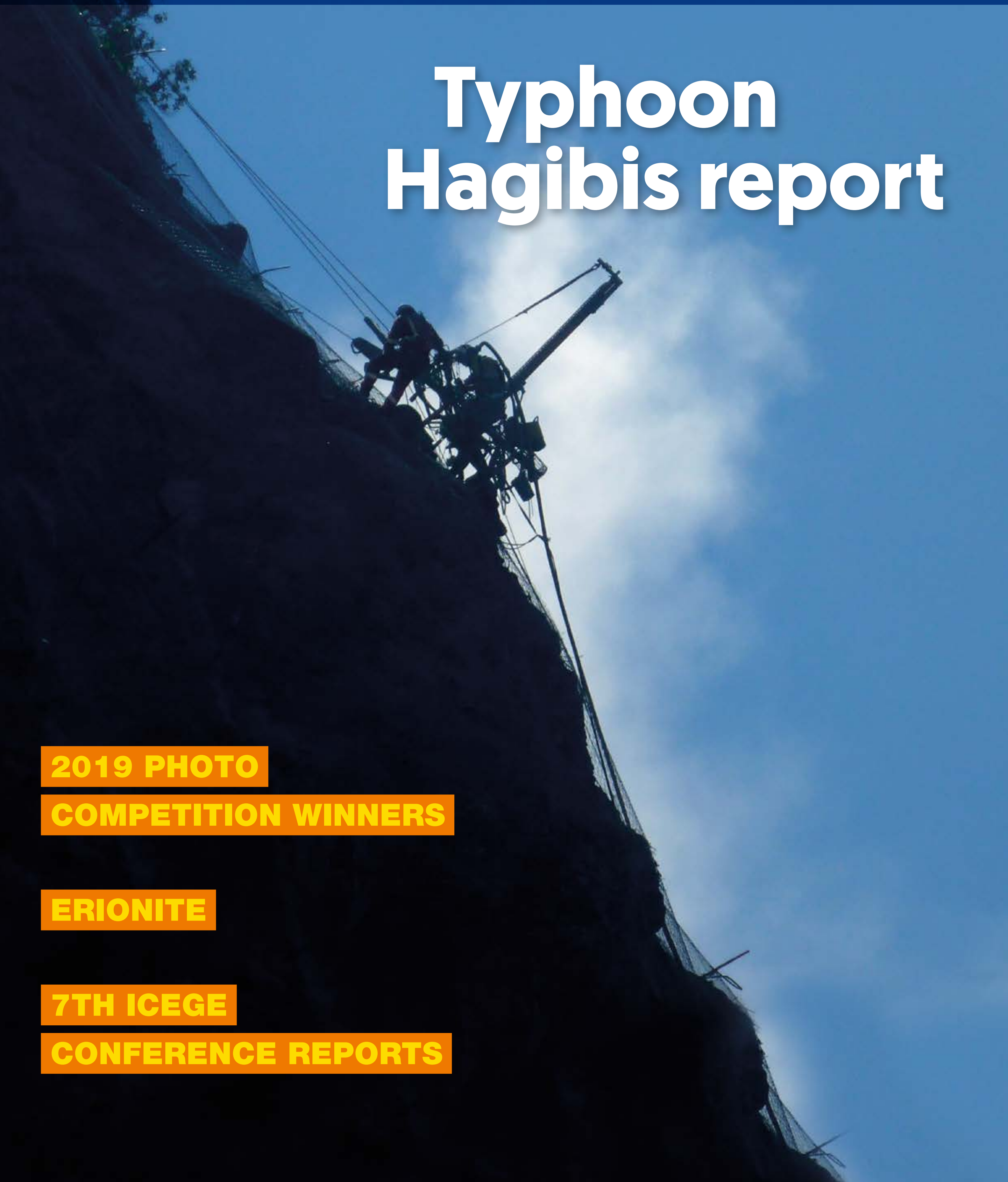
NEW ZEALAND GEOTECHNICAL SOCIETY INC

DECEMBER 2019 issue 98

NZ GEOMECHANICS NEWS

Bulletin of the New Zealand Geotechnical Society Inc.

ISSN 0111-6851



Typhoon Hagibis report

2019 PHOTO COMPETITION WINNERS

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		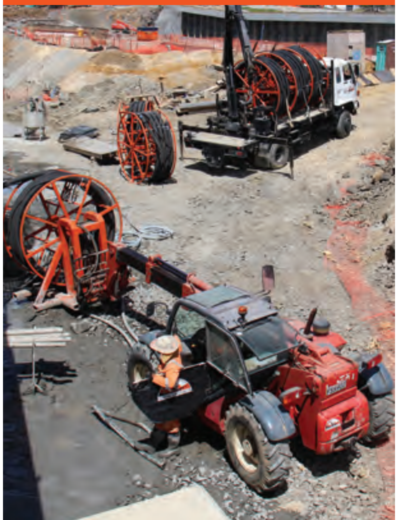	

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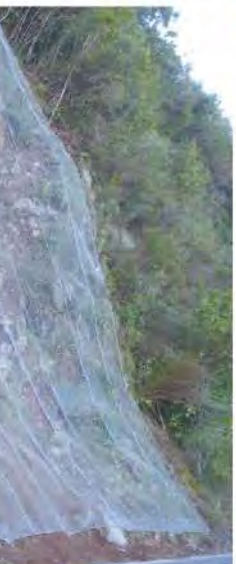

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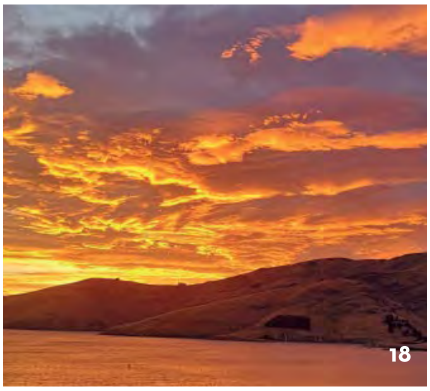
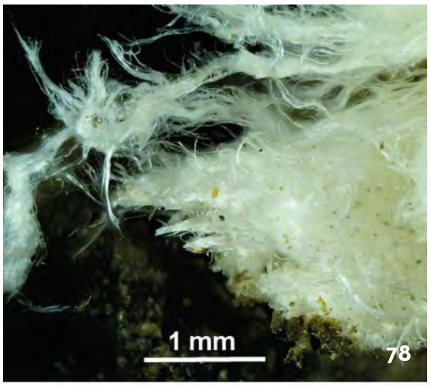
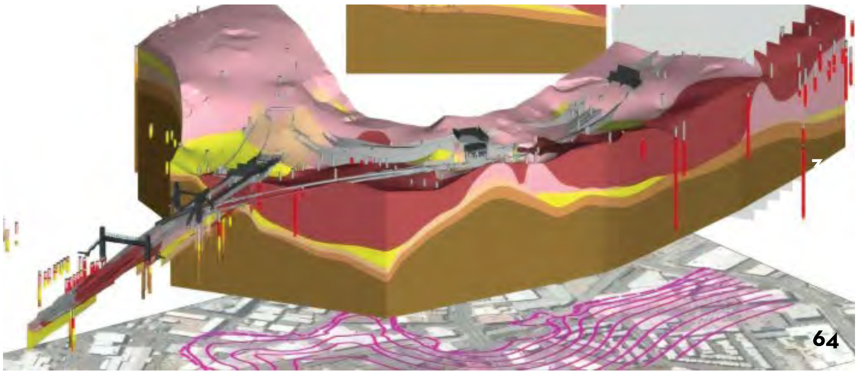






COVER IMAGE: Photo Competition Winner; **Scott Barnard** *AECOM*, Drilling at site SR20, Kaikoura (drillers are from Rock Control)

Ross is Auckland Council's geotechnical and geological practice lead, which involves managing all aspects of geotechnical and geological risk. This ranges from emergency management and geohazard studies to geotechnical design, standards and policy.

Ross Roberts
Chair, Management Committee

IF THE LAST six months have felt busy to you, you're not the only one. Despite notable failures, overall the construction sector continues to grow strongly, and forecasts suggest this will continue for some time yet. The National Construction Pipeline Report (MBIE, 2019), anticipates continued growth in residential and infrastructure sectors until at least 2024, with a peak in the non-residential building sector in 2021.

To highlight the pace of growth in recent years, Figure 2 shows the growth in residential consents processed in Auckland.

Figure 1: All building and construction in New Zealand forecast to 2024 (MBIE, 2019)

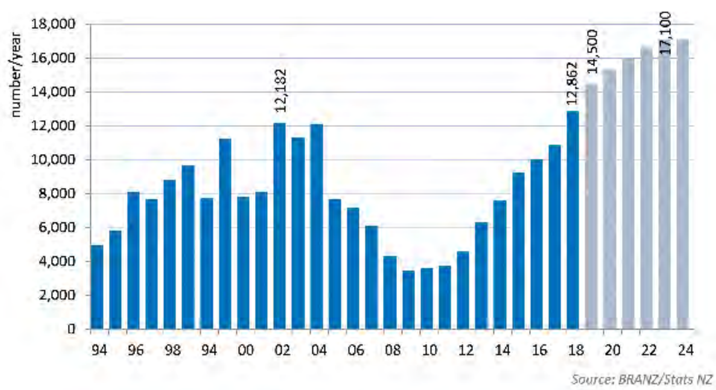


Figure 2: Dwelling units consented in Auckland forecast to 2024 (MBIE, 2019)

It's no surprise that the last six months have kept the geotechnical sector in New Zealand busy, and NZGS activities have been just as hectic. The growth in the sector has driven demand for training, and (especially in light of the lessons learned from recent earthquakes) a real need for new guidance and improved standards. These link with the aims of the NZGS, which are:

- To advance the education and application of soil mechanics, rock mechanics and engineering geology among engineers and scientists.
- To advance the practice and application of these disciplines in engineering.
- To implement the statutes of the respective international societies in so far as they are applicable in New Zealand.
- To ensure that the learning achieved through the above objectives is passed on to the public as is appropriate.

The new NZGS committee was elected in September and has made a strong start on projects aligned with these aims. We've run a successful series of short courses, prepared for our next symposium, continued to develop guidance and standards, and advocated on your behalf to government agencies. I'll summarise some of the highlights, and introduce you to your new committee members.

INTRODUCTIONS

Newly elected committee members Sally Dellow and Jen Smith will be taking the lead on our programme of short courses and have already prepared a fantastic programme for 2020. In the last six months we've run one-day courses on GIS for Geotechnical Professionals, Geotechnical

Sally Dellow

Jen Smith

Olivia Gill

Áine McCarthy

Engineering in Residual Soils, Design and Construction Techniques in Soft Ground, and Cone Penetration Testing.

Proposed courses for next year include rock slope stability, soil slope stability, geotechnical earthquake engineering, earthquake design of foundations, and landslide hazard and risk assessment. These will be presented by national and international experts to provide very high-quality CPD. For more information contact courses@nzgs.org.

Olivia Gill is also new to the committee, having been co-opted to manage our website. As our communications become increasingly internet focussed her role is particularly important, and we welcome any suggestions about how we can improve the site for your benefit. Please send any questions to website@nzgs.org.

Áine McCarthy has taken over as Young Geotechnical Professional co-ordinator and has already made a huge impact on the 2020 YGP Symposium which will be in Cairns next year. Áine and the YGP teams around the country have managed a very successful regional series of mini-symposia which have been very well received by our young members. You can contact Áine using ygp@nzgs.org.

FAREWELLS

Sadly, we have to say farewell to some of our most influential and hard-working committee members. Kevin Anderson and Stuart Read have reached the end of their terms, and Gavin Alexander has handed over his role as ISSMGE Australasian Vice President to Phil Robins while he recovers from illness. I cannot overstate how hard these three individuals have worked during their time on the committee, providing many hundreds – or thousands – of hours of their own time. Without their huge efforts the NZGS, and our industry, would be significantly poorer.

We are hopeful that all three will be able continue with their involvement in a less formal capacity. Kevin is working hard on a guideline for anchors, Stuart is taking the lead on an update to the Field Guide for Soil and Rock Description, and we hope that Gavin will be resuming his involvement in the finalisation of the Earthquake Geotechnical Engineering Modules before too long.

NZGS SYMPOSIUM

Eleni Gkeli, our new treasurer and vice-chair, is continuing her role as convenor of our NZGS Symposium which will take place on 15-17 October next year in Dunedin. We've had an incredible response to the call for abstracts, so this four-yearly event promises to be spectacular. Start to prepare your business case to attend because there is a real risk that this could sell out.

INTERNATIONAL SPEAKERS

Sally Hargraves continues her role looking after the branches and co-ordinating international speakers. She has been hugely successful at getting speakers from around the world to visit New Zealand to share their knowledge and has already secured Jackie Skipper (Glossop Lecturer) for 2020. Sally has had great success at getting international speakers to visit our regional centres, and will continue to drive for this as well as supporting recording and live streaming to make these talks as accessible as possible to all our members.

FUTURE OF THE NEW ZEALAND GEOTECHNICAL DATABASE

The New Zealand Geotechnical Database (NZGD) is a fantastic success story. With over 113,000 freely available data points, New Zealand is leading the world in sharing geotechnical data in a way that benefits us all. I'm very pleased to report that the NZGD will be fully funded by the Earthquake Commission (EQC) until 2022, so its short-term future is secure. We are greatly indebted to Jo Horrocks of EQC for funding this project, to the Building Systems Performance team at the Ministry of Business, Innovation and Employment (MBIE) for supporting this for so long, and particularly to John Scott for his huge efforts setting up this database and driving it forward. I have no doubt that without his influence the NZGD would never have got off the ground.

MBIE have generously agreed to fund a working group including representatives from NZGS, MBIE, EQC and Engineering NZ to identify the most appropriate long-term funding source and operating model for the database, and plans are already in place for a project to make sure this is properly managed.

OCCUPATIONAL REGULATION

The NZGS committee have been working closely with Engineering NZ to give advice to MBIE on occupational regulation, and particularly the changes proposed following the Royal Commission.

MBIE have been working on the building law reforms since submissions closed in June this year, and have divided their work into two bills. The first bill covers topics such as prefabrication and off-site manufacture, building product information and responsibilities, strengthening Codemark etc. This first bill has already been through cabinet, and could be passed into law before mid-2020.

The second bill will address changes to occupational regulation, including licencing engineers which will have significant consequences for the status of CPEng. Work on this has recently re-started, having been on hold while details of the first bill were worked out. This is of particular interest to us, and we will continue to advocate for the geotechnical profession. MBIE intend to make significant progress on this before the next national election.

OTHER NZGS ACTIVITIES

In addition to all the above, the committee has plenty of other projects to keep us busy. Rolando Orense will continue in his role co-ordinating our awards and providing valuable links to the academic sector. Please contact him if you have any suggestions for NZGS members who should be entered for international awards.

I have continued to work with MBIE representing the geotechnical profession on their Building Code Technical Advisory Group (BCTRAG). This group meets quarterly to raise technical issues and recommend improvements for MBIE to consider. We've discussed liquefaction in the context of the definition of good ground, which has already led to a change limiting the application of the B1 Acceptable Solution B1/AS1 so that it may not be used on ground prone to liquefaction or lateral spreading, but also are considering much wider issues such as how to adapt the building code to respond to climate change, building repairability after ULS events, and risks in other sectors such as structural and fire engineering. If you have any issues that you'd like raised with MBIE please contact me using chair@nzgs.org.

We are also supporting MBIE in their development of a programme of work to improve geotechnical practice through amendments to standards and the building code. One of their first areas of interest is NZS 4431, but there is a significant effort planned for further work on other standards as well. We are delighted that MBIE have employed two geotechnical engineers (Tony Kao and Kiran Saligame) which bodes well for the future.

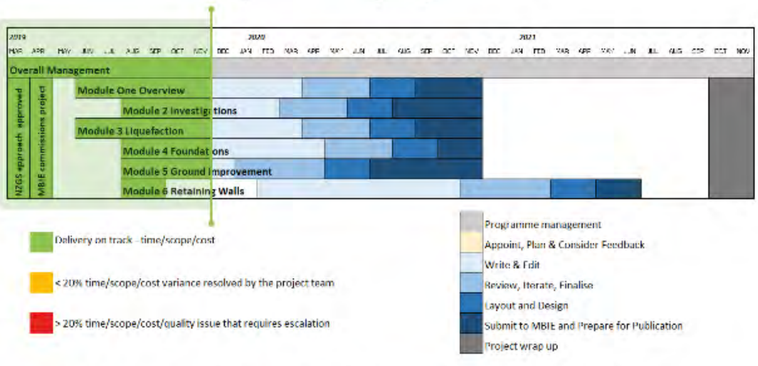
We are working closely with Engineering NZ and MBIE to finalise the Earthquake Geotechnical Engineering modules. These were originally published in "preliminary draft" form. They've now been tested and some really good feedback has been received, so it is time to finalise the documents. This two-year programme is now six months in and is currently on track for time and budget. (See figure below).

Tony Fairclough is leading the NZGS involvement in the joint NZGS/SESOC project "ASG Piling Specification Review and Update Project". The first meeting of this group on was Thursday 21st November in Auckland, and progress reports will be circulated at a later date.

New projects in our work programme for this year are:

- An update to the Field Guide to Soil and Rock Description.
- Creation of a practice guide for slope stability.
- Updates to the New Zealand Ground Investigation Specification to incorporate feedback.
- Creation of a guideline for ground anchor design.

These projects are still in the scoping phase, so the programme

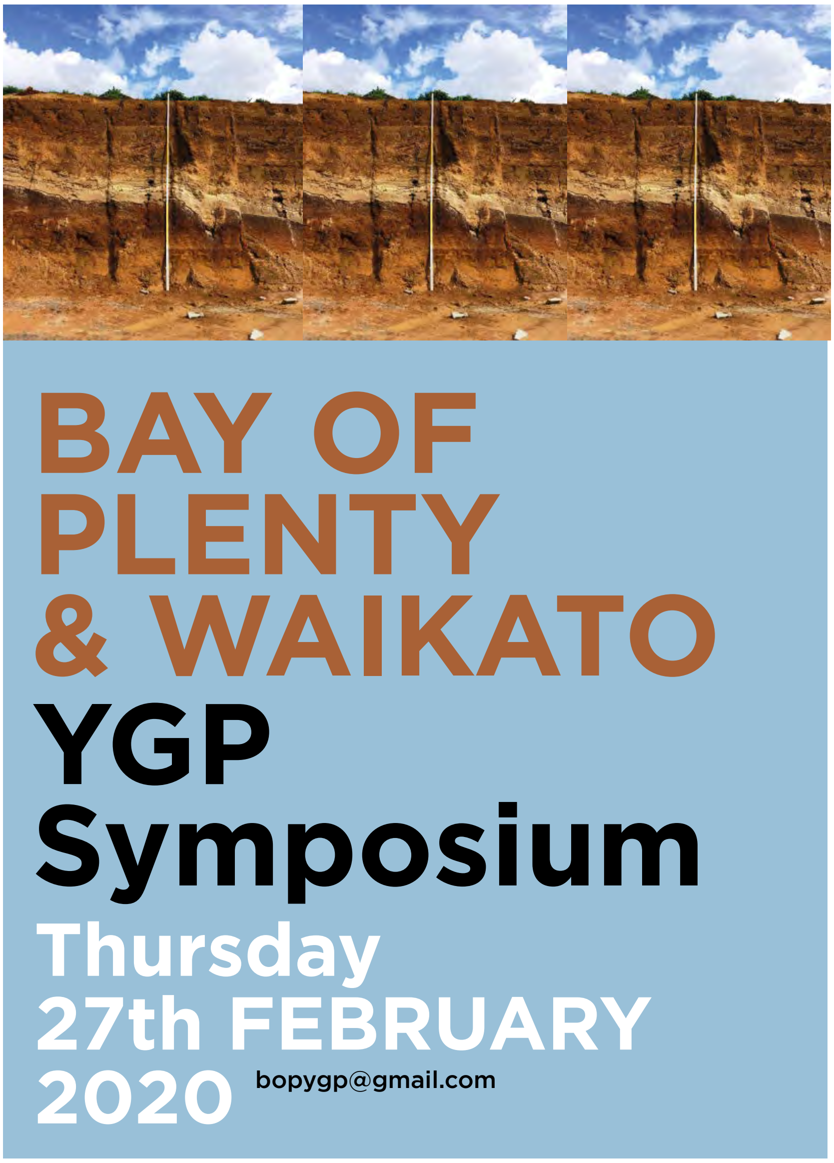


Note: Indicative timeline updated after feedback, author availability and dependencies were considered in August 2019 and details are yet to be confirmed. We've had a fantastic response to our call for volunteers to assist with developing these, and expect to see them start in the new year.

CONCLUSION

These are busy times for our profession and for our society. We have a huge work programme, and some compromises will have to be made if we're to make real progress on the most important issues. Our current priorities are the 2020 Symposium as well as our training courses, branch events, the Earthquake Geotechnical Engineering Modules, and our liaison role with MBIE. We are truly grateful for your ongoing support and would welcome any offers from members who would like to become more involved to help us drive the other projects forward.

Ross Roberts
NZGS Chair



Through the Boots

GEOTECHNICAL ENGINEERING IS the first and most important aspect of any infrastructure or urban development project. The engineering geologist usually hits the ground first and is charged with developing a geotechnical ground model that makes sense to the engineer who will be designing the structure (road, dam, tunnel or building). Over the course of my career many new trends have developed and many have become standard practice in analysis, design and construction, and/or in associated site investigations. Not all of them have been good for our profession. In particular, I live in fear of software that purports to build a believable geological model, and I'm even more fearful of those who believe in and unquestioningly use such models.

GIS and UAV's are marvellous things, LiDAR and InSAR offer opportunities we didn't have not very long ago, and mobile phones that know lots of tricks are great toys. But, as Don U Deere (the RQD man) once said in a Review Meeting: "Geology is done through the boots". I have never forgotten that pearl of wisdom – it was the truest truism of my career! And I want every young engineering geologist and geotechnical engineer to remember it – and more importantly, believe it!

The ground will always surprise us. Most of us can tell stories of finding ground conditions within metres of a drillhole or test pit that were completely different from those predicted from the data. I have personal experience of a well-drilled slope that turned out not to be a landslide despite apparently convincing drillhole data (although to be fair, less convincing geomorphology). And that 'landslide' model was not generated by a computer, it was hand-drawn from careful, detailed consideration of a lot of point data. Maybe the computer could have done better (probably not back in 1990), I know it would have thought a lot faster, but given the complexity of that particular site that was exposed by the excavations I choose to remain sceptical. "Geology is done through the boots" does not refer only to field inspection of ALL sites for which you have responsibility, it also includes thinking about every piece of data, how it fits (or does not) the conceptual model, what the implications are for the model and for the way in which the ground might behave.

Once you have a story, get it reviewed by someone else! I can tell horror stories about sites where the interpretations were not reviewed or challenged – ultimately these just make lawyers happy. You do not want to go there.

And talking of surprises – read the article on erionite! Like me, you may have never heard of it, but for some of us it might be VERY important to know more.

Don Macfarlane

Don Macfarlane has worked as an applied engineering geologist for nearly 40 years and has accumulated some knowledge, a fair bit of wisdom and a few brickbats along the way.
His real interest is dams and associated issues (seismic hazard, slope instability) but any good geohazard affecting an engineering structure will do. These days he is a Technical Director with AECOM in Christchurch.
NZ Geomechanics News co-editor

Gabriele is a Senior Lecturer in Geotechnical Engineering at the University of Canterbury. Gabriele's research interests include earthquake geotechnical engineering and related problems; constitutive modelling for geomaterials; development of advanced laboratory and field testing devices; geo-hazard reconnaissance and mitigation; reuse and recycling of industrial granular wastes as sustainable geomaterials.
NZ Geomechanics News co-editor

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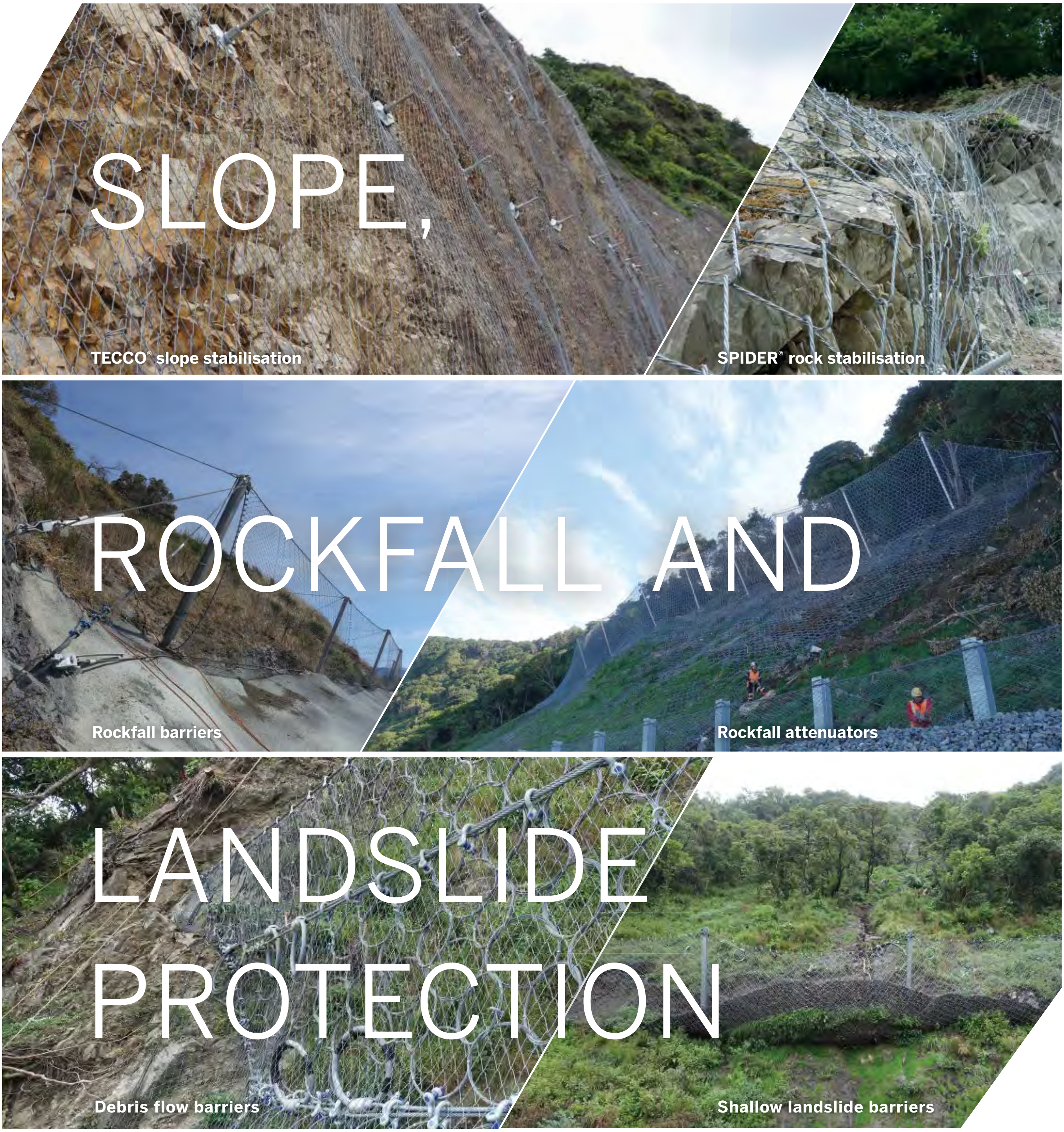

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News – In Brief

BIGGEST EVER METEORITE COLLISION IN THE UK

EVIDENCE FOR AN ANCIENT (1.2 billion years old) meteorite strike was first discovered in 2008 near Ullapool, NW Scotland by scientists from Oxford and Aberdeen Universities. The thickness and extent of the debris deposit they found suggested the impact crater made by a meteorite estimated at 1km wide was close to the coast, but its precise location remained a mystery.

In a paper published in Journal of the Geological Society in June 2019, a team led by Dr. Ken Amor from the Department of Earth Sciences at Oxford University, show that the crater is located 15-20km west of a remote part of the Scottish coastline, buried beneath both water and younger rocks in the Minch Basin.

Using a combination of field observations, the distribution of broken rock fragments of impact debris known as basement clasts and the alignment of magnetic particles, the team was able to gauge the direction the meteorite impact material took at several locations, and from this they plotted the likely location of the crater.

It is thought that Earth's collisions with an object about 1 km across (as in this instance) occur between once every 100,000 years and once every one million years but estimates vary. One of the reasons for this is that our terrestrial record of large impacts is poorly known because craters are obliterated by erosion, burial and plate tectonics.

Summarised from: Physics.org https://phys.org/news/2019-06-site-biggest-meteorite-collision-uk.html (10 June 2019)

FOOTNOTE: The Minch is a strait in north-west Scotland that separates the north-west Highlands and the northern Inner Hebrides from the Outer Hebrides.

We're delighted to announce that Misko Cubrinovski has been appointed as chair of ISSMGE Technical Committee 203 (Earthquake Geotechnical Engineering). This is a great honour for both Misko and New Zealand.

TELL US ABOUT YOUR PROJECT, NEWS, OPINIONS, OR SUBMIT A TECHNICAL ARTICLE. WE WELCOME ALL SUBMISSIONS, INCLUDING:

• technical papers • technical notes of any length • feedback on papers and articles • news or technical descriptions of geotechnical projects • letters to the NZGS or the Editor • reports of events and personalities • industry news • opinion pieces

Please contact the editors (editor@nzgs.org) if you need any advice about the format or suitability of your material.

NZGS SYMPOSIUM 2020

Good grounds for the future

15–17 October 2020 • Dunedin • New Zealand

The 21st Symposium of the New Zealand Geotechnical Society will take place between 15 and 17 October 2020 with an optional workshop & field study preceding it.

In this Symposium we will explore the challenges and opportunities of our future, by learning from the failures and achievements of our past. The theme ***Good grounds for the future*** is inspired by the profound changes currently being experienced in New Zealand and internationally.

Ross W. Boulanger
Professor and Director, Center for Geotechnical Modeling, University of California at Davis, USA

George Gazetas
Professor of the National Technical University of Athens, Greece

Chris Haberfield
Principal, Golder Associates, Melbourne, Australia

Sissy Nikolaou
AVP, Principal of Multi-Hazards & Geotechnical Engineering, WSP Fellow of Earthquake Engineering, USA

Workshop & Field Study

Make your way to Dunedin a memorable experience!

QUEENSTOWN WORKSHOP: 14TH OCTOBER 2020

FIELD STUDY: 15TH OCTOBER 2020

Join us in Queenstown before the Symposium, for a workshop followed by a field study that will take you through the Cromwell Gorge landslides (by bus) and the spectacular Taieri River Gorge (by train).

Disembark the train at the station in time for the welcome reception at the adjacent Toitū Otago Settlers Museum!

We are happy to announce confirmed workshop speakers Robert Sharon and Steve Parry. Robert is an open pit and underground mining specialist and an expert in slope monitoring techniques. Steve's expertise is in natural slope and landslide hazards.

Abstract submissions

Abstract submissions have closed. The organising committee is pleased to advise it has received an exceptional number of submissions. We are looking forward to a robust programme with themes to include (but not be limited to):

- Major infrastructure projects
- The NCTIR project
- Soil/structure interaction
- Revisions to Standards & Practices
- Slope stability and landslides
- Resilience
- Geotechnics and climate change
- Sustainability
- International practice

New Zealand Geotechnical Society

"Geotechnical engineering and engineering geology are now widely perceived in New Zealand as an integral part of our modern communities." — **Eleni Gkeli, 2020 Convenor**

For more information head to nzgs2020.co.nz

Questions? nzgs2020@confer.co.nz

LIQUEFACTION-PRONE GROUND NEEDS TO BE MAPPED UPDATE FROM MBIE

INTRODUCTION

We've changed B1/AS1 to require robust foundations for liquefaction-prone ground. This change is already in place in the Canterbury region, and will now be extended to all of New Zealand. This will provide clarity to both councils and engineers, ensuring new buildings are being built safely and strongly enough to withstand liquefaction risks.

WHY WE NEEDED THE CHANGE

The focus on liquefaction and lateral spreading is a result of the experience of the Canterbury earthquakes and responds to recommendations made by the Royal Commission of Inquiry. Currently, this limitation on the application exists for the Canterbury region only. Specifically, this change is to update the definition of 'good ground' within the definitions of the B1 Acceptable Solutions and Verification Methods document, and specific references to the term 'good ground' within B1/AS1.

WHAT THIS MEANS

Foundation solutions on land prone to liquefaction and/or lateral spreading would need to be consented as a Verification Method or an Alternative Solution. TAs/BCAs will have the flexibility to develop, implement and enforce policies on how they address land instability risks in their regions. Affected stakeholders include: developers, home owners, geotechnical contractors, engineering consultants (geotechnical, civil, structural), TAs and BCAs, suppliers and manufacturers, and MBIE.

These stakeholders will all be invariably affected by the change, some positively, and some negatively but by large we have received positive feedback saying this change is very much necessary and are supportive. The sector believes that the proposed changes will increase the cost of building upon liquefaction-susceptible land but will be offset by a gradual increase in the level of seismic resilience and corresponding reduction in post-earthquake disruption to New Zealand's residential housing stock.

This change will affect a number of different stakeholders (as mentioned above) but doesn't come into effect immediately as there is a transition period of 24 months (November 2021).

Feedback from the consultation indicated the purpose/intent of the transition period didn't allow sufficient time to TAs/BCAs and for the sector to be in line with the proposed change. Accordingly, an awareness campaign will commence targeting the general sector and advising key stakeholders of Building Code update changes. Education will be targeted towards regional councils, territorial authorities, building consent authorities and engineers helping to make the transition as smooth as possible.

Key outcomes of this change include:

1.) Better understanding of communities' seismic risk.
2.) Achieve greater resilience by appropriate initial geotechnical investigations.
3.) Increase sector efficiency through communication, collaboration and education.

NOTE: MBIE/MfE liquefaction planning guidance serves as the basis for completing future maps. MBIE along with different stakeholders (MfE, EQC) consider it is in everybody's interest to have a consistency of mapping approach across New Zealand. The existence of the relatively comprehensive New Zealand Geotechnical Database (NZGD) also provides the opportunity to better define and update the level of hazard and hazard boundaries nationally.

THE BIANNUAL BUILDING CODE UPDATE PROGRAMME

Twice a year, MBIE consults with industry to ensure continuous improvement to NZ's Building Code clauses. The next consultation for biannual Building Code updates will open in February 2020. Find out more about the Building Code update programme: https://www.building.govt.nz/building-code-compliance/biannual-building-code-updates/

SESOC / NZGS PILING SPECIFICATION PANEL – CORRECTION

The Panel of Experts for the review and update of the Auckland Structural Group "Piling Specification" document has been confirmed as below. Paul Berriman was inadvertently omitted from the list published in Geomechanics News (page 6) in June 2019. NZGS apologises for the error.

Panel Chair:

- Anthony Fairclough: NZGS, Christchurch

Geotechnical Engineering Panel Members:

- Andrew Langbein: Tonkin & Taylor Ltd, Auckland
- Nicola Ridgley: Beca, Auckland
- Martin Larisch: Golder, Waikanae
- Andy Dodds: Arup, Auckland

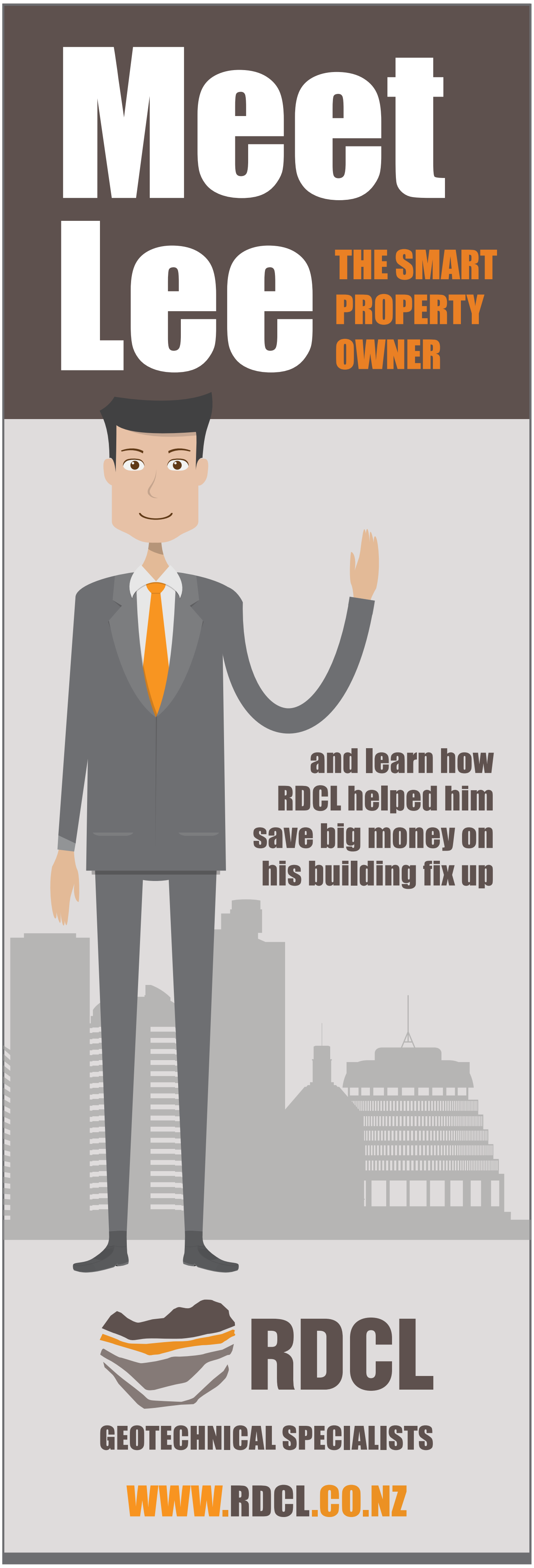
Construction and Supplier Panel Members:

- Nick Warmby: March Construction, Christchurch
- Paul Berriman: Brian Perry Civil, Auckland
- Malcolm McWhannell: Brian Perry Civil, Auckland
- James Harrison: Fulton Hogan, Christchurch
- Lian Ching Oh: Firth Industries, Auckland

Structural Engineering Panel Members:

- Michael Robinson: Beca, Auckland
- Rob Presland: Holmes Consulting, Wellington
- Ryan Clarke: Dunning Thornton, Wellington
- Tessa Beetham: Aurecon, Wellington

As previously communicated, the Panel is to review, update as appropriate and reissue the Auckland Structural Group "Piling Specification" as a national document jointly published by SESOC and NZGS.



The following Brief is modified from an article published in GeoDrilling International, August 2019

ENSURING SPT HAMMERS PROVIDE ACCURATE DATA

Every structure built relies on proper support and a strong foundation. A properly supported foundation is essential to longevity for any structure. A common means of analysing soil strength and conditions is by using standard penetration testing (SPT). This soil exploration tool uses an SPT hammer to drive a drill string with a split-barrel sampler attached at the bottom of the string. The split-barrel sampler recovers soil samples and the bottom of the borehole after it has been advanced to the required sampling depth. Using this test provides clarity to the engineers and is essential to understanding foundation conditions.

SPT hammer efficiencies vary, which influences the resulting N-values. For this reason, many authorities, including the Federal Highway Administration in the US, require SPT hammer calibration. In addition, period calibration is required by many US Departments of Transportation.

ASTM D1586 recommends that a measured N-value be normalised to 60 per cent drill rod energy, N_{60} by multiplying it by the ratio between the measured energy transferred to the rod and 60 per cent of the theoretical potential energy. This compensates for the variability in efficiency, and therefore, improves the reliability of soil strength estimates used in geotechnical designs.

But how can we be sure of correct test results? The following advice comes from GRL Engineers, an SPT calibration specialist.

To perform the SPT calibration, attach an SPT rod, instrumented with strain gauges and accelerometers, to the SPT drill string rod. As the drill string is driven into the ground, the strain gauges and accelerometers obtain force and velocity signals with each hammer blow. The signals are transmitted to a pile-driving analyser that displays the force, velocity and energy transmitted to the drill string, calculates and displays the maximum transferred energy value, and stores the complete time record of force and velocity for all SPT hammer blows. GRL typically acquire several SPT energy measurements per hammer at a given test location, in accordance with ASTM.

With this testing, engineers can provide a quantitative calibration report presenting transferred energies, energy transferred ratios and the SPT N_{60} value for each sample interval tested.

Updating NZGS (2005)

Kevin Hind published a detailed article in the December edition of NZ Geomechanics News (p106 -110) including a call for an update of NZGS (2005). His main thrusts related to properties of fine-grained soils, in particular plasticity, and their classification highlighting inconsistencies between NZGS (2005) and overseas practice documents such as ASTM D2487-17, D2488-17. I support his call for such a review and this note makes a couple of comments on a similar theme, noting that reference made to standards or guideline is by title only.

The primary title of NZGS (2005) is “Field Description of Soil and Rock” followed by “Guideline for the field classification and description of soil and rock for engineering purposes”. If one is to follow the practice outline in Australian standard AS 1726:2017 that ‘soil classification can occur after soil composition has been described’, then it can be argued that the definitions and use of classification (identity) and description (in situ properties) terms in NZGS (2005) should be examined. ASTM D2488 outlines practice for description and identification of soils (visual manual including soil name) while ASTM D2487 outlines practice for classification of soils for engineering practice (unified soil classification system – USCS with Group Symbols) based on laboratory determination of particle size distribution, liquid limit and plasticity index. European practice is similar with separate documents for identification and description of soils (BS EN 14688-1:2018) and classification of material characteristics (BS EN 14688-2:2017). In the cases of BS5930:2015 and AS1726 they are combined into single documents with differing approaches as to the inclusion (or not) of classification Group Symbols for coarse-grained soils and different subdivisions of the (Casagrande) plasticity chart by Group Symbol for fine-grained soils. NZGS (2005) as a single document with its classification and description terminology does not include Group Symbols.

In most cases fine-grained soils are described in the field through an evaluation of several properties, in particular dry strength, dilatancy and toughness, with plasticity added based on observations made during the toughness test. ASTM D2488, BS EN 14688-1 and AS1327 have tabulations of these behavioural observations in defining a soil as silt or clay by a soil symbol, primary soil fraction or soil description respectively. BS EN 14688-1 defines plasticity as the propensity to undergo permanent deformation when kneaded by hand and plastic behaviour as a similar propensity for fine soil. BS5930 notes that the term for plasticity derived from the tactile (toughness related) plastic limit test with high or low values is different from that in the classification based on the (Casagrande) plasticity chart with use of the A-Line and Liquid Limit. It should also be noted that the USBR Earth Manual states that the Liquid Limit is used to distinguish between clays of high compressibility (H) from those of low compressibility (L), not plasticity as became apparent in earlier versions of BS5390.

Kevin pointed out valid inconsistencies between practice areas and the call to update NZGS (2005) is appropriate. This has been acknowledged by the NZGS committee, with inclusion of the description of rock, for which some aspects, such as the description of weathering, need a similar level of consideration as plasticity. Challenges for the update include consistency in use of terms (e.g. classification) and definition of properties (e.g. plasticity) while providing appropriate guidance without becoming a long and tedious document or erring on the side of brevity and leaving out necessary items.

Stuart Read

Protective shield

Maccaferri has developed a new product coating invention for its steel wire mesh products .

The environmental conditions on our planet are becoming more aggressive and are predicted to worsen in the future. The 20 warmest years on record have all occurred within the last 22 years, levels of CO_2, CH_4 and N_2O all continued to increase in 2018 and there was a continuation of the trend of lower pH levels in our seas.

Extreme weather events are occurring with greater intensity and frequency according to the European Academies Advisory Council. In order to prepare for these adverse conditions, we must construct current and all future projects with more resilience so that there is a clear reduction in maintenance. There is a growing argument that the initial design assumptions made by engineers should be made more onerous.

