broader submarine cable industry was both motivated to assist the people of Tonga but also understand the

mechanisms that damaged their international and domestic submarine cables in order to develop industry-specific lessons learned.

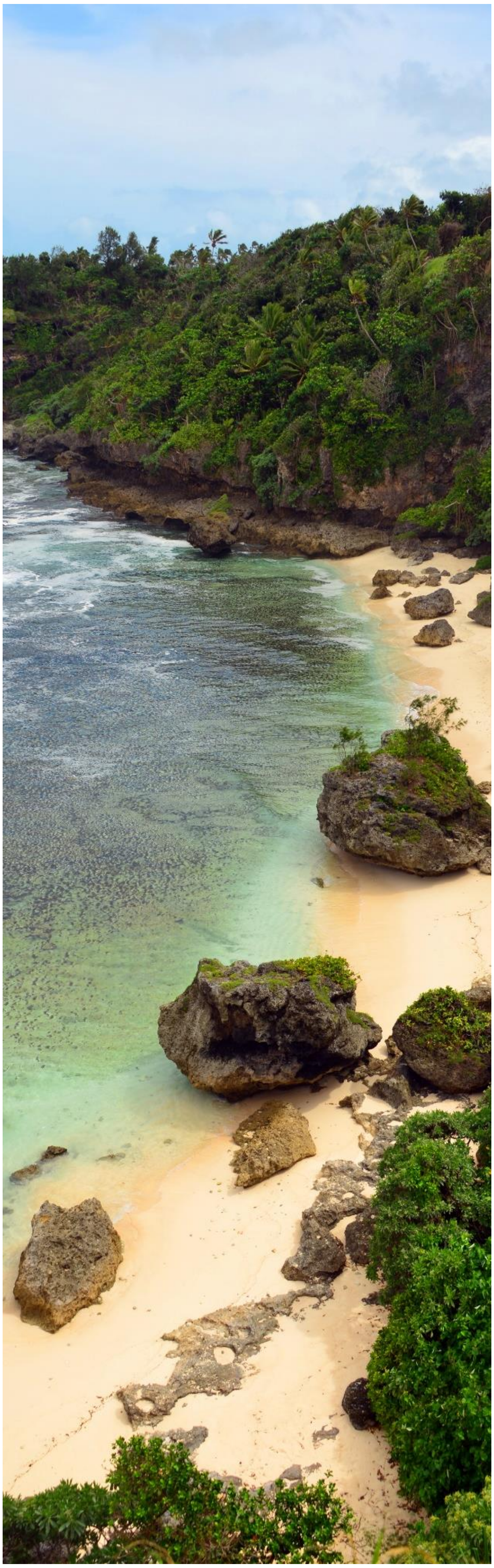
Submarine telecommunications cables are vital international connections for island nations that offer lower latency and higher capacity for digital communications and IP transit compared to the use of satellites. Due to the high capital cost of submarine cable systems, most remote island nations may only have one, perhaps two international submarine cables coming to shore. The more redundant connections for any country, the more resilient their overall connection is to the world.

Submarine fibre optic cables are designed for a 25-year life while submarine power cables are designed for about a 40-year life. Within these periods, it is statistically rare that a natural hazard such as a volcanic eruption would occur in this design lifetime and in proximity to a cable such that it is damaged. Volcanic hazards represent a very small proportion of cable faults and natural hazards, in general, represent less than 5% of cable faults annually. But clearly, these events do occur.

When the submarine cable industry and ICPC became aware of the Tonga eruption and the damage to their international and domestic submarine fibre optic cables, the industry came together with many cable owners (and ICPC Members) contributing vital spare cable and equipment to enable the repair of these systems. As ICPC's Vice Chair, Dean Veverka, commented at the time 'our immediate concern was for the health and safety of the people of Tonga and reestablishing communications with the rest of the world . . .' Concurrent with this, the ICPC recognised a role we could take to enable collaborative research to help understand the impact of these infrequent but impactful events on communities and communications. The ICPC's Marine Environmental Adviser, Dr Mike Clare, with support of ICPC, successfully secured research funding from the UK's Natural Environmental Research Council with international collaborators (including [New Zealand's National Institute of Water and Atmospheric Research](#)) to perform a survey around the submerged volcano and along the cable routes, within three months of the eruption. The study findings were used to inform the cable repairs in real-time and will guide the routing and protection of new cables in volcanically active areas elsewhere.

