

# NEW ZEALAND GEOMECHANICS NEWS

DECEMBER 2005, ISSUE 70

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## CHAIRMAN'S CORNER

This edition of Chairman's corner may well be shorter than usual as I have had to interrupt another busy day (evening!) to pen this short message under pressure from our gracious but determined editor. The feedback I have been receiving from members around the country is that every one is flat out and struggling to keep up with demand for our services in what Dr Bollard is convinced is an overheated economy. I'm sure he's right, at least it seems that way down here in the boiler room.

Under these conditions every one of us finds it harder and harder to contribute the time and energy necessary to keep a voluntary organisation such as the NZGS functioning and vibrant. Special thanks then to those of you who continue to work for the Society and those who have made the considerable effort to contribute to the organisation and to prepare papers for our upcoming biennial symposium in Nelson (17-18 February 2006).

As we go to press we have already received a good number of excellent papers for the symposium with more in the pipeline. The technical quality of the symposium is assured together with plenty of opportunity for social interaction and catching up with old friends and new, with an al fresco spit-roast vineyard dinner sure to please. The trade displays are fully subscribed and as a new innovation, an exciting live demonstration of new technology is included. Several interesting field trips are planned for the Sunday including an excursion to the Nelson Lakes area. By the time you receive this edition of *Geomechanics News* many of you will have already registered, those who haven't please hurry. After such a frantic period for our industry we all deserve a break, a chance to let our hair down, and time to catch up with new developments. What better opportunity than sunny Nelson in February? Be there or be square!

The theme for our symposium is *Earthquakes and Urban Development* – somewhat timely given the present vacuum of guidance regarding geotechnical design for earthquake resistance in the urban environment. The old NZS 4203 *General Structural Design and Design Loadings for Buildings* at least gave us some guidance for design of earth retaining structures subject to earthquake loading, even though the main implicit criterion was that retaining structures could fall down as long as they didn't damage buildings. This guidance was not perfect, but at least it provided some uniformity of approach. Design using the "equivalent static method" was encouraged with relatively low seismic coefficients ensuring that significant deformations would result during large earthquakes. Not necessarily compatible with actual soil pressures



developed against rigid basement walls though, amongst other problems. But NZS4203 is to be replaced by AS1170, which effectively excludes consideration of soil retaining structures stating that they should be the subject of a "special study". Not necessarily practical for every retaining wall we have to design!

Perhaps the time has come for the Society to step forward and help to fill the gap. Instead of sitting on the sidelines waiting for structural engineers to tell us how to design earth structures perhaps we should get involved with setting some guidelines that we can live with and that we decide are rational and represent the best state-of-the-art. To this end, we are planning to hold a panel session at the upcoming symposium to give you all a chance to air your views on this important subject. With sufficient interest and support the Society might establish a working group and seek funding for the development of some proper guidelines. Come along and have your say.

I look forward to catching up with you all in Nelson.

Best regards

**Kevin McManus**  
Chairman

## EDITORIAL

### Standards, excellence and professional development

I'm looking forward to the Society's Nelson Symposium in February. These events are a good opportunity to catch up with what's happening in the industry but also to catch up with colleagues and friends that we don't always see very often. Presently there are about 50 papers being reviewed. You can bet that *Geomechanics News* will be sending Phil Flash to capture the event.

The theme of the symposium is of course Earthquakes and Urban Development, and there will be a focus around the new loadings standard, particularly seismic lateral earth pressures and seismic slope stability and ground deformations. The Loadings standard deliberately left out seismic loads on retaining structures as a number of professional organisations asked to contribute (including the Geotechnical Society) could not agree on design principals. The Loadings Standard have been designed such they are modular and sections can easily be updated as required. It is the design professionals with experience in this area that need to contribute to the Standard and, as the Chairman indicates in his comment in this issue, the Geotechnical Society should step in and provide a robust guideline.