The construction market is already demanding better performance solutions to increase resilience, reduce maintenance and reduce environmental impact.

Appreciating these demands, PoliMac coating has been developed by Maccaferri as a polymeric coating for steel wire mesh products including rockfall mitigation systems, soil reinforcement and traditional gabion walls.

PoliMac is applied to heavily zinc-aluminium galvanised steel wire before it is woven into engineered double twist mesh products.

This has been made possible by a specific polymer recipe and innovative extrusion technology unique to Maccaferri.

PoliMac-coated products offer greater abrasion resistance, better performance at lower temperatures, higher UV and chemical resistance properties which are significantly superior to the performance offered by traditional polymer coated wire mesh products.

The result of using this coating is that the products last longer even in extreme environmental exposure conditions. One particular benefit of the greater abrasion resistance offered by PoliMac coated Reno Mattresses is within hydraulic works such as river channelling and bank protection works.

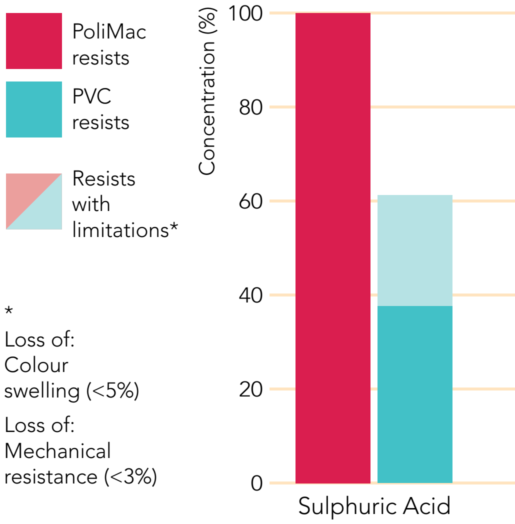
The same benefits are realised within rockfall protection works where the coating provides a long life even in coastal works.

Within soil reinforcement, Terramesh soil reinforcement can be used with more aggressive fills than previously suitable. This result is an exciting solution that is more resilient, durable, requires less maintenance and future-proofs clients from worsening environmental conditions.

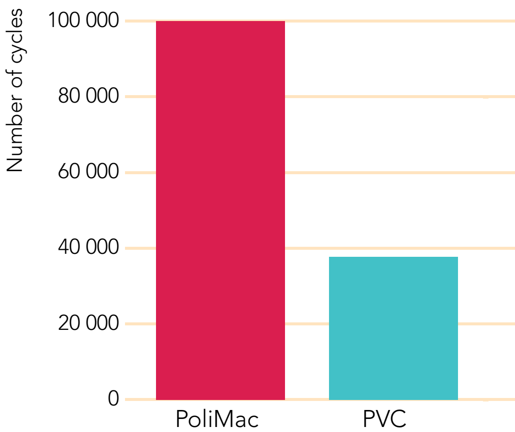
It has been argued that traditional polymer coatings could be harmful to the environment as they degrade. PoliMac does not contain heavy metals, phthalates or chlorides, making it a greener solution.

Through vigorous laboratory testing in accordance with international standards, PoliMac withstood 100,000 cycles of abrasion; 10 times that of traditional polymer coatings.

Traditional heavily zinc-aluminium galvanised coatings have a galvanising protection layer less than half the thickness of a human hair; an additional abrasion resistant coating is needed to meet the future demands. This coating has to provide front-line

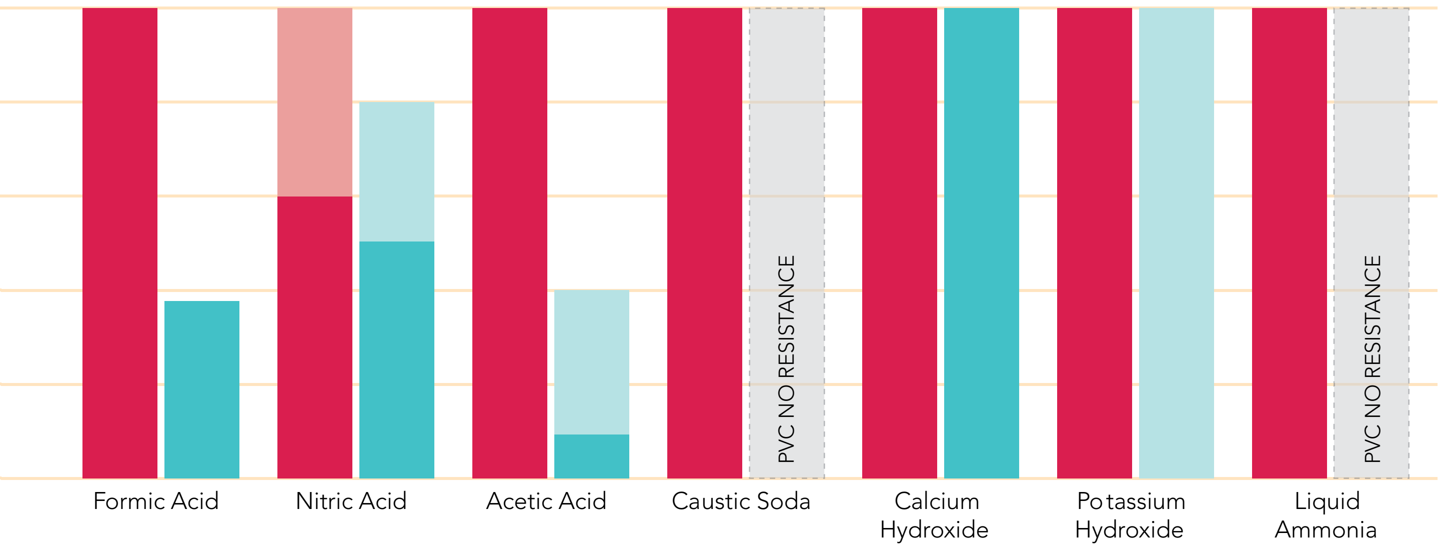


Abrasion resistance tests PoliMac showed excellent performance by withstanding 100 000 cycles of abrasion in accordance with test method desribed in EN 60229-8.



POLIMAC PROTECTIVE SHIELD

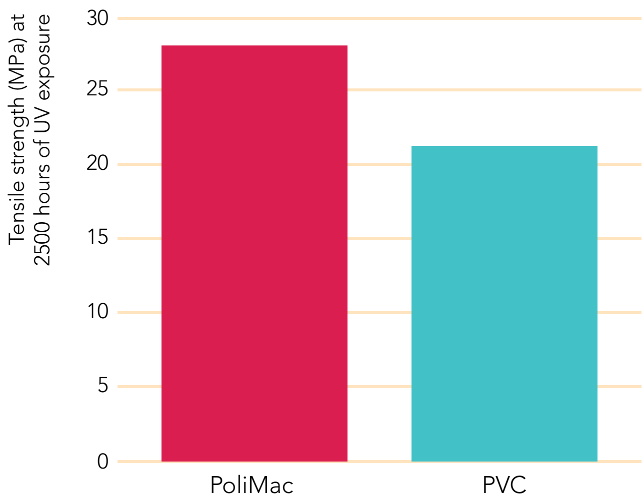
THE NEW POLIMAC POLYMER COATING IS MORE RESISTANT TO CHEMICAL ATTACK, BOTH IN ALKALINE AND ACIDIC PH CONDITIONS VERSUS TRADITIONAL POLYMERIC COATINGS FOR STEEL WIRE

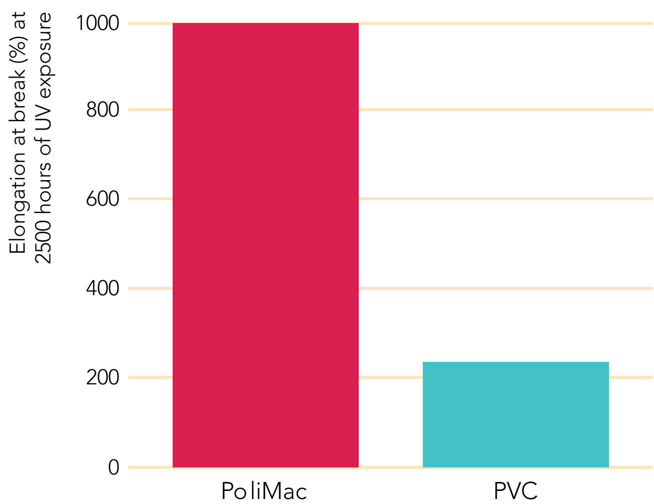


BETTER RESISTANCE THAN TRADITIONAL POLYMERIC COATINGS

UV resistance tests

As a result of severe accelerated ageing, PoliMac achieved conformance with ISO 4892-3, EN 10223-3, showing better tensile strength resistance and elongation than other traditional polymeric coatings after 2500 hours of exposure to UV.





defence that prevents abrasion or chemical attack deteriorating the galvanised layer. Maccaferri PoliMac meets this need.

PoliMac protection increases the life of wire mesh products, reducing maintenance and repair costs. The benefits of a reduced maintenance commitment are clear in saving costs, manpower and the impact on our ever changing, delicate environment.

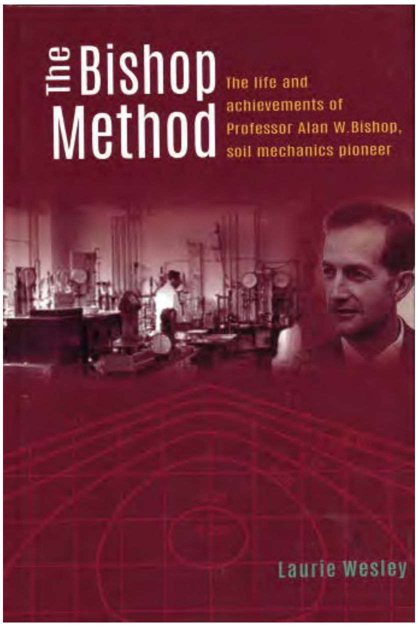
PoliMac® available exclusively from GEOFABRICS Smarter Infrastructure

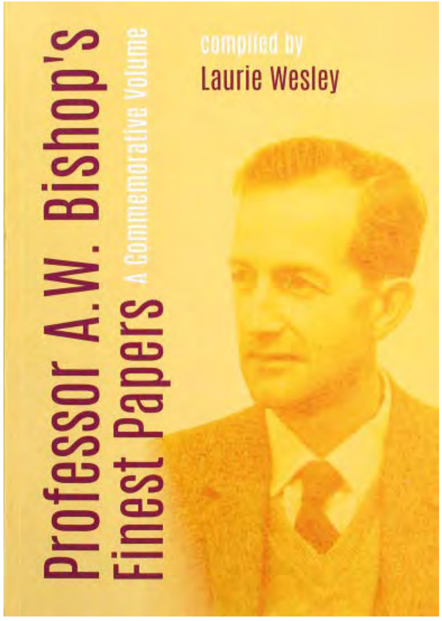
We had an excellent collection of entries to the Photo Competition with a wide range of topics offered. This made it hard to choose and rank the winners but the judges finally agreed on the following as the Top 5.

FIRST – **Scott Barnard** *AECOM*, Drilling at site SR20, Kaikoura (drillers are from Rock Control)

2. Matt Howard *Golder*, Time to start work. Sunrise over Lyttelton Harbour from the Sumner Road job site **3. Miles Buob** *Aurecon*, In high places. A 2019 ground investigation in the hills north of Whitianga, Coromandel for a telecommunications tower. No, we did not find any rock. **4. Olivia Ellis-Garland** *EnGeo*, Geotechnical Construction Monitoring next to a 40m high cliff at Fuipisia Falls in Samoa. **5. Charlotte Stephen-Brownie** *Davis Ogilvie*, Wet sand created these patterns reminiscent of wax on a candle on the side of the digger bucket.

Professor A.W .Bishop – Two Major New Books





THE BISHOP METHOD – Laurie Wesley

Whittles Publishing, Caithness, Scotland, 2019. £35.
ISBN 978-184995-439-6

A VERY INTERESTING and wonderfully readable book, subtitled: The life and achievements of Professor Alan W Bishop, soil mechanics pioneer.

The book is in three parts: Bishop's life story; Bishop, Soil Mechanics Pioneer; and Memories of Bishop: anecdotes, stories and tributes.

First, information about Bishop's life, which covers his early years and schooling, time at Cambridge University as an undergraduate, early work at the London Metropolitan Water Board (where Bishop developed his first triaxial apparatus), and the Soil Mechanics group at the Building Research Station, and from there, in 1946, to Imperial College. There is a brief outline of Bishop's work at Imperial and also the travels he undertook to international conferences. The later stages of his life are recounted: his retirement in 1980 and his marriage, for the first time, in 1981. Bishop died in 1988. Given that many of the important players in Bishop's career were deceased when Laurie started work on this biography it is quite an achievement, the fruit of Laurie's careful detective work, to piece together so much information about Bishop's life. The writing is so engaging and a joy to read. Reading this account one realises just how far soil mechanics has come since the early days of the Building Research Station in the 1940s and what a significant role Professor Bishop played in this development.

Second, Bishops contributions to soil mechanics are reviewed and discussed in some detail; particularly Bishop's fascination with the principle of effective stress. On reading this section it occurred to me that the 90 or so pages are so well written they could form the basis of a graduate seminar on the principles of soil behavior. Bishop's great talent as a designer of laboratory equipment is also covered in this section. The Bishop and Bjerrum paper "*On the relevance of the triaxial test to the solution of stability problems*" (regarded by many as Bishop's most important paper), presented at the 1960 ASCE conference on the Shear Strength of Cohesive soils is discussed. Another paper, that must also rank high in the list of his most important papers, is that of Bishop and Skinner: "*The influence of high pore pressure on the strength of cohesionless soil*" published in 1977 in the Philosophical Transactions of the Royal Society. This is a particularly important paper which, unfortunately, is comparatively unknown because of the obscure place of publication. Not only does it provide high quality data verifying the principle of effective stress but also demonstrates very sophisticated skills in the conception and design of highly complex soil testing apparatus.

Third, the book is rounded out with a collection of anecdotes about Professor Bishop and some of his eccentric ways. All most interesting and some even quite amusing.

If you have even the slightest interest in the history of soil mechanics and the life of one of its pioneers, this is a book you will delight in reading.

PROFESSOR A W BISHOP'S FINEST PAPERS – compiled by Laurie Wesley

Whittles Publishing, Caithness, Scotland, 2019. £40
ISBN 978-184995-442-6

THIS VOLUME COLLECTS many of Bishop's papers. It includes the 1960 Bishop and Bjerrum paper and two papers from the Philosophical Transactions of the Royal Society, one of which is the Bishop and Skinner paper on effective stress, as well as some of Bishop's *Geotechnique* papers, and several conference papers. The volume also contains a paper by Laurie and his friend Richard Pugh. They were the last two PhD students fully supervised by Bishop. Both were to have written papers co-authored by Bishop but because of Bishop's illness and early death the papers were never written. With a research grant Bishop had employed Laurie and Richard to investigate the properties of the soft clay along the north coast of the Thames Estuary. Laurie did the laboratory work and Richard the field work. Their paper shows how comprehensive their testing was and how clearly Bishop was behind it all. Laurie's contribution is impressive because he both co-designed the Bishop-Wesley triaxial apparatus and carried out a large number of various types of triaxial and other tests. This is a valuable collection bringing together in one place documentation of a number of significant steps in the development of soil mechanics.

Reviewed by: *Mick Pender*

We occasionally receive or learn of new books of interest.

If you would like to review new books for us, please contact the Editors.

Artist impression of the Central Rail Link Auckland

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14th ISRM International Congress on Rock Mechanics and Rock Engineering

ROCK MECHANICS FOR NATURAL RESOURCES AND INFRASTRUCTURE DEVELOPMENT

THE 14TH ISRM CONGRESS, jointly hosted by Brazil, Argentina and Paraguay, was held in the Brazilian city of Foz do Iguacu close to the common border between the three South American countries. Prior to the congress a wide range of themes generated 805 abstracts resulting in submission of ~480 papers from 42 countries (dominated by Brazil, China, NZ 1 Australia 21). The congress, which was over three days between 16 and 18 September 2019 was attended by over 650 registrants, a good proportion of whom were young professionals (under 35) or students. Over 450 papers were presented (~190 orally, ~260 on posters).

Plenary sessions, with two award lectures (8th Muller – Prof Peter Kaiser, Rocha) and eight keynote plus one invited lectures, were held in an amply sized room. Oral presentations, with four parallel sessions in variably sized rooms, were divided into 12 special sessions with 20 minute timeslots, 26 technical sessions with 15 minute time slots and two early career forum sessions (10 first-time presentations plus two overviews). An entertaining feature was the enthusiastically contested Rockbowl student quiz with 16 teams entered (8 from outside Brazil) leading to the final between teams from Canada and Brazil (winners).

Morning and afternoon teas were held in a large area spread between the trade displays for the eleven conference sponsors and reasonably well-spaced posters. Industry sponsored moments were in some of the session rooms during lunch breaks, with meals separately available in the venue restaurant. Social events were pretty standard with a welcome reception and a dinner at which six new ISRM fellows (one - Bill Bamford - from Australasia) were inducted. A moving tribute session for past-president Prof John Hudson was held immediately prior to the Congress closure. A field trip – to the nearby 12,600 MW Itaipu Dam on the Brazil Paraguay border - was available on the day after the Congress.

Several of the keynote addresses gave worthwhile reminders on the value of observation, common sense, keeping thinking simple, plus the benefits of technology when usefully applied complemented by some historical reviews. The technical sessions gave expositions on the formulation and calibration of numerical models using a wide array of numerical techniques, and updates on laboratory testing techniques, in particular related to strength and permeability plus case histories for both surface and underground civil works and mining with a touch of petroleum geomechanics. We were also reminded of Karl Terzarhi's input to engineering in karst terrain, encouraged to keep a geological perspective when deriving rock properties and updated on the challenges of the low confining tensile stress part of strength envelopes, all with the now present risk and health and safety overprints. Although topic areas (e.g. numerical modelling, laboratory testing, weak rocks) were reasonably streamed, there were inevitable clashes for those with wider interests, sometimes not helped by less than strict timekeeping.

Overall the congress was a successful event that provided a worthwhile update on a wide range of rock mechanics topic areas. There was some dilution from the topic broadness, something naturally associated with an international society flagship four-yearly gathering, but the emphasis on early career activities added worthwhile content. The several presentations that make attendance worthwhile were there, along with the ever present networking opportunity. The proceedings, as two separate volumes, one for keynote the other for main stream papers, are an awkward ebook in VitalBook format for registrants and will be available through the Taylor & Francis website.

The next congress will be in Salzburg, Austria in October 2023.

Reported by:
Stuart Read

AUSTRALIAN GEOMECHANICS
SPECIAL ISSUE SEPTEMBER 2020

AUSTRALIAN GEOMECHANICS SOCIETY

Collaboration in Geotechnical Engineering Call for Papers

www.australiangeomechanics.org

In 2018/2019, forums in the local chapters of AGS and NZGS explored collaboration and its impact on practice and academic research, and there was enthusiastic participation in the discussions. A plenary session at the 13th Australia New Zealand (ANZ) Conference on Geomechanics in Perth, Australia in April 2019 was devoted to the topic of "Collaboration in Geotechnical Engineering – Impact on Research and Project Delivery". The stated objectives of the plenary session were,

- to promote collaboration among various stakeholders in academic research and project delivery; and
- to stimulate discussions and communication in the geotechnical fraternity to produce best project outcomes.

Additional details from the ANZ session are provided in http://issmge2014.ust.hk/jun2019/3b.Conference_report.
The above sessions provoked discussions about several aspects that are relevant to collaboration, including academic research and industry involvement, the great divide between designers and constructors, traditional vs collaborative and agile project management approaches, examples of collaboration between industry and academia, knowledge sharing and dissemination, transferring research into practice and project risks management considerations.

This special issue of *Australian Geomechanics* on Collaboration in Geotechnical Engineering will enable those interested to provide further development in their thoughts and recommendations, as well as to provide a more substantial and referable body of information to encourage and nurture collaboration in geotechnical engineering.

THEMES

The following areas are some suggested topics for the special issue of *Australian Geomechanics*:

- Case histories documenting triggers for collaboration and benefits derived
- Revisit some projects with great outcomes and seek to better understand what collaborative practices made challenging technical delivery possible
- Where can geotechnical engineers collaborate to make our profession/ businesses much better for our clients and community, and in overcoming current and emerging difficulties in the industry, e.g. tailings dams, confidence in the construction of high-rise residential buildings, data gathering, sustainability, climate engineering etc.
- Industry/ academia and academia/ academia collaboration and what can we do to improve, and how do we demonstrate value
- Examples from other technical fields/ practices where collaboration has been attempted, and lessons learned
- Impact of digital on industry collaboration in geotechnical engineering
- Role of clients and governments in promoting collaboration and collaborative practices

PAPER SUBMISSION

Papers submitted for consideration in the themed edition should be submitted no later than 31 May 2020 to Kim Chan (kim.chan@ghd.com)

For further guidance on the preparation of papers for *Australian Geomechanics* please refer to the Editorial Policy available on the AGS website. If you are unsure whether your paper is suitable for publication in this special issue then please prepare an abstract and send to Kim Chan at the email address provided above for consideration. The abstract should be not more than 300 words.

Papers selected for publication will be based on their quality and relevance to the topic **Collaboration in Geotechnical Engineering**. We encourage submissions from all stakeholders in the geotechnical engineering profession.

NZGS-7ICEGE Reports

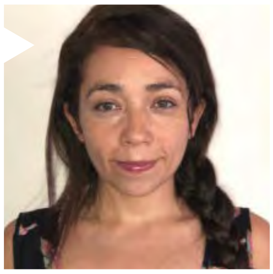
The New Zealand Geotechnical Society (NZGS) provided scholarships to young geotechnical professionals for them to participate in the 7th International Conference on Earthquake Geotechnical Engineering (7ICEGE) which took place in Rome, Italy last 17-20 June 2019. As part of the conditions of the scholarship, the 5 recipients submitted conference reports when they returned to New Zealand. Below are excerpts from their submitted reports.)

Maxim Millen·
Post-doctoral Fellow, University of Canterbury

It was a great honour to be selected by the New Zealand Geotechnical Society to attend the 7ICEGE. In 2017-2018, I was working in the European research project: 'LIQUEFACT - Assessment and mitigation of liquefaction potential across Europe: a holistic approach to protect structures / infrastructures for improved resilience to earthquake-induced liquefaction disasters'. The 7ICEGE conference was the first major opportunity to present the findings from our work, where there was a special session for the LIQUEFACT project, and over 15 papers outlining the project's research findings. Given the wide international attendance of the conference, this was a great opportunity to get feedback from other researchers of liquefaction from around the globe before the project is completed in November 2019.

I found the sessions on recent earthquakes very valuable as it highlighted the wide number of geotechnical related disasters that have occurred over the last four years, and how they have impacted communities. The data collected from these events has challenged our understanding of some geotechnical problems (e.g. the unprecedented flowslides during the 2018 Sulawesi earthquake), and is an invaluable resource for further research. The difficulties of obtaining high quality data after an event highlighted to me the importance of setting up permanent field monitoring stations at key sites to obtain recordings during events.

Overall, the most important part of the conference for me was to re-connect with the international researchers that I am collaborating with and to share ideas with them that cannot easily be communicated by email or phone. In this respect, I hope that these collaborative efforts, and the sharing of ideas with the world, will lead to significant benefits to the New Zealand Geotechnical Society.
Maxim Millen



Gislaine Pardo
PhD student, University of Auckland

It was a very enriching experience, where people from academe and industry coming from different parts of the globe met to share new insights and to discuss common practices related with earthquake geotechnical engineering. As in previous years, the conference was divided in subtopics addressed through parallel sessions in which the most recent developments in earthquake geotechnical engineering were presented and discussed, covering also the technical and scientific interaction within the fields of seismology, geophysics, geology, structural as well as infrastructural engineering.

I had the opportunity to present part of my research in one of the parallel sessions on laboratory testing. My topic was the undrained response of laponite-treated specimens; this material is a nano-clay that when dispersed in water can modify it, transforming it into a gel with thixotropic properties, and the results of undrained cyclic simple shear and undrained monotonic simple shear tests were presented. This was an opportunity to showcase the research that is being done in the University of Auckland and in New Zealand. After the presentation, I received several questions regarding the behaviour of the laponite, and during the break I had some insightful discussions with the knowledgeable attendees.

There is no doubt that this scholarship has provided me with a great opportunity not only to attend and present part of my research at this conference, but also to learn and connect with so many people working in earthquake geotechnical engineering related projects. I feel honoured and grateful to attend this conference as representative of the University of Auckland and the New Zealand Geotechnical Society.

- Gislaine Pardo

Ribu Dhakal
PhD student, University of Canterbury

From receiving the conference program and looking through the speakers, one of the first things which stood out was the wide range of research being conducted around the world. Even under a specific area of research like earthquake geotechnical engineering, several topics showcased the range of case histories, testing methods and numerical tools being utilised. Parallel sessions provided a great opportunity to attend specific focus areas, and I was fortunate enough to attend sessions on recent case histories, field and laboratory testing, site effects, issues on liquefaction, seismic slope stability, and seismic design of foundations and earth structures. These sessions gave insights into the projects and work being conducted around the world and led to interesting discussions with many other PhD students and young researchers on the future direction of these projects. It was a great opportunity to learn more in areas of research with less emphasis in New Zealand.

I was fortunate enough to be able to present my paper via an oral presentation on 'Site Characterization for Liquefaction Assessment of Gravelly Reclamations at CentrePort,

Wellington'. This paper characterised the soils and site at the port of Wellington and presented results from liquefaction analysis in comparison to the ejecta manifestations observed after the 2016 Kaikōura earthquake. This presentation led to interesting discussions with professors, who then gave insights and feedback on my current outputs. The guidance and comments were very helpful in identifying key issues and areas of focus for future research. Fruitful discussion and collaboration with other research teams around the world have also stemmed since this conference, for which I am very grateful.

Overall, 7ICEGE was a well-organised conference with many highlights. It allowed for participants from around the world to share their research and foster collaboration. Holding the conference in the 'Eternal City' of Roma was very appropriate. With many attractive and emblematic locations around the city, and impressive cultural heritage, it really felt like we were part of an important occasion. Not to mention, Italian food was also great.

- Ribu Dhakal

Baqer Asadi

PhD student, University of Auckland

Attending the 7ICEGE in Rome provided me with an opportunity to discuss with professors from other international universities. Also, listening to many other interesting presentations was very helpful in developing my understanding in geotechnical earthquake engineering. My presentation at the conference was attended by a number of people that included many senior professors. I received positive feedback on my presentation and my paper from the audience; in particular, comments and suggestions from Professor Kenji Ishihara was very insightful. Also, after the presentations, I had the opportunity of having a short meeting with other experts discussing over my research findings, and received important suggestions regarding preparing guidelines for dealing with the challenging pumiceous sands.

Among other presentations, I found a presentation from Professor Koseki (University of Tokyo) very interesting and relevant to my PhD study. His research focuses on the liquefaction susceptibility of sands during consecutive earthquakes; similar to the sequence of earthquakes that happened in Christchurch in 2010-2011. Another interesting presentation was from Professor Cubrinovski (University of Canterbury), who illustrated key aspects of liquefaction assessment of soils other than uniform clean sands. The findings and suggestions from the presentations will be considered while dealing with the crushable pumiceous sands.

Overall, attending the 7ICEGE conference was an excellent experience that will be very beneficial for the rest of my PhD study. I would like to take this opportunity to thank the New Zealand Geotechnical Society for their scholarship, which enabled me to attend such an important geotechnical earthquake engineering conference.

- Baqer Asadi

Aimee Rhodes

Geotechnical Engineer, WSP-Opus

The Conference was a great way to network with others in my profession. During 7ICEGE, I was able to discuss the CentrePort resilience project (WSP Opus). This allowed me to update myself and other team members (at the University of Canterbury) on the status of the project, and to glean new ideas from discussions with those outside of the project team. I was also able to strengthen existing relationships with those I have met before, as well as meet new people working on similar projects.

My paper was accepted for a poster presentation which I presented on the final day of the conference. I found the poster session one of the most valuable aspects of the conference. During the session, I had a number of valuable discussions with people I knew, and with people from around the world whom I had never met before. I also discussed the project with senior academics. As a result, I have new ideas about how to approach the CentrePort project. These discussions also inspired me on where to direct the scope of my PhD. I made some new contacts from the poster session.

As a side note, I think poster presentations can sometimes be viewed as a secondary form of presentation. However, in my recent experience, the opportunity for discussion provided by this form of presentation is invaluable. I would recommend anyone presenting at a conference to partake in a poster session at least once given the opportunity.

- Aimee Rhodes

Metro Sport, Christchurch

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MENARD

Thoughts for geotechnical engineers at the opposite end of their careers to my own – Laurie Wesley

AMONG THE TOPICS that were suggested to me when I was invited to contribute an item for this journal was career planning. It is not a topic I'm well qualified to speak on, never having done any, but I will make a few relevant comments here and there. To begin, I believe there are two things that you should think about early in your careers. These are

1. That you will enjoy your work
2. That whatever engineering you do will be good engineering

On the first item, try to be aware of your own strengths and weaknesses, and what you really want to achieve as a geotechnical engineer. Your job opportunities are mainly in the private sector - mostly consulting companies but also construction companies. The very competitive market of today's world is inevitably a source of workplace stress - some people seem to thrive on stress, others do not thrive but get by comfortably, and some do not cope and suffer mental health issues - and in some cases look for a different career. Apart from consulting and construction companies, there are job opportunities in government agencies and in local authorities, which are generally free of the main sources of stress in the private world.

Most of you reading this article will have already made your initial career choices but I will make a few comments regardless. There are two things worth thinking about - will you be getting good experience, and what will the stress level be. In general I think you will get better experience and training in a large company than in a small one. However, the work atmosphere in a small company may be less stressful and more to your liking than in a big company, and some small specialist companies may still give you very good experience, though possibly of relatively narrow scope. If you are thinking of project management then a construction company is likely to be your best choice.

Regarding the second issue- you may well ask what I mean by good engineering. Perhaps you think civil engineering, by its very nature, is good - but this is not necessarily so. Engineering can be judged good or bad on two counts. The first and obvious one is: *Is it good technically?* There are factors over which you have limited control that may result in poor quality work and the outcome is not "*good technically*". The leaky buildings tragedy is largely the result of engineers, architects and builders giving into the demands of greedy developers, which resulted in short cuts being taken, inferior materials used, and inadequate quality control during construction. Various technical "excuses" have been made for leaking buildings, and in a sense these are valid, but the basic reason is the greed and unscrupulousness of developers and the failure of professional engineers and architects to stand up to them. Sadly, ethical scruples in today's world are being lost sight of, or as is said "*our moral compass now points in many directions other than the right direction*". More about this in the next paragraph.

The second count on which good engineering can be judged is: *Is it of benefit to society?* Auckland's casino has a very impressive tower which is held up by many as a fine example of clever engineering. Technically that may well be correct, but the tower

Laurie Wesley

At the start of his career as a geotechnical engineer Laurie spent two terms of four years working for the Indonesian government interspersed by five years with the New Zealand Ministry of Works. Following this he completed a PhD at Imperial College, and returned to Auckland to work for Tonkin and Taylor for eleven years. He then lectured at Auckland University for 15 years, and still does some part time teaching, in Auckland, Indonesia, and Chile.

exists solely because it is part of a casino. And the casino is fundamentally a means by which those with money and power make more money by exploiting the poor and gullible. Our politicians were warned of the damage that would be done to society because of the gambling addiction associated with casinos, but they still went ahead and allowed them. When the addiction problems became acute and evident, the government of the day put a stop to more casino licenses. For me, the Sky City tower will always be very second rate engineering, nothing more than a beacon for a gambling den regardless of its technical excellence. I believe one structural engineer resigned from the company he was working for because of its involvement with the design of the casino.

Engineering simply cannot be good engineering if it is harmful to society. An extreme example of good or bad engineering is the gas chambers used by the Nazis to exterminate Jews. I understand that technically they were well designed - minimised fuel costs and maximised deaths. But I think most people would agree that they were evil creations and have to be judged on that basis regardless of their technical excellence. To close this section on ethics, there is an important issue that I became aware of because of my involvement in projects in Indonesia and Malaysia, and that is the issue of paying bribes in order to obtain jobs. I know of one New Zealand company that was prepared to pay a bribe, and another one that would never consider it. The USA has very strict laws that forbid their companies paying bribes in both their own country and other countries. We have no such laws regarding overseas work

Now for some comments regarding technical competence. Geotechnical engineers come in a range or types with varying degrees of competence. My experience is that at each end of that range there are two distinct types. The first is what I would call "textbook engineers", that is, those with a sound grasp of conventional theory and methods of analysis, but lack what I would call a "feel" for the subject. The second type is those who have a similar grasp of fundamentals but also have a good "feel" for the subject. For want of a better term I will call these mature engineers

Text book engineers tend to solve problems by identifying the appropriate formula or method of analysis (or which computer programme to use) and putting it to use. As long as they have followed a learnt or standard method they will be satisfied with whatever answer they get. Mature engineers will have a sufficiently good "feel" for their subject that they may well know (at least approximately) the answer

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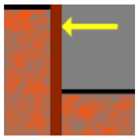

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before they make use of formulas and methods. What makes a "text book" geotechnical engineer and a "mature" geotechnical engineer is an interesting question. It is not necessarily a progression from completing a degree to many years of relevant experience (though relevant experience certainly helps). This difference may already be present among new graduates, depending on the environment in which they grew up and gained their education. Those whose childhoods have involved building dams with sand on the beach, or building tree huts in the bush, or watching their parents build an extra room on the house are likely to have a good idea of how the physical world works and can relate their lecture material to that world.

On the other hand, some students without these experiences may still do well in learning what is taught but their understanding of the material may not extend much beyond the piece of paper in front of them. In other words they do not relate what they learn to the physical world they have experienced (or not experienced) around them. Asian students tend to be at a disadvantage here because many grow up without doing the sort of things in the physical world that Kiwi children do (or did when I was young). In New Zealand the situation has changed markedly since I grew up. In my day we took our bicycles to pieces fairly regularly for routine maintenance, which meant dismantling the hubs and re-greasing them. (and hopefully putting back the same number of ball bearings as we took out). Many of us got our pocket money mowing people's lawns with a Masport hand mower. We knew how to take it apart and grease the bearings and clean out the gunk that jams up the gravity ratchet mechanism. I still mow my lawn with a Masport hand mower, and still take it to pieces for "servicing" when the need arises (I won't be upset if this brings dinosaurs to mind - we enjoyed playing with them).

Let's forget about the labels and I'll try to answer the question you probably want answered:

What should I be doing to become a good (mature?) geotechnical engineer?

I think a clear grip of basic soil behaviour is an essential attribute. You may already have this, but to add to it you need to practice observation, which was one of Terzaghi's dominant attributes, but is lost sight of today. You should observe behaviour in the field whenever the opportunity arises to do this. I don't mean special opportunities, just the opportunities you come across incidentally in daily life. These include excavations, especially deep ones, trenches, and the cut slopes beside highways or even footpaths. Trenches are particularly useful because they are so plentiful these days - for installing or repairing (or re-repairing) services Also, you should use every opportunity to familiarise yourself with laboratory testing and spend time in the field observing drilling and sampling techniques and the execution of other in situ tests, especially SPT and CPT tests. Without such exposure you will not be in a position to judge the reliability of data coming from field or laboratory tests. And we should be clear on one thing - a prime challenge for geotechnical engineers is making judgements as to the extent to which theoretical concepts can be applied to the situations they are addressing..

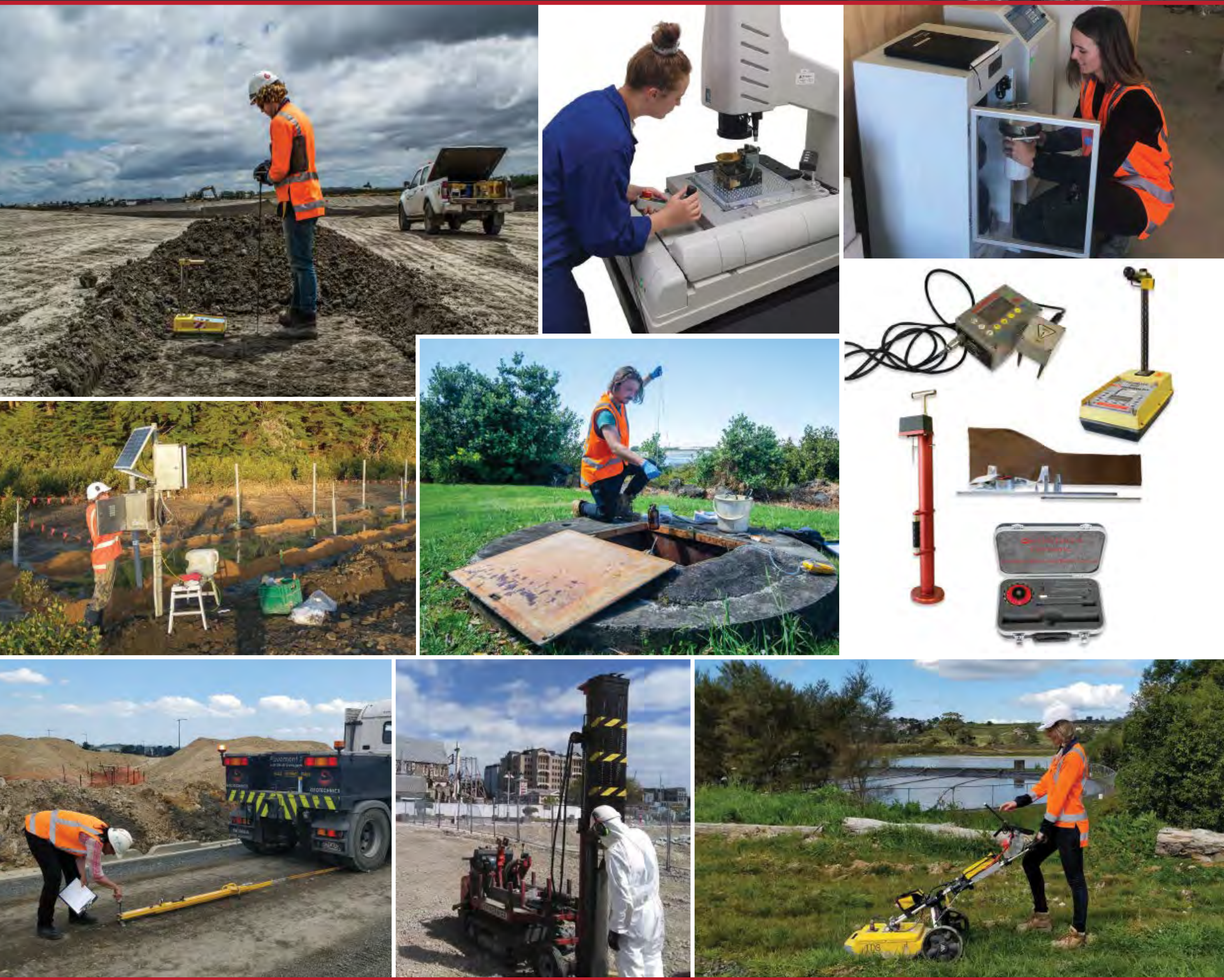
An all pervasive influence today that I never experienced during my education and while working as a geotechnical engineer is the computer. For the analysis of complex situations it is a marvellous tool but for routine geotechnical issues I'm not sure that its positives outweigh its negatives. Sound geotechnical engineering cannot be done in front of a computer screen, although it is easy to think so. I have reviewed reports on the stability of natural slopes that rely entirely on pages of computer generated printouts of slip circle analysis, but make no mention of what a visual inspection of the site has revealed. Pages of multi coloured slip circle printouts certainly impress clients with no knowledge of soil mechanics, but leave others cold. The idea that theoretical analysis of natural slopes can take the place of other non-analytical methods, especially careful visual inspection of the site, is ludicrous. I once heard of an American consulting company that forbade its new staff from using computers for the first several years of their employment. I thought that was a very sound idea.

Finally, do not blindly believe everything you have been taught at university or even read in text books and papers. Think about these things and take any opportunities that arise to see if they make sense in the light of what you observe in the field.

Finally (again) It seems that unplanned careers can be just as satisfying as planned ones. Maybe this is because those who don't plan their careers don't have specific aims and thus have no difficulty achieving them. That at least has been my experience, but I'm not suggesting this an example for you to follow. Actually, what I have just written is not quite truthful (it is alternative truth in the US president's words). My aim when I graduated was to use whatever ability I had wherever it would be most useful, which is why I went to work in Indonesia under what was known at the time as the Volunteer Graduate Scheme (for Indonesia).

Note: *For a more comprehensive discussion on ethical issues in civil engineering see my letter in the June, 2015, edition of New Zealand Geomechanics News.*

GEOTECHNICS



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Damage Caused by Typhoon Hagibis in the Kantō Region, Japan: A Quick Report

ABSTRACT

On 12 October 2019, super-typhoon Hagibis (locally referred to as Typhoon No. 19) made landfall in Japan and caused extensive damage to a wide area, especially in the Kantō Region. Considered as the strongest typhoon to hit the country in 60 years, the typhoon with wind speed exceeding 200 km/hr dumped record-breaking amount of rainfall and caused extensive flooding in many places, necessitating mass evacuation advisories, paralysing transport systems and shutting down commercial facilities. This quick report presents some preliminary findings on the flooding-related disasters that occurred in Tokyo and adjacent areas caused by the passage of the typhoon, based on the first-hand experience and subsequent reconnaissance work conducted by the author, who was in Tokyo when Hagibis pummelled Japan. Supplemented by additional information from newspapers and online resources, various torrential rain-induced damages, such as slope failures, collapse of river embankments and other sediment-related disasters, are described and their impacts to the built environment are discussed. Finally, major observations and lessons learned from the large-scale disaster are summarised.

1 INTRODUCTION

Record-breaking rainfall, hurricane-force winds and widespread flooding devastated many areas in the central, eastern and northeastern Japan when Typhoon Hagibis (locally referred to as Typhoon No. 19) made landfall on 12 October 2019, with direct impact to Tokyo and adjacent areas. Considered as a Category 5 super-typhoon (with winds of 259 km/h) prior to landfall, Hagibis (which means "speed" in Filipino) was downgraded to a Category 2–equivalent typhoon when it hit Izu Peninsula (located southwest of the capital), but it still caused serious damage in many places, necessitating mass evacuation advisories, paralysing transport systems and shutting down commercial facilities.

While on research and study leave at Tokyo City University (TCU), the author experienced first-hand the wrath of the typhoon, including submergence of the TCU dormitory (where he was staying) under >1.3m of floodwater. With the TCU campus closed for two weeks due to severe flooding, he then took the opportunity to conduct his own field survey and desktop investigation to learn more about the impact of the typhoon on the affected areas.

This quick report summarises his personal experience and his investigation results, supplemented by information from various online sources, over a ten-day period after the typhoon. Focus is on torrential rain-induced damages, such as flooding-related disasters, collapse of river embankments and other sediment-related disasters in the Kantō Region (which covers seven prefectures: Gunma, Tochigi, Ibaraki, Saitama, Tokyo, Chiba, and Kanagawa, and home to nearly a third of Japan's total population). In addition, the impacts of the typhoon to engineering structures and the effectiveness of soft-type countermeasures (hazard maps and alert systems) are described. Finally, lessons learned from the disaster and their relevance to New Zealand are presented.

2 TYPHOON HAGIBIS

2.1 Overview of the Typhoon

Typhoon Hagibis developed into a tropical storm on the sea near Minami-Torishima on 6 October, proceeded to the west towards the Mariana Islands and developed into a "large and violent typhoon", the highest category on Japan Meteorological Agency (JMA) typhoon scale. It then proceeded towards Honshu, Japan's main island, making landfall on the night of 12 October (see Figure 1a). Data from the Environmental Modeling Center (EMC) showed that on 10 October, the typhoon had maximum sustained wind speeds of 259 kph (tagged as Category 5 typhoon), and then weakened when it made landfall two days later (see Figure 1b).