Collaboration has been a necessity in the implementation of submarine cables, as it is in the repair of cables. And collaboration, as a human initiative, is very apparent in the event of natural disasters. The ICPC is proud to have been in a position to assist with this research effort and for our Members who helped serve the people of Tonga. This edition of Submarine Cable Protection and the Environment tells the story and results of this research initiative.

Sincerely,
Ryan Wopschall
ICPC General Manager



INTRODUCTION

- On the 15th January 2022, an eruption in the South Pacific Ocean escalated to produce the most explosive volcanic event this century with almost no warning, creating impacts that were felt worldwide.
- The eruption triggered tsunamis that devastated Tongan islands and travelled across the ocean, ejected a plume that extended above the stratosphere, and atmospheric shockwaves that travelled multiple times around the globe.
- One of the most profound impacts did not occur on land, but instead, surprisingly deep under the surface of the ocean; affecting underwater telecommunications cables[1].

▼ The initial phases of the eruption of Hunga volcano on 14th January 2022 witnessed at sea; the day before the main explosive eruption. Photo credit: Taaniela Kula, Tonga Geological Services.

INTRODUCTION

- Data traffic between the Kingdom of Tonga and the rest of the world suddenly came to a halt. The only submarine cable connecting Tonga to the rest of the global network was damaged just over an hour after the biggest explosion of Hunga volcano, effectively shutting down an entire nation's international digital communications.
- Due to extensive damage to Tonga's international cable, people could not communicate with their families and loved ones, business transactions stopped, and international aid efforts were hindered, all in the midst of a volcanic crisis.

This edition of *Submarine Cable Protection and the Environment* explores the events that explain the sudden and widespread damage to the subsea cables that connect Tonga, what we can learn from the Hunga volcano eruption, and more widely what the subsea cable industry has learned to enhance resilience for the global network of subsea cables.

THE IMPORTANCE OF SUBMARINE CABLES TO REMOTE ISLAND NATIONS

While many people are unaware of their existence, subsea telecommunications cables are critical to so many aspects of our daily lives, keeping us all connected across the globe. A network of more than 1.4 million kilometres of cables crosses the oceans, mostly no wider than a garden hose. This global network carries more than 99% of all digital data traffic worldwide, underpinning the internet, enabling remote working, telemedicine, online education, and trillions of dollars in financial transactions each day [2].

For remote island nations such as Tonga, subsea cables are particularly critical; providing both links to the rest of the world and access to essential services. Almost half of Tonga's Gross Domestic Product comes from remittances; money sent back from family that are abroad. When the internet was disconnected, this money stopping coming in. It was almost a week before people could receive any funds, only after satellite coverage was established. Banks had difficulty transacting and businesses almost came to a standstill as they could not import or connect with overseas customers. Even when satellite coverage kicked in, four days after the blackout, the connectivity was 1% of that before the eruption. This meant that communications were initially largely limited to very basic messaging. It was five weeks before the international cable could be repaired, restoring full digital communications to the main island of Tongatapu. A domestic cable, which serves the island groups to the north, was also damaged by the eruption and repairs to restore connection to these island groups took a year and a half.

CABLE DAMAGE BY NATURAL HAZARDS

Around 150-200 faults occur each year on the global network of underwater telecommunications cables; however, these are generally repaired very quickly as they are mostly individual instances of damage in shallow water[2]. Most cable faults relate to human activities, arising from accidental snagging by fishing gear or dropping of anchors and can be mitigated against by re-routing data traffic along other cables. Cable faults that are caused by natural hazards only account for less than around 15% of all cable faults historically[3]; however, when they do occur, these can have a major impact. Natural hazards, such as underwater landslides, earthquakes and tropical storms, may affect very large areas of seafloor, damaging multiple cable systems synchronously, unlike accidental human activities which typically only damage a single cable[2]. As an example, in 2020, underwater sediment flows triggered by flooding of the Congo River occurred in a deep-sea canyon offshore West Africa. Multiple cables were damaged along the course of the powerful sediment-laden avalanche that travelled more than 1000 km on the seafloor, impacting internet connections during the early COVID-19 lockdown[4].

▼ Photograph of Hunga volcano erupting on 14th January 2022. Photo credit: Taaniela Kula, Tonga Geological Services.