The new Building Act 2004 also has an impact and particularly how councils are interpreting Sections 71 and 72. Some local authorities are being somewhat overly cautious until case law under this new act is established. This may result in more work for the industry in an already "overheated" environment.

The new Guideline for the Classification and Field Description of Soils and Rocks for Engineering Purposes are presently being finalised and will be available from

the website in mid-December with an official launch at the Symposium. These have been the subject of robust debate but should provide a new improved tool for the Geotechnical industry.

The New Zealand Geomechanics Society Award is presented to the society member or members producing the best published paper in the last three years that is distinguished in its contribution to the development of geotechnics in New Zealand. The Management Committee are pleased to announce that the paper title "Rock Mass defect patterns and the Hoek-Brown failure criterion" by Stuart Read, Laurie Richards and Greg Cook is the winner of the award. The paper was presented to the ISRM 2003-technology roadmap for rock mechanics in South Africa in 2003 and published in the proceedings. It is republished in this issue of *Geomechanics News*. Congratulations to Stuart, Laurie and Greg who are all members of the society.

Finally, this is my last issue as editor of *Geomechanics News*. I have enjoyed putting the Magazine together with great assistance from the team. I haven't enjoyed constantly having to harangue members for their overdue, promised content and reports, and from now on I will always be providing my contribution before the specified deadline. If there is anyone out there who would like to take the magazine on and take it to a new standard, then please contact me, or any member of the committee.

**Phil Glassey**  
Editor

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## EDITORIAL POLICY

*NZ Geomechanics News* is a biannual newsletter issued to members of the NZ Geotechnical Society Inc. It is designed to keep members in touch with matters of interest within the Geo-Professions both locally and internationally. The statements made or opinions expressed do not necessarily reflect the views of the New Zealand Geotechnical Society Inc. The editorial team is happy to receive submissions of any sort for future editions of *NZ Geomechanics News*. The following comments are offered to assist potential contributors. Technical contributions can include 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
- comments on papers published in *NZ Geomechanics News*
- descriptions of geotechnical projects of special interest.

### General articles for publication may include:

- letters to the NZ Geotechnical Society
- letters to the Editor
- articles and news of personalities
- news of current projects
- industry news.

Submission of text material in camera-ready format is not necessary. However, typed copy in Microsoft Word is encouraged, particularly via email to the Editor or on floppy disk or CD. We can receive and handle file types of almost any format. Contact us if you have a query about format or content.

Diagrams and tables should be of a size and quality appropriate for direct reproduction. Photographs should be good contrast, black and white gloss prints or high resolution digital images. Diagrams and photos should be supplied with the article, but also saved separately as 300 dpi JPGs. Articles need to be set up so that they can be reproduced in black and white, as colour is limited.

*NZ Geomechanics News* is a newsletter for Society members and articles and papers are not necessarily refereed. 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 submitted by members will be forwarded to the contributing member for a right of reply.

Persons interested in applying for membership of the Society are invited to complete the application form in the back of the newsletter. Members of the Society are required to affiliate to at least one International Society and the rates are included with the membership information details.

## THE SECRETARY'S NEWS

As we approach the end of 2005 it is appropriate to mention the number of important events that have occurred this past year.

- New Zealand Geotechnical Society Student Prize Award is currently in process with flyers sent out in the Northern and Southern regions.
- The recipient of the New Zealand Geotechnical Society Geomechanics Award has been assessed and the winning paper published in this edition.
- There have been a number of interesting guest speakers and topics at various Branches.
- New ISSMGE VP Australasia Professor John Carter took over the role from Grant Murray in September.
- NZGS's IAEG representative Ann Williams presented our bid to host 11th IAEG Congress in New Zealand in 2010. Decision will be made in 2006.
- Preparations are well underway for the February 2006 NZGS symposium in Nelson. We look forward to seeing you all there.

Society membership is currently flourishing with a total of 521 members.



### New Members

It is a pleasure to welcome 16 new members into the Society since the last issue of NZ Geomechanics News.