Rolando Orense

Rolando is the Geomechanics Group Leader at the Department of Civil & Environmental Engineering, University of Auckland. His research interest is earthquake geotechnical engineering, and he has extensive experience in doing research, teaching and consulting works related to soil liquefaction, ground response analyses and seismic soil-structure interaction.

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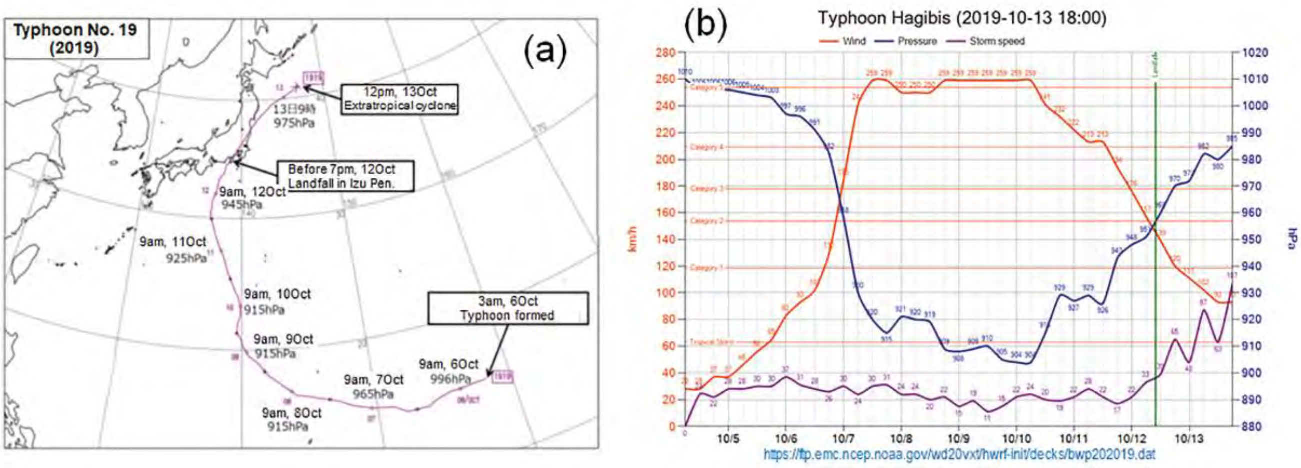


Figure 1: (a) Path of typhoon Hagibis (JMA 2019); (b) development of Hagibis in terms of wind speed, pressure intensity and storm speed (EMC 2019).

Typhoon Hagibis, the 19th to enter Japan this year, has been considered as the strongest typhoon to hit Japan in 51 years. Typhoon Ida (locally, Typhoon Kanogawa) struck in September 1958, causing the Kano River on the Izu Peninsula to overflow and flood its basin, killing 1,269 people, destroying 16,743 houses and inundating 521,715 houses (National Institute of Informatics website). It should also be mentioned that in September 2019, typhoon Faxai (locally, Typhoon No. 15) caused significant damage to the Kantō Region, with at least three people killed, hundreds of thousands of households remained without power for over a week and numerous homes lost their roofs.

It is worth mentioning that in the morning of 12 October, just hours before the typhoon hit the Kantō Region, a tornado was reported in Ichihara City, Chiba Prefecture. Late afternoon of the same day, a magnitude 5.7 earthquake occurred off the coast of Chiba Prefecture, registering a peak seismic intensity of 4 in Japan intensity scale of 7.

2.2 Rainfall Records

The typhoon dumped record breaking amounts of rain over a wide area. Table 1 shows the highest 24-hr and 1-hr rainfall intensities recorded during the typhoon. The rainfall intensity in Hakone is depicted in Figure 2, where it is seen that the total amount of rainfall that fell in the area during the passage of the typhoon was well in excess of 1,000 mm. Also indicated in the figure is the average monthly rainfall intensity for October in the area, which is 334.3 mm. This indicates that the amount of rain that fell in Hakone during the passage of the typhoon is about three times the monthly average for October.

Table 1: Maximum recorded rainfall intensities due to Typhoon Hagibis (data from JMA 2019).

24-hr Rainfall		1-hr Rainfall	
Station	Intensity	Station	Intensity
Hakone (Kanagawa Pref.)	942.5 mm	Fuyo (Iwate Pref.)	95.0 mm
Yugashima (Shizuoka Pref.)	717.5 mm	Omoto (Iwate Pref.)	93.5 mm
Urayama (Saitama Pref.)	647.5 mm	Hakone (Kanagawa Pref.)	85.0 mm

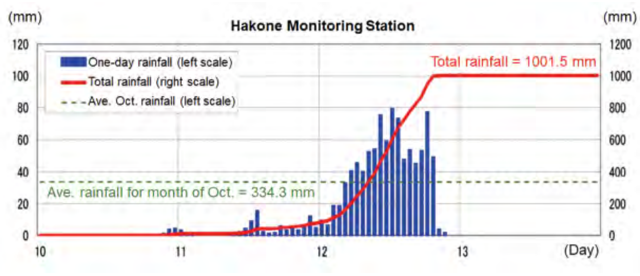


Figure 2: Rainfall intensity recorded in Hakone, Kanagawa Prefecture (from JMA 2019).

With such record-breaking rainfall, JMA, for the first time, issued a Level 5 special warning for heavy rain (the highest in their scale) to 13 prefectures. The warning level advised millions of residents within the affected areas to evacuate to more secure buildings or move to higher floors.

3 GENERAL FEATURES OF DAMAGE

Based on data as of 21/10/2019, Hagibis left at least 70 people dead, 12 people missing and 408 people injured. In addition, 275 houses were completely destroyed, 1,711 houses partially destroyed and 2,997 suffered some form of damage. Moreover, 29,707 houses had their ground floor flooded while 23,386 houses had underfloor inundation. In terms of non-residential building damage, 190 public and 1,061 private buildings were also affected (FDMA 2019).

Following the emergency alerts issued, more than 800,000 households across 13 prefectures were urged to evacuate. In addition, more than 210,000 households suffered power outages across the Kantō region and Shizuoka Prefecture.

As of 21/10/2019, the following damages were reported (MLIT 2019):

- **Damage to river networks:**
  - Nationally-administered rivers: 108 sections in 26 rivers (mostly river overflow, levee collapse and inland inundation)
  - River management facilities: 51 sections in 24 rivers (mostly bank failure, breakage, seepage, and erosion)
- **Sediment-related disasters:** in total, 79 cases broken down as follows:
  - Debris flows – 8cases (in 6 prefectures)
  - Slope failures – 65 cases (in 23 prefectures, with 5 cases in Tokyo Metropolitan area)

  Landslides – 6 cases (all in Niigata Prefecture)
- **Road networks:**
  - State highways: 9 sections along 8 routes
  - National roads: 24 sections in 10 routes
  - Prefectural roads: 74 sections of 41 routes
- **Railway networks:**
  - 56 routes operated by 16 railway companies affected
- **Airport facilities:**
  - While there was no reported damage to airport facilities, 2,622 flights were cancelled
- **Wastewater:**
  - Treatment plants: inundation damage occurred at 13 plants and treatment function stopped
  - Pump stations: suspended at 9 locations due to flood damage
  - Manhole pumps: 12 pumps affected due to flooding and ground damage (in 6 cities, 1 town and 1 village)

In addition, based on reports from various news sources, the passage of the typhoon affected some international events. These included the cancellation of several rugby matches, the first time in Rugby World Cup history, as well as the disruption of the Suzuka Grand Prix. The typhoon also forced the first-ever all-day shutdown of Tokyo's Disneyland and DisneySea theme parks in Chiba Prefecture.

4 FLOOD-RELATED DISASTERS AND LEVEE PERFORMANCE

Severe flooding triggered by the torrential rain submerged large areas in central Japan. Most of the affected areas were located near rivers, where in many cases, the levees and floodwalls either collapsed or were overtopped. In other cases, areas underwent inland flooding due to the intense rain that overwhelmed existing drainage infrastructure.

4.1 Rate of Floodwater Increase

One of the surprises this typhoon showed was how fast floodwater rose and how quickly it disappeared. Figure 3 shows how the water level in Tama River, a major river that separates Tokyo Metropolitan Area and Kanagawa Prefecture, changed during the passage of the typhoon. The water level shown in the figure was monitored near Futako Bridge in Setagaya Ward, Tokyo by the Keihin Office of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). It can be observed from the graph that at this monitoring station, the water level rose at a rate of approximately 0.4~0/5 m/hr, peaking in excess of 9 m at about 10 pm on the night of the typhoon. When the rainfall intensity finally subsided, the water level decreased at almost similar rate.

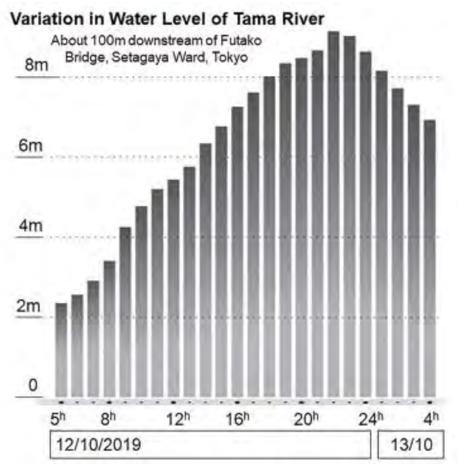


Figure 3: Variation of water level in Tama River during the passage of typhoon Hagibis (from https://dot.asahi.com/print_image/index.html?photo=2019102100087_2).

A visual description of such rapid change in water level is depicted in Figure 4, which illustrates the flooding that occurred at the author's 4-storey accommodation (photos taken from the second floor) near Tokyo City University (see location on Figure 5). The white car and white container at the middle of the photos can be taken as reference. The sequence of photos showed the floodwater rose by about 0.5 m in 6 hrs, half-submerging the car, which was at an elevated position with respect to the road. At sunrise the next day, all the water was gone. Subsequent measurements showed the road in front of the accommodation building was inundated by at least 1.7 m high floodwater.

Figure 4: Photos showing the changes in floodwater level at various times due to inland flooding.

4.2 Damage along Tama River

Major cities in Japan built near river systems are located in areas below the design high water levels. Hence, when levees break or floodwalls are overtopped, serious inundation can occur. Levee management is one of the most important flood control activities in Japan.

The author's accommodation was adjacent to Tama River, which extends over 138 km between Tokyo Metropolitan Region and Kanagawa Prefecture (see Figure 5). Levees all along this river were designed for a 1-in-200 year rainfall event. At the Ishihara Monitoring Station located in Chofu City (see figure), water levels reached their peak at 6.24 m by 11 pm on the night the typhoon struck, in excess of the target 5.9 m level the levees were designed for. Fortunately, an additional 1.5 m safety margin is provided beyond this threshold level. Thus, the total levee height at this monitoring station was 7.4 m and the levee survived the typhoon with just a little above a metre to spare. Note that any levee failure along the Tama River could have caused devastating flooding to many areas downstream of the river, severely affecting millions of residents in Tokyo and Kanagawa. For the first time ever, the Kawasaki City Office (located in Kanagawa Prefecture, downstream of the Tama River)) issued an emergency warning to all its one million+ residents to evacuate by 7 pm that night. Similarly, the author received similar urgent warnings.

Figure 5: Tama River and some of the observation points of interest (base map from Google Maps).

In order to accommodate the extra floodwater, the levees in Japan are constructed some distance away from the river itself. Typically, the open area between the levees and the river are converted into useful belt of parks, greenery and playing fields. In both banks of the Tama River, sports fields, playgrounds, parks and golf driving ranges have been constructed. However, a visit to the area the day after the typhoon indicated that most of these have been obliterated by the raging waters of the Tama River, as seen in Figure 6a. What used to be tennis courts and soccer fields were covered by mud and debris, with many of the sporting facilities washed away. Several portaloos were also damaged, an indication of the force the raging floodwater had as it flowed downstream towards the sea. Debris and other materials carried by the flood were also observed along the river levees, indicating the maximum possible heights by which the floodwater rose. In Figure 6b, the floodwater was just < 2 m away from overtopping the levee at this location.

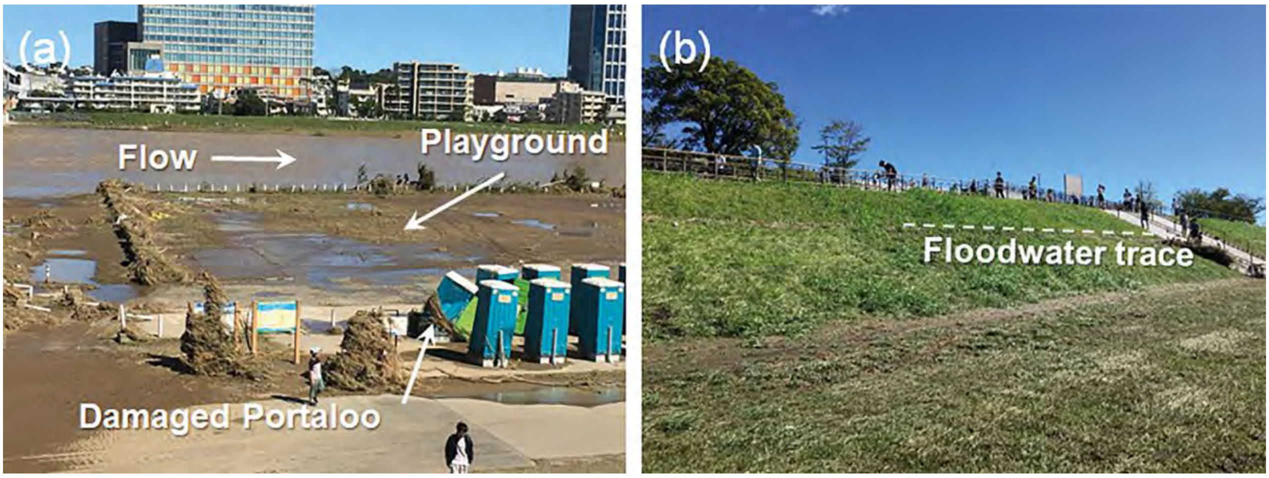


Figure 6: (a) Washed out playgrounds and sports field adjacent to Tama River; and (b) trace of floodwater on the levee.

Because of flooding in the past, levees have been constructed all along the Tama River to protect neighbouring residential areas, except for approximately 540 m-stretch section southwest of Futako-Tamagawa Train Station (see Figure 7a). This area has undergone extensive redevelopment in recent years and has been transformed into upscale residential and shopping neighbourhood, with large hotels, high-rise residential buildings and shopping complexes. Interview with local residents indicated that over a century ago when it was still a sparsely populated fishing area, local authorities planned of building levees as flood protection measure. However, restaurant owners who have been occupying the area for a very long time refused to re-locate, prioritising river view over the possibility of flooding. Hence, the authorities then yielded to their demand and instead built a levee behind the restaurants. More recently, some residents in the area still opposed the plan of increasing the height of the riverbank, again prioritising the river view. Accordingly, the 540 m section where the levee should be was not erected, while levees were constructed in other sections along the river. Then, on the night of 12 October, the Tama River overflowed from that low-lying bank and water gushed through the opening, flooding several residential houses facing the river (see Figures 7b and 7c).

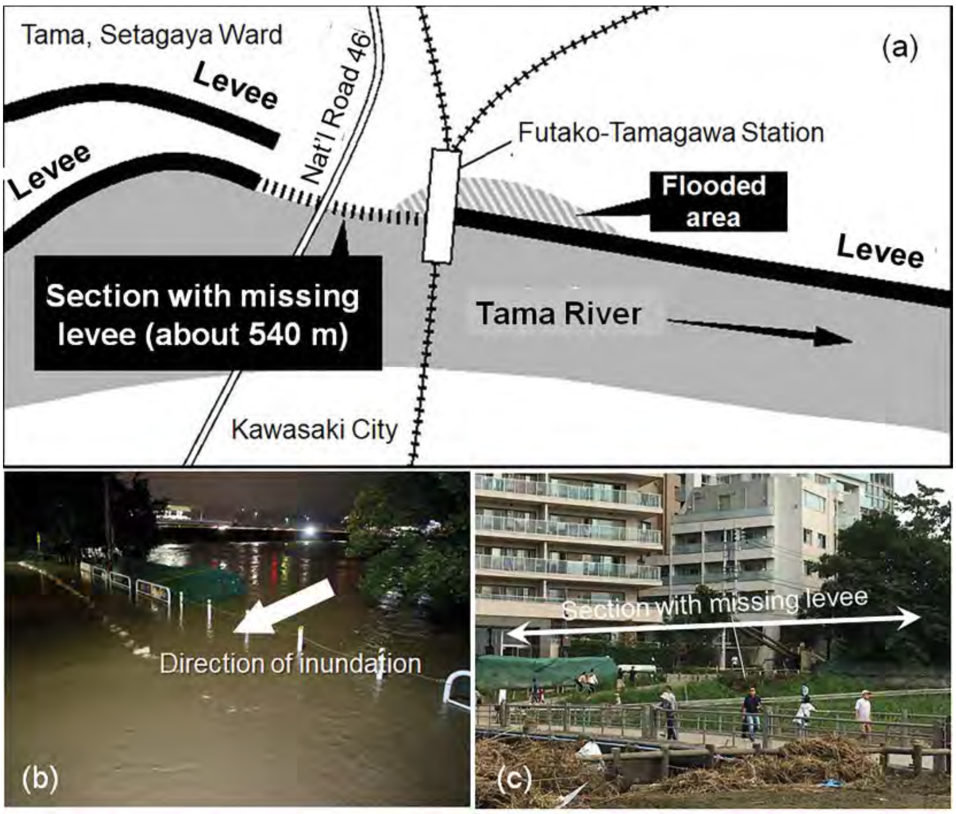


Figure 7: (a) Map showing location of missing levee in Futako-Tamagawa (modified from MLIT document); and (b) condition during inundation (view towards the river) (from https://mainichi.jp); and (c) condition after the typhoon (view towards inland).

Just south of the Futako-Tamagawa Station, on the Kawasaki City side of the river, another localised flooding occurred (see Figure 8a). Here, Hirase River, a tributary of the Tama River, flows towards the east to join the main stream. The affected zone, which was about 50 m away from the confluence of the two rivers, was sandwiched between the floodwalls of the Hirase River and the levee, which was apparently built in the mid-Edo period (i.e. 1700s). All the residential houses and apartment complexes were built lower than the ground. Interviews with local people indicated that the water level of Hirase River was already very high by the late afternoon of 12 October. From this time, emergency warnings to evacuate were frequent. By 8 pm of that day, the river overflowed and the adjacent road was flooded. The ground floor of many residential houses were then inundated in less than 15 min. An elderly resident died, apparently from drowning. Figures 8b and 8c depict the conditions of the area the morning following the typhoon.

It is unclear why residential houses were allowed to be built in the area on the north side of the levee. Inspection done on-site showed that houses located on the south side of the levee escaped flooding, because of the protection provided by the levee. Detailed investigation through residents' accounts showed that in the past, there have been frequent inland flooding in the area because rainwater could not be drained. The city authorities has set up pumping facilities as a measure to direct rainwater to the Hirase River. Although the pump was operated again this time, the water level of the Hirase River, which was the destination of the pumped water, rose very rapidly.

The fact that only the region at the confluence between the two rivers was affected suggests the possibility that the flow of Hirase River was blocked by the higher water level in the Tama River. Known as "backwater phenomenon", the flow of the tributary (Hirase River) rose too high and overtopped its banks because it was blocked by its main stream (Tama River), which was filled with far more water than usual from the record amount of rainfall that fell in the mountainous area of the upper Tama River.

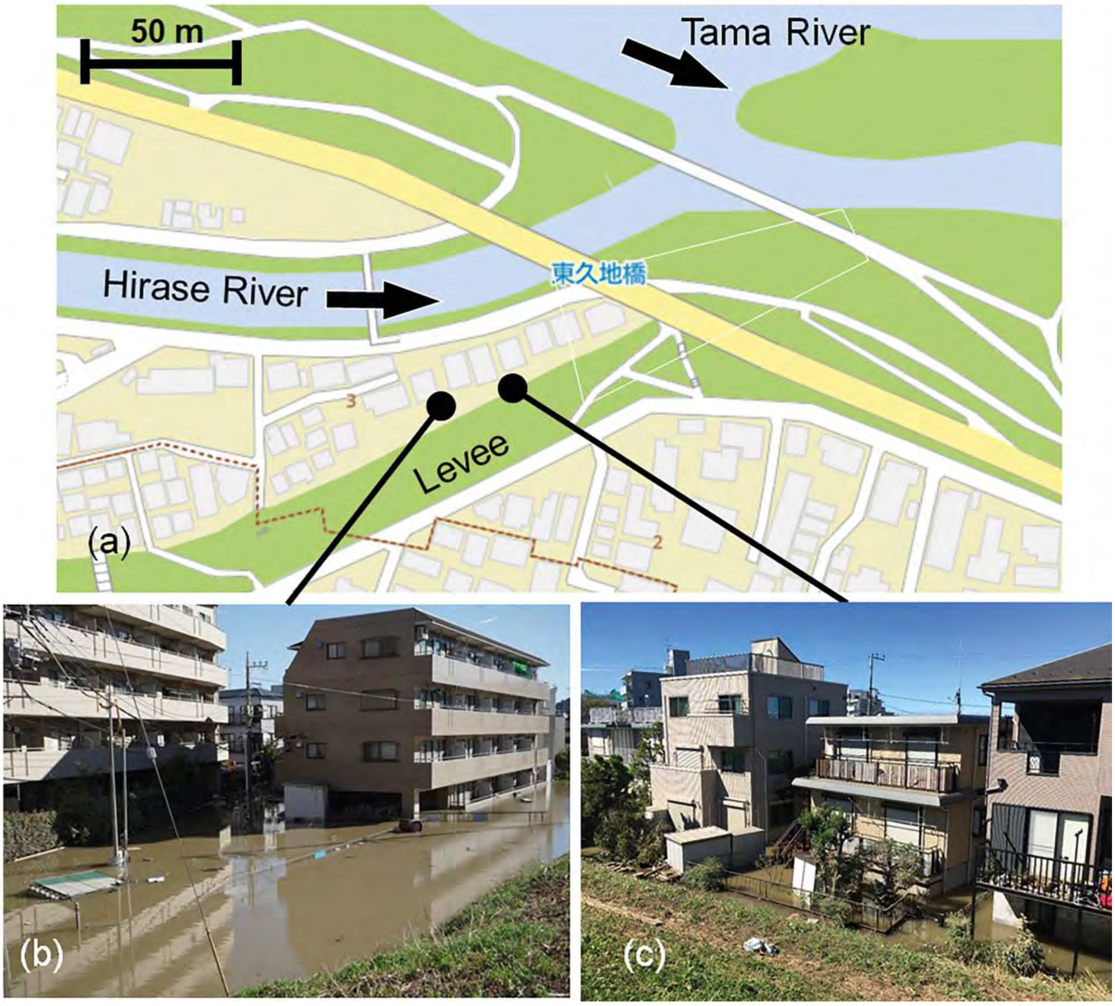


Figure 8: (a) Map showing the location of affected zone in Takatsu-ward, Kawasaki City (base map from https://www.mapion.co.jp); (b) flooded condominiums; (c) inundated residential houses.

4.3 Condition in other parts of Kantō Region

As in most cases in Japan, many rivers in the Kantō region are characterised by their moderately short lengths and substantially steep gradients because of the narrow and rugged topography of the region. Following the passage of the typhoon, many low-lying areas adjacent to rivers were also inundated in, more or less, the same fashion as those observed near the Tama River. Breaching of levees and floodwalls as well as inland flooding were the main culprits, as the enormous amounts of rainfall raised up water levels of many rivers in Tokyo, Saitama and Tochigi prefectures (Figure 9).

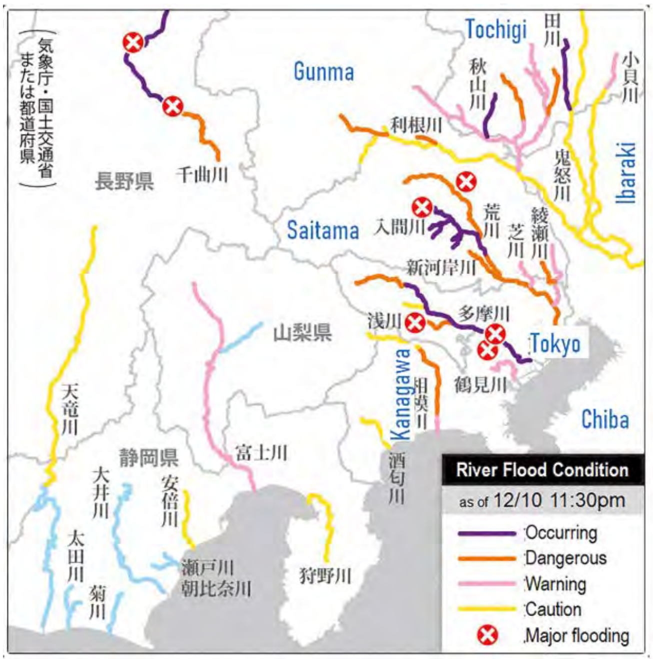


Figure 9: Reported river inundation condition during the typhoon, with data from JMA, MLIT and prefectural offices. Fonts in blue are the prefectures comprising the Kantō region (modified from https://mainichi.jp/articles/20191012/k00/00m/040/266000c)

An example of a collapsed section of levee occurred in Akiruno City, located on the outskirts of Tokyo (see Figure 5) adjacent to the swollen Aki River, a tributary of the Tama River. The collapsed portion of the levee, about 70-80 m long, allowed floodwater to inundate the community (see Figure 10a). In Ushinuma, 13 houses located along the Aki River suffered various amounts of tilt when the foundation of the 5 m high revetment wall in the area was eroded; one of the houses eventually collapsed into the river (see Figure 10b). As a result, the city's fire department placed entry restrictions to the remaining houses.

At the time of writing, other levee breaches reported in the Kantō Region include:

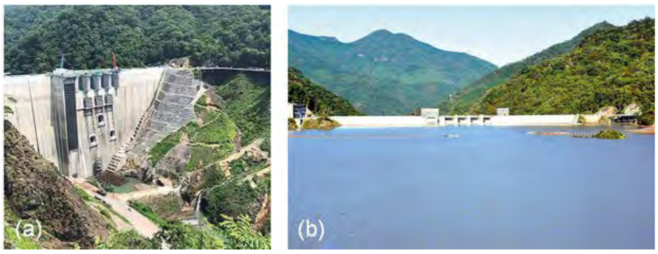
- one location in Higashi-Matsuyama City, Saitama Prefecture, on the Toki River;
- two locations in the cities of Higashi-Matsuyama and Kawagoe, both in Saitama Prefecture, on the Oppe River;
- three locations in the cities of Naka and Hitachiomiya, both in Ibaraki Prefecture, on the Naka River;
- three locations in Hitachiomiya City in Ibaraki Prefecture on the Kuji River.

In addition, news reports mentioned that the operators of several dams in mountainous areas, such as the Shiroyama Dam in Sagamihara (Kanagawa Prefecture), released water during the typhoon to prevent the collapse of the dams. This added to the volume of water that flooded many downstream areas.

Interestingly, the newly constructed Yamba Dam, a multi-purpose dam constructed in the middle of the Azuma River, the main tributary of the Tone River, and located in Gunma Prefecture (see Figure 11a), was put to a test by the typhoon. The 116 m-high dam, with storage capacity of 107.5 million cubic metres, just started "initial impoundment" (test flooding) on 01/10/2019 to confirm

Figure 10: (a) Collapsed portion of the levee along Aki River (from https://times.abema.tv); and (b) collapsed house in Ushinuma adjacent to the river (from http://www.asahi.com).

safety before going into full-scale operation. However, before it could begin actual operations, rainfall from Hagibis filled it nearly to the capacity level it was designed for (see Figure 11b). According to the Maebashi Local Meteorological Observatory, 442 mm of rain, one-third of the annual precipitation, fell upstream of the dam within 48 hours from 6 pm on 11/10/2019. There was no confirmed damage in the basin where it is located. Had Yamba Dam been in full operation, the space reserved for floodwater storage likely would have been smaller, increasing the risk for the dam and the downstream areas. The construction of the dam started in 1952, but was stopped several times due to protests from local residents.



4.4 Conditions outside the Kantō Region

Other prefectures in the central and northeastern part of Honshu Island were devastated by the typhoon as well. Among the worst affected areas were Nagano, Miyagi and Fukushima Prefectures.

Some of the spectacular flood-induced failures were reported when a 70 m-stretch of the levees on the Chikuma River in Nagano Prefecture were breached, and water gushed into the residential area and inundated many houses (Figure 12a). News and social media footages reported of people standing on the second floors of their houses, waving to grab the attention of the Self-Defence Forces in helicopters flying above (Figure 12b). A railway bridge along the Bessho Line of the Ueda Dentetsu Railway Company, which crossed the Chikuma River, collapsed into the water below (Figure 12c). Figure 12d depicts half-submerged Shinkansen (bullet) trains in the rail yard in the aftermath of the levee collapse. As a result, the inundated trains may be scrapped due to serious damage to their electrical systems.

Figure 11: (a) Photo of the just completed Yamba Dam taken in 4/08/2019 (by Akira Sakurai); and (b) the dam last 13/10/2019, filled to near capacity due to heavy rains brought by Hagibis (from http://www.asahi.com/ajw/articles/AJ201910150058.html)

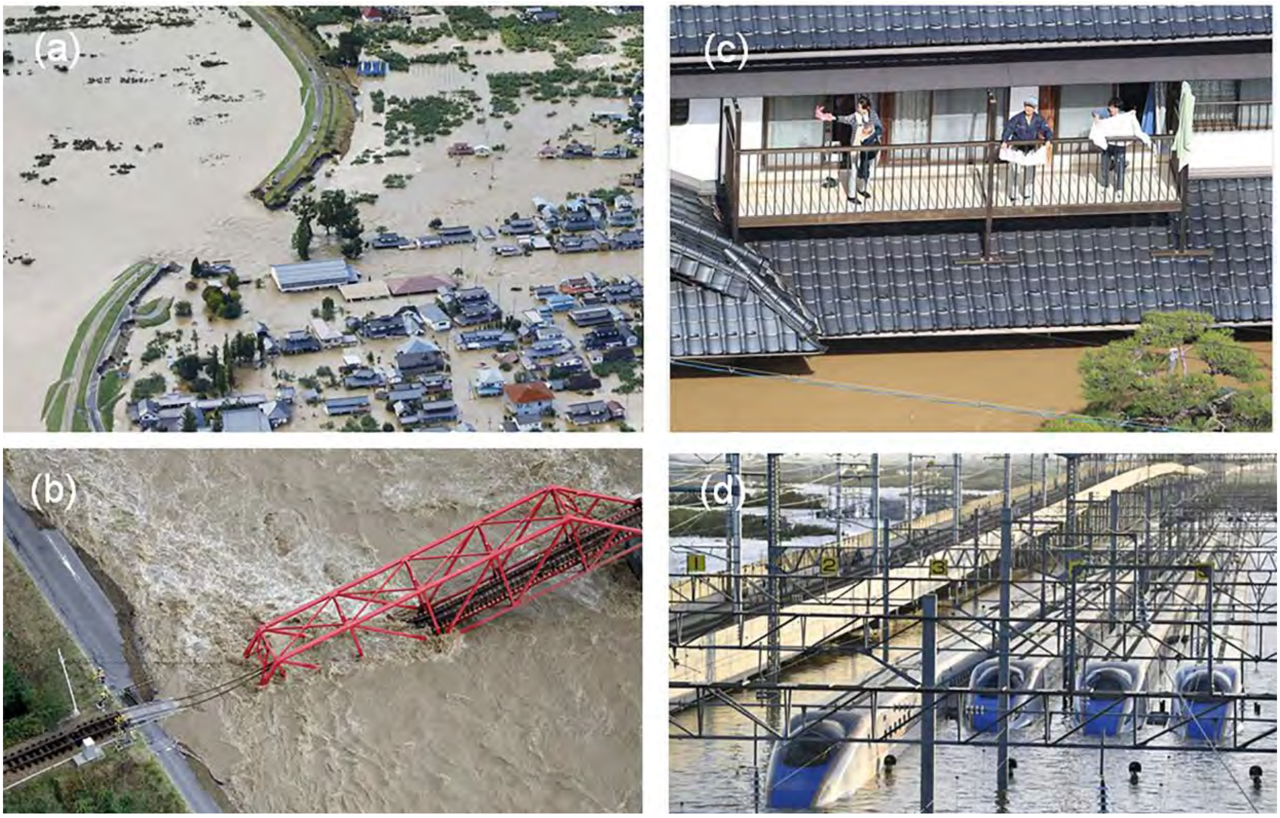


Figure 12: (a) Photo showing the collapsed portion of the levee along the Chikuma River that resulted in inundation of a large area near the river banks (from http://japan-forward.com); (b) residents stranded by the flood and waiting to be rescued by the Self-Defence Forces (from https://www.sankei.com); (c) a collapsed railway bridge crossing the Chinuma River (from https://www.theatlantic.com); and (d) flooded Shinkansen train rail yard near the bank of the river (from https://www.japantimes.co.jp).

5 SEDIMENT DISASTERS

Sediment disasters (土砂災害) is the general term used in Japan for phenomena involving large-scale movement of soil and rock that threaten human life and property, typically due to heavy rain and earthquakes. According to IDI (2004), sediment disasters can be classified as debris flows, slope failures, and landslides. In the context of this report: (1) *debris flow* involves soil and rock mix with water (rainwater and groundwater) flowing down rivers and mountain streams; (2) *slope failure* (i.e. rock/soil fall) comprises abrupt collapse of slope when the soil becomes unstable due to heavy rain; and (3) *landslide* has soil mass moving downward slowly at the boundary of the discontinuous surface under the influence of groundwater and gravity.

As indicated in the previous section, majority of the sediment disasters that occurred due to the passage of Hagibis were in the form of slope failures (65 cases) while some were debris flows (8 cases), which in turn affected many residential houses. This is not surprising because the Japanese archipelago has predominantly rugged and mountainous terrain and therefore the lack of habitable area has driven people to modify the hillside for residential purposes over many centuries. When the typhoon dumped significant amount of rainfall in such mountainous areas, both slope failures and debris flows were mobilised.

Slope failures occurred in at least eight sections along National Highway 413 in Sagamihara, Kanagawa Prefecture. The failures were triggered when the typhoon dumped more than 700 mm of rain in the area. Figure 13a shows one of the failed sections, which is part of the Olympic cycling road racecourse scheduled on 25/07/2020 for men and on the following day for women. About 30 km of the Olympic road racecourse runs through Sagamihara. On the other hand, Figure 13b shows a 23 m section of the track ballast between Miyanoshita and Kowakidani stations, located in the tourist town of Hakone, which disappeared because of slope failure. The intense rainfall, topping 1,000 mm in Hakone, caused major disruptions in at least 20 locations of the tracks, operated by Hakone Tozan Railway Co.

6 EFFECTIVENESS OF SOFT-TYPE COUNTERMEASURES

Because of its location, which is characterised by intense rainfall, rugged topography and criss-crossing river networks, Japan has experienced many flood events since ancient times. Learning from experience, the national government and administrative authorities have developed mitigation measures to minimise the impact of flood-induced disasters. Aside from hard-type (or structural) countermeasures (e.g. flood protection works, embankment and levee constructions, drainage system provisions, etc.), soft-type (or non-structural) countermeasures (e.g. rainfall and flood forecasting, flood/rain warning systems, hazard mapping, etc.) have been developed and implemented. The latter has been tested during the passage of typhoon Hagibis.

Figure 13: Typical sediment disasters: (a) slope failure along National Highway 41 in Sagamihara, Kanagawa Prefecture (from https://www.japantimes.co.jp); (b) slope failure affecting a railway track in Hakone (from https://mainichi.jp).

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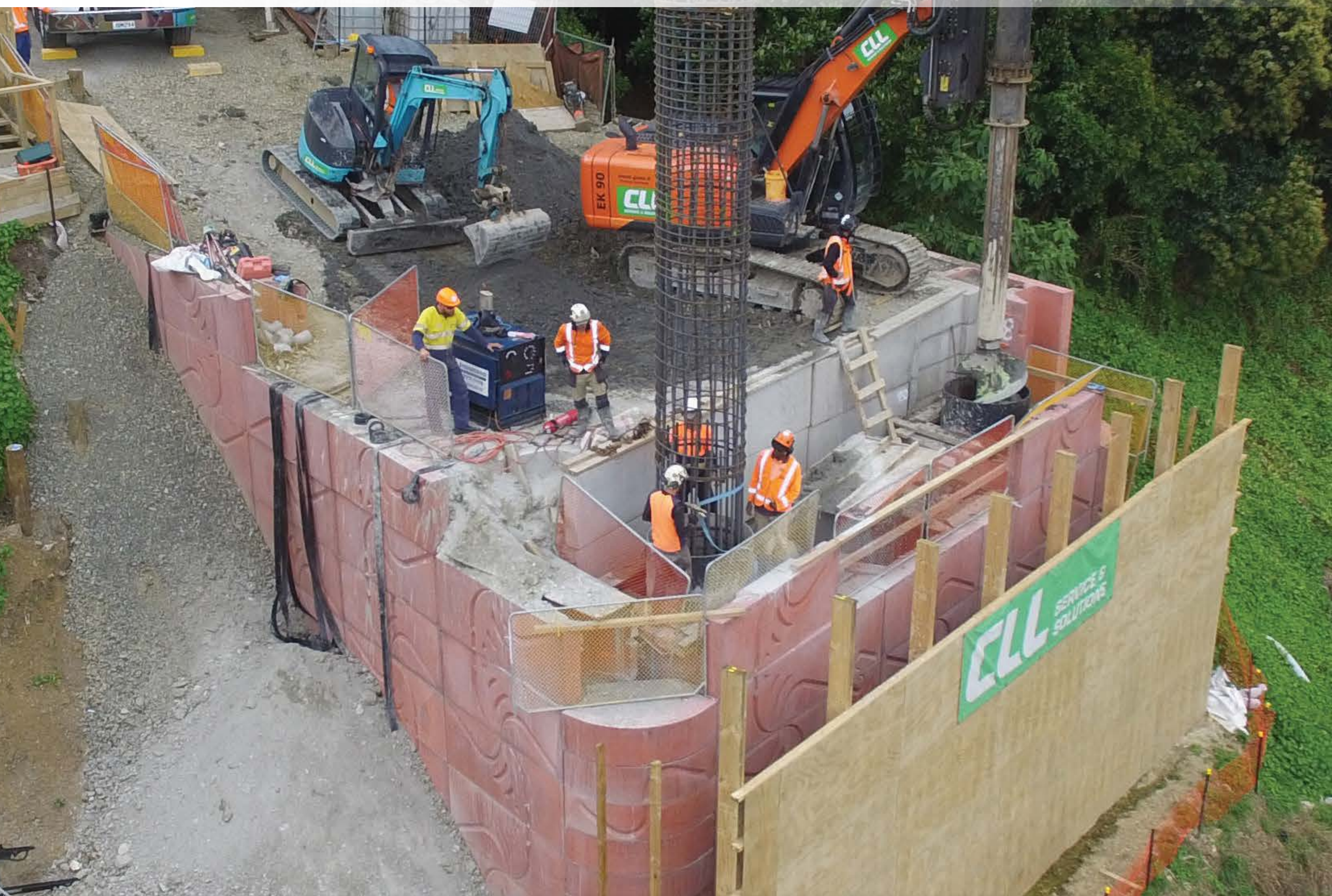

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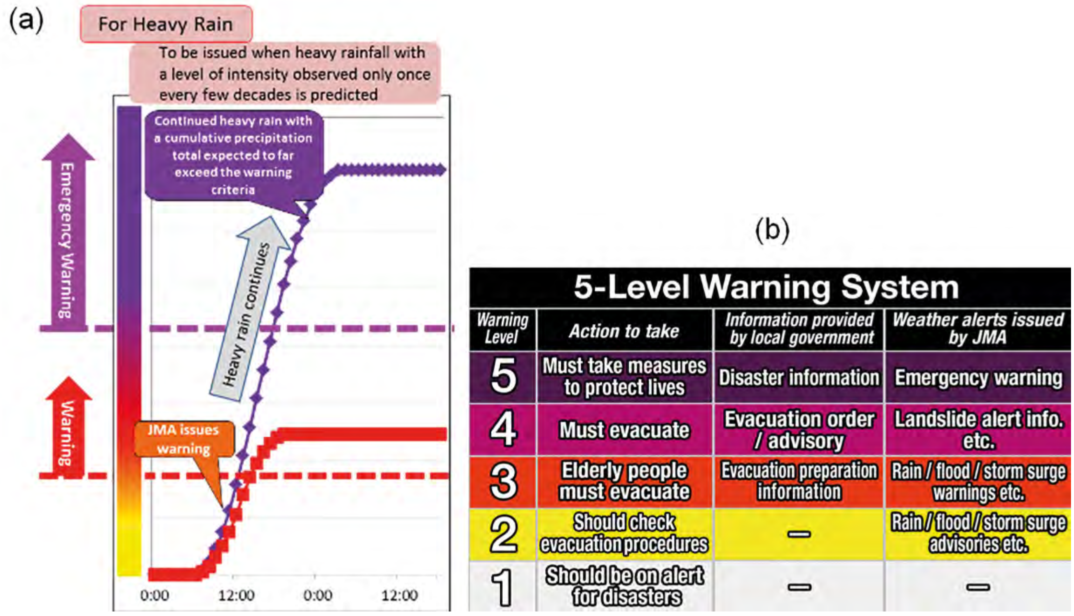

Figure 14: (a) Overview of the emergency warning system for heavy rain (from JMA 2013); and (b) the simplified 5-level warning system for floods and landslides (from https://www3.nhk.or.jp).

6.1 EMERGENCY WARNING SYSTEM

In addition to warnings, advisories and other bulletins associated with possible catastrophes that may be caused by extraordinary natural phenomena, the Japan Meteorological Agency (JMA) has begun issuing emergency warnings since 30 August 2013. This is to notify people if the scale of a particular natural phenomenon would be of extraordinary magnitude such that it will far exceed the warning criteria (JMA 2013). Figure 14a illustrates the overview of the emergency warning in case of heavy rain.

In early 2019, JMA rolled out a new five-level disaster warning scale to be used for floods and landslides. Designed to simplify the existing system and to reduce casualties by speeding up evacuations, the warning system includes clear instructions tied to the scales. Figure 14b shows the 5-level warning system. For example, Level 4 means all residents must evacuate, while the elderly and physically challenged must evacuate at Level 3. The emergency message is sent to smartphones of residents (causing the devices to ring so loudly to catch attention) and is also delivered via loudspeakers.

During the passage of Hagibis, the author received seven emergency alerts in his mobile phone, starting as early as 3:42 pm of 12 October (Figure 15a). The warning was Level 4, advising residents in the ward (where I was staying) to evacuate because the water level in Tama River has reached dangerous level. The same warning advised to seek information from various media (television, ward homepages) and listed possible evacuation centres. If going out is dangerous, it advised residents to move to second floor or higher. Later at around 10:34 pm, the warning issued was the highest at Level 5 (Figure 15b), and residents were advised to take measures to protect their lives. A couple of minutes after, another emergency alert was received (Figure 15c), warning residents in the ward that water has started to gush out though the portion of the Tama River without levee (as discussed in Section 3).

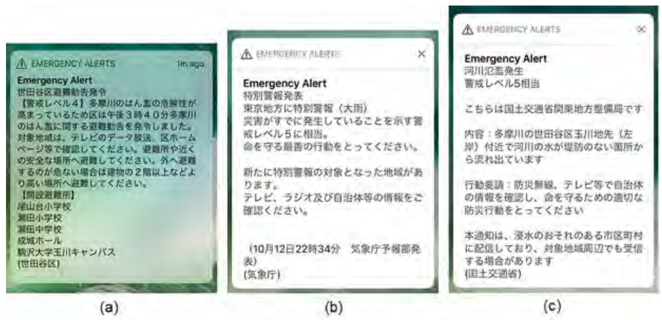

Figure 15: Screenshots of emergency alerts received at various times during the passage of typhoon Hagibis.