Remote island nations, such as those in the South Pacific, are particularly reliant on submarine cables; however, they are often located in regions that are prone to natural hazards, such as earthquakes, tropical storms, underwater landslides, and volcanic activity[5]. Diversity in cable routes and landing station locations ensures that most regions are sufficiently resilient to the impacts of both human and natural hazard-related cable damage; however, islands that have fewer connections are more vulnerable. In the case of the Kingdom of Tonga, a single international cable connects this island nation to the rest of the global network.

VOLCANIC HAZARDS AND SUBMARINE CABLES

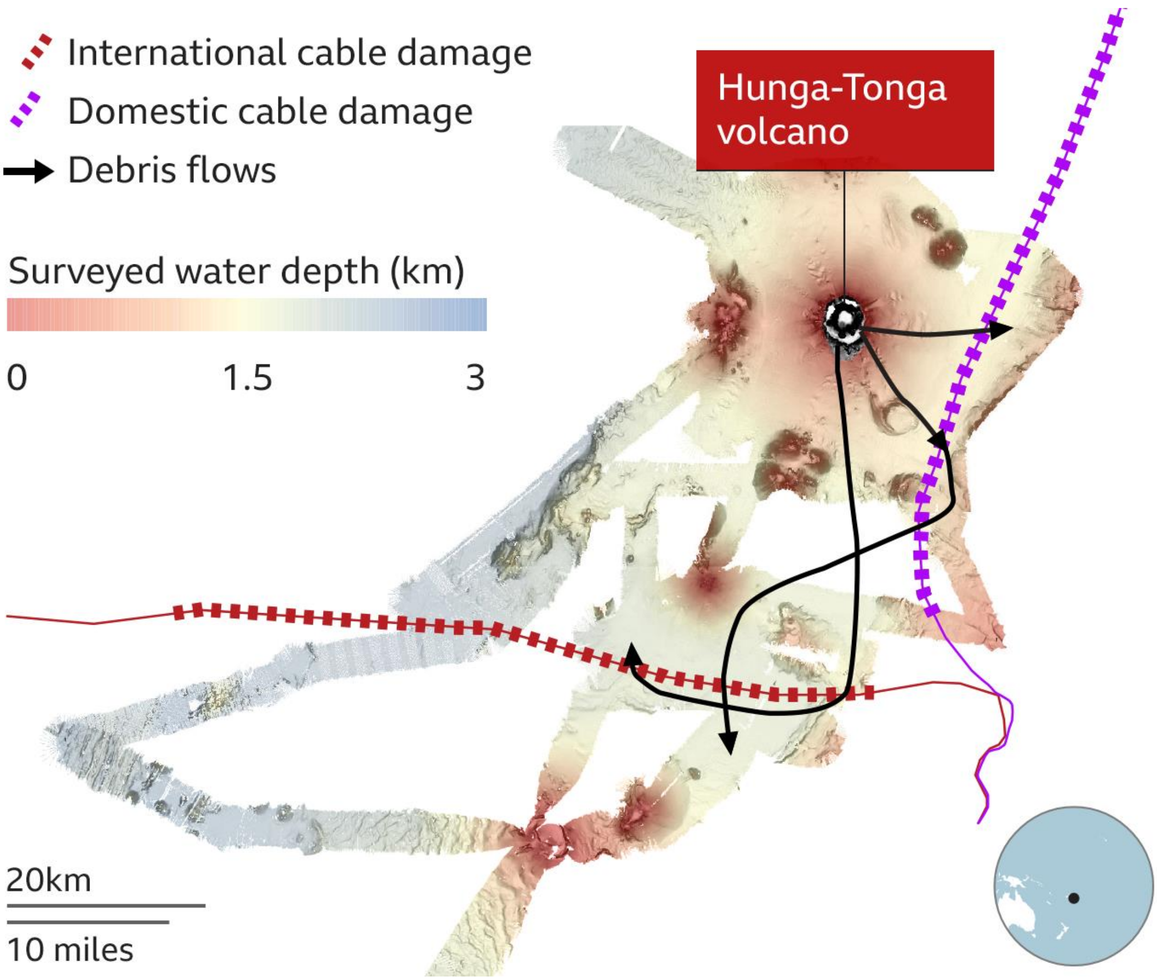
Cable faults related to volcanic hazards are particularly rare, largely because cable routing aims to avoid active volcanic areas. However, it is not always possible to avoid such settings, particularly where the islands to be connected lie on a volcanic chain or arc. A socioeconomic push to connect small island nations that lie in volcanically active regions such as the South Pacific and Caribbean means that there will likely be an increase in cable routes that cross volcanically active areas, or even connect volcanic islands, meaning that associated hazards cannot necessarily be fully avoided in the future. The Hunga volcano eruption is not the only cable damage attributed to volcanic hazards, and a handful of examples are known. Many of these were not directly linked to the eruption itself.