### Subscriptions

Your subscription invoices for 2005/2006 – year have now been sent out. Please don't file them in the pay sometime later file. PLEASE PAY YOUR SUBSCRIPTIONS PROMPTLY. Thank you.

Please do contact me for any assistance you might require or any queries you might have.

**Imrana Azimullah**

Management Secretary  
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## Check it out – we are online!

- Regularly updated
- Has a comprehensive list of what is on
- Includes the Shear Vane Guidelines
- Employment Opportunities Listing



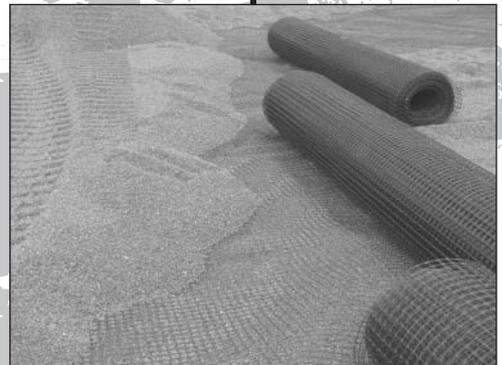
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## INTERNATIONAL SOCIETY REPORTS

### ISSMGE Australasia VP Report

#### REPORT ON COUNCIL MEETING – SEPTEMBER 2005

The ISSMGE Council met at the Grand Cube, International Convention Centre, Osaka, Japan, on Sunday, 11th September 2005.

#### Membership

Membership of ISSMGE on 31 August 2005 was 16330 in 76 Member Societies. This compares with 16242 members in 76 Member Societies reported to the Council Meeting held in Prague on the 24 August 2003.

#### Technical Committee Activity

The President reported that some Technical Committees had produced detailed reports on their achievements and that these would be published on the ISSMGE website. He also indicated that there had been discussion with the Sister Societies (ISRM and IAEG) on the formation of number of new Joint Technical Committees (JTC). JTCs existing or proposed are:

- JTC1 Landslides (lead by ISSMGE)
- JTC2 Representation of Geo-Engineering Data in Electronic Form (ISSMGE)
- JTC3 Education and Training (ISRM)
- JTC4 Professional Practice (ISSMGE)
- JTC5 Sustainable Use of Underground Space (IAEG)
- JTC6 Ancient Monuments/Historic Sites (IAEG)
- JTC7 Soft Rocks and Indurated Soils (ISRM)
- JTC8 Offshore Geotechnical Engineering (ISSMGE)
- JTC9 Geophysical Methods (ISRM)
- JTC10 Geo Environmental Engineering (ISSMGE)

#### Technical Committee Guidelines

Guidelines for Technical Committees have been approved and it was agreed that these were needed to amplify the Statutes and Bylaws, to establish conditions for membership, to encourage participation by industry, and to clarify funding issues. At the time of drafting the guidelines there were 25 existing TCs, and one joint (with ISRM and IAEG) Technical Committee on Landslides.

The purposes of a Technical Committee were to appraise current research and practice, promote dialogue with practitioners, collate information and disseminate their findings. TCs operate within the Terms of Reference agreed with the President. Their activities may include organising discussion sessions and symposia, and undertaking surveys and literature reviews. It is essential that TCs have tangible output at the end of a four-year term, and it was suggested

that there should be emphasis on the transfer of research to practice.

#### Election of Regional Vice-Presidents 2005-2009

The President advised the meeting that the elected ISSMGE Regional Vice-Presidents for 2005-2009 were:

Africa	Professor Mounir Bouassida
Asia	Professor M R Madhav
Australasia	Professor John P Carter
Europe	Professor Roger Frank
North America	John Seychuk
South America	Professor Waldemar Hachich

#### Election of President for the Period 2005-2009

The three candidates for the presidency were: Max Ervin (Australia), Suzanne Lacasse (Canada), and Pedro Sêco e Pinto (Portugal). Professor Pedro Sêco e Pinto was duly elected President of ISSMGE for the period 2005-2009.