Having just arrived in the ward 10 days earlier and with his NZ mobile phone not registered anywhere, the author was amazed at how efficient this emergency alert system worked. Such constant alerts and updates provided to residents are indispensable, especially during the times when the power was cut-off and there was no other source of information available. (Note: It was fortunate that the author can "decipher" the emergency message, written in Japanese; many foreign residents complained in social media because they could not understand what the message was all about, delivered in an emergency situation such as during this very strong typhoon.)

After the typhoon passed, the media reported that at least six million people were told to evacuate their homes. If all those people heeded the emergency alert, flood-related casualties would have been significantly minimised. Obviously, not everybody believed the emergency messages. Possible reasons are: (1) people tend to underestimate the likelihood of a disaster and its possible impact, i.e. there is a common human tendency to believe things will be fine under any circumstances; and (2) during the passage of previous typhoons, relatively high warnings at levels 3 or 4 may have been issued quite frequently and the "expected disasters" did not occur in those cases; hence, people may have ended up ignoring the warnings during this particular typhoon. In any case, no matter how many warnings JMA and other agencies issue, actually evacuating is up to each individual. Nevertheless, the warning system gives opportunities for people to take action to save themselves.

6.2 Hazard maps

Because large urban areas, such as the seaside cities of Tokyo and Yokohama, have several rivers traversing them, they are susceptible to flooding after intense rains. For this purpose, local government websites have available hazard maps that delineate the area most vulnerable to flood, particularly when overflowing of major rivers occur. As an example, the hazard map of Setagaya Ward (Tama River version) is shown in Figure 16, which was published in 2016 by the MLIT's Keihin River Office based on an estimated total 2-day rainfall of 588 mm in the Tama River basin. The map shows the expected inundation area, inundation depth, shelter, etc. when the Tama River levees break down during a heavy rain and flooding occurs. The map is available to residents in order to provide them with general information, including the location of evacuation shelters in case of emergency, so that they can discuss possible actions during evacuation with their family members.

Figure 17, on the other hand, compares the estimated flooded area near Futako-Tamagawa Station and the flood hazard map in the area. Reports indicate that the flood during the typhoon was several centimetres deep in the affected area, which correspond to the region expected to undergo 5~10 m of floodwater in the event of design overflow of the Tama River. While the actual rainfall intensity did not reach the design rainfall used in developing the map and Tama River did not actually breach the levee, as the water found its way through the

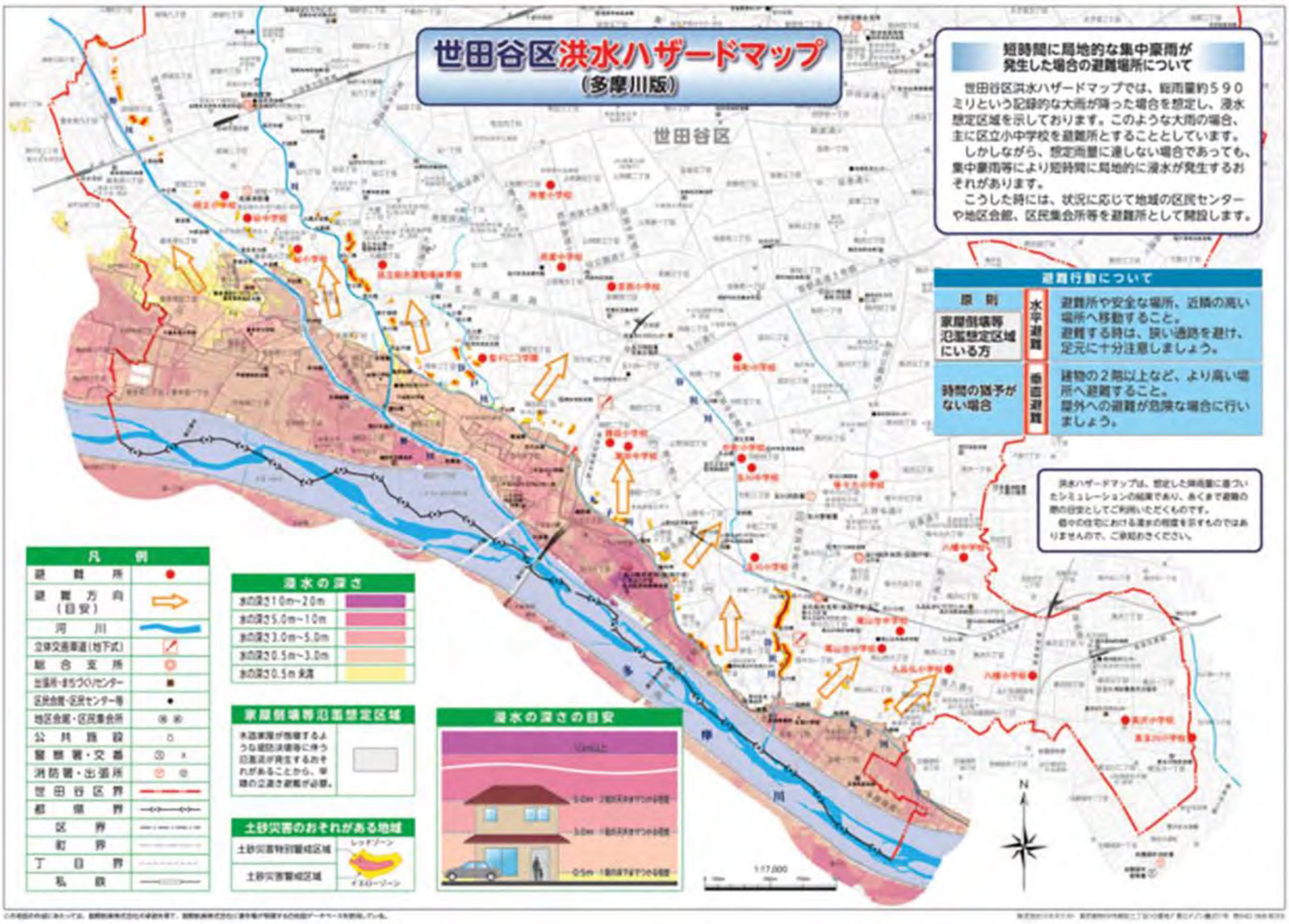

Figure 16: Hazard map of Setagaya Ward (from https://www.city.setagaya.lg.jp)

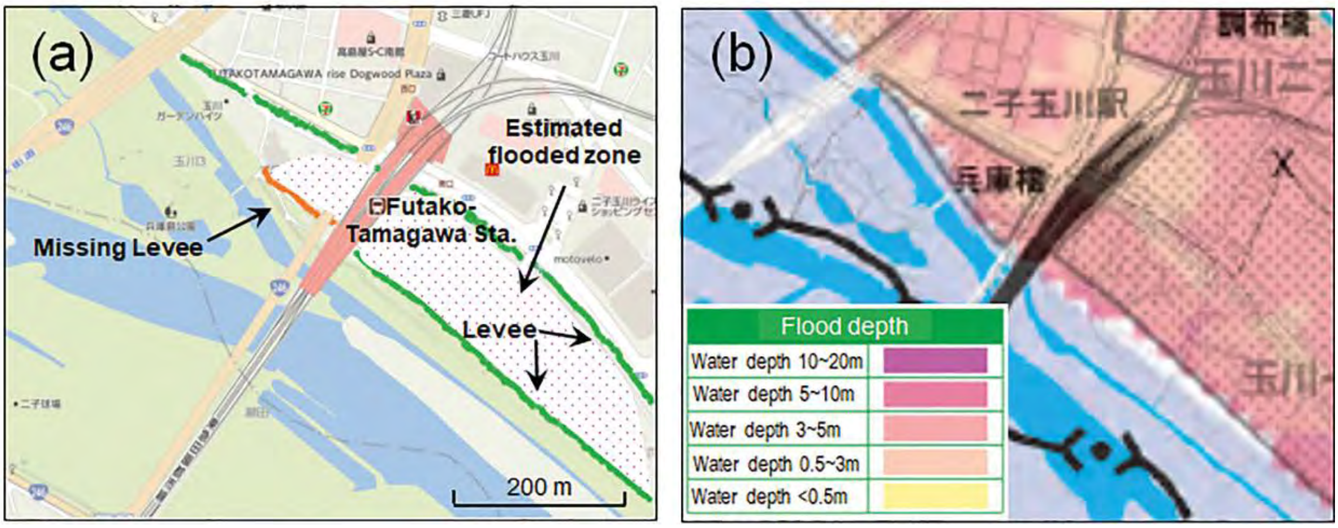

Figure 17: Side-by-side comparison between: (a) estimated flooded area in Futako-Tamagawa (base map from Google Maps); and (b) the flood hazard map in the area, enlarged from the full-scale hazard map (from https://www.city.setagaya.lg.jp)

section with missing levee, it can be surmised that the spread of the floodwater coincided well with the map projection.

Similar observations have been reported in some news bulletins, notably in areas adjacent to Chikuma River in Nagano City. According to Mainichi Shimbun (www.mainichi.jp), the predicted flood areas in the hazard map compiled and circulated by the Nagano Municipal Government corresponded almost exactly with the locations that actually flooded.

It appeared that many residents in areas that were flooded failed to use local hazard maps to consider evacuating because they did not know the maps existed. Hence, there is a need for local administrative bodies to consider more effective ways to distribute information about hazard maps and for residents to make good use of them to devise evacuation plans in anticipation of flooding.

7 KEY OBSERVATIONS AND LESSONS LEARNED

From the ground survey and information collected from various sources, the following are the main observations from this large-scale disaster.

- The amount of rain that fell during the passage of typhoon Hagibis was unprecedented. More than 1,000 mm of rain fell in some areas, three times more than the monthly average rainfall intensity. This caused extensive flooding in many places due to overflowing of rivers through floodwalls and levees, destruction of some river embankments, and inland flooding when the rainwater was not able to drain out. The intense rain and flooding necessitated the issuance of mass evacuation advisories. It also paralysed many of the region's transport systems and shut down commercial facilities.
- Honed up by many last-scale disasters in the past, various disaster mitigation systems that have been developed appeared to work. Many of the flood control measures, such as the levees along the Tama River, were able to withstand the large amount of water collected in rivers. National and prefectural authorities issued warnings and advisories for floods and sediment disasters before and during the passage of the typhoon. In the days and hours prior to the typhoon's arrival, television/radio stations provided important information and advised residents to take precaution. Although there were still casualties and some hiccups in local responses, it was clear that the lessons of past disasters have been gradually put to use. However, the intensity of the typhoon and the amount of rainfall it brought were unprecedented, almost beyond what the systems were designed.
- Many commercial establishments, railway networks and other public transportation operators announced very early the cancellation of their operations with extraordinary speed, i.e. 2-3 days before the typhoon's arrival. This action minimised public exposure to the extreme weather event, although the fact that the typhoon struck over a weekend when the number of commuters was fewer also helped.

Based on the experience, both national and local authorities need to consider the following issues.

- As a country frequently experiencing natural disasters, Japan has developed various disaster mitigation measures. These include "hard" measures, such as strengthening river dikes, and "soft" measures, such as promoting evacuations of hard-hit areas.

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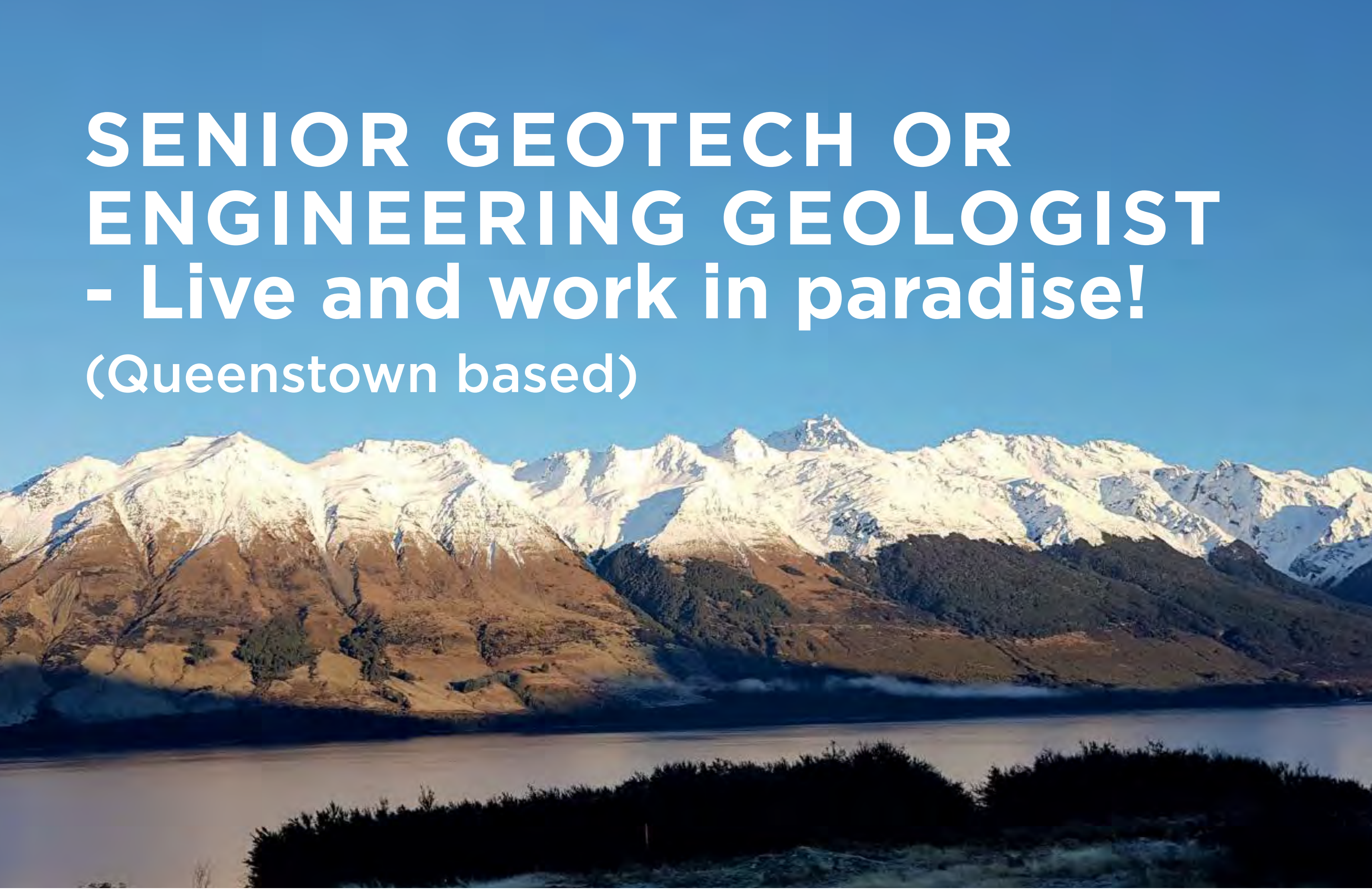

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However, community planning and urban structures designed on earlier assumptions may be inadequate to deal with intensifying natural disasters.

- While many river levees withstood the typhoon well, there is likelihood that, considering the progression of climate change, more intense typhoons would strike Tokyo and other metropolitan areas in the future and those levees are not designed to handle larger volume of water. There is a need to for a thorough review of the nation's flood control countermeasures in order to prepare for such increasingly abnormal weather.
- Businesses and schools must put plans in place for strong typhoons and other disasters. At the same time, homeowners need to realistically assess the geographical risks and other features of their homes and agree on measures to take to protect lives when disasters occur.

While the national government and other administrative authorities have implemented measures that were designed to minimise lost in life and property, there are limitations to what they can do. Many of the casualties in this typhoon died while trying to escape the rising flood; however, they have been adequately advised, with emergency alerts issued hours (or even days) before the typhoon struck. Each individual citizen need to be aware of what would happen in the face of such massive disaster and should adjust their behaviour accordingly.

8 RELEVANCE TO NEW ZEALAND

Widespread flooding induced by intense rainfall and levee breach is not new to New Zealand. For example, in April 2017, water from the Rangitāiki River breached a stopbank protecting Edgecumbe, and caused extensive flooding across the whole town. In March 2019, a local state of emergency was declared in Westland District when record rainfall hit the area and the flood destroyed a bridge and several roads. As extreme weather is becoming more frequent and catastrophic due to global warming, NZ's coastal regions are becoming more prone to storms and flooding, while inland regions are facing heatwaves and flash flooding.

Hence, all the lessons learned from the impact of typhoon Hagibis discussed above are equally applicable to New Zealand setting. Various flood protection and sediment disaster measures designed from past experiences need to be re-evaluated. While structural (hard-type) approaches, including building stronger flood defence systems like stop banks, drainage systems, etc. would work, there appears to be a limit to their effectiveness when viewed from the perspective that intense rainfall is becoming the new norm. Non-structural (soft-type) approaches, such as improved flood warning systems, can significantly reduce the impact of flooding and potentially save more lives. Efforts should also be focused on increasing public awareness by educating people about these disasters and their potential risks so that when they happen, people could act appropriately.

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Use of Small Unmanned Aerial Vehicles and Related Digital Data In Geotechnical and Natural Hazard Impact Assessments

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ABSTRACT

Unmanned Aerial Vehicles (UAVs or drones) facilitate data collection that allows rapid and enhanced geotechnical assessment of the risks associated with landslides, slopes and structures, during normal conditions and following natural hazard events.

WSP Opus has used UAVs over the past 10 years in New Zealand to assist engineering assessments for highways, railways, and infrastructure for local authorities, government departments and private clients. The early uses were mainly for occasional geotechnical slope and site mapping purposes. However, since 2011 UAVs have been systematically used for surveying and geotechnical applications. Examples are presented in this paper of the use of UAVs for assessment of slopes and existing landslides, as well as for post disaster assessments.

UAVs were utilized following the damaging February 2011 (M6.3) Christchurch Earthquake, the 2011-2015 storm events in central New Zealand, and the November 2016 (M7.8) Kaikoura Earthquake to inspect and provide damage records of sections of highways, slopes, and river stopbanks (levees), and to facilitate rapid development of remedial options.

The data gathered from UAVs have been used with post processing of imagery to create 3D terrain models. Comparison of periodic UAV derived models or comparison with previous LiDAR models enabled the detection and monitoring of slope change in areas affected by slope failures along transportation corridors. UAVs were also used to inspect and obtain geological data to assist with the assessment of rock slope stability. As seen in the Blue Mountain's Rail Corridor (NSW) in Australia, the use of UAVs provided a much safer alternative than having staff carry out observations directly (for example by rope access), given the hazardous nature of these locations. A comparison of geological and other data obtained from

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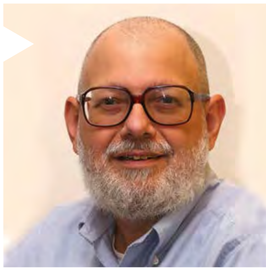

David Knott

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UAV inspections with those gained from conventional methods showed good correlation.

In addition to the safety benefits, the use of UAVs has enabled better and early decisions to be made to manage the risks associated with hazardous sites, and the rapid development of remedial solutions.

1. INTRODUCTION

The use of Unmanned Aerial Vehicles (UAVs) or drones, has grown rapidly in the past few years, largely through the rapid advancement and availability of affordable technology and the ability to rapidly process the captured data.

Many UAVs incorporate gimbal stabilised photography and high definition video capture with GPS geolocation of imagery. Relatively large areas can be rapidly captured and modelled accurately by post processing imagery utilising 'structure from motion' photogrammetric software. Software outputs typically include detailed ortho-corrected photo mosaic imagery and accurate 3D models of structures or terrain. These outputs can also be used for many CAD and GIS applications. Through these combined outputs, UAVs provide a means of rapid assessment of structures and slopes, and development of remedial options.

Continued rapid advances in the technology are anticipated with developments such as UAVs that can fly in all weather, advanced obstacle avoidance capability and the use of new sensors on UAVs such as infrared and LiDAR (Light Detection and Ranging). Such technologies are discussed by Olsen and Gillons (2015).

The current paper provides a summary of our findings regarding the usefulness and applications for UAVs in various phases of geotechnical engineering and natural hazard response over the past 10 years.

2. UAV TECHNOLOGY

2.1 Early UAV Inspections

One of the authors has used UAV technology in the Auckland Region from 2007. Initially this was using a frangible foam 'Easystar' model, electric powered, glider-type fixed-wing, radio controlled model aircraft carrying a remotely triggered Pentax 12 Mega Pixel compact digital camera (Figure 1). The 'Easystar' was largely based upon a hand launched hobbyist radio control training plane. It had a 1.4 m wingspan, and was able to remain airborne for up to 30 minutes, and operate up to 600 m away from the operator while remaining in visual control range. The camera was remotely triggered by an infra-red controller and could be positioned to take either oblique or vertical imagery of subject material. The aircraft was initially developed and utilised for remote access to difficult sites, slide inspections, site progress photography, and providing promotional aerial photos for clients and company flyers. While the 'Easystar' was launched and flown in left-hand circuits around the subject, most of the photography was 'guesswork' undertaken without any downlink or telemetry.

The first practical usage of the 'Easystar' for emergency response aerial support came during August 2008. Severe winter storms and extremely heavy rainfall reactivated an old deep-seated block slide on Turei Hill in Kawakawa Bay in the Auckland region. The slide threatened the closure of the coastal road and cutting off communications to a number of east coast communities. The 'Easystar' was utilised at Auckland City Council's request to provide rapid response visual survey of the extent of cracking and movement of the slump block. A number of reconnaissance surveys were undertaken over a number of weeks; with the photos being then "mosaicked" and compared with previous imagery. The imagery was subsequently used to disseminate visual information to local community groups and multiple media outlets, to help the public understand the risks.


Figure 1: The "Easystar" fixed-wing radio controlled aerial camera aircraft with camera setup for vertical images (left) and oblique images (right). The UAV was developed in-house by one of the authors of this paper.

2.2 Later UAV Inspections

From July 2014, as more advanced UAV technology became commercially available, the DJI Phantom quadcopter UAV became the most common UAV (Figure 2) used by WSP Opus. The Phantom is operated by a tablet based application that incorporates gimbal stabilised 12 or 20 Mega Pixel photography or high definition video capture. While it is essentially a 'prosumer' level UAV, the ability of the Phantom to take-off vertically, hover in a GPS assisted stationary position (not affected by wind drift) combined with live image and video capture (some of the Phantoms can live-stream video via YouTube) have revolutionised the ability to quickly and safely carry out inspections and assess hard to access unstable terrain and structures.

The Phantom can also be operated in an autonomous mode, flying to pre-programmed waypoints or flying along gridlines for detailed surveying. Typical flight times vary between 15 and 20 minutes.

Figure 2: DJI Phantom multi-copter in use for inspection of landslides along railway 50 km north of Wanganui

The location of the central New Zealand sites highlighted in this paper are shown in Figure 3, with relevant Figure numbers indicated.

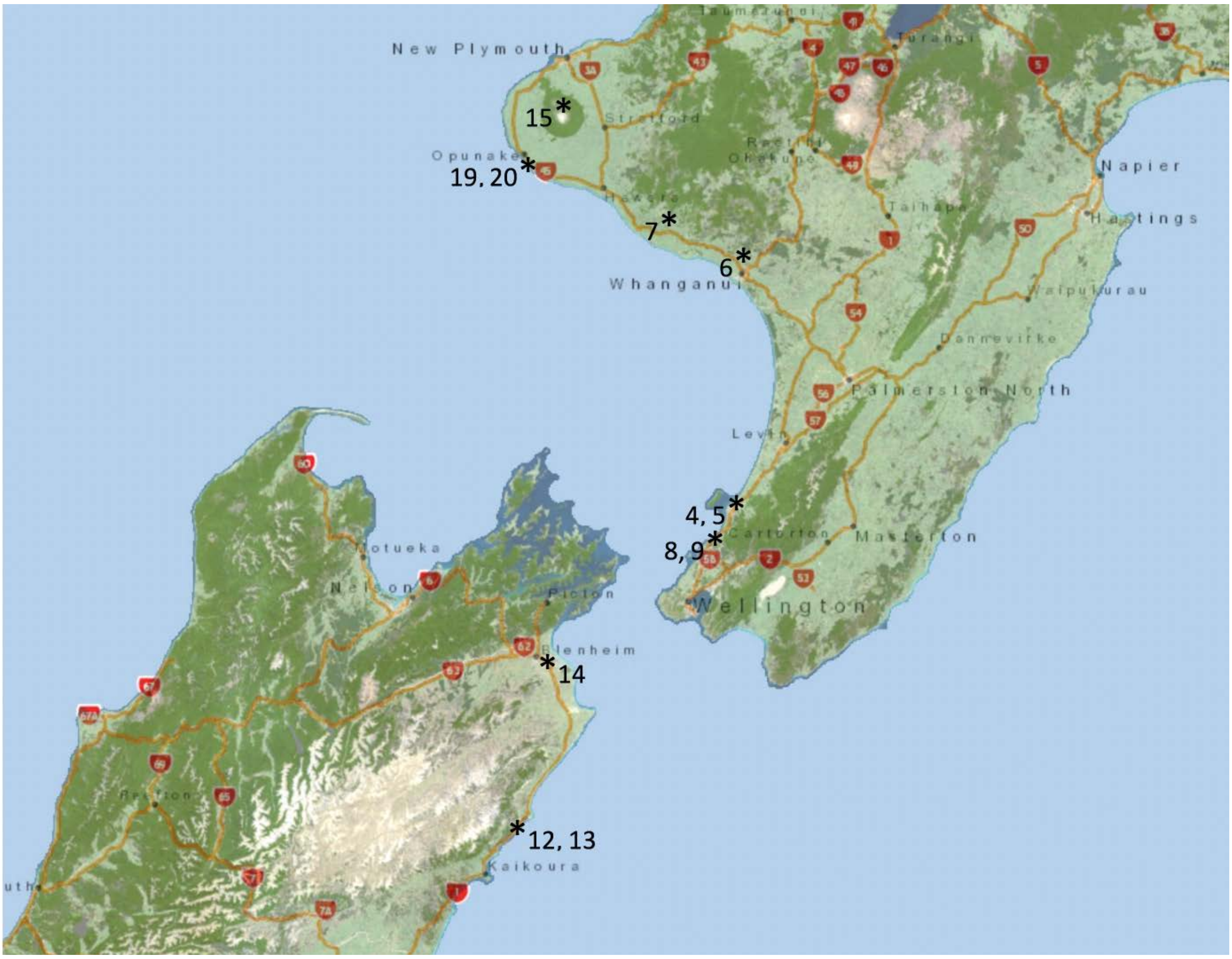

Figure 3: Location map of figures of central New Zealand sites presented in this paper

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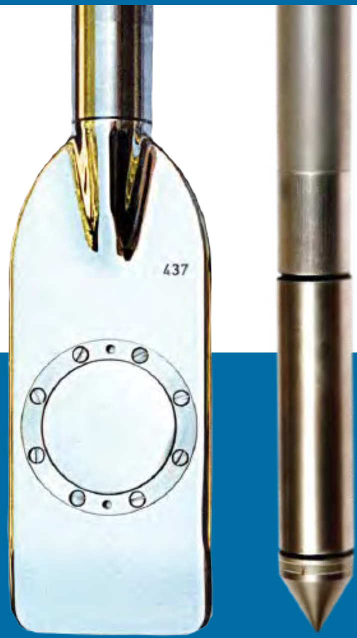

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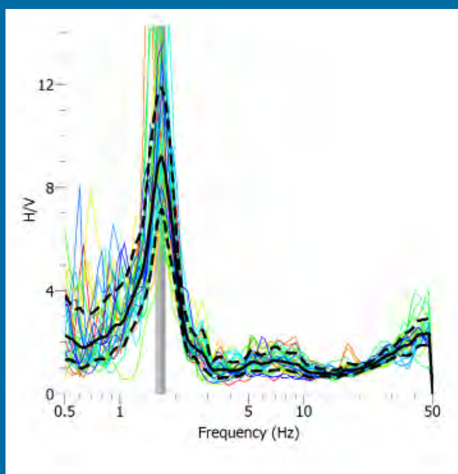

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Main pic - Port Hills, Christchurch; Slope Stabilisation – Frances Hodgkins Home; Dunedin; Rock Anchors – Wainui, Akaroa Harbour; Rockfall Netting & Catch Fences – Westport Water Supply; Design & Build – Anderson Creek Bridge, Old Ghost Trail, Buller.

3. SURVEYING SITES WITH UAVS

We have implemented the use of structure-from-motion (photogrammetric) software in conjunction with our UAV operations. Structure from motion software has revolutionised photogrammetry as it can automatically process imagery acquired by UAV, aircraft or ground based platforms purely on image content. This process enables the conversion of images into precise, customisable digital data for a wide range of applications including for GIS and CAD (Figure 4).

The use of UAVs in conjunction with good survey control has given the ability to easily capture up-to-date site conditions and produce an accurate 3D terrain model that can be compared with subsequent captures. This has enabled:

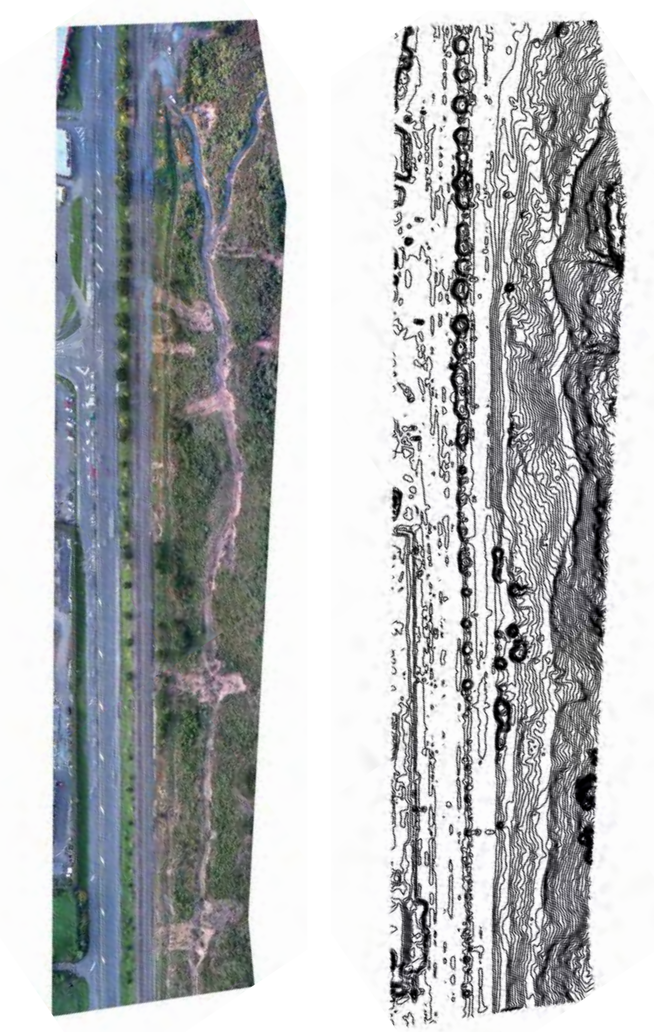

Figure 4: Ortho-mosaic image showing May 2015 debris flows near Paraparaumu (north of Wellington) and corresponding 1 m contour plan of same site, from post-processing UAV imagery

a) The creation of base plans for use by field staff in mapping
b) Assessment of the areas and volumes of earth at affected sites
c) Preparation of cross section and plan outputs for use in the assessment
d) Rapid design of engineered remedial works, and
e) Comparison of 3D model outputs with data from previous flights, for example, for screening for slope changes as shown on Figure 5.

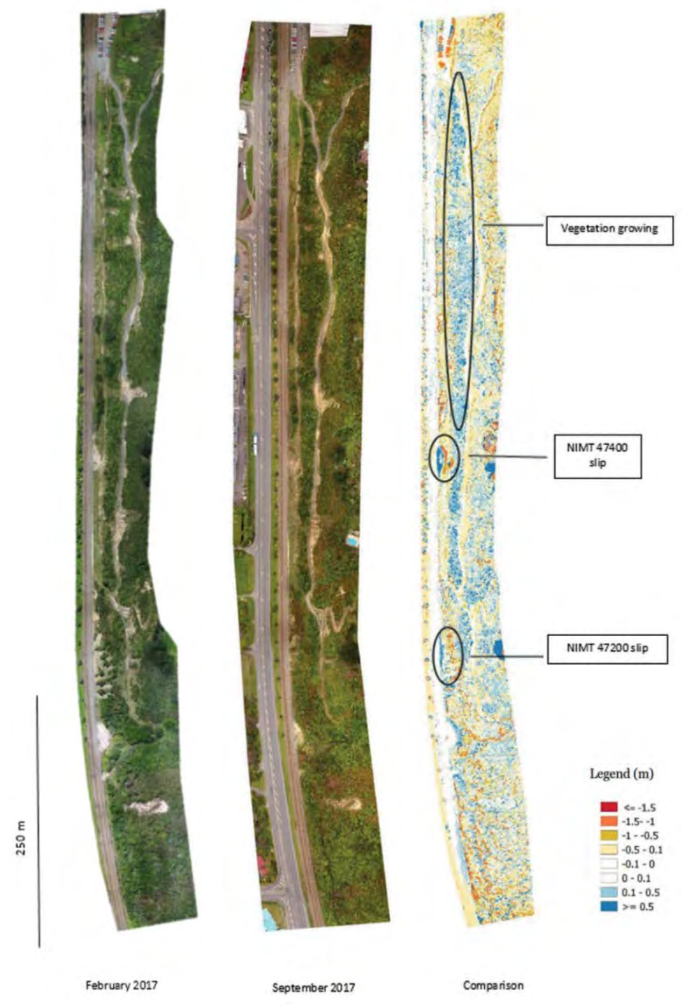

Figure 5: UAV ortho-photos from February 2017 and September 2017 of a 1 km length of slope south of Paraparaumu Station, and a comparison of the two UAV 3D models, with blue indicating an increase in elevation and yellow/red a decrease in elevation. Two known landslide sites are circled, as is an area of growing vegetation.

4 POST STORM EVENT UAV INSPECTIONS

A significant storm event in June 2015 resulted in extensive flooding and land sliding in the Wanganui and Taranaki regions of NZ. Helicopter inspections were used for immediate response by authorities, such as KiwiRail and the Wanganui City Council. UAVs were used in the following weeks to provide data to characterise the extent of damage and to facilitate assessment and design of remedial solutions.

The 4 km long section of railway immediately north of Wanganui known as the Westmere Bank was subject to numerous landslides both above and below the railway line. Due to the long sections of railway to be assessed, a fixed wing UAV (Figure 6 inset) was used to capture imagery of this section and also a 2 km section of damaged Council road. From the photos taken, Ortho-mosaic strips were generated within 24 to 48 hrs of the flight allowing 1:1000 scale base maps to be created and used to enable field reconnaissance and characterisation of the landslides (Figure 6). Landslides and site features were clearly visible on the Ortho-photo base maps which enabled rapid and accurate recording of site damage.

A Phantom multi-copter UAV was used during the reconnaissance to capture imagery at lower altitudes at specific sites within the Westmere Bank and a critical damage site 50 km north of Wanganui. This provided higher resolution ground models and video footage to enable better definition of the extent and nature of slope instability (Figure 7). Production of cross sections from the multi-copter's 3D model(s) aided rapid assessment of the risk to the railway line. The use of the multi-copter UAV enabled more rapid assessment of the condition of the rail corridor to enable decisions to be made about reopening. These included UAV inspection of:

- Steep slopes below the railway line that would otherwise only have been visible by abseil but not safe to access, and
- Extensive unstable areas above the railway line, which enabled clarification of the extent and mode of failure of land sliding.

An earlier storm in May 2015 affected the southern part of the North Island. In parts of the Kapiti Coast, it was the heaviest recorded for more than 50 years, with peak rainfall exceeding monthly averages in a single day.

The Phantom UAV was deployed in the Wanganui

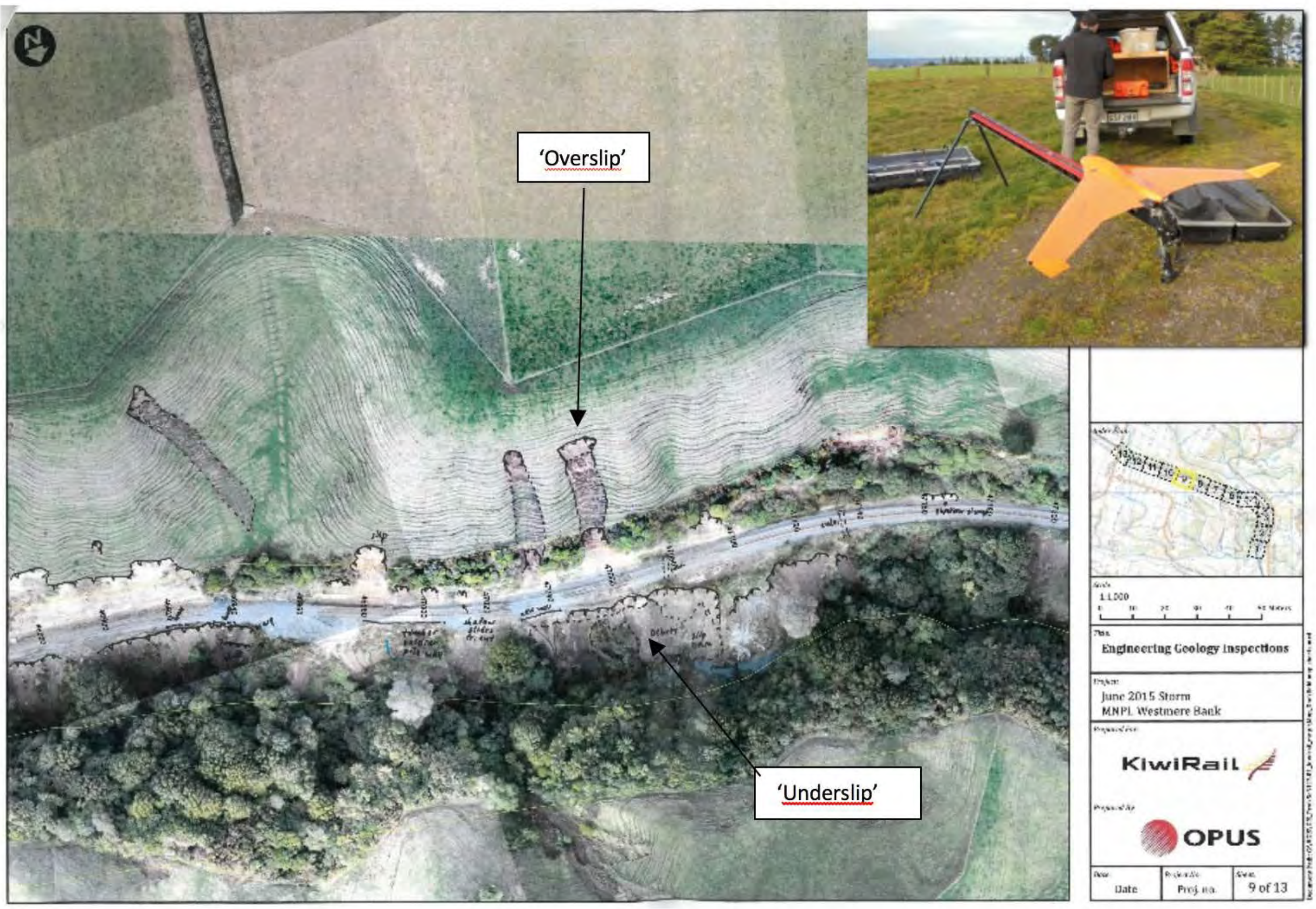

Figure 6: Base map showing 'recent' storm damage, generated from fixed wing survey (Fixed wing UAV shown inset, top right) with geologist's landslide observations drawn / overlaid.

Figure 7: Ortho-photo of slide site generated from multi-copter imagery (launch site is shown in Fig.2 and is located on hazard free flat land at far right)

and Wellington Districts to assist with the assessment of unstable terrain created by the deluge of rain and associated flooding. Two example sites are discussed below.

The Paekakariki coastal road section of State Highway 1 (SH1) and the adjacent North Island Main Trunk (NIMT) railway line, north of Wellington, were closed due to a large debris flow which originated in the steep hills above (Figures 8 and 9). The source and likelihood of further debris flows at the site, were not able to be identified immediately prior to clearance of debris and reopening. Utilising live video feed, the Phantom UAV was flown up the inaccessible stream valleys and successfully identified the source of debris which blocked the rail and road during the storm.

Figure 8: Remnants of a debris flow which came downstream (top) and blocked rail and road. UAV was flown from shore platform (foreground).

5. POST EARTHQUAKE EVENT UAV INSPECTIONS

5.1 CANTERBURY EARTHQUAKES 2010 - 2011

The 2010 Darfield earthquake struck with a magnitude of 7.1 on 4th September 2010. Numerous damaging aftershocks followed, the strongest of which occurred on 22 February 2011 had a magnitude 6.3 (Christchurch earthquake). Because this aftershock was centred very close to Christchurch, it was much more destructive and resulted in the deaths of 185 people. This event had a maximum peak ground acceleration of 2.2g, the largest ever recorded in New Zealand. Liquefaction damage on low lying terrain was widespread and significant areas of rock fall and potential rock fall risk created significant risk to life and property in the Port Hills area of Christchurch. Identification of the extent of damage as soon as possible was a priority, which in the Port Hills area, in particular, was greatly assisted by the use of UAV technology.

5.2 UAV INSPECTIONS, POST FEBRUARY 2011 EARTHQUAKE

Following the February 2011 earthquake, and after considerable consultation with the Emergency Response Management, the 'Easystar' UAV was deployed on the 8th of March to obtain high quality imagery of ground damage on very steep and high bluffs in the Port Hills area of Christchurch. These bluffs were vulnerable to rock fall and landslides, both during the quake and post-quake aftershocks. The 'Easystar' was operated from safe, remote locations and utilised to photograph and identify the various rock fall sources and patterns to help assess the residual rock fall risk to property, roads and personnel working on remedial efforts (refer Figures 10 and 11). The imagery captured was particularly useful for determining safe access routes where site access was deemed risky for access on foot and for abseiling teams. The imagery was shared with a range of organisations involved in post-disaster response for visualisation and forward planning.

Figure 9: Close-up of May 2015 debris flow source enabled: talus and debris undermined by rapidly flowing and swollen stream originating in steep country (right).

Figure 10: 'Easystar' imagery of earthquake effects in the Port Hills, east of Christchurch. Boulder strewn slopes and road damage near Mt. Cavendish Gondola

Figure 11: Cliff line cracking (arrowed) near Sumner Heads east of Christchurch, this area eventually failed in later aftershocks.

Figure 12: Earthquake induced landslide damage to State Highway 1 and the South Island main trunk railway line near Clarence River north of Kaikōura. Ground damage extended to near the centre line along a nearly 500 m long section of SH1 at what became known as "the sand pit" due to the sand substrate at the site

Figure 13: An accurate 3D model of the 'sand pit' site was produced from UAV imagery with survey of ground control points (crosses visible in Figure 12) to allow remedial works options assessment to proceed at an early stage, in advance of receiving new LiDAR data.

5.3 UAV inspections following 2016 Kaikōura Earthquakes

The M 7.8 Kaikōura earthquake of 14 November 2016 caused widespread ground and structural damage in the upper South Island and localised damage also in Wellington in the lower North Island of New Zealand. The main north - south road and rail access routes were severely damaged in the northeast transport corridor of the upper South Island. UAV imagery, in conjunction with survey of ground control points, allowed rapid production of 3D models and orthophotos to document the actual positions of tension cracks and other ground damage (Figure 12). In particular they provided valuable early documentation of damage at a number of sites prior to evidence being removed.