- In 1883, the massive eruption of Krakatau volcano severed a submarine telegraph cable that crossed the Sunda Straits in Indonesia[6] .
- In 1902, eruptions of Mount Pelee, Martinique and La Soufriere, Saint Vincent led to damage to five submarine telegraphic cables as a result of hot pyroclastic flows that entered the ocean and

suspected underwater landslides[7].

- Eruptions on the south-west flank of Montserrat in the Caribbean caused major disruptions to the regional telecommunications network in the Caribbean in 1997 following pyroclastic flows and dome collapse[8].
- A 2015 eruption of the submarine Kick 'em Jenny Volcano in the Caribbean led to damage of two subsea cables tens of kilometres away, caused by a landslide and debris flow that originated from a collapse of the crater rim and flank[9].

▼ **Figure 1**: The pathways of powerful seafloor flows triggered by the Hunga volcanic eruption that damaged seafloor cables offshore Tonga. Image credit: NOC/NIWA/NERC/BBC.



THE 2022 ERUPTION OF HUNGA VOLCANO AND THE DISCONNECTION OF TONGA

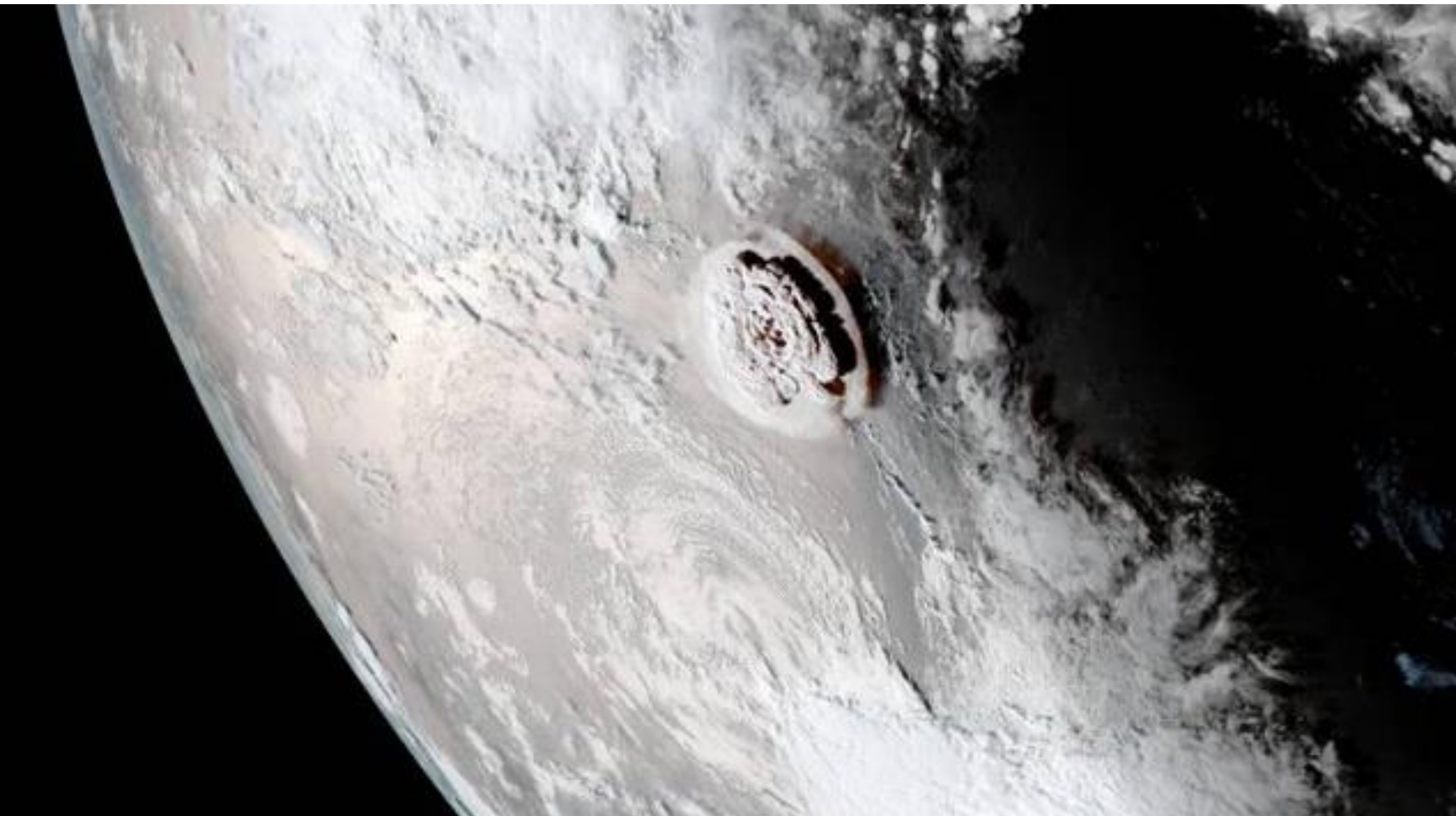
Unknown to many, Hunga volcano started erupting in late December 2021, when relatively small explosions occurred that produced steam plumes that reached heights of around 16 km [10,11]. While the volcano is almost entirely submarine, two small sections of the crater rim emerge above the ocean surface. During the early phases of the eruption the main vent was positioned almost directly between these islands, and the new erupted material built a land bridge connecting them[12]. On the 14th January 2022, a slightly more explosive eruption occurred and satellite imagery revealed that the bridge that had grown over a period of several weeks, had been removed. On the following day, several extremely large explosions occurred from a vent closer to the middle of the volcano, generating sonic booms that triggered an atmospheric pressure wave and tsunami that travelled around the world [3,14]. Tsunami waves were triggered with heights of up to 18m where they reached the nearby islands of Tonga and Fiji, destroying buildings and damaging property and infrastructure[13,14]. The material thrown upwards by the eruption formed an eruption plume reached more than 20 km in height, parts of which quickly began to collapse back into the ocean[10].