#### Membership of New Board

In addition to the President, Secretary-general and the Regional Vice-presidents listed above, John Christian (USA), Osamu Kusakabe (Japan) and Michael Lisyuk (Russia) were also invited by the incoming President to become members of the Board of ISSMGE for the period 2005-2009.

#### Task Forces

Reports of the following task forces were presented at the Council meeting by members of the outgoing Board: Education (Professor Sêco e Pinto), Professional Practice (Professor Poulos), Industrial Liaison (Mr Day), International Conferences (Professor Poulos), Information Technology (Mr Murray).

The objectives of the *Industrial Liaison* Task Force were to ascertain Industry's needs, to ensure that ISSMGE meets these needs, and to encourage greater industry participation. A number of surveys had been carried out. From these, it seemed that a common perception was that ISSMGE focused on researchers and academics, while neglecting practitioners and suppliers. There was a strong preference for more speciality conferences, as well as symposia dealing with lessons from failures, courses on practical design and construction. Services requested included: a library of geotechnical literature, news of geotechnical projects, specialised journals and a newsletter. In general, respondents did not feel the >

need for a web based forum, a supplier database, nor a professional register. To address Industry's needs, the Task Force proposed new guidelines for Technical Committees and a new package for Corporate Sponsors.

The main objectives of the Task Force on *International Conferences* had been to increase participation in the International Conference, to encourage presentations on current state-of-the-art and state-of-practice, to raise awareness among decision-makers and to allow more wide-spread participation in technical sessions. The Task Force suggested modifications to the format of the international conference, some of which had been adopted for Osaka 2005. The role of the international conference was to summarise state-of-the-art and practice, to enable interaction among professionals, to provide means of public exposure and to enable social interaction. The main suggestions adopted for Osaka were the poster presentation sessions that now included actual presentation of papers, and the Academic-Practitioner Forum. Other suggestions for future conferences were to have all the plenary sessions on first two days, followed by two days of technical sessions running in parallel. This format implied that a large conference hall would only be needed for two days, which might result in reduced costs. The plenary sessions would include authoritative lectures given by leading academics and practitioners, with invited participation by decision-makers. The technical sessions would allow in-depth issues to be presented and discussed, and would wherever possible involve the Technical Committees. Also, consideration should be given to integrating a Young Geotechnical Engineers Conference with the main International Conference. The Secretary General provided a brief update on the use of the Conference Manual that had been introduced following the 2003 Council Meeting.

The objectives of the Task Force on *Information Technology* had been to provide an effective and efficient modern means of communicating with all members, to improve administration of the society, to disseminate information on the activities of the Technical Committees and their publications and to provide a calendar of activities. These had largely been achieved with the introduction of the new ISSMGE website.

### 16th ICSMGE, Osaka 2005

Professor Kamon gave a brief overview of the 16th ICSMGE prior to its commencement. The Conference had attracted a large number of delegates. (Post conference figures confirmed by Professor Kamon were 1534 regular delegates and 102 students. There were approximately 150 accompanying persons.) In addition there were approximately 100 delegates registered for the International Young Geotechnical

Engineers' Conference. In addition, there were 90 exhibitors. Highlights of the Conference included outstanding keynote lectures delivered each morning of the conference, and two lively and very interesting Academic-Practitioner forums, chaired by Professor Harry Poulos. Professor Poulos was also awarded the Kevin Nash Gold Medal during the Conference.

### Subscription Fees

The issue of Subscription Fees had been considered during the Council Meeting in Prague, August 2003. A Task Force of the ISSMGE Board had taken into account the comments made at that meeting and reviewed a number of suggestions for changing the method of determining subscription fees payable by the ISSMGE societies.

The present formula included GNP and GNP/capita, as an attempt to enable less affluent societies to participate in the society. However, poorer societies were often faced with a greater per capita fee relative to the more affluent member societies which generally had a much larger membership. In order to develop a new formula for fees, the Board considered the following:

- The subscription fee of a society should be a direct function of the number of members;
- The relative wealth of Member Societies would be based on Purchasing Power Parity (PPP);
- All members must pay, but a sliding scale would be used to reward large Member Societies;
- Maximum and minimum fees would be established;
- A minimum size for a Member Society would be established.