Though comprehensive aerial LiDAR survey was subsequently carried out to provide a topographic survey to allow engineering assessments and remedial works design to proceed, because it took some time to procure the LiDAR data UAVs proved very useful for providing rapid documentation to allow response and geotechnical assessment (Figure 13).

Capturing UAV imagery along the banks of rivers affected by lateral spreading allowed rapid documentation of the location of tension cracks and liquefaction ejecta, prior to these being obscured or repaired (Figure 14). This allowed the development of remedial measures to upgrade the damaged stop banks.

Figure 14: UAV capture of tension cracks resulting from lateral spreading of river bank slopes toward the Taylor River in Blenheim, in response to liquefaction induced from the 14 November 2016 Kaikōura Earthquake. Survey control cross just visible (circled) between track and river at top of photo

6. ROCK FACE STRUCTURAL DATA FROM UAV SURVEYS

In addition to being able to remotely carry out inspections using UAVs, the 3D models generated from UAVs can be much more comprehensive than from other sources due to the ability to 'sight the site' from multiple perspectives. The 3D models generated have been used to obtain rock defect (or facet discontinuity) orientations through software packages manually or automatically. This gives the potential for a much more comprehensive assessment of a site than would typically be possible from a site visit. Notwithstanding this, checks are required to validate the data, typically involving independent checks of defect orientations on site.

6.1 Mt Taranaki Rockfall

A rain induced rockfall of about 500 m^3 buried the popular Mt Taranaki round the mountain walking track in February 2018. Detailed inspection of the rockfall source area was carried out using a UAV from a safe distance (Figure 15 left) with more detailed assessment carried out in the office using 3D mesh and point cloud models. The point cloud model enabled remote mapping of rock defect orientations using automatic facet picking (Figure 15 right), as well as manual measurements of facet orientations using different software. In this case the main defects controlling the stability of this rock face are the overhanging (purple) joints (providing a toppling mechanism), in conjunction with moderate angled outward dipping (green) joints providing a planar failure release.

6.2 Rock Cut Stability Assessment In Blue Mountains, NSW

A multi-copter UAV was used to obtain data to assess the stability of a rock cut at a New South Wales rail tunnel portal (Figure 16). The site was dominated by a large, near vertical, approximately 15 m high rock exposure above and behind a tunnel portal. A rock block on the main exposure appeared to be free-standing and separated from the main

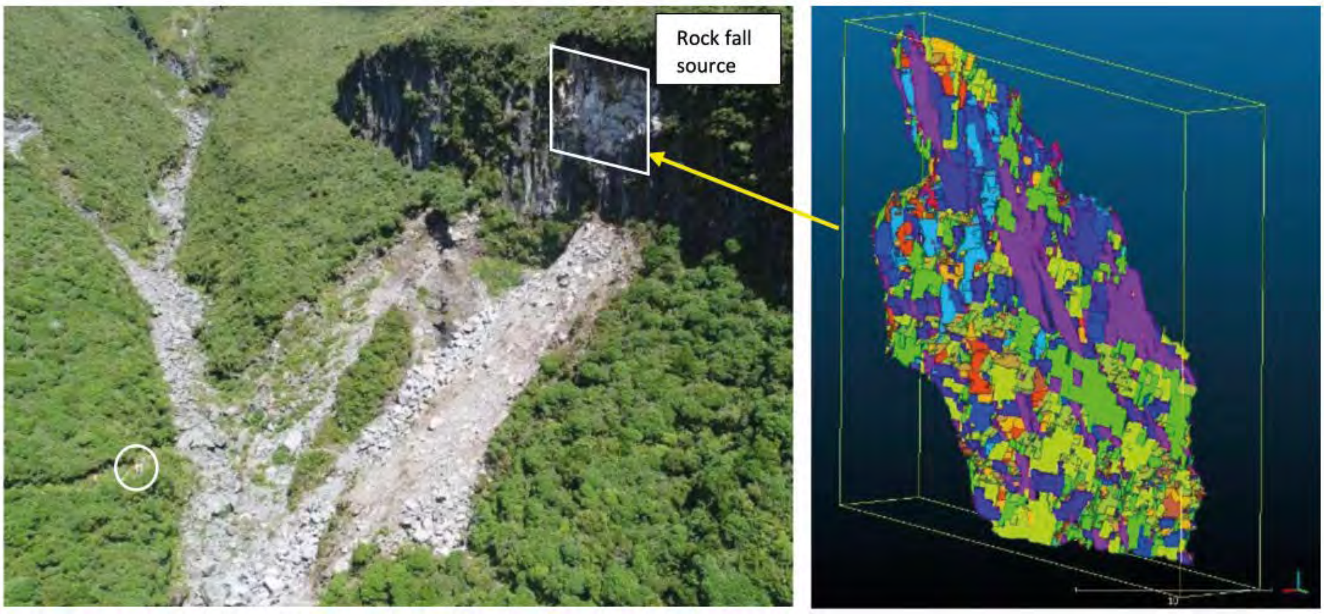

Figure 15: UAV image of rockfall site on Mt Taranaki walking track, with UAV pilot visible (circled) just to left of stream bed. Rockfall source area is white area near top of 50 m high vertical lava bluff (left). Cloud Compare facet analysis of point cloud data for the 30 m wide and 20 m high source area is shown at right, with facets (defect) sets colour coded by orientation.

Figure 16: General site layout labelling features (left), focused image on main instability concern positioned above tunnel portal (right)

rock exposure by a continuous sub-vertical stress relief joint. The block was previously supported by an anchored concrete buttress, however, its stability was of concern. Safe access to the site posed a number of challenges due to the potential instability, working at height concerns (cliffs), heritage-significant structures and overhead wiring. Use of a drone provided not only a greater level of access to the entire rock cut exposure, but a safer and more cost-effective alternative to rope access. Manual collection of discontinuity data was performed in areas with safer access to compare with the data obtained by the drone.

A number of survey reference points were placed on each rock exposure before capturing high-resolution geo-referenced images with the UAV. Due to the large quantity of data and images that became available through this method, the rock exposures at the site had to be divided into a number of sub-groups for processing. Subsequently, they were then combined into a single point cloud and a high-resolution 3D rendering of the site (Figure 17). The 3D model fed into a user-led and algorithmic assessment, with aid from software 3DM Analyst Suite (by Adam Technology). The assessment involved the identification and marking of rock face discontinuities and planes, then represented them by oriented coloured disks (Figure 18). Disc data, consisting of discontinuity assignment group, orientation, dip, persistence and additionally assigned geotechnical properties were then stereographically represented. This allowed for a kinematic analysis of failure mechanisms and the development of stabilisation measures. The data obtained from conventional rock-face mapping methods obtained from more accessible areas showed strong correlation with the drone obtained data.

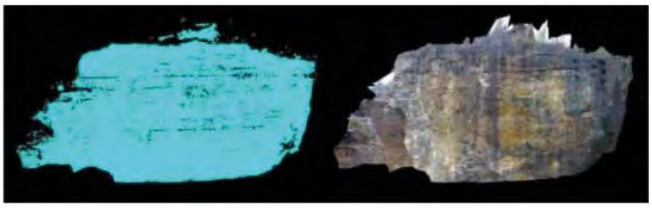

Figure 17: Example point cloud (left) and corresponding geo-referenced image overlay, isolating the exposure above the portal (using 1 of 9 sub-groups)

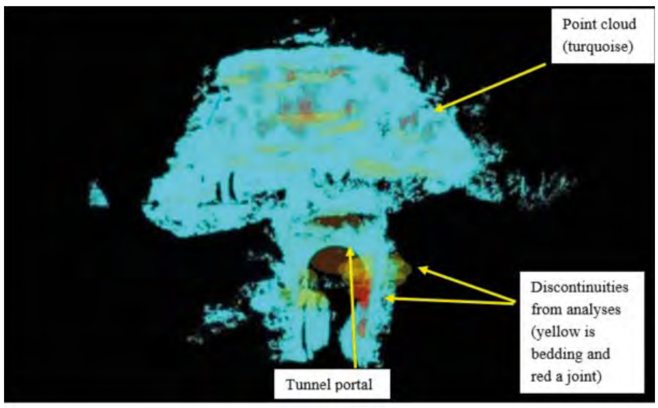

Figure 18: 3D Point Cloud with Mapping Planes. Turquoise surface formed by points with yellow and red disks representing some observed discontinuity planes. Tunnel 3 portal is visible in the middle at the bottom of image.

In areas where vegetation, lighting and overhead wiring restricted image and point cloud quality, the drone was still able to capture rock features and image angles not visible from the ground. This approach was 'safer' than rope access methods. The nature of the digital data also allowed for an increased review of data and a higher level of input from field staff and more senior professionals.

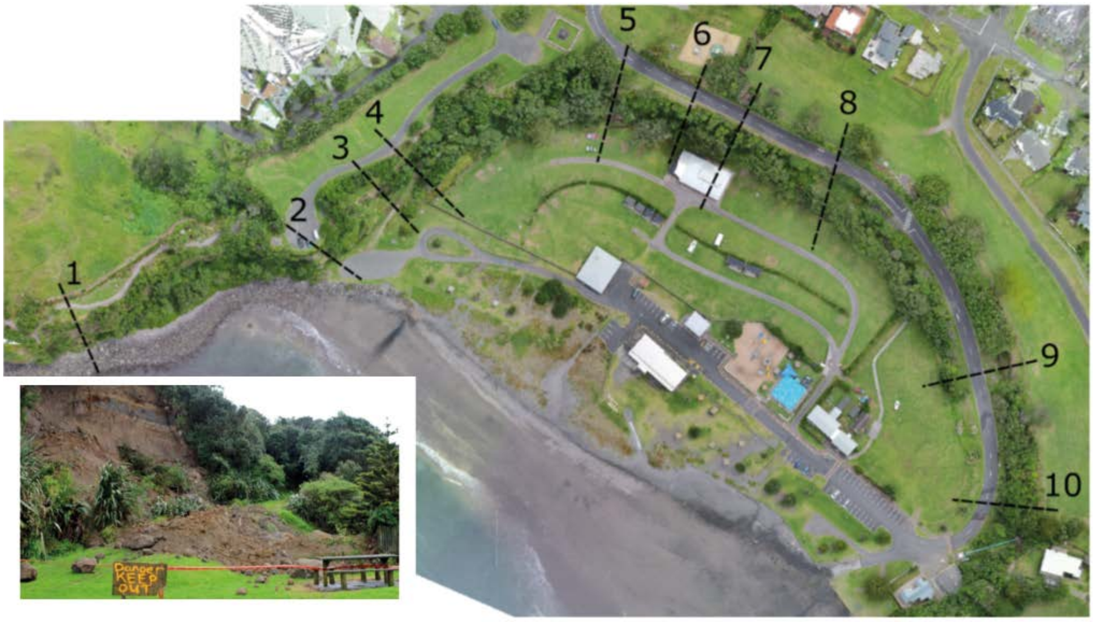

Figure 19: Ortho-photo base map of Opunake Holiday Park from UAV imagery, showing locations of cliff cross sections generated to assess different sectors of the site. 2015 landslide (inset photo) occurred on cross section 3.

7. RISK ASSESSMENT FOR CLIFFS IN CAMPING GROUND

An example of the effectiveness of assessing a larger site is illustrated in the assessment of cliff stability risks for the Opunake Holiday Park in Taranaki. The site has a history of rock fall and landslide events affecting the facilities (Figure 19 inset). In order to facilitate the assessment, UAV imagery was captured with survey control placed around the site to enable an accurate 3D model which allowed preparation of an accurate basemap (Figure 19) and cross sections at strategic locations (Figure 20). While the 3D model does not have full ground coverage due to the vegetated escarpment, ground coverage has been maximised by obtaining UAV shots at varying angles. Interpolation of ground levels was made manually on some profiles in areas where the ground was not visible in the model (Figure 20). The various outputs allowed a robust and rapid assessment of site characteristics and visually demonstrated clearly the options available for the local council to manage the risks.

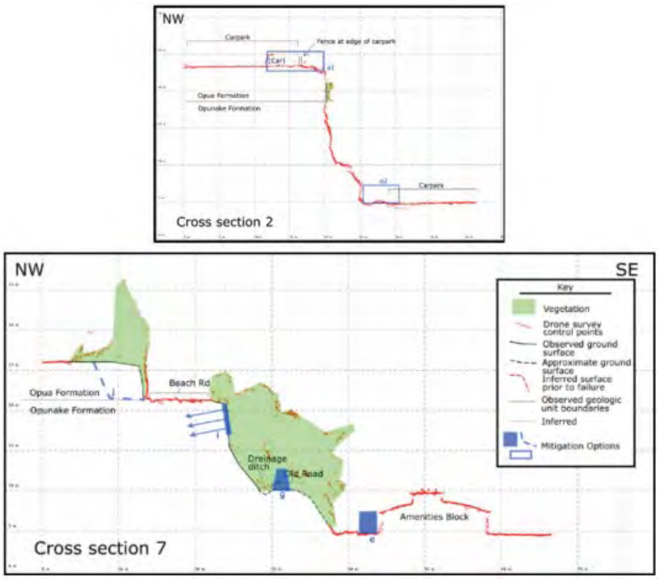

Figure 20: Cross section 2 highlights the hazard areas at carpark areas above and below an 18m high cliff and cross section 7 shows the main access road and amenities building, showing risk mitigation options to reduce risks from slope failures, including cutback, anchoring and barriers.

8. CERTIFICATION FOR UAV PILOTS

UAV operators have a duty of care to the public and the owners of the land and facilities they fly over, and hence are required to be operated safely in gathering site data. UAV rules in Australia and New Zealand do differ. In New Zealand, prior to 1 August 2015, skilled but essentially untrained operators were able to use UAVs in many applications within public airspace (operating under the old Civil Aviation Authority (CAA) model aircraft Part 101 rules). More stringent CAA regulations introduced at that date require operators to gain permission from property owners and all people beneath the intended UAV flightpath prior to operating. Many authorities in New Zealand now require UAV operators to be certified under the new Part 102 rules, as the new default 'minimum standard' for UAV operations.

In Australia, the options through CASA are a lightweight UAV license which provides limited scope, or a full professional licence which provides greater freedom (in line with what a helicopter operator would have) than the New Zealand CAA Part 102 certification. At this stage licenses are not transferable from one country to the other.

9. DISCUSSION ON THE USE OF UAVS FOR SITE ASSESSMENT AND RESPONSE

Low cost UAVs can provide invaluable information on otherwise inaccessible sites. The appropriate use of UAVs and robotic vehicles can provide major benefits in terms of safety of field staff, and due to their small size and typically short inspection duration usually have negligible impact on immediate (emergency) response operations and subsequent operation of the facility (e.g. road).

While UAVs can provide near instantaneous coverage of the effects of a natural hazard event site, ironically sometimes it has taken days or in some cases weeks to convince authorities to understand and adopt the use of this technology. This illustrates the importance of pre-planning to ensure that authorities are aware of the full capabilities and benefits of the UAV based data capture, and the safety measures that are in place. This will enable more effective use of the UAV technology to assist with assessment and event response.

In terms of choosing appropriate UAV technology, the following comments are provided:

Fixed wing UAVs typically cover larger areas and therefore, require fewer launch areas and shorter field time than Multi-rotor UAVs, but have a disadvantage in that they require large open spaces for landing/recovery.

Multi-rotor UAVs are able to be held stationary and are ideal for close-up inspections of key features e.g. using high definition video or high density photography for production of detailed 3D models. Because of their small size, we have found that the DJI Phantom UAVs lend themselves very well to inspections adjacent to live highways, providing suitable precautions are taken to minimise driver distraction while working at quite close quarters.

Systematic photography of a site enables subsequent production of 3D models. The 3D models facilitate rapid production of survey quality base map plans and cross sections, which can be used to quickly assess current conditions and associated risks. Survey control can be either inbuilt within the UAV (e.g. RTK GPS) or introduced by way of independently surveyed control points that are visible within the images. 3D model fly-through visualisations also provide a very useful tool to allow decision makers to understand the extent of damage and other constraints at the site (e.g. proximity of overhead services).

One significant current challenge for the photogrammetry based modelling used is that it picks up the vegetation canopy rather than the ground surface, with the more costly LiDAR based system typically much better at penetrating through to the ground surface.

In some cases, the UAV operator needs to be chosen for the specific task. In many cases a UAV operator specialising in a particular discipline e.g. geotechnical or structural engineering can expedite and optimise the data collection, by focussing on the key elements of potential concern. To expedite the value of the UAV outputs, these can be made available on a shared server or website. Plan / drawing outputs should be clearly labelled with a statement of accuracy/disclaimer to prevent subsequent inappropriate use.

11. CONCLUSION

UAV technology has been increasingly used for site assessments including natural hazard event assessments by the authors, and the case studies presented illustrate the value of this tool. The use of UAV technology greatly helps facilitate the rapid collection of data for subsequent processing, and use for assessment and monitoring. Collection and the rapid dissemination of imagery and accurate base maps generated from 3D models typically can expedite event response. Subsequent repeat UAV imagery collection at sites of interest can be used to accurately determine the site changes that have occurred over time, particularly if accurate survey control is incorporated, e.g. from land movement or from site earthworks activities. The use of UAVs has revolutionised the inspection, survey and assessment of slope instability, particularly after severe storm events and earthquakes. The potential value of UAV technology and software applications for UAVs for geotechnical applications is expected to continue to increase rapidly, in parallel with the rapid development of supporting technologies. Such applications are expected to rapidly enhance the value of digital engineering in geotechnical engineering practice.

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Three dimensional geological models in ground engineering: when to use, how to build and review, benefits and potential pitfalls

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Camilla Gibbons

Camilla Gibbons is an Associate in Aurecon's Christchurch office. She is an engineering geologist specialising in the mitigation of geohazards, landslides and rockfall. She has a passion for developing new digital solutions to current manual geological fieldwork and data management.

Adam Lander

Through work on major infrastructure projects throughout Australia, Ad-am has developed an interest in identifying and effectively communi-cating the key aspects of ground models and ground behaviour to the project team. He recently led the geotechnical discipline for the West Gate Tunnel Project and now runs the Melbourne office of specialist ge-otechnical consultant EDG Consulting.

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ABSTRACT

Three dimensional geological models are increasingly being used to characterise the world of ground engineering. Soil, rock, geological structures such as faults, rock fall zones and slips are often best examined in 3D. In addition, geomorphology of materials above, below or surrounding project sites must be well understood by design and construction teams to optimise both safety and costs. This is especially true for large, complex or unsafe sites or for forensic investigations in both terrestrial and offshore settings. As we shift away from a 2D (long sections, cross sections and design software programs) way of working to a fully 3D system of design it is important to follow suit with site characterisation tools. There are many advantages to thinking and working in 3D as well as some serious pitfalls when using such models. Models must always make sense geologically and geomorphologically and preferably be reviewed by a geologist/engineer team. The geologist does not necessarily have to be a specialist engineering geologist, they could be a pure geologist but one who can thoroughly and clearly explain all issues and features to the engineering team. Models described herein are geological models first and foremost with an emphasis on being geologically and geomorphologically accurate. The modelling process introduces the engineering aspects once the geology is well understood. These models must always be used with a degree of caution and updated with new information from all sources such as pile excavation records, new drilling, earthworks changes mapping of faces in tunnels and excavations. Those who construct models must always assess confidence levels in the end-product and communicate that level of confidence or areas of ambiguity to all users.

3D Geological models are more suitable for large projects or projects that have potentially complex ground or hazardous site conditions. Examples of suitable types of project include; tunnels, deep excavations, large slopes, landslide remediation, involving soft/hard ground interfaces, areas with structural complexity such as folds or faults, slips and rock fall etc. In addition, forensic investigations may be enhanced by the application of 3D models.

1. INTRODUCTION

Digital geotechnics is developing rapidly in many different applications and forms. Much of the development appears to be heading towards a Virtual Reality (VR) output or end use. This paper explores 3 types of application for 3D geological models including photogrammetry and laser scanning, pure 3D geological and engineering geological models for large infrastructure projects and models in VR using case studies from recent investigations. There are several publications such as Parry et al (2014) (Engineering geological Models: an introduction IAEG commission 25), Stapleton (1982) (subsurface engineering-in a search of a rational approach) and Knill (2003) Core values: the first Hans Cloos Lecture that explore the merits of geological models that discuss issues relating to geological and engineering properties. According to Parry et al (2014), the definition of an engineering geology model is "An approximation of reality created for the purpose of solving a problem". Both Knill (2003) and Fookes (1997) described engineering geological models as more than purely geological in nature and describe pure geological models as either "Inadequate" or needing to be "More than simply geology that is useful for engineers". The authors of this paper broadly concur with this conclusion with the proviso that first and foremost the geological correctness of the model is established as the guiding principle. Once the geology is reviewed and assessed as being as close as possible to reality using the available data overprinted with geological doctrines then the last stage in the 3D modelling process can be accomplished. Finally, the introduction of engineering properties into the model can be carried out to complete the process.

The geologist/engineer partnership in this process is critical to achieving success within the project in terms of design and eventual construction. Baynes et al (2005) described two types of model:

1.) The conceptual approach which is not related to 3D space or time and is built up using what might be anticipated in an area by using geological maps, local knowledge and experience.
2.) The Observational approach which is based on the observed and measured distribution of engineering geological units and processes.

Occasionally, geological conceptual models are not used well in the planning phases of investigations and models have to make do with the drilling patterns that are set out without much regard for underlying geology. Most of the models described herein have conceptual and observational elements in that they are built using drilling and mapping data collected first during site investigations. 3D modelling software packages such as Leapfrog are designed by engineers and geologists and rely on algorithms within the software package. The model may require 'assistance' from a reviewer (usually a geologist at this stage) using geological and local knowledge to produce correct geological shapes and distributions of soils and rock. Occasionally patterns and shapes that are not possible in nature can be created by modelling software. An example of this experience is where a basalt flow would have to move upslope during deposition prior to cooling and solidification (which is not possible). Above all 3D geological models must evolve and be updated when new information comes to hand. Any change must make sense geologically.

Examples used herein include: one from Christchurch from a site that had severe access and safety issues, selected projects in Melbourne, Auckland and Queensland containing complex geology. In addition, examples of VR applications from projects in NSW and Christchurch are also presented. The VR aspect allows geotechnical specialists to showcase the extent to which 3D imagery and models can be used to aid design, assist with helping all designers, not just the geotechnical specialists to understand their project or site. Importantly, this approach allows the client to see the project at a scale and in a way that is enlightening.

2. WHEN TO USE A THREE DIMENSION GEOLOGICAL MODEL

Whilst many projects can be enhanced using 3D geotechnics, not all are suitable and may not require use of this technology. Below is a guide to assist where and when these applications may be best used or not as the case may be.

2.1 Potential Projects More Suitable For 3D Geological Model Use

1. Where sites contain geological complexity that cannot be adequately represented on 2D sections
2. Specific areas where complexity and risk are high, however geological processes must be recognised and understood
3. On forensic projects where a tight drilling pattern is needed to help identify issues

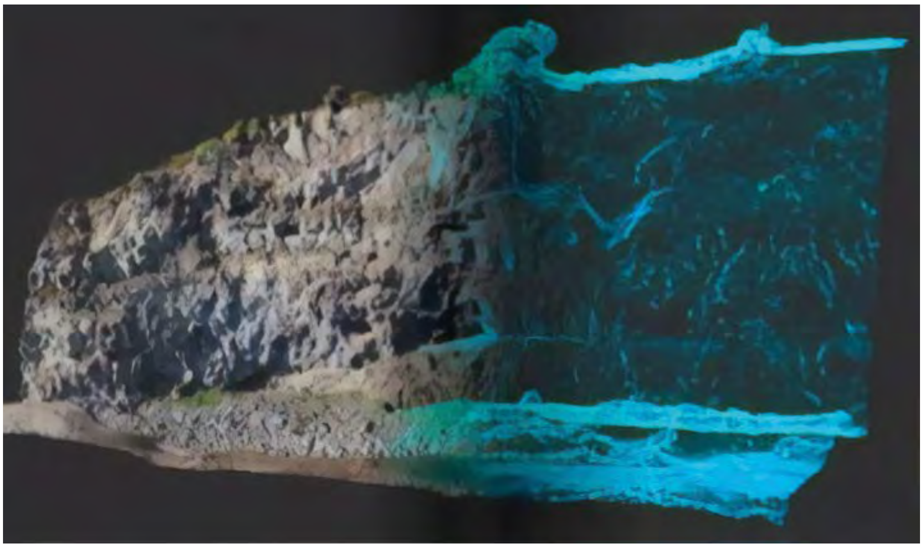

Figure 1: Combined photogrammetry and laser scan model (left) transitioning to the laser scan model only (right)

4. There is sufficient drilling density and other data (seismic, topographical etc) to build a meaningful model
5. The effects of geomorphology and depositional patterns if recent depositional processes need to be well defined
6. Projects where the works methodology will vary with the ground conditions such as dredging in mainly soft ground with potential for the presence of hard rock or dense materials such as gravels

2.2 Potential Projects Less Suitable for 3D Geological Model use

1. Where sites are geologically simple, i.e. contain a single uniform layer
2. Specific areas where complexity and risk are low and ground conditions very well understood
3. When there is insufficient drilling density and other data (seismic, topographical etc) to build a meaningful model
4. In projects that may be faulted or contain slip surface and there is not a good understanding of the geological processes involved
5. Projects where the works are not sensitive to the ground conditions

3. 3D Model Types How to Build and Review

3.1 Photogrammetry and laser scan Models

With the increasing availability of affordable Unmanned Aerial Vehicles (UAV / drones) on the market, there is a huge opportunity to use them for engineering projects. Drones can be used to “visit” places otherwise not easily accessible or inherently unsafe on foot and can in many cases be used to undertake inspections of cliff faces without the need for scaffolding or roped access. The key limitation being that one can only see the rock without being able to touch it, but often this may not be that important. Photogrammetry techniques enable accurate 3D digital models to be developed from the photographs taken from UAVs. The process uses readily available commercial software and when combined with traditional survey or laser scanning data, the models can be just as accurate as traditional survey techniques but with far more detailed coverage, see Figure 1.

The principal enemy of photogrammetry for use in slope stability applications is vegetation, however with the increasing ability of artificial intelligence, already standard photogrammetry software is including tools to automatically identify isolated objects within the models to aid in “cleaning-up” models. For slopes with limited

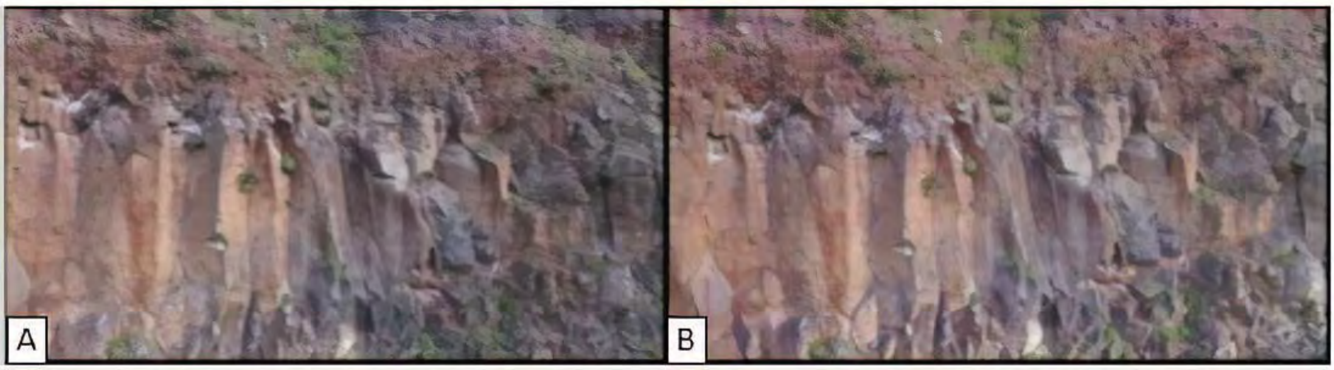

Figure 2: Comparison of a real photograph (A) and a screenshot of the photogrammetry model (B)

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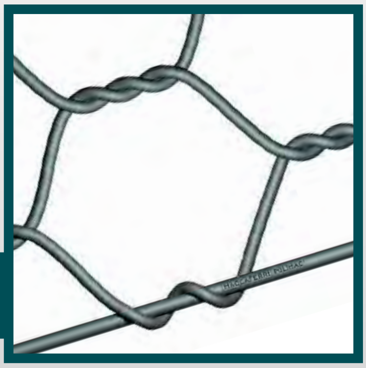

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Figure 3: 2D rockfall analyses undertaken on cross sections re-imported back into the 3D environment

vegetation however, the quality of the data is nearly indistinguishable from a real image of the site, see Figure 2.

Models comprise a point cloud where each point has its own x,y,z coordinate. Recent models have a point every 3mm across a site that is hundreds of metres in size. This level of detail is often unnecessary for some applications, however for engineering geological applications the data can be incredibly valuable. Currently, slope stability models are typically undertaken on an assumed profile, or perhaps a detailed cross section may comprise a surveyed point every 500mm but this is only undertaken by providing the surveyors with a specified line to measure. If a more critical section is discovered later then ideally the survey crew should be sent out to site again to measure the new section. A photogrammetry or laser scan model negates this requirement, providing an accurate model across the entire site and if a new cross section is required then it is a case of simply extracting the data from the 3D model. This technique has been used to extract very accurate cross sections of a cliff on which to then run 2D rockfall analyses. The results of the 2D analyses can then be brought back into the 3D environment. An example of this is presented in Figure 3 below, the rockfall modelling was used to manage health and safety on a seismically active site in Christchurch, New Zealand.

3.2 3D Geology Models in Large Infrastructure Projects

3.2.1 City Rail Link (CRL): Auckland, New Zealand

The project comprises twin 3.5km long rail tunnels linking the CBD's Britomart terminus with the Mt Eden Station.

Located in the heart of the CBD, there is abundant historic ground investigation data in the project corridor. Project-specific geotechnical investigations have largely followed a traditional site investigation philosophy with preliminary investigations (Stage 1), a large main investigation (Stage 2), supplementary investigations (Stages 3 and 4) targeting specific ground risks or design changes and tenderers requests (Stage 5). Figure 4 below depicts the traditional 2D section approach to tunnel investigations and design.

The main lithology for the project will be the relatively benign East Coast Bays Formation (Miocene sedimentary rock). There is, however, significant complexity and geotechnical risk principally at the north and south portal areas due to deep weathering profiles, Pleistocene geomorphology, local Quaternary volcanism and soft Holocene marine sediments. Risks from natural ground are compounded by potential clashes with the existing built environment and limited access to some areas of the site (i.e. with consequent difficulties obtaining additional drilling investigations).

Early work on the ground models for the project were by traditional borehole database with output to CAD or GIS (sections and plans). 3D modelling was initially adopted as a trial (2014) to explore an area of the project with adverse geology interpreted mainly from historical data of varied quality. Leapfrog software was used to construct a 3D model, firstly by using long sections and cross sections placed in 3D within Leapfrog and snapped to the alignment. The model was then constructed using the borehole database and cross checking against the sections. Figure 5 below shows the long section and cross section placement for model checking and refinement.

3D geology modelling has now been fully developed (Figure 6) in three areas of the project where there are specific geotechnical risks and/or design challenges relating to the ground conditions. These areas are at each end of the projects where tunnels or other development is at shallow depth and where ground conditions are most

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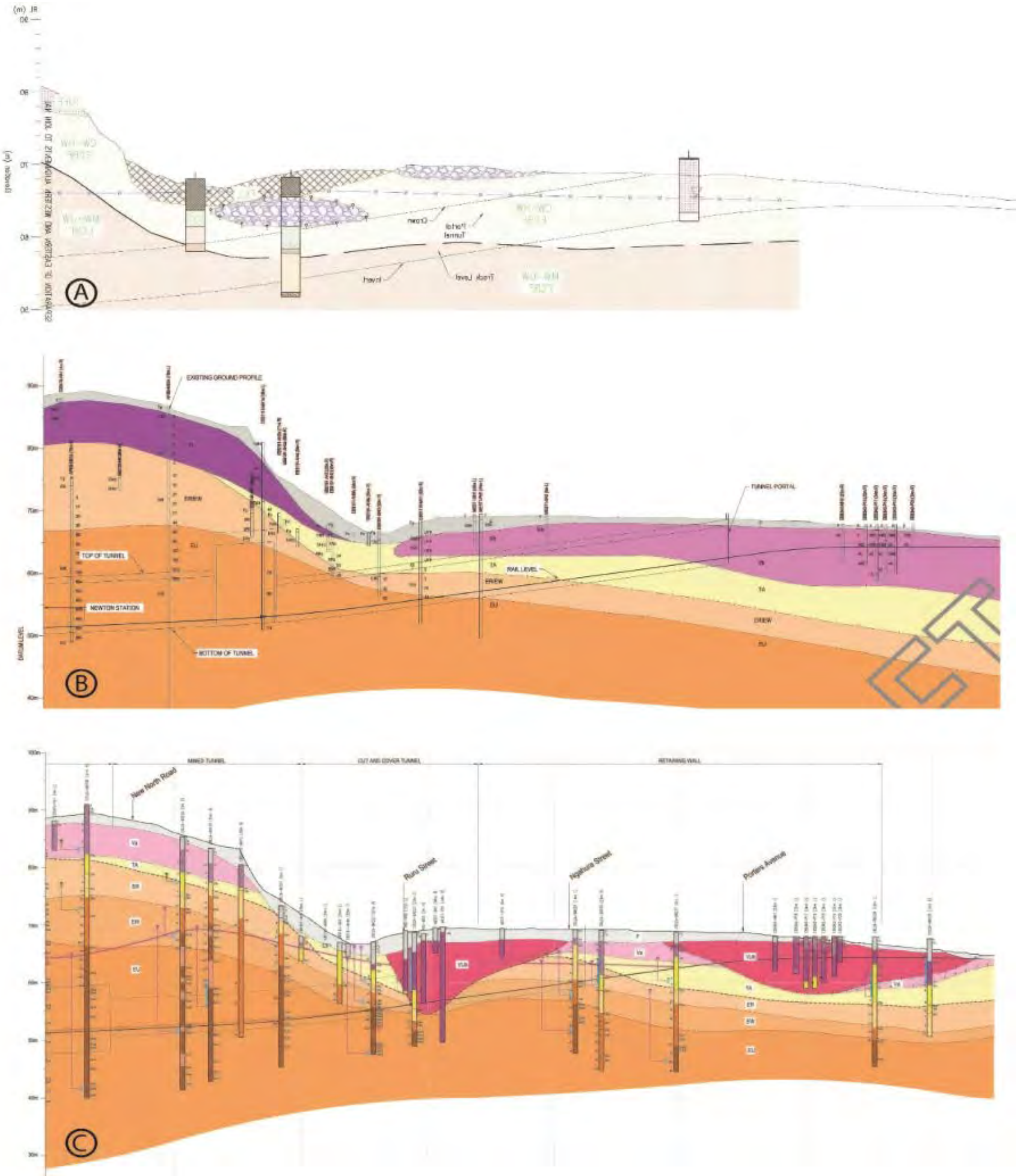


Figure 4: Traditional 2D sections from the early stages of the City Rail Link project showing iterative development of model (as desk-study and early GI data become available), and the implicit 2D 'language' of uncertainty: A) Concept Design inverted to match sections B and C; B) Geotechnical Desk Study; C) Geotechnical Interpretative Report

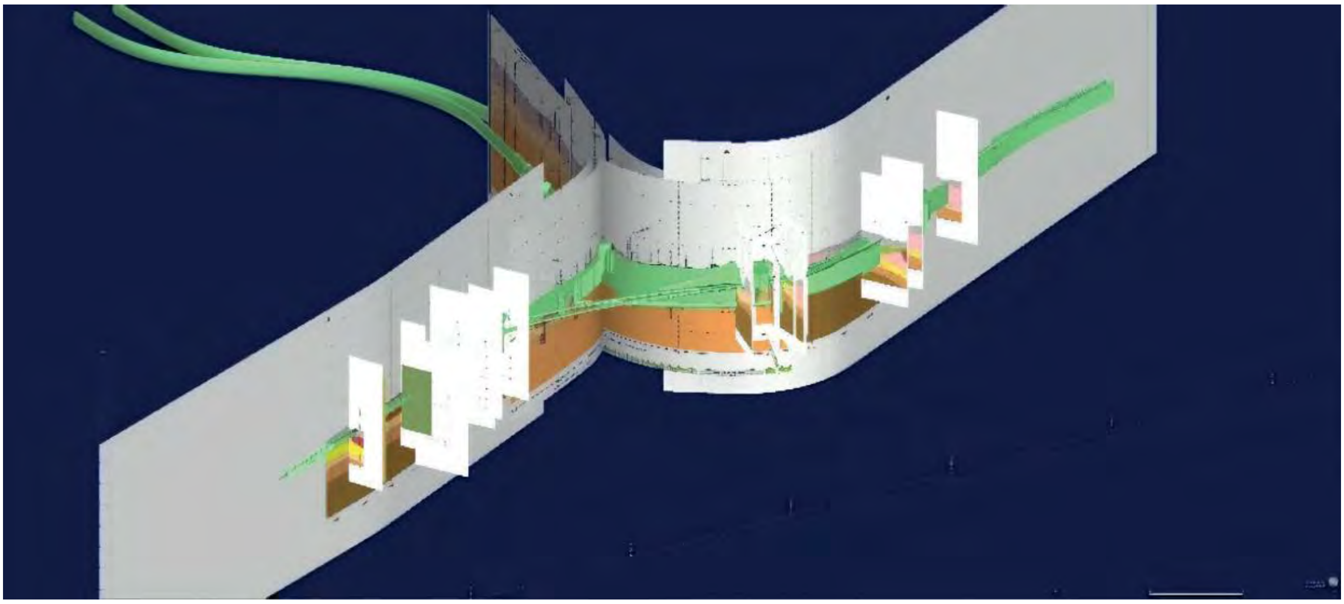
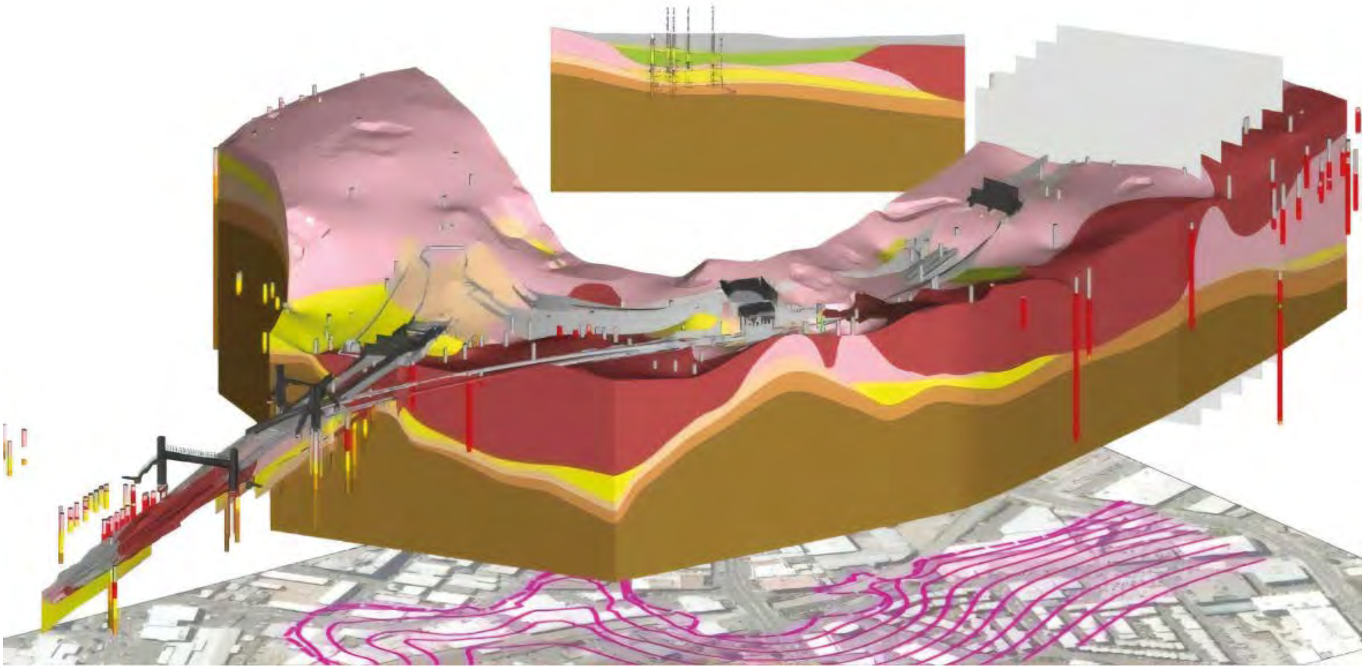


Figure 5: Using long sections and cross sections to build and refine the CRL project. Complex geology and curved alignments challenge the 3D understanding of potential users.



F**igure 6:** Fully developed 3D geological model for the CRL project in Auckland

complex, and at an intermediate station where a faulted band of harder rock posed potential groundwater issues (and provided some opportunities for foundations).

In each case progress of the models is iterative – the process of modelling lends itself to establishing decision points where value of the model can be assessed and benefit of further development assessed. There has been a cautious stepwise approach to 3D model adoption. The earliest model was internal to the client-side support and used to inform risk and design processes. The latest model was issued (for information only) to tenderers for information with the relevant construction contracts. Models are used to support traditional presentation of ground conditions as sections, and contract baselines have used traditional forms.

3.2.2 Westgate Tunnel Project, Melbourne

The West Gate Tunnel Project comprises 2.8km and 4km tunnels beneath Yarraville in Melbourne. The complex geology encountered within the tunnel alignment includes existing fill embankments, Holocene soft clays, Quaternary alluvium and infilled palaeochannels, high strength basalt of the Newer Volcanics, Tertiary clays and sands of the Brighton Group and Newport Formation, deeply weathered basalt of the Older Volcanics and underlying Tertiary clays and lignite of the Werribee Formation, often appearing as interflow deposits within the Older Volcanics.

During the development of engineering solutions, two key features of the 3D geological model became apparent; the infilled palaeochannel beneath the existing freeway near the inbound south portal and the weathering profiles within the Older Volcanics.

The Stony Creek palaeochannel is infilled with Holocene soft clays and is overlain and partially displaced by predominantly coarse, granular fill (gravels and cobbles) placed around 50 years ago as part of the construction of overpass embankments for the West Gate Freeway. The development of the 3D model for the infilled palaeochannel used a combination of the available borehole information (four sections containing moderately spaced boreholes across the palaeochannel), historic aerial photographs of the former creek and drawings for the construction works as there was, quite reasonably, insufficient investigation information to fully delineate the palaeochannel based on interpolation from boreholes alone. Sections cut at 40m centres along the 400m length of palaeochannel were used to develop the 3D geometry of the palaeochannel around the bends of the former creek alignment (Figure 7).

The 3D geological modelling of the weathering within the Older Volcanics presented a different challenge in that the variably weathered material may range from a residual soil to an extremely high strength, fresh basalt over short distances. The uncertainty and ambiguity associated with modelling non-continuous, variable surfaces between sparse borehole information along the tunnel alignment and extrapolation of this away from the tunnel alignment can become difficult to represent in a 3D model.