Around 15 minutes after the most intense explosion, Tonga's domestic cable stopped transmitting data. Just over an hour later, all data transmission to Tonga came to a halt, when the international cable that connected to Fiji, and onto the rest of the world, stopped working. Internet traffic flatlined. The delay of these cable faults after the eruption raised questions about what had caused the damage. Was it due to earthquakes after the main eruption, or perhaps due to localised collapses from the steep slopes adjacent to the cable routes? To answer these questions an international research team set out to perform new seafloor surveys around the volcano. Unusually for this region, high-resolution seafloor surveys had been performed around Hunga volcano in 2015 and 2016[15][12] so this allowed them to map the elevation change attributable to such a major eruption for the first time[1,12]. They discovered that powerful and far-travelling flows of volcanic debris sculpted the seafloor and these remarkable flows caused extensive damage and burial of the underwater cables.

▼ The January 15th 2022 explosion of Hunga volcano was seen from space. Image credit: GOES-West NOAA/RAMMB/CIRA

RAPID OFFSHORE SURVEYS REVEALED MAJOR SEAFLOOR CHANGE

An internationally collaborative effort between academic researchers and the subsea cable industry was initiated soon after the eruption, to try and mobilise a ship to map the seafloor impact. Thanks to funding from the UK's Natural Environment Research Council and The Nippon Foundation, the research vessel 'Tangaroa' was sent to Hunga volcano within just three months of the eruption, crewed by scientists from the National Institute of Water & Atmospheric Research in



Aotearoa New Zealand. The offshore team quickly discovered that there was a huge change in elevation on top of the volcano, with more than 900 m thickness of material removed.[12]. This accounts for at least 6 km^3 of material, which was erupted from the volcano; an equivalent volume to all the sediment transported by the world's river to the ocean every year[16]. While this change occurred within the central caldera of the volcano, other distinct features were created during the eruption on the volcano flanks. Deep scours were carved into the submerged flanks, in some cases more than 100 m deep. Elsewhere, the seafloor was blanketed in dark-coloured volcanic sediment, smothering the pre-existing seafloor life. Around 12 km from the volcano, the domestic cable was locally buried by more than 20 m thickness of volcanic material, explaining why it was not easily located during the initial repair operations. Seafloor coring recovered granular volcanic deposits with features that indicate their emplacement by fast-moving underwater avalanche-like flows. This combination of seafloor evidence allows the research team to build a picture of what happened under the ocean[1,12]