The new proposed formula uses a Basic Fee per Capita (BFC) of CHF22.20 (Swiss Francs). The Fee per Capita (FPC) used to determine the fees for a Member Society is the BFC less any discounts for low Purchasing Power Parity ( $D_{PPP}$ ) and for high membership numbers ( $D_{Members}$ ). The discount for relative wealth ( $D_{PPP}$ ) is applied to Member Societies with a PPP less than 15000 and has a maximum value of 75% of the BFC. The discount for members ( $D_{Members}$ ) applies to Member Societies with a membership larger than 250 and the members above the 250 threshold are charged at 40% of the Basic Fee per Capita. The Fee per Capita is then given by:

$$FPC = BFC - D_{PPP} - D_{Members}$$

The Member Society Annual Subscription (MSAS) is then calculated from the Fee Per Capita (FPC) times the number of members in the society NM. It was proposed that the minimum size of a Member Society should be 30 members.

This new proposal would apply as from the 2007

invoices (to be issued in January 2007) to allow Member Societies to prepare for budgetary changes. If applied today, this new subscription model would mean that the per capita fees will increase from CHF11.06 to CHF13.11 for Australia and from CHF14.08 to CHF20.36 for New Zealand.

There was significant discussion of this proposal during which New Zealand commented that some societies were relatively wealthy, and had large memberships, and so both discounts would apply. He proposed an amendment, such that if a country's PPP is greater than 25000, the PPP discount would not apply.

The amendments suggested by New Zealand and another by Nepal were not seconded, so the vote proceeded on the motion as presented. The motion was carried, and the new formula will be applied from the beginning of 2007.

### Venue of Mid-Term Council Meeting

Two new Bylaws were proposed and adopted, and came into effect at the end of the Council meeting:

#### *Bylaw 12B.2*

With a view to distributing meetings evenly among the Regions, Member Societies from a Region that has recently hosted a mid-term Council Meeting (i.e. a meeting held between International Conferences) shall refrain from offering to host the next two mid-term Council meetings unless no acceptable invitation is received from the remaining Regions.

#### *Bylaw 14B.3*

With a view to distributing International Conferences evenly among the Regions, Member Societies from a Region that has recently hosted an International Conference shall refrain from offering to host the next two International Conferences unless no acceptable invitation is received from the remaining Regions.

### Venue for 2007 Council Meeting

The President confirmed that two offers to host the 2007 Council Meeting had been received, from the 10th ANZ Conference, Brisbane, Australia, and from the 14th European Regional Conference, Madrid, Spain. Organisers of the 13th Pan-American Conference and of the 13th Asian Regional Conference had both expressed their regret at being unable to extend an invitation to host a Council Meeting. The Secretary General had not had a response from the organisers of the 14th African Regional Conference in this regard.

Professor Dapena (Spain) announced that in the spirit of the previous item, as organisers of the 14th Regional Conference, they were withdrawing their bid in favour of

that of the Australia-New Zealand conference. Australia thanked Spain for their generous offer. The President then announced that the 2007 Council Meeting would be held in Brisbane on the occasion of the 10th ANZ Conference, and this was greeted with applause. A presentation for the 10th ANZ, which had the theme "Common Ground", was then made.

### Conference Advisory Committee for Regional Conferences

The President reported that the Board had considered introducing a new Bylaw that would clarify the establishment of a Conference Advisory Committee for the Regional Conferences. The motion was carried and the new Bylaw would apply to the organisation of the 2007 and subsequent Regional Conferences.