A beneficial outcome that was observed during the modelling is that the development of the model strongly

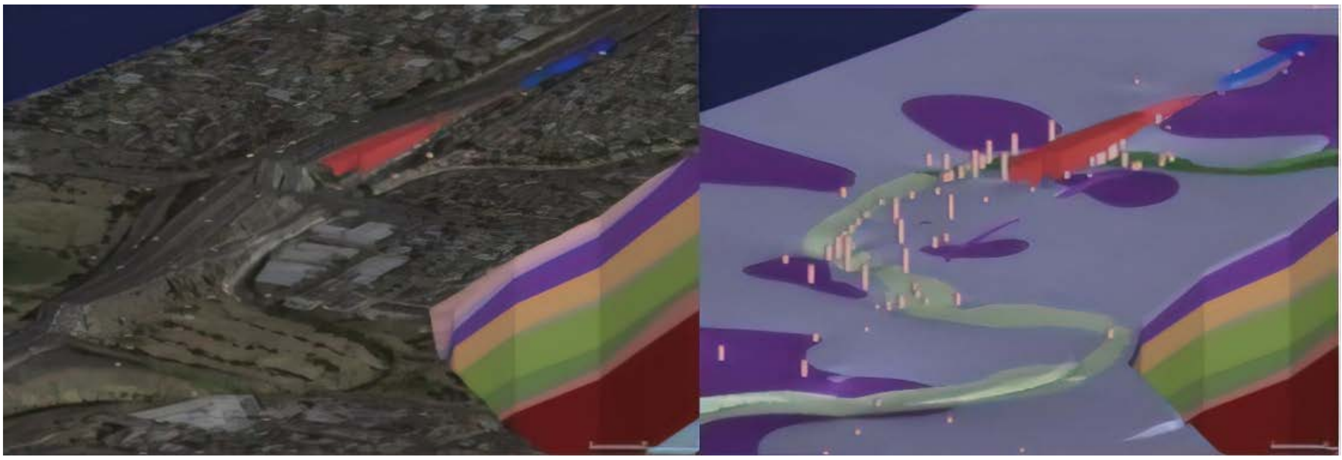


Figure 7: Development of 3D geological model for Stony Creek palaeochannel

encouraged 3D thinking based on 'Geo-logic' and clearly identified gaps in the available information and understanding.

3.2.3 Infrastructure project, Brisbane

An investigation for a section of already constructed infrastructure was undertaken in Brisbane two years ago. A closely spaced drilling pattern of 6 boreholes in an area of 30m by 30m was employed with a cross-hole seismic refraction investigation carried out to look at ground conditions between boreholes and 25m below surface and ground level. Boreholes drilled at 70m apart had originally been completed for the detailed design phase of the project. The area of interest was very small and fell between the original borehole locations. Drilling information from the new and old boreholes was incorporated into a data set that

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Figure 8: Viewing 3D models in Mixed Reality (left) and Virtual reality (right)

was used to construct a 3D model using Leapfrog software. The 3D model allowed the investigation team to interrogate the geology model constructed from borehole data and enhanced by the seismic refraction data from many different angles, views and levels of magnification. An ability to look at this area in detail with a 3D element resulted in a fault with a small throw being identified at the location of the drilling. This fault was unknown and not expected but provided a neat explanation of the ground conditions encountered during the site investigation.

3.3 The use of Virtual Reality and 3D MODELS

VR incorporating 3D geological a model is a powerful way to combine the latest technology into a useful design tool and client visualisation product. Two actual examples of this combination are described below. The first for a project in Christchurch and the second on a roads project in NSW.

3.3.1 Augmented and Virtual Reality used in Christchurch project

3D models clearly have the advantage of enabling design in three dimensions, which is particularly useful for complex projects, however once the model exists, there is the significant additional advantage of being used for consultation with stakeholders. Figure 8 shows an example of a model viewed through the Microsoft HoloLens. This provides a large virtual model that can be "placed" on a table and stakeholders or designers can collaborate, all viewing the same virtual model in three dimensions. The models can also be viewed within a virtual reality environment where they can be marked up for use as site inductions prior to going to site as the example in Figure 8 shows. The ability to have had a virtual site induction prior to going to high risk sites can have a hugely beneficial impact on health and safety, but also can reduce the need for some site visits where the sole purpose is a high-level review of progress.

3.3.2 Virtual Reality used on the Newcastle Inner City Bypass project, NSW

A series of models for Newcastle Inner City Bypass project in NSW were constructed and then combined. Firstly, a 3D fly through and model of the entire project including cuts, embankments, pavements and bridges was constructed for client visualisation. A 3D Leapfrog geology model was then constructed separately for a single cutting area using existing borehole information and exported into an industry standard #D format. At this point the model was brought into the VR model and attributes for each rock unit added. This method allows the user whether that is the designer or the client to walk around the infrastructure. In this case the geology was visible for this cut and could allow subtle design changes to optimise bench location for drainage or batter angle on specific benches where geological features such as coal deposits are known to exist. This is only possible because the user gains an appreciation of all components of the model in 3D. Screen shots from within the VR model are presented below in Figure 9 and Figure 10. These depict the visual output and how a rock unit can be interrogated for geotechnical parameters.

4. BENEFITS AND POTENTIAL PIT FALLS WHEN USING 3D MODELS

4.1 Benefits of 3D Models

4.1.1 Expected benefits of 3D modelling can be quickly realised

1. The software provides an effective work-platform for geologists to explore a wide range of data types (in conjunction with GIS and other data management tools)
2. Although there is an up-front cost to develop an initial model, later model changes are usually quick and the effort to generate sections is reduced (i.e. there are cost savings with parts of the documentation process)

Figure 9: Geology from the 3D model projected onto the design model (note the location of the black coal measure layers)

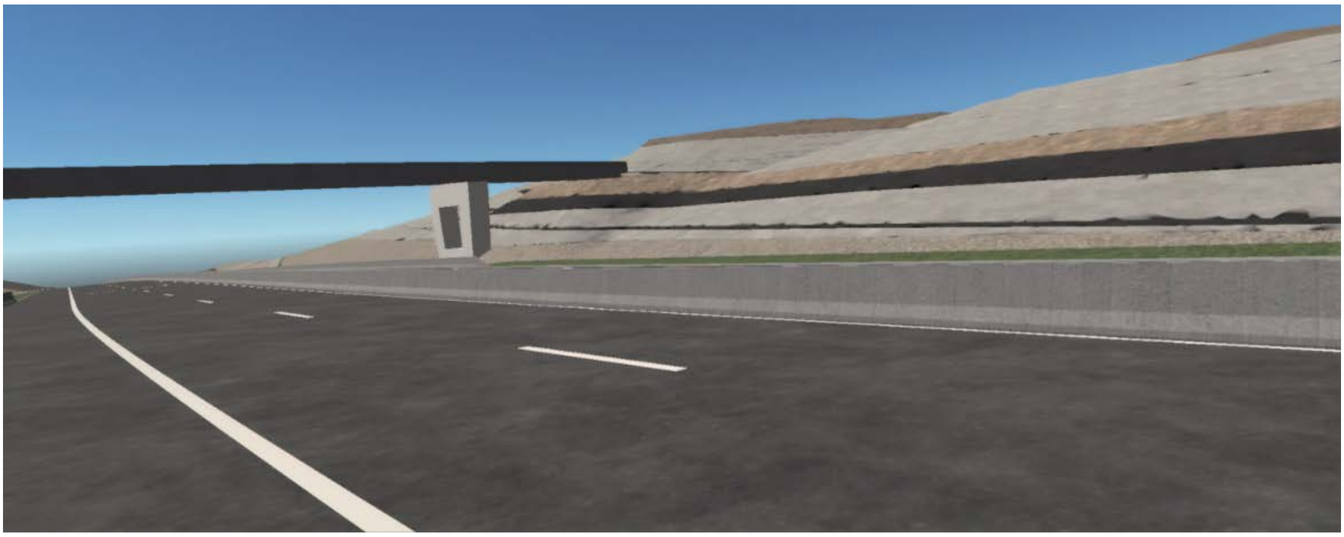

Figure 10: Interrogation of a particular rock unit for name and typical UCS value

3. Communication with designers is significantly improved and where geometry becomes complex and inputs are varied the improvement in the quality of communication can be dramatic
4. Improved communication with clients regarding ground risk, potential requirements (and benefits) of additional GI

4.1.2 Benefits – largely unanticipated when we adopted 3D – can be

1. Synergy across modelling from multiple disciplines – a considerable effort is required to federate models within a project, but the benefits are significant
2. Unexpected visualisations – 'lithology painting' where engineering geology unit symbology is used to colour the outside surface of a modelled structure (existing or in design) is a favourite visualisation and just one of many possible when model interoperability is achieved
3. A wider reach within the project team was achieved, as ground models become available within project models. For example, planning teams quickly appreciated the addition of ground models in the project 3D environment to aid communication with external stakeholders. On CRL, a 3D-illustrated discussion about local streams and volcanoes with local 'tangata whenua' (people of the land) representatives was memorable.
4. On many projects there has been some opportunity to further develop ground models with data obtained during construction. This has been particularly instructive regarding communication of model reliability and uncertainty (see below). The potential benefits of a 'whole of life' ground model can be seen, if not quite realised at present ("BIM for Dirt" as described by a colleague from the Buildings team).
5. Availability of 3D ground models has enabled a wide range of analysis. Hydrogeological analysis is well supported by import/export to the main groundwater modelling packages, and beyond that opportunities to develop a range of applications to extract geometry and properties into other geotechnical applications exist.

4.2 Disadvanatges of 3D ground Models

Adoption of 3D ground models has not been without problems, with the key issues perhaps related to over-enthusiastic use of the models (without referencing associated sections).

Traditional sections provide an interpretation with clear documentation of investigation support (i.e. investigation strip logs with offset distance) and a well-established implicit language around uncertainty (line-style, question marks, and reliability as diagrams or in supporting text, as shown in the CRL case study in Figure 4). In 3D models, there is a coverage of GI positions, but this can easily be separated from interpretations of geometry and/or material properties (most commonly when exporting a model from one software package to another). The 3D interpretations/interpolations themselves have no integrated indication of reliability, and the visual quality of a preliminary model is indistinguishable from that of a fully developed model.

This loss of, or de-emphasis of, indications of uncertainty have led to inappropriate reliance on a surface that may be speculative or is poorly constrained by existing GI. Designers relatively unfamiliar with the process of ground model development may make requests of modellers that carry significant risk (warning requests - "just give me that surface" or "extend the area of the model to .."). The relative ease with which models can be re-generated, re-sampled and re-distributed adds risks concerning model currency, model verification and appropriate design sensitivity to variance from the model.

Works in hand to address risks associated with 3D models include:

1. Integration of reliability information within 3D model data structures
2. Classification of models (or features within models) according to level-of-development
3. Control of model development including versioning and QA control
4. A balance of deterministic modelling and stochastic modelling of uncertainty for critical aspects of the model

CONCLUSIONS

Designing and presenting in three dimensions using 3D geological models is becoming common practice. This powerful tool allows designers, stakeholders and clients to see 'The same thing' in terms of geological and engineering complexity below the ground prior to design and construction.

The modelling process can also play a part in guiding where data in the form of boreholes, mapping etc is targeted. In order to achieve the best outcome in terms of a 3D geological model usefulness users might consider the following process which is similar to the Baynes et al (2005) discussion and the C25 model proposed by Parry et al (2014). This is essentially a three-staged process with hold points for review and is also potentially iterative by returning to the conceptual model phase (Figure 11). Conceptual (Stage 1) and Observational (Stage 2) stages are where the geologist/engineering geologist, assisted by the engineer is seeking out 'truth in geology and geomorphology' or at least the closest possible approximation of the facts. The third stage (Analytical) is where the engineer takes a leading role and is assisted by the geologist/engineering geologist following the introduction of engineering parameters into the model for design and construction purposes.

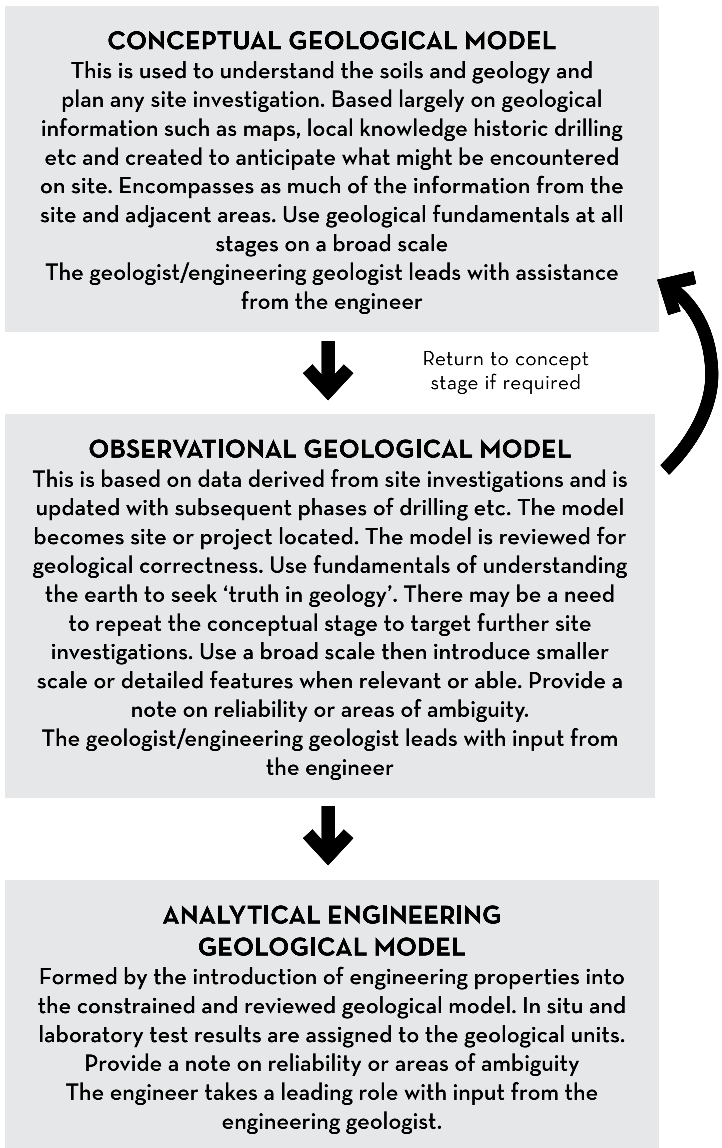

Figure 11: Suggested Geological Modelling process modified after Parry et al (2014)

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There are several different types of model that can be employed today using the above geological modelling process. 3D modelling options include: photogrammetry or laser scanned models of topography for rock fall or slip hazards and 3D geological models for tunnelling, excavations or foundation design. Finally, 3D geological models can now be incorporated infrastructure models and ultimately into VR. Detailed assessment of how geological elements and their engineering parameters might interact with bridge foundations, cut batters and drainage design is now possible on a more granular scale. Caution must be used with these models as there is always an element of ambiguity. Reliability must also be assessed and conveyed to users, designers, stakeholders and clients. This field is a rapidly developing aspect of our industry, requiring some standardisation in the near future.

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Exposure to erionite: health effects and implications for geotechnical risk management in the New Zealand construction sector

INTRODUCTION

Erionite is a naturally occurring "asbestiform" mineral that belongs to a group of silicates called zeolites. It is listed by the International Agency for Research on Cancer (part of the World Health Organization) as a Group 1 known carcinogen (Pacella et al., 2018). Studies have demonstrated that erionite is more carcinogenic than asbestos (Giordani et al., 2017). Erionite exists in two forms: woolly and crystalline (Figure 1). It was first identified, described in deposits from an opal mine in Oregon and named by Eakle (1898). At the time, it was described as having white, wool-like fibres, and was considered extremely rare. Indeed, it was not reported upon again until 1959 when it was identified in crystalline form in Nevada and Wyoming in the USA (Deffeyes 1959). In these cases, the crystals were discovered in vesicles of basaltic lavas, or as microscopic fibrous crystals in diagenetically altered, silicic tuffs, deposited in lacustrine sediments. Here, although the erionite originated from silica-rich volcanic rocks, it was later dissolved and recrystallized as a zeolite, and found in the local sedimentary rocks.

Crystalline erionite, found in sedimentary rocks, crystallizes as needle-like (acicular) fibres of nanometer to micrometer in width, and the disturbance of rocks containing erionite can generate airborne fibres that are similar in dimension to asbestos fibres (Figure 1). This form of erionite has been identified in several parts of New Zealand, but in particular, in the Auckland Region, in rocks of the Waitakere and Waitemata Groups (e.g., Davidson and Black, 1994). It can be identified from rock samples using several different laboratory approaches, including X-ray diffraction (XRD), as well as Raman spectroscopy.

ASBESTIFORMS AND CANCER

Asbestos-related malignant mesothelioma (MM) is of worldwide concern but particularly in New Zealand (Sjoeberg and van Zandwijk, 2015). This is cancer of the thin tissue (mesothelium) that lines the lung, chest wall, and abdomen, and is often caused by asbestos exposure. The highest MM incidence in New Zealand is found in the construction and building trades (Gluckman, 2015). Asbestos-induced MM for both men and women is of increasing concern, in part due to the discovery of the potential transfer of asbestos from the workplace to the home, and the death of relatives of workers who had been exposed to asbestos in the workplace (Glass and Clayson, 2017).

Erionite is highly pathogenic, similar in appearance and properties to asbestos, but from tests on humans and rodents, its toxicity and carcinogenic potential largely exceeds that of asbestos (Matassa et al., 2015). This may be due to erionite being able to accumulate iron on its surface, despite its very small content of this element (Bertino et al., 2007), as well as its in vivo durability, respirable size, and very high surface area. Thus, the inhalation of erionite has been shown to be correlated with diseases similar to those known to result from exposure to asbestos.

In the 1970s, it was realised that residents of three villages in the Cappadocia Region of Turkey had epidemic-level rates of MM caused by erionite exposure; and in one of the villages, the mortality was 52%. The cause of the mesotheliomas in the area was determined

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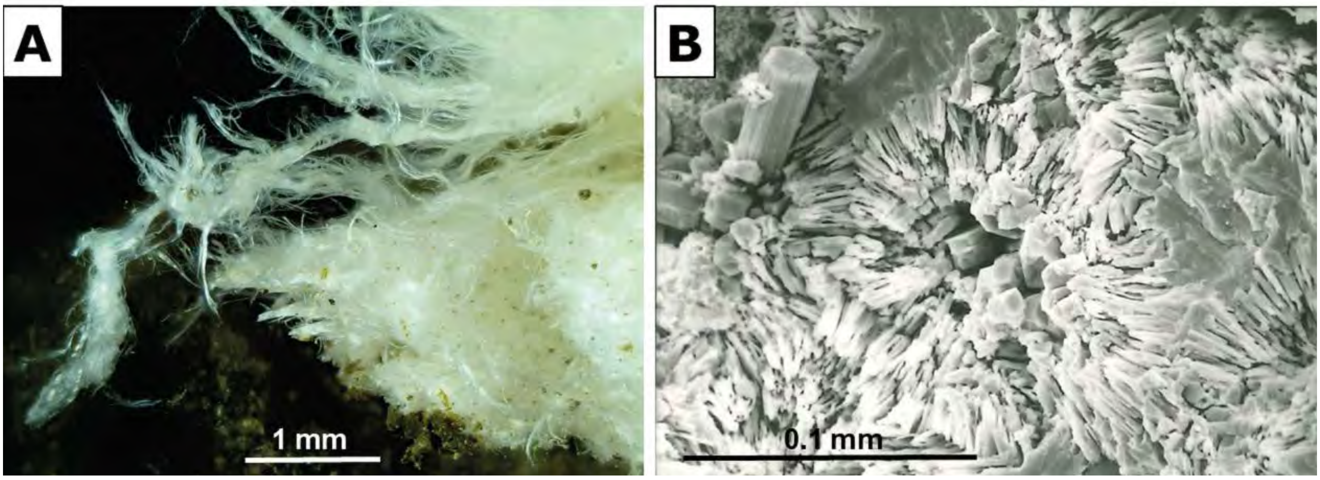

Figure. 1: (A) Example of "woolly" erionite from Te Henga Road Quarry, Waitakere Ranges (Rod Martin); (B) crystalline erionite (hexagonal crystal and acicular habit) from the Waitemata Group, Hobsonville (sample AU42046).

to be from environmental exposure to erionite in the homes and living areas of residents. Residents were found to have inhaled the erionite fibres during excavations for housing, as well as from the erionite fibres present in the region's unpaved roads, soils and building stones (Van Gosen et al., 2013).

More recently, in the USA, several clusters of MM have been identified in North Dakota and Nevada, and have been unequivocally caused by erionite exposure (Pacella et al., 2018). In this region, erionite deposits encompass large areas, and subsequent urban development has resulted in exposure of the local population to the deposits. In addition, 450 km of roads were covered in erionite-containing gravel, which has the potential to generate high levels of airborne erionite when disturbed. Thus, occupational exposure to erionite from road maintenance is thought to be a significant health risk. However, a further particular concern in North Dakota was the public health risk; elevated air concentrations of erionite were found alongside roads at school bus stops, and inside buses, even with the windows closed (Carbone et al., 2011). Nevertheless, safe occupational exposure limits (OELs) and public health exposure limits have yet to be developed for erionite in the USA or elsewhere in the world.

ERIONITE IN NEW ZEALAND

Despite the recognised impact of erionite exposure on mortality rates overseas, the extent of the contribution of erionite to occupational or public health in New Zealand has yet to be identified.

A range of zeolites have been identified from several parts of the country (Brathwaite, 2017), and, in some cases, extracted for various industrial purposes (Figure 2). In New Zealand, zeolites are found in three main geological settings:

1. Hydrothermally-altered rhyolitic pyroclastic rocks of the Quaternary age in the Taupo Volcanic Zone;
2. Marine tuffs and volcaniclastic sandstones of Miocene age in Northland and in Auckland;
3. Weakly metamorphosed marine tuffs and volcaniclastic sandstones of Triassic–Jurassic age in Southland and in southwest Auckland (Brathwaite, 2017).

The presence of erionite in the Auckland Region has been known for several decades (Davidson and Black, 1994), and in 2015, New Zealand's then Chief Scientist, Sir Peter Gluckman, acknowledged that erionite was a more potent carcinogen than asbestos (Gluckman, 2015). However, while his report correctly described the presence of erionite in volcanics in New Zealand, it neglected to outline that in addition, erionite is present in sedimentary rocks, including in the Miocene Waitemata Group of the Auckland Region. This is in addition to the presence of erionite in the Waitakere Group volcanics, which have been quarried for aggregates over many years.

Auckland is New Zealand's fastest growing region, with large infrastructure projects that often include, and have included, tunnelling. The Waterview Connection saw twin tunnels driven through weathered and unweathered Waitemata Group rocks, generating c. 800,000 m3 of spoil. The material was excavated from tunnels, and transferred via conveyor, before being trucked to Wiri Quarry. The City Rail Link (CRL) and Central Interceptor excavations will also generate significant volumes of spoil. Moreover, there are other open excavations being carried out in the city, suburbs and region leaving Waitemata

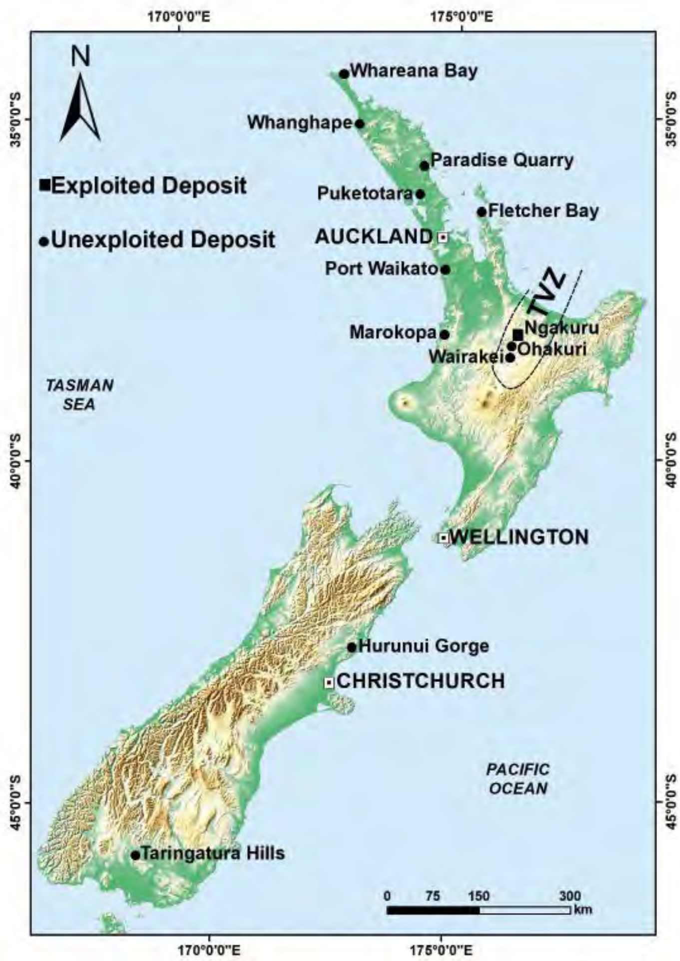

Figure. 2: Map of sedimentary zeolite deposits in New Zealand (based on data in Brathwaite, 2017).

Group and Waitakere Group rocks exposed. Thus, there is the potential for the exposure of Auckland's population to erionite-bearing dust, not just in occupational settings, but also in residential and central urban areas, where the material is disturbed, transported, and disposed of.

IMPLICATIONS AND CONCLUDING REMARKS

Although it has been almost two decades since the ICE/DETR report "Managing Geotechnical Risk" (Clayton, 2001) was published, the main recommendations and essential principles are still pertinent. These include recognising that:

- The ground is a common cause of significant delay and cost increase in construction projects.
- There is a need for systematic risk management to be carried out, starting early with both a desk study and a walk-over survey, the expert identification of geotechnical hazards and risks and communication.
- There are implications of conditions of contract for risk sharing and methods of dealing with unforeseen ground conditions.
- The importance of design in minimising risk.

Given the evidence from overseas, it seems that erionite should be listed in at least some of the project geotechnical risk registers in New Zealand. The inclusion of erionite in geotechnical risk registers should be required for works involving excavations of rock that is known to contain erionite. The degree of risk (R) is determined by combining an assessment of the probability (P) of the hazard occurring with an assessment of the Impact (I) the hazard and the associated mitigation that it will cause if it were to occur (R = P x I). Then, an appropriate hierarchy of controls would be able to be applied to the hazard, in order to develop mitigation options.

Finally, erionite in Auckland, and other areas presents significant source-to-sink problems. Some challenging questions remain, and there are at least five key areas for further study and the analysis of erionite (and other zeolitic asbestiforms) in New Zealand. Future study is necessary to:

1. Develop techniques to identify erionite in the field in fresh excavations, soils and other environments;
2. Develop geological models of the distribution and concentration of erionite in key regions (in particular, in Auckland);
3. Monitor the airborne transport and dispersal of erionite;
4. Undertake research into the epidemiology of erionite exposure (e.g. malignant mesothelioma clusters) among quarry and construction workers, and the public, in particular in areas where erionite-bearing rock has been excavated or disposed of; and
5. Develop, with international partners, safe occupational exposure limits (OELs) for erionite.

ACKNOWLEDGEMENTS

Rod Martin is thanked for detailed discussions and permission granted to use images.

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Trials and Tribulations: Creating Solid Ground for Christchurch's New Metro Sports Facility

– By Jonathan Hale, Business Development Manager, Menard Oceania and Andrew Vencer, Project Manager, Menard Oceania

Jonathan Hale

As Pre-Contract & Business Development Manager NSW | WA | NZ at Menard Oceania, Jonathan has been working with Menard over the past six years. He has been involved in some of the most challenging ground improvement and remediation projects in Australia. Prior to joining Menard, Jonathan worked as a consultant with WSP for over six years and has a passion to combine his geotechnical world with the environmental one.

Andrew Vencer

Andrew is Project Manager for Menard March on the Christchurch Metro Sports Facility. He joined Menard in 2007 and has been involved in ground improvement projects throughout the Middle East & Central Asia. He's deeply experienced across a range of specialist geotechnical techniques including Stone Columns. Being project manager for Menard March gave him the opportunity to help solve some of the geotechnical challenges facing the Christchurch rebuild.

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IT WOULD BE an understatement to say that the Christchurch earthquake created a series of major headaches for those tasked with the monumental challenge of rebuilding the city. But it also presented an opportunity to utilise new technology and systems and build iconic structures like the new Metro Sports Facility.

From August 2018 to May 2019 the 30,000m2 plus site has been an exciting yet rewarding project for our team to be part of. It's one that has caused a lot of interest among the international construction community, all curious to know more about how we would rise to the geotechnical and more importantly, the seismic challenges of the site.

Being a global expert in geotechnical contracting, Menard Oceania, and local civil contractor and sister company March Construction, were delighted to be appointed as March Menard Joint Venture (MMJV) to the project by Ōtākaro Limited in August 2018. Ōtākaro is tasked with delivering all Crown-led anchor projects in central Christchurch and responsible for managing the design and construction of the Metro Sports Facility project.

When completed, the Metro Sports Facility will be the largest aquatic, indoor recreation and leisure venue in New Zealand with a 50 metre, 10-lane competition swimming pool, a separate diving pool, five hydro slides, fitness spaces and nine indoor sports courts.

In consultation with Ōtākaro, MMJV's responsibility has been to develop a robust and sustainable ground improvement solution that would stabilise the ground, making it ready for construction of the new Metro Sports Facility. MMJV responded to the challenge at hand, bringing in experts and equipment from around the world to come up with the best solution available to create a solid foundation for Christchurch's new landmark sporting facilities.

LAYING THE GROUNDWORK

Centrally located, the site for the new sports centre had an interesting previous life as the former home of Canterbury Brewery, along with several other commercial properties. It was also once a motor vehicle workshop. After what was left of these buildings following the earthquakes was demolished and materials cleared, work began on fully assessing the site. We did discover asbestos piping but once it was identified we were able to manage its safe removal in accordance with our accidental discovery plan.

Engineering and infrastructure specialists Aurecon surveyed the site to ensure we had an up-to-date topographic map of the land including identifying any ground level changes as this remedial work had altered the sites topography.

Although the topography of the site was generally flat, the elevation of the existing ground surface did show variance between 15.2 and 16.4 mRL (meter Reduced Level). The bottom (or toe) of stone columns that we needed to install varies in different areas and it is based on elevation (mRL). As a result, some columns should be longer than others. Knowing the existing ground level, and the toe level from the designer, provides the site team the length of stone columns that need to be installed.

Prior to start of the stone column installation, the MMJV conducted a pre-level survey to determine the topography of the jobsite to accurately identify the correct length of the stone columns to be installed.

CHOOSING A ROBUST METHOD

A geotechnical-developed design report prepared by Aurecon identified that the site lies close to the epicentres of the recent significant earthquake events. Dealing with land in an area prone to seismic activity brought new challenges to consider. It is well-known the city has been prone to liquefaction, and after extensive geotechnical investigations were carried out on site, we knew the area designated for the Metro Sports Facility needed future proofing.

To achieve this, the stone columns ground improvement that we designed were in accordance with Aurecon's design specification. Central to this was stiffening and strengthening the upper plastic soils, providing adequate bearing capacity and stiffness for a shallow foundation and minimising long-term settlement.

Also important was the need to suppress liquefaction and ground softening effects so that the factor of safety against liquefaction triggering is greater than 1.2 in clean sands and greater than 0.7 in siltier soil.

Liquefaction mitigation by vibro-replacement stone columns has shown itself to perform well during major earthquake events. In earthquake conditions, stone columns create a base that are effective at overcoming liquefaction because they increase the drainage of the soil. When an earthquake hits, underground water is displaced and works its way through the soil. The stone columns hold their place, stabilising the ground, unlike the original sand layers that would move under the pressure.

After much consideration, stone columns were determined to be the best technique for this ground improvement project and signed off by Ōtākaro.

For the new sports facility, ground conditions were improved through both densifying and reducing earthquake induced liquefaction in lower sand layers and strengthening and stiffening the upper silty sand layers with the intent to provide a stiff, non-liquefiable crust raft for the building robust shallow foundation and slab to bear on.

This method accepts that liquefaction may occur, and with the construction of a non-liquefiable surface, with a sturdy, shallow foundation system, will reduce the potential of damage happening to the building's superstructure in the future.

TRIALLING STONE COLUMNS TO ASSESS IF MODIFICATIONS WERE NEEDED

As part of the Metro Sports project requirement, the

stone columns designed by MMJV increase soil bearing capacity on the underside of the shallow foundation and control both total and differential settlement under static loading conditions.

A total of 7,200 stone columns needed to be installed to support the sports centre. But before work began, the teams started with a trial to make sure their method worked. This meant installing 96 stone columns to a depth of up to 15.5 metres.

The trial was designed to prove our technique could reach the required depth, desired diameter of the stone column, and verify improvements of the ground. It showed the ground conditions improved dramatically. The earth's surface became denser, and the chances of earthquake-induced liquefaction was reduced in the lower sand levels and on the upper silty, sand crust. This means the sports centre can reply on a shallow foundation to support the venue. Once the trial proved the required depth and diameter was achievable, the rest of the stone columns were given the green light by Ōtākaro.

CHALLENGES FACED ALONG THE WAY

The stone column technique utilised for the groundwork is a well-established ground improvement solution and used throughout New Zealand, however it did not come without its challenges. Due to the project size, specialist equipment had to be sourced from around the world to supplement the equipment available in New Zealand. Specifically, Australia, Germany and the Middle East.

As well as equipment, Menard ground improvement experts from around the world travelled to Christchurch to play a part in this project. Emphasis was placed on building a positive working relationship with all significant parties involved to ensure everyone was working effectively together. With the combined New Zealand and international expertise, an impressive installation pace was set, to ensure all 7,200 columns would be completed within six months.

The project also had a slow start as the team learned to coordinate four stone column cranes and other associated equipment. The importance of putting in place correct set-out and validation processes was also established, and this contributed to a successfully implemented project.

The consistency of the ground became an obstacle that needed to be worked through as harder pockets of ground resulted in difficult installation. For much of the project the vibroflot reached 9m without too much effort, extending past this depth to 15.5m became difficult as the earth became harder. To navigate this project risk a pre-drilling machine had to be utilised to loosen the localised soil and allow easier penetration of the vibroflot. This process ensured all columns were installed to the design depth and without impacting on the program.

MAKING THE PROJECT WORK

The Menard March's contract duration was 180 calendar days and the stone column installations, including post testing, were completed four days ahead of schedule. This was largely achieved through excellent planning by the site team to keep all cranes working productively until the last day.

A key reason this project worked smoothly was because the different groups involved work effectively with each other. The MMJV worked closely with Ōtākaro to make sure they were delivering the results Ōtākaro were expecting in a safe and timely manner.

This relationship wasn't hard to achieve because we share the same values and are committed to a safe workplace where everyone onsite returns home safely at the end of each day. This was recognised earlier this year when Ōtākaro named MMJV its contractor of the month, acknowledging our commitment to health and safety.

CREATING A STABLE FOUNDATION FOR CANTERBURY SPORTS

Since the 2011 earthquake, the number of facilities locals have access to has been limited making the centre's completion an essential part of Christchurch's regeneration. With the stone columns firmly in place, a stable ground has been laid making way for the completion of the Metro Sports Facility. Once construction is finished in late 2021, the centre will be a home for school sports, regional and national competitions, and a place for families to take their children to enjoy all that is on offer.

Menard and March are proud to have been part of this landmark project, and to have demonstrated the use of stone column foundations as an affordable and robust foundation solution for major infrastructure projects. The lessons learnt will form a valuable input for future projects in addressing the challenging geotechnical environment for Christchurch and the wider New Zealand construction industry.

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Development and Testing of a Modular Rockfall Protection Wall to Mitigate Earthquake-Induced Slope Hazards

Prepared for the 69th Highway Geology Symposium, September, 2018

Rori Green
Rori has 25 years' experience as a consulting Geological Engineer, working on projects associated with mining, dams, and, since 2011, earthquakes. She has worked on various stages of projects from planning through to construction and has an affinity for technical aspects around rock mechanics, slope stability and rockfall. She has project experience in the US, NZ, Panama, Iceland, Fiji and Nepal. Rori is an Independent Consultant based in Christchurch.
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ABSTRACT
The November 2016 M7.8 Kaikoura earthquake resulted in excess of 40 landslides that directly impacted the key road and rail corridor on New Zealand's South Island. Within two months, the New Zealand Government formed the North Canterbury Transport Infrastructure Recovery (NCTIR) alliance, a team of more than 1700 workers who were tasked with restoring road and rail service by the end of 2017.

The work has involved a wide variety of landslide hazard mitigation measures that have included source treatment, installation of passive rockfall protection measures and relocation of sections of road further away from the base of the slope onto new seawalls. One of many challenges facing the geotechnical design team is space limitations along the narrow coastal corridor.

A modular rockfall protection wall has been developed to add to the suite of permanent rockfall protection structures in use on the project. The wall comprises interconnected concrete blocks with an upslope energy-absorbing layer of sand-filled and rock-filled gabions. The key advantages of the wall are a narrow footprint and a relatively fast installation time.

It was necessary to demonstrate the performance and capacity of the wall before it could be approved for use on site. Full-scale physical testing was performed at a vehicle impact testing facility. Six tests were undertaken to investigate sliding and overturning failure modes; impact energies were 250 and 750 kJ. Data collected during testing includes multiple high-speed videos and pre- and post-test laser scans.

The wall performed successfully, and it has been approved for use on site. The first installation is anticipated by mid-to-late 2018.

INTRODUCTION

The November 2016 M7.8 Kaikoura earthquake caused significant damage to transportation infrastructure located in the northeast of New Zealand's South Island. Part of the damage was due to nearly 1 million cubic metres of rock falling onto the Main North Line (MNL) railway and State Highway 1 (SH1) from more than 40 primary landslides, cutting off a major transportation corridor and isolating the town of Kaikoura and surrounding rural communities.

By the end of 2016, the New Zealand Government made the decision to form an alliance to undertake work to restore the coastal transportation corridor. NCTIR, the North Canterbury Transport Infrastructure Recovery, is an alliance partnership between the New Zealand Transport Agency (NZTA), Kiwirail and four major construction contractors *(1)*. The alliance team has consisted of up to 1700 people from more than 100 organisations. They were given the challenge of re-opening the corridor by the end of 2017.

One of two NCTIR geotechnical design teams was tasked with works related to characterization and mitigation of slope hazards along 28 km of coastal corridor affected by landslides. The work involved design and construction of landslide hazard mitigation works, from mapping and characterization of landslides to design and construction of protection structures.

A key part of the work involved finding robust rockfall protection solutions for fragile, earthquake-damaged slopes that could be constructed relatively quickly within a narrow corridor. To this end, a modular rockfall protection (MRP) wall has been developed and tested for use on the NCTIR project.

Overview of Earthquake and Damage

The 14 November 2016 M7.8 Kaikoura earthquake was a complex event that involved rupture along multiple faults. Figure 1 shows the area most affected where significant ground shaking occurred. The event was felt throughout

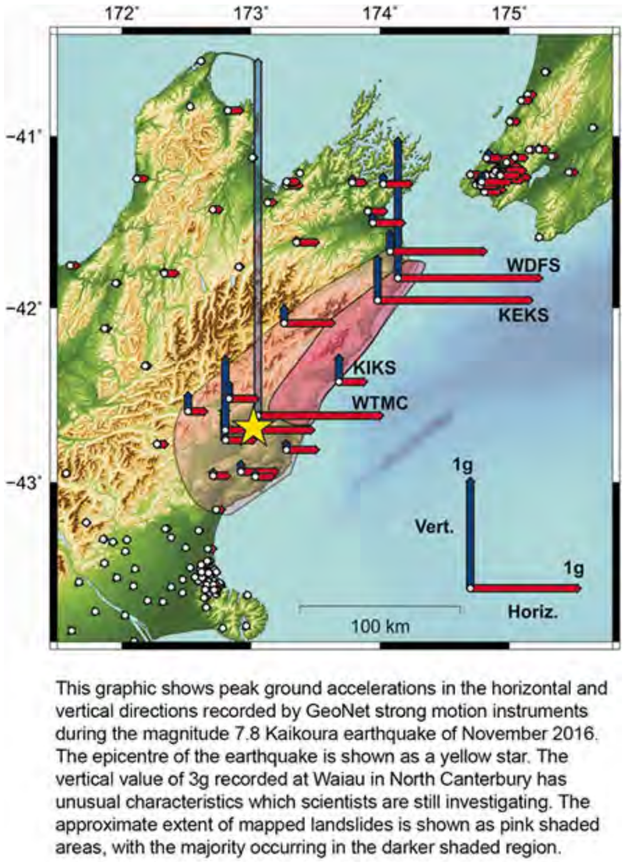

Figure 1: Area affected by November 2016 M7.8 Kaikoura earthquake (2)

Figure 2: Panoramic views of SH1 / MNL north (upper) and south (lower) of Kaikoura; bare areas along the lower slopes are where landslides have occurred

Figure 3: Two of the largest landslides affecting the corridor; for scale, the landslide on the right is up to about 250 m high.

most of New Zealand. Fault rupture propagated northwest from the epicenter; surface ground rupture was observed along at least 20 faults spanning a distance of about 100 km.

Due to the significant ground shaking, more than 10,000 landslides were generated over an area of about 10,000 km^2 (3). The area affected by landslides is shaded red in Figure 1.

More than 80 landslides either directly affected or occurred upslope of the transportation corridor. The main part of the transportation corridor affected by landslides extends for a distance of about 7 km south and 21km north of Kaikoura; the location of Kaikoura is shown by the KIKS station in Figure 1. Figures 2 and 3 show the transportation corridor and provide some general context for the project setting and scope.

MODULAR ROCKFALL PROTECTION WALL

An additional rockfall protection solution with a relatively narrow footprint and low deformation under impact loading is needed along several areas of the corridor where there are space constraints between the slope toe and road/rail alignment. The slopes in many of these areas contain varying quantities of potentially unstable material and are expected to generate multiple rockfalls over time. Flexible barriers such as rockfall fences are not considered a practical option in some areas given the anticipated barrier deformation and the amount and frequency of rockfalls.

Stacked mass concrete blocks have been used in these areas as temporary rockfall protection walls, however the energy capacity, deformation and damage response of these of structures is unknown. The question arose as to whether a permanent rockfall protection wall could be developed using stacked concrete blocks that could be quickly erected at locations where the space requirements did not suit existing protection systems. Given the anticipated range of rockfall energies, the rockfall protection solution would need to be able to withstand moderate impact energies in the range of 300 to 400 kJ (or more, if possible).

Development

Work undertaken by others has been considered in the development of the MRP wall configuration. The concepts of particular interest are the use of gabion baskets as an energy-dissipating layer and the performance of concrete in rockfall protection structures. The work considered includes two separate PhD research projects involving cellular (gabion) structures (*4,5*) and concrete roadside barriers (6), and their use as rockfall protection structures. Both studies included physical testing programmes; the findings related to the behaviour and performance of structures during physical testing were considered in the development of the MRP wall configuration and its testing.

Cellular Gabion Wall

Researchers in France have undertaken work to evaluate the use of gabion baskets in rockfall protection structures. This work has included an evaluation of the deformation of individual rock and sand-filled gabion baskets, and small-scale and full-scale testing of cellular gabion sandwich structures composed of layers of rock-filled and sand-filled gabions (*4, 5, 7, 8, 9*).

Of particular interest for the development of the MRP wall was the performance of the rock and sand gabion layers in terms of deformation and dissipation of impact energy. The researchers undertook full-scale testing of a 2m-thick, 4m-high cellular wall backed by an earthen embankment; and a 3m-thick, 4m-high cellular wall. The cellular walls were formed by 1m-thick rock gabion and sand gabion layers. The test energies ranged from 200 kJ to 2200 kJ (8). This work was the basis for selection of rock gabion and sand gabion layers as a composite energy-absorbing layer, and it also helped to guide the selection of impact energies used in testing the MRP wall.

Concrete Barriers

The Ohio Department of Transportation (ODOT) recently sponsored research aimed at better defining the performance and energy capacity of concrete roadside barriers used as rockfall protection (6). Part of work involved physical testing of precast and cast-in-place concrete barriers. The barrier designs were modified to investigate the effects of various energy-absorbing features on the energy capacity and resulting damage to the barriers. This included varying the reinforcing steel type, size and spacing; as well as using different types of fibre-reinforced concrete. Test energies were up to 160 kJ. ODOT used the results of the work to modify the design of concrete roadside barriers where they are used as rockfall protection.