Fortuitously, as the timing of eruption and the timing and location of the damage to the two cables were known, it was possible to estimate a speed for the flows responsible for the damage. Based on the time between the collapse of the eruptive column (revealed by remarkable video footage taken at sea during the eruption) and the cable damage, an averaged velocity of 68-122 km/hour was calculated for these flows. This is the fastest velocity ever documented for any underwater current. The fastest velocities previously reported were up to 72 km/hour - based on sequential seafloor cable breaks following a large underwater landslide offshore Newfoundland in 1929, following the 1954 Orleansville earthquake offshore Algeria, and as a result of the 2006 Pingtung earthquake offshore[17] Taiwan[2].

WHY WERE THE SEAFLOOR FLOWS SO FAST AT HUNGA VOLCANO?

As the volcanic eruption column collapsed into the ocean from tens of kilometres height, it dumped huge volumes of dense volcanic material onto the steep submerged volcano flanks, creating fast-moving density currents. Density currents are a type of flow, similar to snow avalanches or pyroclastic flows on land. Seafloor coring revealed that these flows were widespread, travelling in all directions from the volcano, reaching distances of more than at least 100 km.[1] Remarkably, these flows were also capable of running upslope, due to their momentum. In some places, flows climbed upslope by more than 600 m. The direct and rapid vertical entry of a fast-collapsing volcanic plume at Hunga Volcano is different to other mechanisms for density flow generation that have been

▼ The R/V Tangaroa surveying the seafloor at Hunga volcano. The two peaks of the islands at the top of volcano extend just above sea level. Image credit: NIWA-NIPPON FOUNDATION.

reported elsewhere, such as river plumes that enter the ocean horizontally, and landslide-triggered sediment density flows that initiate on far lower angle slopes and where material in the initial flow must first disintegrate and mix. The findings from Hunga volcano reveal a totally new mechanism for the initiation of such seafloor flows, and therefore highlight a previously-unrecognised, albeit relatively rare, hazard.

WHAT CAN BE DONE TO ENHANCE CABLE RESILIENCE?

Resilience to extreme natural hazards can be increased through:

- **Increased diversity of routes and landing points.** Additional and more geographically-diverse cables routes and landing stations would provide greater resilience; however, identifying alternative appropriate routes is challenging in regions where there is sparse, detailed seafloor data and as geologically complex as the Tonga-Tofua Arc. Steep slopes lie to the east and north of the islands of Tonga where they transition to a deep-sea trench. This is the focal point for major earthquakes. The steep slopes can also be prone to slope failure and are incised by submarine canyons, and hence are sub-optimal locations for cable routing.
- **Increased backup stocks of cable for repairs.** One of the biggest challenges facing the repair operation offshore Tonga was the unprecedented extent of damage and burial, requiring significant lengths of new cable. Holding a more local stock of replacement cable could mitigate this in the future; however, the damage caused by the 2022 eruption was unprecedented and this would need to be assessed on a cost-benefit basis.
- **Broader availability and coverage of complementary communications (e.g., low-level satellites).** It was back up satellite communications that first restored any digital connection

with the rest of the world; however, this only covered a very small proportion of the previous connectivity. Greater investment in low-level satellites for remote island states will enhance resilience to future disruptions.

WHAT HAS BEEN LEARNED FROM THE HUNGA VOLCANO ERUPTION?

The 2022 eruption is estimated to be on the order of a 1 in 1000-year event for Hunga volcano. Therefore, a repeat event from this volcano is unlikely within the 20-30-year lifespan of the repaired cables. However, scientists still know very little about why this particularly eruption escalated so quickly and became so explosive, and what the risks are from the many other active volcanoes along the Tonga-Tofua Arc and elsewhere. Recent seafloor mapping around nearby volcanoes has revealed very similar-looking features to those on Hunga volcano, indicating that these other volcanoes have also experienced equally explosive eruptions. However, detailed seafloor surveys have not been performed for much of the South Pacific, meaning that most of the volcanoes in the region are un-surveyed. Greater coverage of seafloor mapping is therefore required to identify potentially hazardous volcanoes, which will be beneficial for future cable routing, as well as improving risk assessments for coastal communities. Repeated seafloor surveys may provide useful insights into how volcanoes are changing, and provide some indication of whether conditions are changing, and if a future eruption may become more likely.