### Federation of International Geo-Engineering Societies

The President introduced a proposal for forming the Federation of International Geo-Engineering Societies (FIGS) that had been circulated with the Agenda. He pointed out that this subject had already been considered by the Council Meetings of the other two sister societies ISRM and IAEG. The main functions of the Federation would be:

- to promote awareness of the importance of geo-engineering among professionals in associated areas, clients, decision-makers and politicians, and to enhance its public image;
- to develop guidelines and codes for professional practice as well as to agree on policy statements in geo-engineering;
- to suggest items for curricula for higher education in geo-engineering taking into account the views of industry and practitioners

In addition, FIGS would be responsible for coordinating technical activity in areas of common interest by establishing Joint Technical Committees.

The Board of the Federation would consist of the President, the Immediate Past-President and the Secretary General from ISSMGE, ISRM, and IAEG. The Secretaries General ensure a degree of continuity and "memory" of the founding societies and are present as advisory members to the Board. The Board would be assisted by a Liaison Committee, comprised of Chief Executive officers of major geo-engineering companies, as well as representatives of interested international geo-engineering groups, representatives of public opinion groups and international organizations. It was agreed to continue the discussions within the ISSMGE on the formation of a Federation of International Geo-engineering Societies. >

## List of Members

The proposal to introduce an ISSMGE Membership Card was discussed. One reason for its introduction was to allow individual members of ISSMGE to be identified, so that they would have access to benefits and to promote a sense of belonging to the members. The associated membership number will be included in an electronic list and it will be possible (optionally) to use this list to print a membership card. The card and membership number will remain valid provided the member is up-to-date with subscription fees. Regarding privacy legislation, a Member Society can choose not to submit any details other than a list of names. In addition, it should be noted that website listing would be of names and membership numbers only.

There was considerable discussion on the actual wording to be used in the proposed new Statutes and Bylaws required to implement these changes and they were voted on as a whole. On a show of hands, the motion to accept the new Statutes and Bylaws was carried.

## Young Members Awards

The following awards were announced:

- Dr Ellen Rathje (USA), Associate Professor at University of Texas, Austin for her paper “Creep behaviour of recycled asphalt pavement backfill” (with C. Viyanant and A. F. Rauch) submitted to the 16th ICSMGE, Osaka.
- Dr Susan Gourvenec (AUS), Lecturer, University Western Australia, Perth for her paper “Bearing capacity under combined loading – a study of the effect of shear strength” submitted to the 9th ANZ Conference, Auckland.
- Dr S.W. Jacobsz (S. Africa), Associate, Jones & Wagener Consulting Engineers for his paper “The influence of tunnelling on piled foundations” (with J.S. Standing and R.J. Mair) submitted to the 16th ICSMGE, Osaka.