Of particular interest for the development of the MRP wall is the improvement in energy capacity and performance with the use of steel fibre-reinforced concrete. The addition of steel fibres significantly reduced concrete spalling and increased the energy absorption capacity by 30 to 100 percent, depending on the barrier type and test impact location.

MRP WALL CONFIGURATION

The modular rockfall protection wall configuration selected for testing (Figure 4) utilises a modified configuration of sea-wall blocks developed for the NCTIR project together with an upslope energy-dissipating layer consisting of sand-filled and rock-filled gabion baskets. The blocks are 2 m x 1m by 1m (L x W x H); each weighs about 5000 kg; they are chamfered on the upslope side to allow for easier installation around curves. The gabion baskets are 2 m x 0.5 m x 0.5 m (L x W x H). The rock fill is as per the gabion manufacturer's specification. The sand fill is concrete sand with a maximum grain size of 5 mm, lightly compacted within a geotextile-lined gabion basket.

The concrete blocks are installed in an interlocking arrangement and are joined together using vertical steel shear bars. The 32 mm diameter steel bars are installed within a 100 mm diameter open duct, affixed with a plate

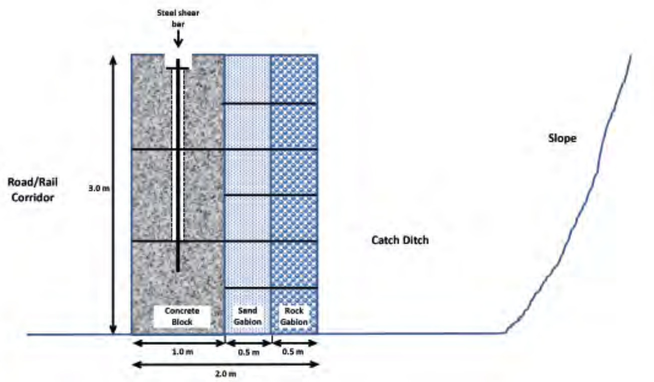

Figure 4: Cross-Section through Modular Rockfall Protection Wall

and nut in the top block. The system is able to dissipate energy on large-scale impact via deformation of the rock and sand gabion layers and sliding and rotation of the individual rigid blocks, while still remaining joined as a coherent barrier to further rockfall.

Development of the wall configuration was a collaborative effort amongst the NCTIR design team, Stahlton Engineered Concrete and Geofabrics New Zealand. Stahlton provided the modified sea-wall block design, including the steel shear bar connections within the concrete blocks. Geofabrics provided general information and advice on the gabion basket layers; this advice included input from Maccaferri who have expertise in rockfall protection solutions.

The motivation for using the sea-wall blocks was two-fold. First, they could be fabricated using the concrete molds developed for the sea-wall blocks, saving both cost and time. Second, with over 7000 sea-wall blocks being planned for use on the project, considerable experience will have been developed in their fabrication and installation.

TEST DESIGN

A testing standard specifically applicable to rockfall protection walls formed with rigid elements does not exist. Instead, researchers and manufacturers have undertaken numerical modelling, physical testing and back-analysis of actual rockfall impacts to evaluate the performance and energy capacity of these types of structures (10). Rockfall protection walls are typically designed on the basis of allowable or acceptable deformation, considering an impact by a design boulder with a specified impact velocity.

Testing Programme

In order to demonstrate the performance of the wall sufficiently, so that it could be approved for use on the project, it was decided to use a European testing guideline developed for dynamic rockfall fences as a basis for developing the testing programme. This was discussed and decided upon by the NCTIR design team, Stahlton and Holmes. The document used is the ETAG 027 Guideline for European technical approval of falling rock protection kits, published by the European Organisation for Technical Approvals (*11*).

The key aspect of the ETAG 027 considered in developing the MRP wall testing programme was the selection of two impact energy levels representing Serviceability and Maximum energy levels. Under ETAG 027, these broadly are:

- Serviceability Energy Level (SEL): The barrier should be able to withstand two impacts with no repairs after the first impact. SEL is typically used as a design criteria where multiple or frequent rockfall impacts are anticipated.
- Maximum Energy Level (MEL): The barrier should be able to stop a single impact. It is expected that the barrier will need substantial repair or replacement after an MEL impact. MEL is typically used as a design criteria where infrequent rockfall impacts are anticipated. MEL is defined as 3 x SEL energy level.

The SEL and MEL designations used in ETAG 027 are for dynamic rockfall barriers and are not terms that are typically used to designate energy levels for rigid-type barriers, such as an embankments or this wall. The terms have been used here to indicate the likely "frequent" (SEL) and "infrequent" (MEL) rockfall impact energies.

In addition to impact energies, the other key factor considered in developing the testing programme was failure mode, either sliding or overturning. These failure modes were tested by varying the impact height. Sliding was evaluated by impacting the wall at mid-height; overturning was evaluated by impacting the wall in the upper third of the wall height.

A total of 6 tests were planned to evaluate the energy capacity and performance of the MRP wall; the testing programme is summarized in Table 1 and illustrated in Figure 5.

Table 1 – Testing Programme

Test No.	Failure Mode	Multiple Impacts (SEL)*	Single Impact (MEL)
1 to 3	Sliding	2 x 250 kJ	1 x 750 kJ
4 to 6	Overturning	2 x 250 kJ	1 x 750 kJ

*no repairs to wall after first test

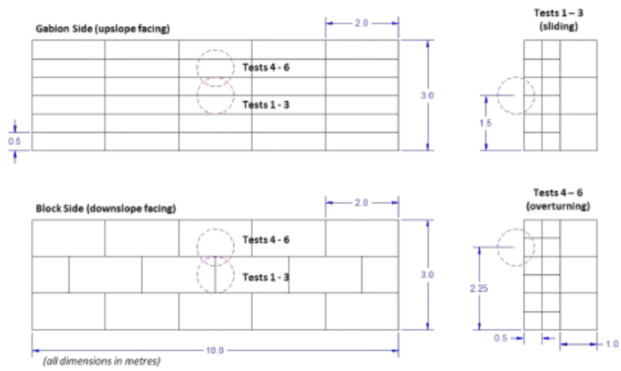

Figure 5: Test impact locations for sliding and overturning failure modes

Test Walls

Two 3m-high by 10m-long walls were constructed for testing (Figure 6). The walls were constructed within a ditch in order to achieve the impact heights; the ends of the walls were not constrained. The two test walls were designated A and B. Test Wall A was used to investigate the sliding failure mode using a 1.5m impact height (Tests 1 to 3). Test Wall B was used to investigate the overturning failure mode using a 2.25m impact height (Tests 4 to 6). The test walls were substantially re-built following the 2 x 250 kJ impacts.

The composition of the concrete blocks differed in Test walls A and B. Test Wall A was constructed using 50 MPa (28-day strength) plain concrete; Test Wall B was constructed using 50 MPa concrete reinforced with steel fibres at a dosage rate of 20 kg/m^3. It was anticipated that spalling of the concrete blocks would potentially be an issue, and the option to add steel fibres to the concrete blocks for Test Wall B was included as part of the testing program.

Test Set-up

Impact energies were delivered to the MRP wall via a rolling bogey fitted with a spherical impacting head. The impacting head consisted of a 1-m diameter concrete-filled, steel-reinforced spherical steel dome (Figure 7). The bogey was fitted with steel ballast to scale the weight up and down to achieve the target impact energies. The bogey travelled along a guide rail and was propelled using a tow rope attached to a drop-weight system. The drop-weight system was composed of a known mass of concrete

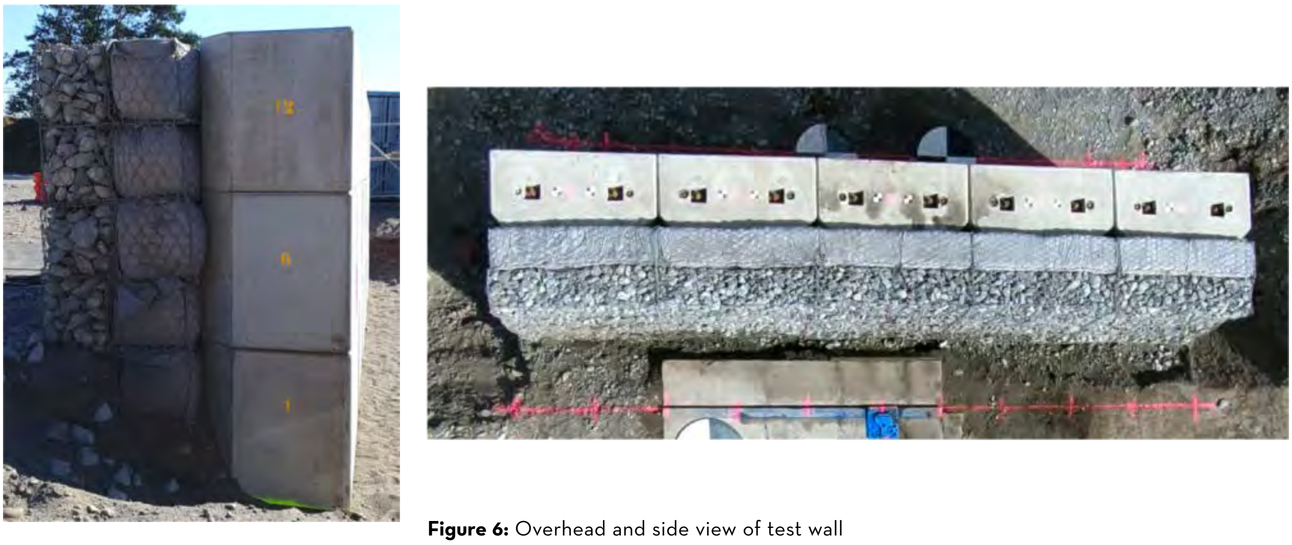

Figure 6: Overhead and side view of test wall

blocks that were lifted with a crane and attached to the tow rope via a system of pulleys (Figure 8). The mass was lifted to a specified height and dropped such that the bogey reached a target velocity on impact with the MRP wall; target impact velocities were in the range of 20 m/s, which is within the mid-to-upper range of possible rockfall velocities. The tow cable dropped off of the bogey immediately prior to impact so that it was travelling freely on impact.

Testing was conducted at the Holmes Solutions testing facility in Christchurch, New Zealand. Holmes Solutions are an ISO 17025 Accredited Testing Laboratory under the International Laboratory Accreditation Cooperation (ILAC) scheme audited by International Accreditation New Zealand (IANZ). Holmes has substantial experience with full-scale dynamic impact testing of roadside safety barriers to US, European and Australia/New Zealand testing standards.

Figure 7: Test bogey and guide rail system

Figure 8: Test set-up

Data Collection

Data collected during the tests consisted of high speed video (up to 300 frames per second) from multiple cameras positioned at the sides, front and above the wall. An accelerometer was installed on the test bogey to record velocity before and during impact. Horizontal displacement measurements were taken manually at discrete locations for all tests. Additional displacement data was acquired via laser scanning to provide a comprehensive survey of the wall before and after each test. Laser scanning was undertaken by Eliot Sinclair surveyors for 4 of 6 tests.

Test Results

A total of 6 tests were conducted for the planned testing programme. The wall successfully stopped the bogey in all tests.

Energy dissipation in the MRP wall was observed through the following mechanisms:

- Deformation of rock gabion layer
- Deformation of sand gabion layer
- Displacement of impacted concrete block(s), both translational and rotational
- Displacement of adjacent concrete blocks; engaged through block-to-block contact and through steel connections
- Deformation of steel connections, both rebar and steel plates
- Deformation of foundation, including slight embedment of the toe of wall and rotation of the wall about the toe

A summary of the actual impact conditions, horizontal wall displacements and rotational displacements are presented in Table 2. The horizontal displacements are

Table 2 – Summary of Test Results

Test #	Impact Height	Impact Velocity	Impact Energy	Maximum Displacement		Maximum Rotational Displacement
				Base	Top	
1	1.5 m	17.4 m/s	246 kJ	95 mm	124 mm	1 deg
2	1.5 m	17.9 m/s	268 kJ	80 mm	61 mm	1 deg
3	1.5 m	24.0 m/s	769 kJ	352 mm	484 mm	3 deg
4	2.25 m	17.1 m/s	268 kJ	44 mm	200 mm	3 deg
5	2.25 m	17.1 m/s	267 kJ	55 mm	104 mm	2 deg
6	2.25 m	22.9 m/s	755 kJ	186 mm	538 mm	9 deg

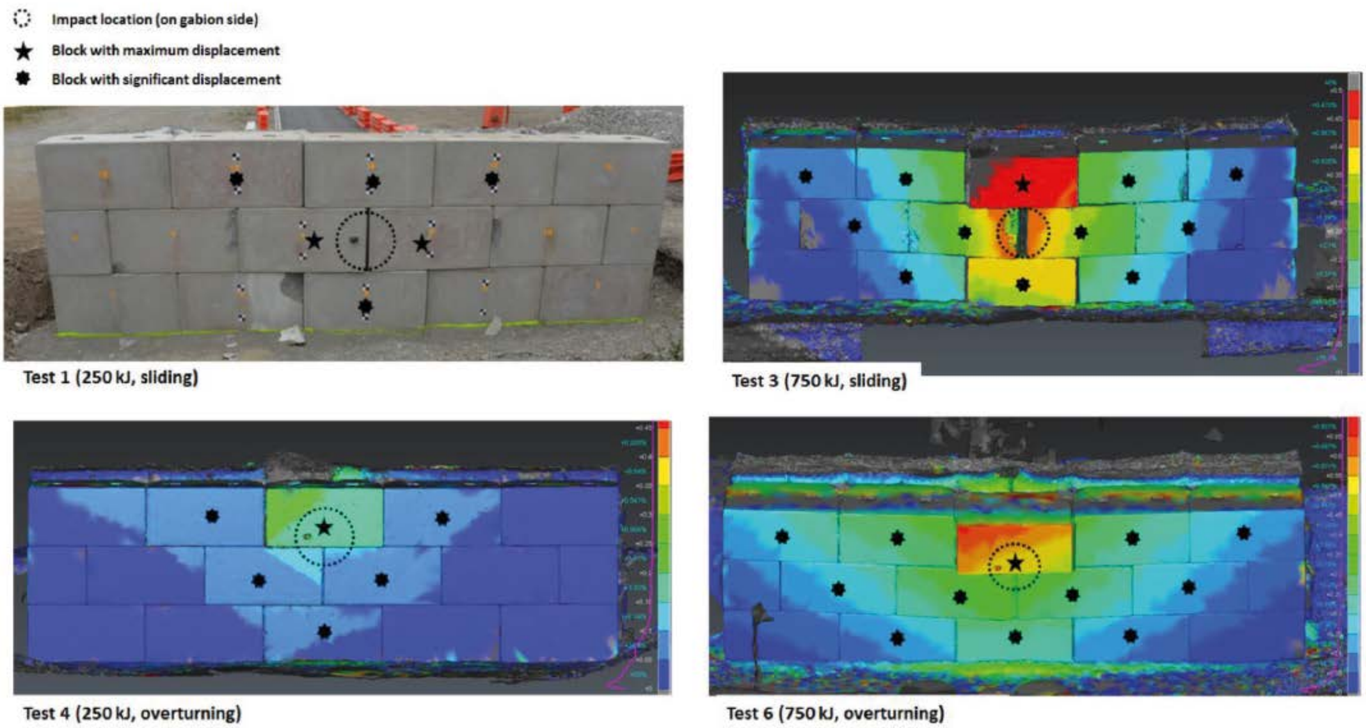

Figure 9: Comparison of horizontal displacements for selected tests (colour scales differ)

measured at the front face of the concrete blocks; the rotation is measured about the front toe of the wall.

Figure 9 shows a comparison of the horizontal displacements for selected tests; laser scan results are shown where available. Of note is the displacement pattern and greater number of blocks engaged for the higher energy impacts. Figure 10 shows the bogey penetration and gabion basket deformation for the same set of tests as in Figure 9. Damage to the gabions was generally confined to the impact zone, however there was increased deformation of the gabions above the impact point.

Figures 11 and 12 show the front face of the wall following the 750 kJ tests for sliding and overturning (Tests 3 and 6). Of particular note is the difference in damage to the plain and steel fibre-reinforced concrete blocks.

Figure 10: Comparison of bogey penetration and gabion deformation for selected tests

Figure 11: Test Wall A following Test 3 (sliding, 750 kJ); plain concrete blocks

Figure 12: Test Wall B following Test 6 (overturning, 750 kJ); steel fibre-reinforced concrete blocks

Figure 13: Damage to steel bars and plates following Test 5 (2 x 250 kJ, overturning)

Spalling occurred in the plain concrete blocks, with relatively large pieces of concrete being lost off the blocks due to contact between the blocks as they displaced during impact. The damage to the fibre-reinforce blocks consisted of cracking and crushing; no spalling occurred. The paint marks in both photos indicate damage that occurred following the 2 x 250 kJ tests; the blocks were re-arranged when each of the walls was repaired following the 250 kJ tests. Minimising spalling is an important road safety consideration if the MRP wall is to be located adjacent to a roadway.

Additional damage sustained by the wall consisted of bending of the steel bars and deformation of the steel plates (Figure 13).

Figure 14: Test Wall B following Test 6

Test to Destruction

A 7th test was undertaken immediately after Test 6 in order to further investigate the failure mode of the MRP wall. No repairs were made to the wall and the test was undertaken using the same target impact energy and height as for Test 6.

The gabion layers were substantially damaged during Test 6 (Figure 14). The rock and sand gabions deformed and had a reduced thickness; additionally the sand gabion would have undergone some compaction.

The impact velocity for Test 7 was 23.1 m/s and the impact energy was 771 kJ. The failure mode was detachment of the upper central block with punching of the steel anchor plates and bending of the steel bars (Figure 14). The 5000 kg block came to rest about 1.6m from the front of the wall with its top face resting on the ground.

Figure 15: Test Wall B following Test 7

FUTURE USE

Based on the results of the physical

testing programme, the MRP wall has been approved for use on the NCTIR project. The recommended energy capacity limits that have been adopted are presented in Table 3.

Table 3 – Recommended Energy Capacity Limits		
Case	**Energy Level**	**Expected Displacement**
Multiple impacts	**250 kJ**	**< 100 mm***
Single impact	**750 kJ**	**< 400 mm**

***for first impact**

Additional work that was undertaken in the order to gain approval includes consideration of seismic and debris loading conditions, design life, and inspection and maintenance.

Some of the advantages of the MRP wall for the NCTIR project are:

- Re-use of concrete molds developed for the sea-wall blocks.
- Leveraging of site experience with fabricating and installing sea-wall blocks.
- Reduced footprint width in comparison with a similar embankment-type structure.
- Anticipated reduced construction time in comparison with similar embankment-type structure; this has the advantage of minimizing the time workers spend in potentially hazardous areas, and it reduces the road closure time.

Potential for staged installation of MRP wall, with concrete blocks installed in advance of gabion baskets; this may allow for use of concrete blocks as temporary rockfall protection.

Potential for further reduction of construction time if gabions are pre-filled and lifted into place.

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This paper was originally presented at the 69th Highway Geology Symposium in 2018 in Portland, Maine, USA and is re-published by permission. Since the paper was prepared, two installations have been completed by NCTIR. Both the New Zealand Transport Agency and KiwiRail are looking to utilise this design in future works.

ACKNOWLEDGEMENTS

The authors would like to thank the following individuals/entities for their contributions to the design and physical testing of the modular rockfall protection wall, and for the additional work that contributed to its approval for use on the NCTIR project:

Stuart Finlan – New Zealand Transport Agency
Daniel Headifen - KiwiRail
Eric Ewe – Geofabrics New Zealand Ltd.
Michal Tutko – Eliot Sinclair
Clive Anderson – NCTIR
Greg Saul – NCTIR
Ryan Jones - NCTIR

DISCLAIMER

Statements and views presented in this paper are strictly those of the author(s), and do not necessarily reflect positions held by their affiliations, the Highway Geology Symposium (HGS), or others acknowledged above. The mention of trade names for commercial products does not imply the approval or endorsement by HGS.

Geotechnical outputs from the EQC – Quake Centre Industry Fellowship programme

The Earthquake Commission (EQC) has, for a long time, been an important investor in high quality research in New Zealand. EQC's research programme spans science, engineering and social science and has played a vital role in supporting New Zealand's improved resilience to natural hazards. Through its support of the Quake Centre, a series of EQC-Quake Centre Industry Fellowships have been implemented over the past five years. The Industry Fellowship Programme is predominantly aimed at mid to late career engineers who have shown leadership in the industry. The purpose of the Fellowship is to allow experienced practitioners time to distil lessons they have learnt and develop tools or guidance that can be shared directly with the industry as a whole. This can be particularly valuable if the practitioner is able to engage with their academic colleagues to integrate new knowledge developed through research with the knowledge and experience gained from years of practice.

Over the next few months a number of outputs and guidance documents will be published which have a strong geotechnical and engineering themes which may be of interest to a wider group people working in the construction industry. Most of these outputs will be standalone documents that can be used straight away by other practitioners. However, some of the projects are best seen as contributing to guidance and processes that are already under development such as the NZGS Guidelines.

PROJECT SUMMARIES

A Risk Based Framework for Earthquake Ground Motion Hazard Estimation, New Zealand

Authors: James Dismuke and Jeff Fraser, Golder Ltd

Earthquakes cause several hazards that affect humankind and the built environment, either directly (e.g. ground shaking) or indirectly (e.g. liquefaction caused by ground shaking). Understanding earthquake the magnitude of ground shaking, or in other words, the earthquake ground motion hazard, is critical to understanding the earthquake risk for planning, design, and development in New Zealand. There are several techniques for determining ground motions for input into the planning and design of built infrastructure. Each technique has its pros and cons, and some techniques are more suited to some projects than others.

This report provides a framework for decision makers, policy makers, developers, owners, engineers, and others to select the level of effort (i.e. appropriate ground motion hazard analysis techniques) to suit the risk-profile of their specific projects. Detailed technical guidance about how to perform these hazard analyses is not in the scope of this report. This report comprises:

- Definition of terms and concepts used in the report;
- Summary of current New Zealand earth ground motion estimation guidance;
- Methods and techniques for determining ground motions for design;
- Risk-informed framework for determining with earthquake ground motions approach is appropriate to the situation; and
- Answers to frequently asked questions.

Spatial correlations of underground pipeline damage with liquefaction-induced ground surface deformations and CPT-based liquefaction vulnerability index parameters

Authors: Dr Sjoerd van Ballegooy and Dr Luke Storie, Tonkin + Taylor; Dr Dimitra Bouziou, Cornell University / GEK TERNA; Prof Thomas O'Rourke, Cornell University

The Christchurch Earthquake Sequence of 2010-2011 caused extreme and widespread damage to the 3 waters pipe network of Christchurch. It is widely accepted that most of this damage was caused by liquefaction and lateral spreading. Researchers and practitioners have learnt many lessons in assessing liquefaction induced damage from these experiences. This report develops tools to assess the potential for pipeline damage based on correlations with liquefaction-induced ground movement and soil come penetration test (CPT) based liquefaction measures and indicators. The correlations and indicators can be used for pre-earthquake event estimates as well as post-event rapid triage of pipe damage. Key inputs to the assessment are a comparison between pre and post-event LiDAR surveys; satellite imagery; CPT-based assessments of liquefaction vulnerability and earthquake induced Peak Ground Velocity data (PGV).

The report explains how the data sets were collated and analysed to develop functions for pipe repair rates expressed in the number of predicted breaks per kilometre of pipeline. These repair rates cannot predict specific damage at any one location, rather they can


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identify areas and pipe types where damage is more likely to occur and areas where it is less likely to occur and provide an expected damage rate for those respective areas. Tools have been developed to facilitate this approach which can be readily applied by practitioners when responding to liquefaction induced damage.

Invasive Seismic Testing – a summary of methods and good practice
Author: Rick Wentz, Wentz-Pacific ltd

Seismic shear wave tests are routinely used in geotechnical engineering for a variety of purposes ranging from assessing static foundation settlement to estimating earthquake ground motions. In particular, an accurate determination of soil shear wave velocity is required for robustly determining the site subsoil class when using the New Zealand seismic loadings standard NZS1170.5, as well as assessment of site-specific seismic response which is used as an input into building design.

In the aftermath of the 2010-2011 Canterbury and 2016 Kaikoura earthquakes, seismic shear wave testing has become more commonly used in geotechnical earthquake engineering. However, several critical aspects of both data collection and data processing are commonly not well understood by either the contractors collecting and processing the data or the geotechnical and structural engineers using the data. This can lead to incorrect and possibly unconservative design assumptions.

This report summarises the invasive seismic test methods typically used in New Zealand geotechnical engineering practice to measure shear and compression wave velocities. It describes the test procedures and data processing that are generally accepted as "good practice" – i.e. the procedures and processing that are necessary to obtain accurate and representative data that can be relied upon by geotechnical engineers for analysis and design. The report also describes the uncertainty inherent in all of the testing methods, including sources of uncertainty and how to quantify it. An example of an assessment of uncertainty using actual field data is provided, as are recommendations for what information should be included when reporting test results.

Guideline for Assessing Technical Resilience of Three Waters Networks – Simplified Assessment Method

Authors: Marcus Gibson, Melanie Liu and David Heiler, Beca Ltd

The guideline has been prepared, based on lessons from the Canterbury earthquake sequence, to support local authorities and the private sector (including asset managers, operators and engineers) at local and regional levels with assessing technical resilience of their three waters infrastructure and in developing strategies to improve network resilience, inform pre-event planning, and post-event emergency support and recovery. The focus is on infrastructure placed in land potentially vulnerable to any geotechnical natural hazard. A particular example is shown in relation to liquefaction prone land - which includes many areas around New Zealand commonly near rivers, harbours and the coast.

The guideline aims to standardise the assessment of technical resilience across New Zealand and to encourage collaboration, while maintaining the ability for users to tailor the assessment approach to fit the specific requirements and needs of their community.

Rock Fall Risk Mitigation: Capturing experience from the Kaikoura and Canterbury earthquakes
Author: Rori Green, Rori Green Consulting Ltd

Landslides and rock falls that occurred as a result of the 2010/2011 Canterbury earthquakes and the 2016 Kaikoura and caused significant damage. This threatened critical transportation infrastructure particularly SH1 and the main rail corridor running down the top half of the east coast of the south Island. Various measures were used to mitigate rockfall risk to the infrastructure and the public who utilises this infrastructure.

Helicopter sluicing (i.e. dropping buckets of water from helicopter) was a key method used following the Kaikoura earthquake to quickly clear potentially unstable debris from slopes and allow recovery works to be undertaken more safely. It is believed that this may have been the largest sluicing project undertaken anywhere in the world. Very little published information currently exists about sluicing. Experience has revealed sluicing was very effective in many cases and less so in others; in a few cases it may have even worsened the situation.

In addition, use of temporary rock fall protection in NZ has increased significantly as a result of recent earthquakes. In some locations, the protection has remained in place for up to 5 years. Temporary protection measures help mitigate risks to people and infrastructure during recovery works until permanent solutions can be installed. Due to its temporary nature, and because it may be deployed rapidly in response to an event, there is often limited design input. Rock fall impact capacity and performance is generally not well understood.

Given there are many locations around NZ where transportation routes and other assets are situated immediately adjacent to steep slopes with rock fall hazards which could be exacerbated by either seismic activity or heavy rainfall, it is likely similar situations will happen again requiring urgent remedial action.

This document will capture the knowledge and experience related to two separate aspects of the mitigation works: helicopter sluicing and temporary rockfall protection works. This document will provide practical information to designers, client representatives/decision makers and project managers that can be utilised on future projects in similar situations.

FINDING THESE RESOURCES

All of the above report are, or will shortly be available through the Quake Centre's Resource Portal found here: https://resources.quakecentre.co.nz/

This portal also contains previous geotechnical, structural and other infrastructure related work developed by the Quake Centre over the past five years. This work has been funded by EQC and our other Industry Partners. Each project has its own industry reference group that has been involved in setting the scope and reviewing the project to ensure that it is technically accurate and meets the industry identified need.

ONGOING AND FUTURE PROJECTS

Debris Flow Guideline

Work is also underway to develop a Debris Flow Guideline. It is envisaged that the final guideline is likely to cover:

1. Debris Flow Characteristics
2. A review of damaging historical debris flows and lahars in New Zealand (and elsewhere as required)
3. Hazard Assessment
4. Mitigation Design
5. Statutory and Regulatory Requirements
6. Worked Examples

Getting involved in future projects

The Quake Centre is always interested in looking at projects that meet a clearly identified industry need, in particular those that align with EQC's strategy of Stronger Buildings on Better Land Supported by Resilient Infrastructure.

If you wish to be involved in ongoing or future projects please contact Greg Preston at greg.preston@canterbury.ac.nz .

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Christchurch YGP One Day Symposium

THE 1ST CHRISTCHURCH regional YGP one day symposium was held on 21 June 2019. It was an absolute success with overwhelmingly positive feedback. The event was made possible by the sponsorship of Geotechnics, WSP-Opus and NZGS. In total, 20 people were in attendance from 11 different consultancies. One of the attendees even drove down from Nelson to attend the event. Our two mentors, Don Macfarlane (AECOM) and Mark Easton (WSP-Opus), added immense value to the event by providing technical guidance, generating discussion amongst attendees as well as inspiring YGP's to follow best practice.

Three prizes were awarded at the end of the symposium. The choice was extremely difficult because all the presentations were of such high standard. The Mentors Choice for the best presentation of the day was awarded to David Rowland (Beca) for his presentation titled: "Empathy in Design". This award included sponsorship for David to present at the 21st NZGS National Symposium in Dunedin in 2020. Two other awards presented were: the People's Choice awarded to Rebecca McMahan (Beca) for her presentation titled: "Mastering Part-Time Study" and the Honourable Mention prize, which was awarded to Tom Revell (Aurecon) for his presentation titled: "Design of a hybrid rockfall protection structure south of Kaikoura".

Unfortunately, we had too much fun and forgot to take a group photo at the symposium venue.

Reported by
Romy Ridl on behalf of the Christchurch YGP symposium organising committee:
Romy Ridl (University of Canterbury), Lauren Foote (ENGEO) and Helen Hendrickson (WSP-Opus)

First Wellington YGP Symposium

THE 1ST WELLINGTON YGP symposium concluded successfully on 6 August 2019 and received lots of positive feedback. In total, 18 people from 11 different consultancies attended the symposium. The event was sponsored by Geotechnics, Engineering NZ and NZGS. 10 presentations on various geotechnical topics were well delivered.

Laurie Wesley (Retired Professor/ Geotechnical Engineer), Beverley Curley (GHD) and Alan Wightman (ENGEO) attended the symposium as senior mentors and they offered valuable feedback to all the young attendees and shared their tips, tricks and aspirations.

Three prizes were awarded at the 1st Wellington YGP symposium. The best presentation of the day, chosen by the senior mentors and voted by all the attendees, was awarded to Christoph Kraus (BECA) for his presentation on "Designing a breakwater in Apia". Christoph has been awarded the opportunity to present his paper at the 21st NZGS National Symposium in Dunedin in 2020. NZGS has offered him a scholarship of $1650 toward his symposium registration and associated costs.

In addition, two People's Choice prizes were awarded to Jack Farrow (CGW consultant. Presentation on "Innovative anvil attachment for scala") and David Molnar (Aurecon. Presentation on "Wellington Metro - Johnsonville Line: an example of digital and innovative techniques used in the rail space").

Wellington YGP symposium organizing committee:
Aimee Rhodes (WSP OPUS), Safia Moniz (Holmes), Jerry Spinks (Jacobs) and Shirley Wang (Tonkin & Taylor)

Bruce Wilson Riddolls MSc (Hons) PhD MNZGS MGSNZ

1 October 1943 – 27 June 2019

PIONEERING ENGINEERING GEOLOGIST

Dr Bruce Riddolls was a noted engineering geologist who played a leading role in making geological considerations an integral part of project investigations in New Zealand. Having studied regional mapping for his MSc at Canterbury University and obtaining a PhD from Exeter University on geological mapping Bruce developed a strong appreciation of the importance of geological context to the safety and viability of major engineering works. This appreciation was greatly enhanced during his ten years (1971-81) with the NZ Geological Survey (NZGS) Division of DSIR (later to become GNS Science). He joined at a time of rapid development of national infrastructure. NZGS had a long-standing role in providing geological advice to government and its Engineering Geology section grew to provide advice on hydro-electric and thermal power development, tunnelling, roading, railways and gas pipeline projects.

At a time when engineering geology was in its infancy in the private consulting engineering profession, Bruce accepted an offer from Worley Consultants (now AECOM) to establish and lead an engineering geology group. During his six years in Auckland, (1981 to 87) as Chief Engineering Geologist, Bruce carried out and led a wide range of assignments on major civil and mining engineering projects across New Zealand and overseas, including Laos, Indonesia and PNG. Engineering geology became recognised as a vital consideration on projects of any scale.

Having established his credentials in the private sector, Bruce set up his own consultancy, Riddolls Consultants Ltd with his wife Patricia, based in Queenstown. His work during that time (1987 to 89) centred on the massive challenges involved in the Clyde Dam development, not just with the dam itself but with the geographically extensive engineering impacts of the establishment of Lake Dunstan – notably the need to stabilise inundated slopes to avoid landslides which could cause overtopping of the dam. Up to 35 engineering geologists were involved and Bruce made strong contributions with his knowledge, insights and analytical skills. He stood out for his ability to visualise and conceptualise and determine the geological setting and its engineering implications. His ability to think laterally to generate bright ideas was much appreciated by his peers – though this ability could frustrate on occasion.

Having established Riddolls & Grocott with fellow engineering geologist, Guy Grocott in 1994, he moved to Christchurch in 1996. For the next four years he applied his skills and knowledge to government and private sector projects. Notable amongst a range of projects Bruce collaborated on was a 1999 report for BRANZ, Quantitative Assessment for Determining Slope Stability Risk in the Building Industry, which is an important reference work for practitioners still being cited in New Zealand geotechnical publications and internationally. Dr Riddolls served four years (1998-92) as Vice President for Australasia for the International Association of Engineering Geology and the Environment, having previously served on the Management Committees of both the NZ Geotechnical Society and the NZ Society for Earthquake Engineering.

In 2000, RGL merged with Golder Associates Ltd a large international geotechnical consulting firm headquartered in Canada. Bruce's focus shifted to project reviews and management of professional services. This broadened his perspectives and experience but did not satisfy his desire to be hands-on. In 2003, with an established reputation for insightful interpretations of geological and geotechnical aspects and concise reports, Bruce re-established Riddolls Consultants to focus on geological reviews, strategies, expert evidence and mentoring. Risks from natural hazards and their implications for major engineering developments formed a strong part of his work in this period. His 2007 co-authored report for EQC, Managing Landslip Risk – Improving Practice, highlights Bruce's understanding of the issues and demonstrates his ability to communicate simply, clearly and succinctly.

During this time Bruce exhibited an entrepreneurial spirit. In 2005, with two colleagues, he helped form B2G Energy Ltd to explore for coal-bed methane gas. B2G Energy was granted an exploration licence in part of the Roxburgh Coal Field but the one hole that the company drilled proved barren.

EXPERTISE

A particular strength Bruce developed in later years was high-level peer review of geological modelling for major projects and in that capacity he was retained by major clients including Transit NZ (now NZ Transport Authority), KiwiRail, Wellington City Council, Canterbury Waste Services Ltd, Fulton Hogan Ltd, and the Department of Conservation.

Bruce continued to provide consulting services until very recently, moving to Auckland in 2014 and then to Pegasus in 2018 where he could once again enjoy being on the Canterbury Plains and close to the Southern Alps.

Bruce Riddolls was not just a dedicated and highly skilled professional. He was passionate about passing on his knowledge and insights and acted as mentor for many younger engineers and engineering geologists. Few people with whom he interacted would realise the breadth of his knowledge and experience or the depth of his insights. He was unassuming and not particularly assertive in putting his views forward. But he was strong-minded with a drive towards excellence in all his work. His contributions were always very much to the point and reflected his deep knowledge and understanding. One of his many qualities was brevity in report writing – if it could be stated in one page, there was no need to say it in 10.

Rarely did he mention that he had spent a season exploring remote parts of Antarctica in 1966-67 – a challenging assignment in those days which gave him the opportunity to put Mt Riddolls on the map.

Bruce recently celebrated his 50th wedding anniversary. He met his geologist wife, Patricia, while studying in Exeter. They worked at NZGS together and formed their consultancy. These common interests no doubt enabled Bruce to refine and develop his knowledge and skills. The Riddolls family, Bruce, Tricia and daughters Ellen and Frances, lived in different parts of New Zealand. Bruce was able to use his innovative DIY and other skills on a range of properties, all to good effect. He was noted for his quiet and dry sense of humour and colleagues recall several (harmless) practical jokes played on them.

Bruce played and watched cricket, golf, football, tennis and squash. He enjoyed travel, reading and listening to music. He sang in choirs and performed on stage, notably in Hello Dolly and Gilbert and Sullivan operas.

With his wide professional and personal experience this man of gentle spirit quickly gained and then retained the respect and admiration of his friends and colleagues who rated him amongst the best of their acquaintance. Someone it was good to spend time with. And who will be sadly missed.

Compiled by

David Hopkins with input and assistance from Ian Parton, Guy Grocott, Ian Brown, Don Macfarlane, Geoff Farquhar, Nick Perrin, Simon Nathan and Patricia Riddolls.

International Association for Engineering Geology and the Environment (IAEG)

THE 2019 ANNUAL IAEG Executive and Council meetings were held at Booyoung Hotel, Jeju Island South Korea on 21 and 22 September 2019. The weekend of meetings was followed by the 12th Asia Regional Conference of the IAEG (23 – 27 Sept). A small number of NZ and Australian IAEG members attended.

A summary of key points from the Executive and Council meetings are:

- IAEG membership is growing slowly and IAEG is financially stable
- Current membership (as time of reporting for council meeting) = 4061
- 39% of member receive the bulletin (42% of NZ and Australian IAEG members subscribe to the Bulletin)
- Five largest national groups are China (585), Germany (496), New Zealand (477), Australia (320) and United Kingdom (265). NZ and Australia represent 19.7% of IAEG membership
- 32 National groups are active with a range of activities supported by members at local levels (similar to AGS and NZGS)
- Bulletin is now only available as E-Version

Changes to EU privacy rules will mean changes to how IAEG collects and manages membership data. A new system is in development and testing; once up and running the privacy and management of data for IAEG should be greatly improved. *This will not affect members directly but may require you to confirm what data you are happy for IAEG to hold, to approve third parties such as Springer for receipt of the Bulletin and acceptance to receive the connector email newsletter.* Watch this space.

- Changes to the Governance and management of IAEG are still in development with four advisory boards being set up and a number of executive reports commissioned to assist in framing and supporting the future direction of IAEG. There is ongoing discussion on development and implementation of the strategic plan developed by the previous Executive.
- Applications for IAEG regional conferences were received and voted on. The following IAEG conferences were supported:
  - 3rd European Regional Conference in Athens 21 – 23 Sep 2020 (combined with 2020 Executive and Council meetings)
  - 13th Asian Regional Conference in Singapore, September 2021
  - 1st South American Regional Conference in Cordoba, Argentina 7 -10 September 2021 (combined with 2021 Executive and Council meetings)
- Discussion also supported the proposed summer school as put forward by the Italian National Group and they were given permission to develop this proposal further.

A lot of the summary points have been reported on in the IAEG connector emails newsletter sent out to members. If you want to know more about what is happening in the world of IAEG please contact me.

Doug Johnson
NZ IAEG Representative

Doug Johnson
Doug has a Master's degree in Engineering Geology from the University of Canterbury NZ (1984). He has worked on many mining, quarrying and civil engineering projects across a range of complex geological terrains, geographies and on both green and brown field site developments. Doug is currently Managing Director of Tonkin + Taylor and is passionate about people, the client experience, and technical solutions providing long term benefits to the community and the environment.

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International Society for Rock Mechanics and Rock Engineering (ISRM)

Major events since June 2019 were in Foz do Iguassu, Brazil with the 2019 ISRM Board and Council meetings between 12 and 15 September 2019, followed by the ISRM Congress a major four yearly event on the ISRM calendar. A new Board for the 2019 – 2023 period was elected and there is a separate report for the Congress.

ITEMS RELATING TO THE BOARD MEETING INCLUDE:

Commissions

The Technical Oversight Committee (TOC) - Doug Stead, chair, Stuart Read and Norikazu Shimizu, prepared a summary of the 2018-19 year activities as well as an overview for the 2015-2019 term. The performance of each of the 18 commissions, which are run on a voluntary basis, was evaluated individually, pointing out highlights or raising concerns at Board level, with recommendations as to their continuance in the 2019-2023 period. Several had been very active, with associated publications (e.g. blue and orange books for testing methods), some less so. One TOC feeling is that Commission outputs should continue to encourage best practice through guidelines rather than preparing standards.

Commissions that wish to be active during the 2019 – 2023 term had been independently sent to the Secretary General for evaluation and appointment by the 2019 – 2023 Board and TOC.

Rocha medal (2020):

Twelve theses for the 2020 award, recognising the most meritorious PhD thesis in rock mechanics, were received (0 from Australia, 0 from New Zealand,). The Board award committee selected the following winner:

Shang, Junlong (China) from University of Leeds with the thesis “Persistence and tensile strength of incipient rock discontinuities”. The award consists of the Rocha medal, a diploma and a cash prize. The award lecture will be given during the Eurock 2020 (www.eurock2020.com) between 13 and 19 June 2020 in Trondheim, Norway.

There was one runner up award for:

Fang, Yi (China) from Penn State University for the thesis “Induced microearthquakes and seismicity-permeability relationships in fractures”.

Franklin Lecture (2020)

The ISRM Franklin Lecture recognises a mid-career ISRM member who has made a significant contribution to a specific area of rock mechanics and/or rock engineering. It honours the memory of Professor John Franklin, ISRM President from 1987 to 1991, and is given every year, at the International Symposium, except for those years when the 4-yearly Congress is held.

The provenance of candidates has been the region in which the symposium is being held (Europe in 2020). This was adhered to for selection of the winner of 2020 award (Prof Frederick Johansson, KTH Royal Institute of Technology, Sweden) with presentation at Eurock 2020 in Trondheim, Norway 13 – 19 June 2020. The selection process may be modified to widen the selection area in future years

Performance Awards (National Group, Commission)

There are two existing performance awards – Best Performing National Group, Outstanding Commission – each with up to two awardees on a two year cycle. The National Group award is in recognition of its outstanding performance and to reward a young and small National Group who is active and growing. On evaluation of the five prepared applications, awards were given to Korea and China. There were no nominations for Outstanding Commission and no awards were made.

Stuart Read

Stuart Read is an engineering geologist with GNS Science. He obtained his degree, in engineering geology from the University of Canterbury, in 1971. His 43 years of engineering geological consulting and research experience has been in the evaluation, investigation, construction and refurbishment of engineering and mining projects. He has taken a leading role in the development of the rock and soil mechanics laboratory for GNS Science and has research interests in the strength and deformation properties of rock and soil masses.

Items from the Council meeting include:

Board election for 2019 – 2023 term

The following ISRM Vice Presidents for the 2019 – 2023 term were elected at the Council meeting, following presentations by individual candidates:

Africa:	Michael du Plessis, SOUTH AFRICA
Asia:	Suseno Kramadibrata, INDONESIA
Australasia:	Sevda Dehkhoda, AUSTRALASIA
Europe:	Leandro Alejano, SPAIN
North America:	Laura Pyrak Nolte, USA
Latin America:	José Pavon, PARAGUAY (Latin as Central and South America)

Apart from Asia (with candidates from three countries – Indonesia, Korea, Indonesia – and voting by Asian countries only) the geographic areas had single candidatures.

The President for the term, Resat Ulusay, TURKEY had been elected at the 2017 Council meeting in Capetown. Luis Lamas and Sofia Mes, PORTUGAL, will continue as Secretary General, and Executive Secretary respectively for the term.