While many volcanoes on land in populated areas are the subject of detailed monitoring, underwater volcanoes remain a blind spot. One reason the eruption of Hunga volcano came as such a surprise was the absence of any monitoring of underwater volcanoes. Seafloor monitoring is logistically challenging and expensive, and requires communication links to transmit data in real-time for early warning. Recent studies have shown how technological advances now enable the use of fibre-optics that lie at the core of modern telecommunications cables as a series of seismometers that can detect tsunamis, earthquakes and volcanic activity[18,19]. *(See Issue 4 of Submarine Cable Protection and the Environment for more details).* Such approaches may be highly beneficial, particularly in areas of the South Pacific where even land-based seismic monitoring arrays are sparse.

The aftermath of volcanic eruptions may pose additional challenges to cable operations for survey, installation, and repair.

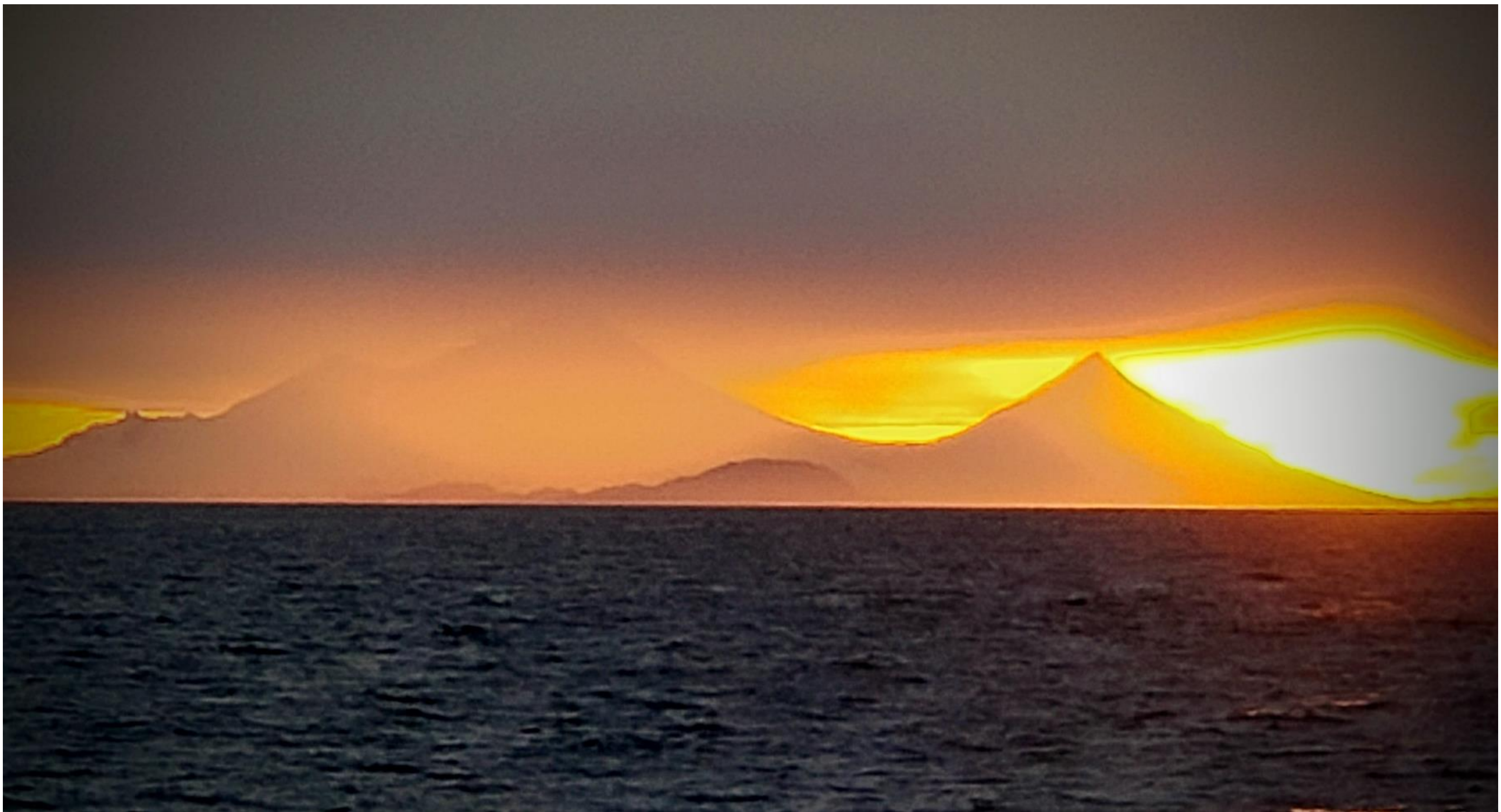
- It is hard to say with any certainty when a volcanic eruption has ended, particularly in remote regions where there is little or no geophysical monitoring, so establishing at what point it is safe to deploy repair vessels requires a judgement call.
- Volcanic eruptions can cause major changes, that may pose navigational hazards to vessels.
- Eruptions may both directly (as a result of ash fall, pyroclastic flows, lava flows or lahars) or indirectly (from the generation of tsunamis) damage nearby ports, coastal infrastructure, and ships, meaning repair vessels may need to travel longer distances to reach the site, or to mobilise for repair.
- Pumice rafts (islands of floating volcanic rock produced by some eruptions) can block vessel water intakes, abrade hulls and endanger operations. These rafts may cover thousands of square kilometres of the ocean, hampering efforts to reach repair sites or carry out repairs once there.
- Exclusion zones are often imposed around volcanoes during and after activity to protect vessels from potential hazards. This may also make reaching damaged sites