Three additional Vice Presidents At Large have been appointed on invitation from the new Board, namely Ömer Aidan (Japan), Yang Qiang (China), Vojkan Jovicic (Slovenia).

2021 International Symposium

There were two candidates for 2021 International Symposium, during which the Board and Council meetings will be held:

Turin, Italy in association with "Eurock 2021"

Asuncion, Paraguay in association with "Latin American Rock Mechanics Symposium".

After presentations from the two candidates, Turin was voted as the successful candidate.

Procedural items (budget, awards, presentations)

Items requiring approval, such as 2018 accounts, winners of several awards (2020 Rocha medal (Shang, Junlong), Franklin award (Frederik Johansson), Best Performing National Groups – Korea and China) were approved.. Presentations were given by the President, Vice Presidents, Committees (Commission, education Fund, Young Members), Secretary General, along with several upcoming conferences (e.g. Eurock 2020).

ISRM Membership:

ISRM individual membership worldwide is currently 8,432 representing 60 National Groups (countries). This is a rise of 3% rise over past year, with 549 in Australasia (7% of total with 357 Australia (4 corporate) and 192 New Zealand). Europe and Asia continue to have the greatest individual membership (>25%), with other regions including Africa and Australasia having ~6% each.

OTHER ITEMS

ISRM Fellow – Bill Bamford

During the congress dinner, which doubles as an awards ceremony, six new fellows were inducted and certificates for best performing National Groups presented. Fellowship is the highest and most senior grade of membership of ISRM, being awarded for outstanding achievement and professional contribution through ISRM.

Bill Bamford (University of Melbourne, Bamford Rock Testing Services), one of the 2019 Fellows to be inducted, was unable to attend the Congress. He has subsequently received his medal during an AGS Victorian chapter symposium in Melbourne on 30 October at which he coincidentally was an invited speaker. Bill joins two ISRM Fellows currently resident in Australasia - Ted Brown (2011) and Jian Zhao (2015 – nominated via Asia).

Rocha medal (2021):

Nominations for the 2021 award are currently open and will close on 31 December 2019 (for evaluation in 2020). The award recognises the most meritorious PhD thesis in rock mechanics, with further details on the ISRM and AGS websites. Nominations should be sent directly to Secretary General (remembering a 10,000 word summary of the thesis needs to be prepared and ISRM membership demonstrated).

ISRM On-line lectures

Two on-line lectures have been given over the last months:

- 26th by Dr José Vieira de Lemos (Portugal) on " Discrete element modelling of dam foundations " presented on 26 June
- 27th by Prof. Derek Elsworth (USA) on "Seismicity-Permeability Coupling in the Breaching and Sealing of Reservoirs and Caprocks" presented on 25 September.

The lectures are available on the ISRM website (ISRM online lectures - e.g. https://www.isrm.net/gca/index.php?id=1380 for Dr Lemos).

Communication:

The ISRM website (www.isrm.net) has information on the society's intent, structure and activities, including conferences, commissions, awards, products and publications. For those AGS members affiliated to ISRM as individual members there is a member area with access to further products. There is also Linked in, Twitter or RSS access.

Regular means of communication (under ISRM information on the website) are:

- ISRM Newsletter, which has been published quarterly since March 2008.
  Last issues No 44, 45, 46 in March, June and September 2019
- ISRM News Journal, now under the editorship of Dr José Muralha (Portugal)
  Last issue No 21 (Dec 2018)

The ISRM Digital Library, which was launched in October 2010, is intended to make rock mechanics material available to the rock mechanics community, in particular papers published from ISRM Congresses and sponsored Symposia. It is part of OnePetro (https://www.onepetro.org), a large online library managed by the Society of Petroleum Engineers.

It includes proceedings from 56 ISRM sponsored conferences and ISRM individual members are allowed to download, at no cost, up to 100 papers per year from the ISRM conferences. To use this facility ISRM members must register each year, with further details given on the ISRM website (https://www.isrm.net/gca/?id=992).

FedIGS (Federation of International Geo-Engineering Societies www.geoengineeringfederation.org/):

The second meeting of the FedIGS board for the 2018 – 2022 term was held between the Board and Council meetings in Foz do Iguassu. The main function of the Board is the exchange of information on management of the four member geotechnical societies (ISSMGE, IAEG, ISRM, IGS) technical activities, current issues and future developments. There are also three FedIGS Technical Commissions for which reports were presented.

This will be my final report as my term as Vice President finished at the Congress. Ongoing reporting will be handled between Sevda Dehkoda, 2019 – 2023 Vice President for Australasia, and Marlene Villeneuve, NZGS liaison for ISRM, who also attended the Foz do Iguassu Council meeting.

Stuart Read

International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) Regional Report for Australasia

Mid-Term Regional Report For Australasia

December 2019

The ISSMGE is the pre-eminent professional body representing the interests and activities of Engineers, Academics and Contractors all over the world that actively participate in geotechnical engineering.

1. INTRODUCTION

As most of you will know, Gavin Alexander has had to withdraw from his role as Vice President for Australasia, a role that I have taken up. Thank you for your excellent contributions to ISSMGE, Gavin. You are an outstanding example to us all. I hope to serve the NZGS and AGS as well as you have, and I will endeavour to continue your goals to increase the profile of the ISSMGE amongst our members.

2. CAPE TOWN BOARD MEETING

The ISSMGE Board Meeting was held in Century City, Cape Town on Saturday 5 October 2019. There were a few items discussed during the all-day meeting that may be of interest to our region. Our President Charles Ng has signed onto the Cooperation Agreement for the Federation of International Geo-engineering Societies (FedIGS). This Agreement was approved in the meeting of the Presidents of IAEG, ISRM, and ISSMGE in Amsterdam, The Netherlands on May 12, 2006, modified by the FedIGS Board in the meeting of the Board Members of IAEG, ISRM, ISSMGE, and IGS in Shenyang, China on 4 July 2015, and modified again by the FedIGS Board in the meeting of the Board Members of IAEG, ISRM, ISSMGE, and IGS in San Francisco, USA on Sept. 24, 2018.

Secondly, ISSMGE is pleased to announce the launch of its Conference Review Platform (CRP). This platform is provided at no cost with the requirement that published papers will become available in open access through the ISSMGE Online Library. The ISSMGE is very excited to make this cyber-infrastructure available to the geo-community and we hope it will further support unrestricted access to scientific material at a global scale.

Thirdly, and as a part of the ISSMGE's President initiatives, a new Technical Committee (TC) on Machine learning and big data was proposed by NGI. Together with other two TCs, all proposals and potential new Chairs were approved and presented to the Board for discussion and final approval:

- TC309: Machine learning (25/1/2018), by Dr. Zhongqiang Liu from NGI (Norway)
- TC219: System Performance (2/4/2019), by Prof. Gang Zheng from Tianjin University (China)
- TC220: Field instrumentation (2/4/2019), by Dr. Andrew Ridley from Geotechnical Observations (UK)

3. ISSMGE COUNCIL MEETING

The Board Meeting was followed the next day by the ISSMGE Council Meeting, which are held every two years and typically occur mid-way between International Conferences. The Council Meeting was well attended by delegates representing many of the 92 member societies. I was honoured to present Gavin's Regional Report to the Council on behalf of the AGS and the NZGS. Towards the end of the Council Meeting, things became a little livelier when the Secretary General presented the proposed ISSMGE budget for the next two years. Following a debate and vote sparked by the delegate from Germany, an increased amount for the ISSMGE Foundation of £40,000 for Financial Year 2021 was carried and approved. The ISSMGE Foundation was created to aid individual ISSMGE members throughout the world to enhance their geotechnical engineering knowledge and practice by providing financial support for participation in technical and professional activities approved by the ISSMGE Foundation. There is no prescriptive list of admissible events and all reasonable applications will be considered, considering the relevance to ISSMGE and active rather than passive participation by the applicant.

The next day, Monday 7th October 2019, the 17th African Regional Conference on Soil Mechanics and Geotechnical Engineering, was kicked off by The President of ISSMGE and the VP-Africa, Etienne Marcelin Kana. The opening addresses include a presentation by Chungsik Yoo, President of the IGS.

4. ICSMGE 2021 SYDNEY 2021

Preparations for Sydney 2021 continue, with the Local Organising Committee, led by John Carter, with Graham Scholey's support and the committee meeting regularly. I am sure that The Conference will be one not to be missed. Mark Jaksa's Technical Program Committee is putting together an outstanding and jam-packed technical program. I encourage you to support them, and this world class event, in whatever way you can.

5. THE CORPORATE ASSOCIATES PRESIDENTIAL GROUP (CAPG)

Peter Day is now the Chair of the CAPG, with our own Sukumar Pathmanandavel being Co-Chair.

It is fair to say that the profile of the corporate associates and CAPG have never been higher or more active than at present.

Very soon, the first New Zealand

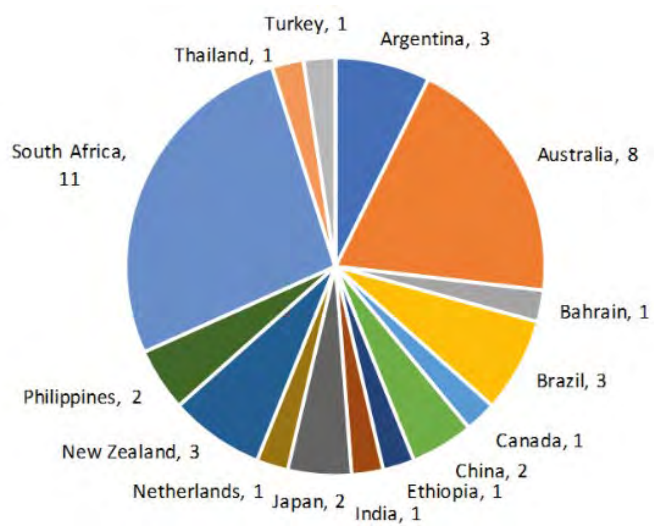


Figure: Distribution of the Responses to Date based company will become a Corporate Associate of the ISSMGE. Thanks to Gavin Alexander for initiating and encouraging Ground Investigation to become a Corporate Associate. Thank you to Marco Holtrigter at Ground Investigation Ltd, we welcome you to the ISSMGE.

Please encourage you Corporate Colleagues to consider joining the ISSMGE as a Corporate Associate. It is a great way to reach out to the ISSMGE membership and cheap way of getting international exposure.

6. "ARE WE OVER DESIGNING?" SURVEY

Sukumar and Peter are committed to making the "are we over designing?" survey highly meaningful and are working to have the findings presented at the Sydney 2021 conference. I would like us to have a strong showing from Australia and NZ. Globally, Peter and Sukumar would like to have a minimum of 200 responses by Dec 2020. ANZ has contributed well to date with 11 responses (see below distribution of the 44 responses to date).

In addition to providing valuable insight into the practice of design across various countries in the world, the survey is also a great opportunity to benchmark your companies approach to design of relatively simple geotechnical problems. No details of the company are required nor would these details, even if provided, be released.

Full details of how to undertake and submit the survey can be found both on the ISSMGE website: https://www.issmge.org/news/are-we-overdesigning-a-survey-of-international-practice and in Geoworld (https://www.mygeoworld.com/file/139638/capg-overdesign-survey).

7. THE ISSMGE APP

On my commute home the other day, I downloaded the ISSMGE App onto my phone. It is a great way to keep up to date with the Society's activities and content. You can take in a webinar or read from one of the international conference proceedings. It certainly made my train ride home go quickly! For more information about the ISSMGE, please visit www.issmge.org

8. NEXT BOARD MEETING

Our next ISSMGE Board Meeting will be in Hammamet, Tunisia on Sunday 8 March 2020 followed by the International Conference on Geotechnical Engineering (ICGE'20) organised by the Research Laboratory in Geotechnical Engineering and Georisk (RLGEG), the 4th edition of the series labelled "Innovative Geotechnical Engineering".

Finally, Graham and I would like to wish you and your families all the best for the festive season and summer holidays.

Best regards,

Philip Robins
ISSMGE Vice President for Australasia
philip.robins@beca.com

Graham Scholey
AGS Liaison with the ISSMGE VP for Australasia
gscholey@golder.com.au

Philip Robins

Philip is a Technical Director – Geotechnical with Beca based in Wellington, with over 20 years' experience specialising in geotechnical analysis and design. He has been involved in the design and construction of major infrastructure projects in New Zealand, California, Hong Kong and Southern Africa. Philip was Chair of the NZGS Management Committee from 2009 to 2010.

NZGS SYMPOSIUM 2020

Good grounds for the future

15–17 October 2020 • Dunedin • New Zealand

The 21st Symposium of the New Zealand Geotechnical Society will take place between 15 and 17 October 2020 with an optional workshop & field study preceding it.

In this Symposium we will explore the challenges and opportunities of our future, by learning from the failures and achievements of our past. The theme ***Good grounds for the future*** is inspired by the profound changes currently being experienced in New Zealand and internationally.

Workshop & Field Study

Make your way to Dunedin a memorable experience!

QUEENSTOWN WORKSHOP: 14TH OCTOBER 2020

FIELD STUDY: 15TH OCTOBER 2020

Join us in Queenstown before the Symposium, for a workshop followed by a field study that will take you through the Cromwell Gorge landslides (by bus) and the spectacular Taieri River Gorge (by train).

Disembark the train at the station in time for the welcome reception at the adjacent Toitū Otago Settlers Museum!

We are happy to announce confirmed workshop speakers Robert Sharon and Steve Parry. Robert is an open pit and underground mining specialist and an expert in slope monitoring techniques. Steve's expertise is in natural slope and landslide hazards.

Ross W. Boulanger
Professor and Director, Center for Geotechnical Modeling, University of California at Davis, USA

George Gazetas
Professor of the National Technical University of Athens, Greece

Chris Haberfield
Principal, Golder Associates, Melbourne, Australia

Sissy Nikolaou
AVP, Principal of Multi-Hazards & Geotechnical Engineering, WSP Fellow of Earthquake Engineering, USA

Abstract submissions

Abstract submissions have closed. The organising committee is pleased to advise it has received an exceptional number of submissions. We are looking forward to a robust programme with themes to include (but not be limited to):

- Major infrastructure projects
- The NCTIR project
- Soil/structure interaction
- Revisions to Standards & Practices
- Slope stability and landslides
- Resilience
- Geotechnics and climate change
- Sustainability
- International practice

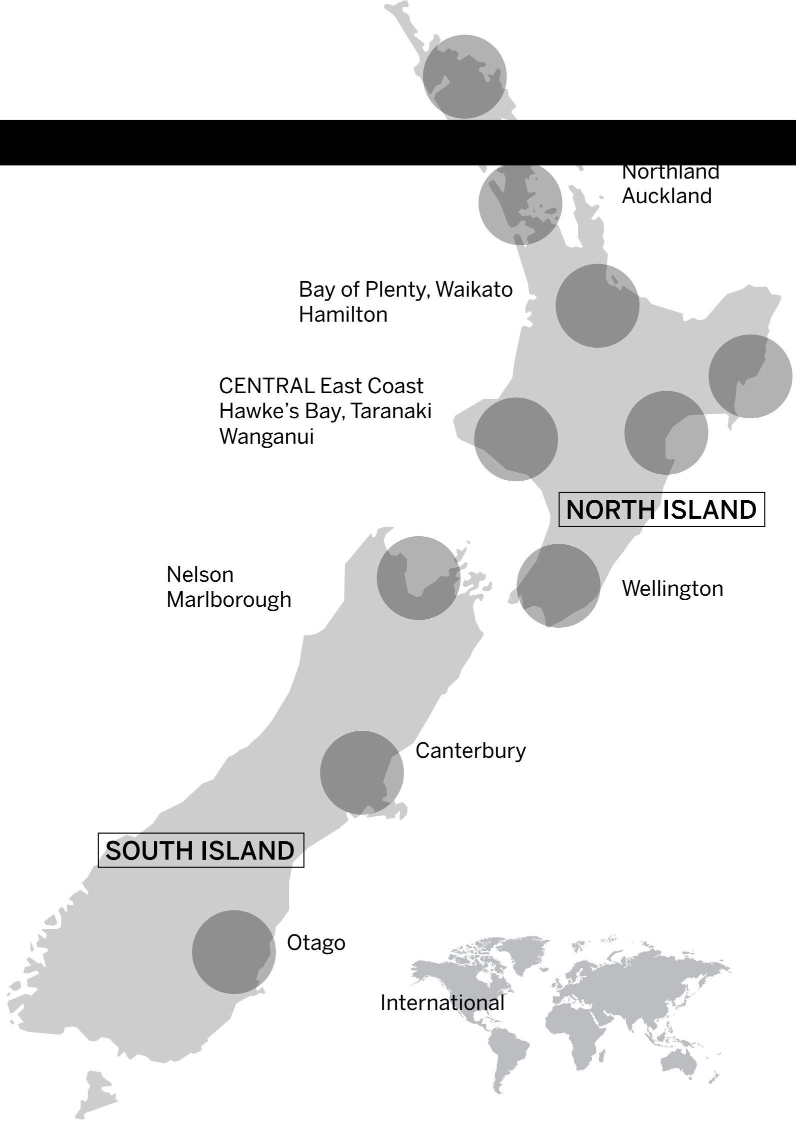
New Zealand Geotechnical Society

"Geotechnical engineering and engineering geology are now widely perceived in New Zealand as an integral part of our modern communities." — **Eleni Gkeli, 2020 Convenor**

For more information head to nzgs2020.co.nz

Questions? nzgs2020@confer.co.nz

Branch reports



AUCKLAND

The Auckland branch kicked off the winter with the appointment of two new branch coordinators, Ben Francis and Jay Doddaballapur. They take over from James Johnson, who we thank for his considerable efforts in running events in Auckland. Presentations brightening up the dull and bleak weather included GIS for Geotechnical Engineers by Colin Mazengarb and Northland Allochthon by Aaron George.

Short courses on Geotechnical Engineering in Residual Soils by Prof. Laurie Wesley, Design & Construction on Soft Soil by Dr. Richard Kelly and Nick Wharmby, Cone Penetration Testing by Geomil, and a Screw Piling Demo Day by Piletech were well attended and received by the audience.

Prof. BK Low of Nanyang, Singapore presented at the joint ASCE-NZGS event in October on Insights from Reliability-Based Design to Complement Load and Resistance Factor Design Approach. At the start of November, a presentation on Chartership for Geotechnical Engineers by Geoff Farquhar and Malcolm Stapleton, with insights from Jeremy Tan & Eli Maynard, and the 2nd YGP Symposium were organised for young professional engineers. The year will be topped off with the Christmas mini symposium in early December where we are expecting close to 100 attendees with keynote lectures by Prof Laurie Wesley and Prof Mick Pender, and several short presentations.

Auckland would like to thanks Geotechnics, Ground Investigation and Engineering NZ for their support of these events.

WAIKATO

On 8 October, Piletech hosted a screw piling demonstration in the underground carpark below the Hamilton Kmart on the corner of Ward Street and Tristram Street, Hamilton.

The screw piles are part of a seismic retrofit to the building, which is soon to house Waikato Regional Council.

The event was well attended by NZGS members as well as structural and geotechnical engineers.

Waikato Expressway – Hamilton Section Site Visit

On 16 October the City Edge Alliance led tour of the Waikato Expressway – Hamilton Section. Raj Ramgobin (Geotechnical Engineer-CPS) and Jessica McLennan (Engineering Geologist-CPS) took us on a grand tour by ute convoy of the southern portion of the new state highway project. The first stop was the Powell's Road large box culvert site to observe the preloads over very soft soils and full array of settlement monitoring instrumentation. The group then travelled to the Mangaonua and Mangaharakeke Bridges to check out dynamic replacement ground improvement, soil nails and contiguous and soldier pile retaining walls. The attendees obtained excellent insights into the design and construction challenges with optimised design solutions employed to successfully achieve performance criteria whilst considering practical construction and programme requirements.

Big thanks also to Dave Sullivan that organised the visit, but sadly couldn't make it on the day.

HAWKES BAY

We currently have plans for proposed GNS presenters to arrange their respective trips to HB

- **Julie Lee** and **John Begg** are presenting updated Hawkes Bay geological, geomorphological and 3d maps/models.
- **Simone Dellow** is undertaking a quantitative risk assessment on the Cape Kidnappers rockfalls which occurred at the start of the year - when it's complete.

The Engineering NZ course "Liquefaction Assessment In Engineering Practice (MBIE/NZGS Module 3)" was very well received by attendees. Local practitioners are very familiar with the module and appreciated the discussion about anticipated future amendments.

WELLINGTON

The Wellington branch was pleased to host the NZGS AGM on 3 September at Engineering New Zealand. Marco Holtrigter opened the AGM with his presentation on "Industry best practice for CPT testing in NZ". In his presentation, Marco described several issues that can affect the quality of CPT Test results and suggested ways that they can be mitigated. It was an interesting presentation. Marco et al. are currently working on a best practice document for New Zealand. This will raise the industry standard for CPT Testing nationwide which can only benefit us all – we look forward to seeing it.

We were also honoured to host Prof. B.K. Low on 8 October to present his paper "Insights from reliability-based design to complement load and resistance factor design" which won the ASCE 2019 Thomas A. Middlebrooks Award. We were also pleased to have Warren Ladbrook (President of the New Zealand branch of ASCE) welcome everyone and introduce Prof. Low. The presentation was attended by a small but enthusiastic group. Thanks to ENGEO for sponsoring the event and to Engineering New Zealand for provided the venue and behind the scenes help.

This year we welcomed Safia Moniz to the Wellington Branch. Already, she has made valuable contributions to the First Wellington Young Geotechnical Professionals Conference as well as other events. We look forward to working with her in the next year.

Looking forward to 2020, we have the opportunity to host a number of international speakers which is a wonderful opportunity for the branch. We are also investigating ideas for a field trip, and to have some QuakeCoRE researchers present their work. We will have the second Wellington Young Geotechnical Professionals Conference (YGP) in the second half of the year, so please start brainstorming ideas. Finally, we are working on a member survey to assess what presentations you would like to see, but in the meantime feel free to contact Shirley, Safia, Jerry or Aimee with your ideas.

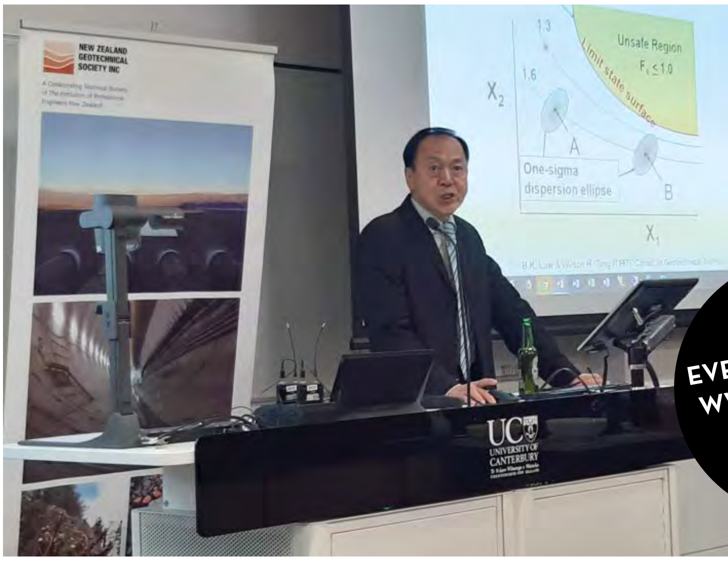
NELSON

Nelson had a busy September with various events in conjunction with the local EngNZ and SESoc Branches, including presentations at the QuakeCore conference, 'things I learnt the hard way' presentations from some of the regions experienced engineers and geologists and a visit from EngNZ representatives from Wellington to talk about the career pathways for gaining chartership and PEngGeol. These we well attended by many of our members and were great events for networking and welcoming any new geologist or engineers

who have arrived in the Nelson and Marlborough regions in the recent months.

Coming up to Christmas we have a presentation from Geo Fabrics lined up and a presentation from Paul Wopereis, Mike Johnston and Francesca Ghisetti about the revised geological map of the Nelson area.

A Christmas event including a wee bit of competition and drinks and food is currently being organised in conjunction with EngNZ and SESoc, so keep your eyes and ears open to find out more information.



Left: The Presentation was Insights from Reliability-based Design to Complement Partial Factor Design Approach by Dr Bak Kong Low at the University of Canterbury on Monday 7th October 2019.

PHOTO: PHOTO BY APRIL LANDER

SEE THE EVENTS DIARY OR WWW.NZGS.ORG FOR FUTURE EVENTS

CHRISTCHURCH

It's been quite a busy few months for us in Christchurch!

We were very fortunate to host Professor Carlo Lai of the University of Pavia on September 12th for his talk *Design vs Threshold Earthquakes at Cultural Heritage Sites*. Given his Italian heritage (and the sheer number of heritage buildings in Italy) it was fascinating for us to learn about the regulations and policies surrounding repairing and assessing such historic buildings. This event was sponsored by Beca and held at the Engineering Core at the University of Canterbury and had close to 50 attendees!

Then on October 7th we were delighted to host Prof. B.K. Low on 8 October to present his paper *Insights from reliability-based design to complement load and resistance factor design* which won the ASCE 2019 Thomas A. Middlebrooks Award. Thank you to Warren Ladbrook (President of the New Zealand branch of ASCE) who welcomed everyone and introduced Prof. Low. This event was held again at the Engineering Core at the University of Canterbury and attended by an intimate audience. Because of the small size of the audience we were able to have lengthy discussions and conversations with Prof Low. Thank you to Geotechnics for sponsoring the event.

Finally, on October 30th we had the pleasure of hosting Dr. Dave Baska, a visiting Erskine fellow from the University of Washington, who presented his talk

The Critical State of Geotechnical Consulting in the USA. This talk summarized they key problems in geotechnical consulting and postulated what the future may look like in geotechnical engineering in the USA. Dr. Baskin was quick witted and engaged with his 20 or so attendees (which, was once again hosted at the Engineering Core at the University of Canterbury). The next day (on Halloween), Opus agreed to sponsor and host a talk on permafrost design with Dr. Jim Oswell, however, Dr Oswell was unable to leave Antarctica due to storms! We hope we can reschedule this talk.

A special thank you to Prof Mark Stringer on facilitating all the talks these past few months. We look forward to the new year and hope we continue to have as many wonderful lectures and discussions.

DUNEDIN

- Matt has joined me as a branch co-ordinator which is great.
- We had a presentation about Abbotsford Landslide a few months ago, which was arranged by Engineering NZ and was well received.
- Apart from that, we have not had any presentations but we are looking to bring at least one or two down this way in the next few months. Obviously the NZGS Conference in Dunedin next year is the big one.

★ GEO-NEWS WEEKLY E-NEWSLETTER ★

Our new weekly email lists all notices and Branch announcements normally sent to members, but in one email. Please send items to include to **secretary@nzgs.org**

NORTHLAND

Jay Doddaballapur
Jay is a Chartered Principal Geotechnical Engineer with an MSc in Geotechnical Engineering from the University of Glasgow. He has worked in the UK, Middle East and New Zealand on buildings, infrastructure and marine projects. He has experience in design and management of temporary and permanent works with a particular focus on providing value engineered, sustainable and buildable solutions. **jay.doddaballapur@aecom.com**

AUCKLAND

Eric Torvelainen
Eric is a senior geotechnical engineer with EGL (Engineering Geology Limited). Eric has a BE(Hons) from the University of Canterbury and his experience includes design and loss estimation for infrastructure projects across New Zealand. Eric began his carrier in Wellington tackling many of the cities geotechnical and earthquake challenges and now supports projects across New Zealand.
eric.torvelainen@egl.co.nz

Ben Francis
Ben is a geotechnical engineer with Tonkin & Taylor in Auckland and has a BE(Hons) and MEngSt(Geotech) from the University of Auckland.
He has a broad interest in geotechnical engineering design, with a focus in liquefaction and geotechnical earthquake engineering.
He works on technically challenging projects across NZ and internationally.
BFrancis@tonkintaylor.co.nz

Christopher Wright
Chris is a geotechnical engineer at Riley Consultants Ltd. He has bachelors degree in civil engineering (University of Southern Queensland) and finance (Massey University) and is currently undertaking post-graduate studies in geotechnical engineering at the University of Auckland.
He began in civil engineering and infrastructure asset management, and progressed to geotechnical engineering.
cwright@riley.co.nz

WAIKATO

Kori Lentfer
Kori is a Engineering Geologist. He graduated in 1998 with a BSc(Tech) in Geology, followed by Masters study at Waikato University and an MSc thesis in Engineering Geology from Auckland University in 2007. Kori has worked for consultants based in the UK, Europe and the Middle East.
koril@cmwgeosciences.com

Andrew Holland
Andrew is a Director of HD Geotechnical. He studied engineering at the University of Auckland, graduating in 2002.
Andrew's experience includes geotechnical investigation, assessment and design for infrastructure, buildings and development. Andrew is a Chartered Professional Engineer (CPEng).
Andrew@hdc.net.nz

BAY OF PLENTY

James Griffiths
James is an Engineering Geologist with Beca in Tauranga. After a previous life working in outdoor education and guiding on the Fox Glacier for 7 years, James studied Geology at Otago University, graduating in 2014 with a BSc (Hons). James has worked on site hazard assessments, geotechnical site investigations and ground modeling for a broad range of clients and market sectors.
James.Griffiths@beca.com

Kim de Graaf
Kim is a Geotechnical Engineer with Beca and is based in Tauranga.
Kim's experience includes earthworks, seismic assessments, building foundation design, 3 waters projects and resilience workshops. Kim is also a Safety in Design facilitator and the Geotechnical Lead for the Safe Roads Alliance in the Bay of Plenty.
kim.degraaf@beca.com

HAWKE'S BAY

Tom Grace
Tom is a geologist who has worked for consulting companies on a large range of projects - predominately mineral exploration, mining feasibility & development and geotechnical projects in Southeast Asia, Canada, Australia and New Zealand. Tom has a strong interest in ground testing (CPT, surface and downhole geophysics, downhole testing).
tgrace@rdcl.co.nz

Sirini De Silva
I work with RDCL as an Engineering Geologist. I graduated with a BSc(Hons) from UoA in 2017 and briefly worked in Kaikoura for the NCTIR project. I have experience in geotechnical site investigations, ground modelling, materials testing, site hazards and liquefaction assessments.
sdesilva@rdcl.co.nz

Jerry Spinks
Jerry is a Chartered Professional Engineer, who graduated from Canterbury University (Civil) then worked in the UK on a large transport and windfarm projects. Since returning to NZ in 2010 he has developed a keen interest in building seismic assessments and strengthening. He enjoys working closely with structural engineers to develop thorough and reliable assessments of the ground.
Jerry.Spinks@jacobs.com

Safia Moniz
Safia is a Chartered Professional Engineer who has worked in the Caribbean and New Zealand since graduating from the University of the West Indies with a Degree in Civil Engineering (Hons) in 2004. She completed a Masters in Geotechnical Engineering at MIT in 2009. Recent projects include deep foundation design and ground improvement for buildings and bridges.
safia.moniz@holmesconsulting.co.nz

WELLINGTON

Aimee Rhodes
Aimee is a graduate geotechnical engineer with Opus. She recently completed her Masters degree in Earthquake Engineering with the University of Canterbury. Aimee has experience with liquefaction analysis and soil characterisation having worked on modelling liquefaction in stratified soils for her Masters research.
aimee.rhodes@wsp.com

Shirley Wang
Shirley is a Geotechnical Engineer with 8 years of experience working at Tonkin & Taylor Wellington Office. She graduated from Canterbury University with a BE(Hons) in 2009. She has experience in seismic assessment, geotechnical and environmental investigation, slope stability, foundation design and construction monitoring.
SWang@tonkintaylor.co.nz

NELSON

Kylie Johnson
I'm an Engineering Geologist for CGW Consulting Engineers based in Nelson. I have been a geologist over much of New Zealand and a keen member NZGS for the past 7 years. I look forward to being part of the team with Rebecca to bring great talks and field trips to our region.
Kylie@cgwl.co.nz

Rebecca.McMahon
A Geotechnical Engineer for Beca, I have been a keen NZGS member for the last seven years and am looking forward to the opportunity to assist Kylie with running events for our region. As I am also a committee member for Engineering NZ. Kylie and I will be looking for ways to combine some site visits and meetings to make the most of the awesome people, projects and places we have here in Nelson.
Rebecca.McMahon@beca.com

CANTERBURY

Duncan Henderson
Duncan is a Geotechnical Engineer at Tonkin & Taylor in Christchurch where he has been since October 2017. He has been involved in a range of projects, most recently in the Geotechnical Structures design team for the NCTIR alliance. Duncan completed his BE(Hons) in 2010 and Masters of Engineering in 2013, both at the University of Canterbury.
DHenderson@tonkintaylor.co.nz

Charles McDermott
Charles is a Senior Geotechnical Engineer with Miyamoto in Christchurch. He is originally from the UK where he graduated with a BEng (hons) in Civil Engineering from Kingston University (2007). Charles moved to Christchurch in 2013 where he has been involved in earthquake recovery and the design of a number of large infrastructure projects.
cmcdermott@miyamotointernational.com

OTAGO

Nima Taghipouran
Nima is a chartered professional engineer based in the WSP-Opus office in Dunedin. Nima graduated from the University of Auckland in 2012. He has been involved in a wide range of medium to large scale projects throughout the lower North Island. His areas of interest include foundation and retaining wall design, slope stabilisation and earthquake engineering.
nima.taghipouran@wsp.com

Matt Fitzmaurice
Matt is an engineering geologist in GHD's Dunedin office. He has 9 years' experience working in both the Western Australian mining industry (predominantly underground), and in New Zealand consultancies. Matt's areas of interest typically revolve around rock mechanics, and he loves to get out of the office and walk around the hills looking at rocks.
matthew.fitzmaurice@ghd.com

QUEENSTOWN

Paul Jaquin
Paul is a Chartered Professional Engineer, and is Work Group Manager for Buildings and Structures in the WSP Queenstown office. He works across a range of disciplines, including building foundations, bridge assessment, retaining walls, rockfall and landslide analysis. Paul holds a PhD in unsaturated soil mechanics and is a recognised expert in mud brick construction, providing advice and engineering expertise internationally.
Paul.Jaquin@wsp-opus.co.nz

NEW ZEALAND GEOTECHNICAL SOCIETY INC

The New Zealand Geotechnical Society (NZGS) is the affiliated organization in New Zealand of the International Societies representing practitioners in Soil mechanics, Rock mechanics and Engineering geology. NZGS is also affiliated to the Institution of Professional Engineers NZ as one of its collaborating technical societies.

The aims of the Society are:
a) To advance the education and application of soil mechanics, rock mechanics and engineering geology among engineers and scientists.
b) To advance the practice and application of these disciplines in engineering.
c) To implement the statutes of the respective international societies in so far as they are applicable in New Zealand.
d) To ensure that the learning achieved through the above objectives is passed on to the public as is appropriate.

All society correspondence should be addressed to the Management Secretary (email: secretary@nzgs.org).

The postal address is
NZ Geotechnical Society Inc,
P O Box 12 241,
WELLINGTON 6144.

Welcome to the last issue of 2019. It has been a busy year with membership continuing to grow as well as many courses, Presentations, Mini Symposiums and local YGP events. There are more events planned for 2020 with your branch Reps working hard to ensure these all run smoothly. I would also like to thank the companies that support us in sponsorship as well as advertising in the New Zealand Geomechanics News. It is greatly appreciated.

Finally, I would like to wish you all a very happy and safe summer break and look forward to assisting you in 2020!

Please remember to contact the Management Secretary (Teresa) if you wish to update any membership, address or contact details. If you would like to assist your Branch, as a presenter or sponsor, or to provide a venue, refreshments, or an idea, please drop a line to your Branch Co-ordinator or Teresa. If you require any information about other events or conferences, the NZGS Committee and NZGS projects, or the International Societies (IAEG, ISRM and ISSMGE) please contact the Secretary on secretary@nzgs.org You may also check the Society's website for Branch and Conference listings, and other Society news: www.nzgs.org

Management Committee 2019-2020

POSITION	NAME	EMAIL
Chair	Ross Roberts	chair@nzgs.org
Vice-Chair & Treasurer	Eleni Gkeli	treasurer@nzgs.org
Immediate Past Chair	Tony Fairclough	TFairclough@tonkin.co.nz
Elected Member	Sally Dellow	S.Dellow@gns.cri.nz
Elected Member	Sally Hargraves	sally@tfel.co.nz
Elected Member	Rolando Orense	r.orense@auckland.ac.nz
Elected Member	Jen Smith	jsmith@tonkintaylor.co.nz
Appointed Member	Teresa Roetman	secretary@nzgs.org
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Co-opted YGP Representative	Aine McCarthy	aineymcc@gmail.com
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ISRM Australiasian Vice President	Stuart Read	S.Read@gns.cri.nz
ISSMGE Australasian Vice President	Phil Robins	Philip.Robins@beca.com

EDITORIAL POLICY

NZ Geomechanics News **is a biannual bulletin issued to members of the NZ Geotechnical Society Inc.**

Readers are encouraged to submit articles for future editions of NZ Geomechanics News. Contributions typically comprise any of the following:

- **technical papers which may, but need not necessarily be, of a standard which would be required by international journals and conferences**
- **technical notes of any length**
- **feedback on papers and articles published in NZ Geomechanics News**
- **news or technical descriptions of geotechnical projects**
- **letters to the NZ Geotechnical Society or the Editor**
- **reports of events and personalities**
- **industry news**
- **opinion pieces**

Please contact the editors (editor@nzgs.org) if you need any advice about the format or suitability of your material.

Articles and papers are not normally refereed, although constructive post-publication feedback is welcomed. Authors and other contributors must be responsible for the integrity of their material and for permission to publish. Letters to the Editor about articles and papers will be forwarded to the author for a right of reply. The editors reserve the right to amend or abridge articles as required.

The statements made or opinions expressed do not necessarily reflect the views of the New Zealand Geotechnical Society Inc.

NEW ZEALAND GEOTECHNICAL SOCIETY INC

NZGS Membership SUBSCRIPTIONS

Annual subscriptions cost $105 per member. First time members will receive a 50% discount for their first year of membership; and student membership is free. Membership application forms can be found on the website http://www.nzgs.org/membership.htm or contact the NZGS Secretary on secretary@nzgs.org for more information.

Letters or articles for NZ Geomechanics News should be sent to editor@nzgs.org.

MEMBERSHIP
Engineers, scientists, technicians, contractors, students and others who are interested in the practice and application of soil mechanics, rock mechanics and engineering geology are encouraged to join.

Full details of how to join are provided on the NZGS website http://www.nzgs.org/about/

Advertisers' Directory

ADVERTISING

NZ Geomechanics News is published twice a year and distributed to the Society's 1000 plus members throughout New Zealand and overseas. The magazine is issued to society members who comprise professional geotechnical and civil engineers and engineering geologists from a wide range of consulting, contracting and university organisations, as well as those involved in laboratory and instrumentation services. NZGS aims to break even on publication, and is grateful for the support of advertisers in making the publication possible.

TYPE	BLACK AND WHITE	COLOUR	SPECIAL PLACEMENTS		SIZE
			INSIDE FRONT OR BACK COVER	OPPOSITE CONTENTS PAGE	
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Full page A4	$600	$700	$1000	$1000	210mm wide x 297mm high
Half page	$300	$350	-		90mm wide x 265mm high 210mm wide x 148mm high
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Flyers/inserts	From $700 for an A4 page, contact us for an exact quote to suit your requirements as price depends on weight and size.

Notes
1. All rates given per issue and exclude GST
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3. A 3mm bleed is required on all ads that bleed off the page.
4. Advertiser to provide all flyers
5. Advertisers are responsible for ensuring they have all appropriate permissions to publish. This includes the text, images, logos etc. Use of the NZGS logo in advertising material is not allowed without pre-approval of the NZGS committee.

National and International Events

LINKS ARE AVAILABLE FROM THE NZ GEOTECHNICAL SOCIETY WEBSITE WWW.NZGS.ORG

2020

18-22 January
Edinburgh, Scotland
2nd International Symposium on Seismic Performance and Design of Slopes

19-20 February
Baghdad, Iraq
International Conference on Geotechnical Engineering

9–11 March
Tunisia
International Conference on Geotechnical Engineering (ICGE'20)

26–29 April
Rio de Janeiro, Brazil
Geoamerica2020

25-27 May
Helsinki, Finland
14th Baltic Sea Geotechnical Conference2020

5-7 June
Beijing, China
1st international Conference on Embankment Dams (ICED020)

June
Trondlheim, Norway
Eurock2020

15-19 June
Columbia
XIII International Symposium on Landslides Cartagena2020

25-25 June
Athens, Greece
International Conference on Geotechnical Engineering Education

29 June – 1 July
Cambridge, England
TC204 Geotechnical Aspects of Underground Construction in Soft Ground

13– 16 July
Roorkee, India
7th International Conference on Recent Advances in Goetechnical Earthquake Engineering and Soil Dynamics

24-26 July
Lisbon, Portugal
4th European Conference on Unsaturated Soils – Unsaturated Horizons

16-19 August
Texas, USA
2020 International Symposium for Offshore Geotechnics ISFOG

30 August – 2 September
Illinois, USA
4th International Conference on Transportation Geotechnics (ICTG)

7-11 September
Budapest, Hungary
6th International Conference of Geotechnical and Geophysical Site Characterization

1– 3 October
Perth, WA
Slope Stability 2020 Symposium

13- 16 October
Oxen Hill, USA
45th Annual Conference on Deep Foundations

23– 27 October
Beijing, China
ARMS11 – 11th Asian Rock Mechanics Symposium

16-18 October
Dunedin, NZ
NZGS Symposium 2020 – Good Grounds for the future

2-6 November
Kyoto, Japan
5th World Landslide Forum

15–18 November 2020
Arlington, USA
10th International Conference on Scour and Erosion

2021

1 June
Torino, Italy
EUROCK I2021

19-21 July
Nanchang, China
6th GeoChina International Conference

20-22 September
Asuncion, Paraguay
Latin American Congress on Rock Mechanics

12-17 September
Sydney, Australia
ICSMGE2021
20th International Conference on Soil Mechanics and Geotechnical Engineering

2022

31-17 June
Helsinki, Finland
EUROCK2022

2023

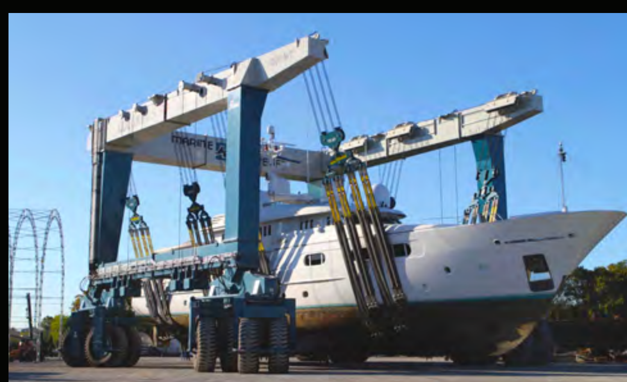
9– 14 October
Salzburg, Austria
15th ISRM International Congress in Rock Mechanics

INITIA

GEOTECHNICAL SPECIALISTS

Sleepyhead Estate – Ohinewai, North Waikato
Mixed-use, master-planned community including a 66ha industrial hub with rail siding access from the North Island Main Trunk railway, 8.5ha of commercial and retail and 33ha of residential development for 1,100 new homes.

Northport Western Expansion Project
Preliminary geotechnical investigations for the western expansion at Northport, Marsden Point, Whangarei including over water barge drilling and CPT's. Early design concepts include a dry dock facility with associated land reclamation.



Orams Marine, Wynyard Quarter, Auckland City
Construction of a new seawall, two commercial/retail buildings (see Left Image) and a new marine services facility for super yachts. The marine services facility comprises new piers extending into the harbour, a heavy-duty pavement capable of supporting a marine travel lift for vessels up to 800t in weight (see right Image) and two large boat sheds for maintenance.

www.initia.co.nz

INITIA

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