logistically challenging. Access can be further complicated where damage to cables has resulted in loss of communications.

- Active and dormant seamounts and other volcanic terrain create a rough seabed relief. Such rough terrain can result in abrasion and damage to cables where they are subject to vigorous seafloor currents.

FINISHING THOUGHTS

The 2022 eruption of Hunga Volcano took the world by surprise, with a wide range of impacts felt around the world. The rapid and collaborative response to this remarkable event has not only improved the industry's understanding of building more resilient submarine cable networks, but has provided important new insights into previously-unrecognised hazards for populations in volcanically-active regions of the world. This collaboration between academic research and the submarine cable industry will continue to make new discoveries about how our planet works, with the mutual benefit of ensuring global digital connections remain as resilient as possible.



Sharing the seabed in harmony with others

The International Cable Protection Committee (ICPC) was formed in 1958 and its primary goal is to promote the safeguarding of international submarine cables against human made and natural hazards. The organisation provides a forum for the exchange of technical, legal and environmental information about submarine cables and, with more than **200 MEMBERS** from over **70 NATIONS,** including cable operators, owners, manufacturers, industry service providers, and governments, it is the world's premier submarine cable organisation. The ICPC comprises of an 18 Member Executive Committee (EC)-led organisation voted in by its Full Members. In addition to the Marine Environmental Adviser (MEA), General Manager (GM) and Secretariat team, the ICPC also has an appointed International Cable Law Adviser (ICLA) as well as a United Nations Observer Representative (UNOR).

Prime Activities of the ICPC:

- Promote awareness of submarine cables as critical infrastructure to governments and other users of the seabed.
- Establish internationally agreed recommendations for cable installation, protection, and maintenance.
- Monitor the evolution of international treaties and national legislation and help to ensure that submarine cable interests are fully protected.
- Liaison with UN Bodies.

Recommendations:

- Taking into account the marine environment, the ICPC authors Recommendations which provides guidance to all seabed users ensuring best practices are in place.
- Educating the undersea community as well as defining the minimum recommendations for cable route planning, installation, operation, maintenance and protection as well as survey operations.
- Facilitating access to new cable technologies.

Advancing Regulatory Guidance:

- Promoting United Nations Convention for the Law of the Sea (UNCLOS) compliance.
- Championing uniform and practical local legislation and permitting
- Protecting cable systems and ships.
- Aiding education of government regulators and diplomats.

Working with Science:

- Supporting independent research into cables.
- Publishing reviews for governments and policy makers.
- Working with environmental organisations.
- Effective public education via various media.

To learn how to become of Member organisation of the ICPC, please click on join here.

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Mike is the Marine Environmental Adviser for the International Cable Protection Committee (ICPC) and is a Principal Researcher at the National Oceanography Centre, UK, where he works as part of the Ocean BioGeoscience Research Group. His research focuses on better understanding the dynamic seafloor, the implications of past and future climate change, impacts of human activities, and quantifying risks to critical infrastructure. Prior to his research role at NOC, he worked for ten years as a geohazard consultant to a range of offshore industries.

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