## 17th ICSMGE - Alexandria, Egypt 2009

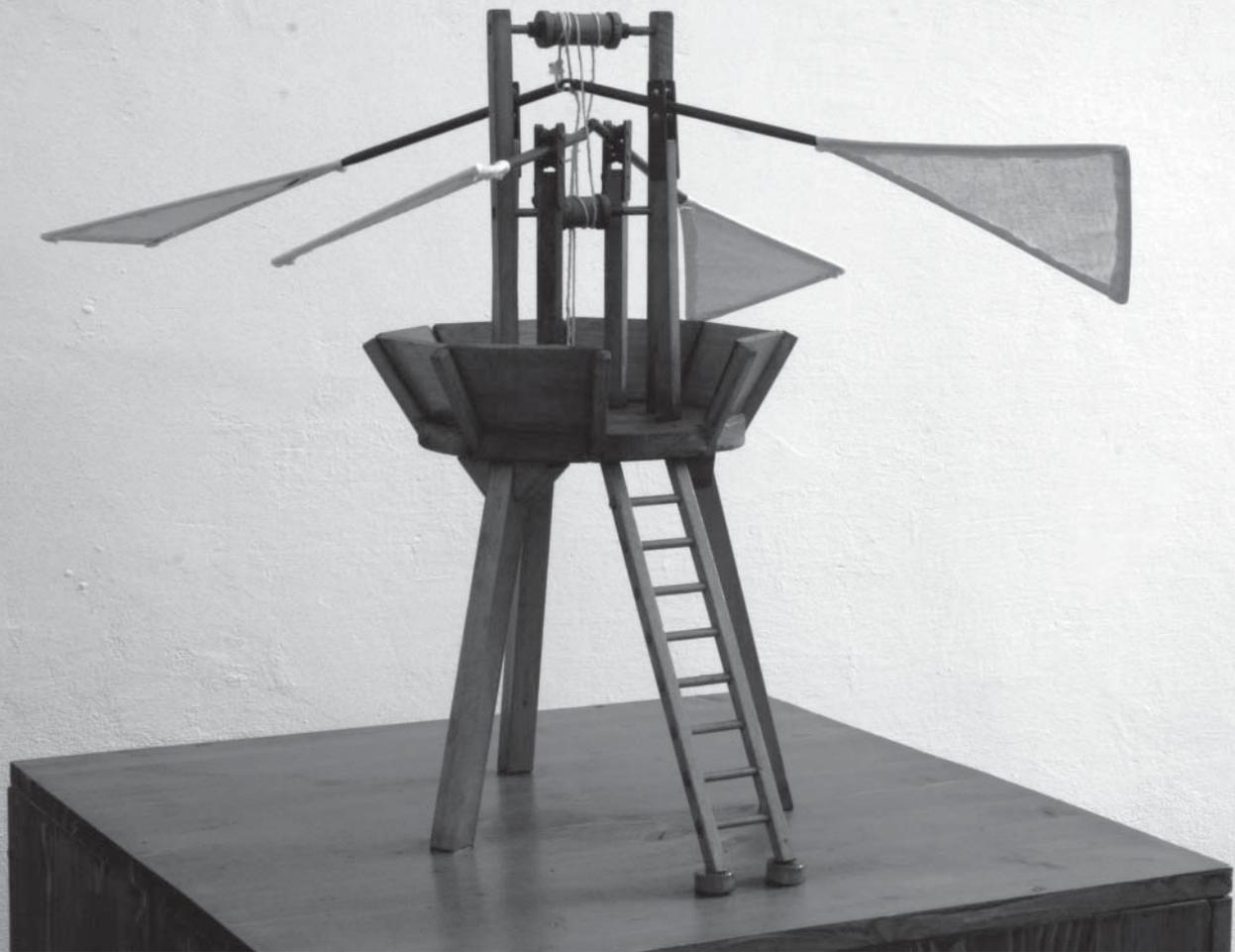
The Egyptian Geotechnical Society had prepared a brief report on the 17th ICSMGE, Alexandria, October 2009 and the President presented it to Council. The conference would be held in the Bibliotheca Alexandrina and the proposed dates for the conference were 5-9 October 2009. The main objectives of the conference were to promote the translation of geotechnical theory and research into practice and to encourage international and regional dialogues on challenging geotechnical issues.

## 5th ICEG Cardiff, UK 2006

The President made a brief presentation on the 5th Congress on Environmental Geotechnics to be held in Cardiff, 26-30 June 2006. The conference had been awarded to the British Geotechnical Association in 2001 and was being organised by the Geoenvironmental Research Centre, Cardiff University with support from the Transport Research Laboratories and the Building Research Establishment. The conference theme was “Opportunities, Challenges & Responsibilities for Environmental Geotechnics”.

## John Carter

ISSMGE VP Australasia



# NEW ZEALAND TO HOST DA VINCI MACHINES EXHIBITION

Working models of Leonardo da Vinci's designs will be on display in Auckland in an exhibition presented by Beca. The da Vinci Machines Exhibition, never seen outside Europe, opens at Auckland Museum on 18 November and will be on show until 5 March 2006. Over 50 models of da Vinci machines have been built and toured by the Italian artisan company Teknoart s.r.l. The exhibition also features Leonardo's famous codices along with pictures, sketches and notes for the machines. Leonardo's futuristic mechanical designs formed the foundation for many inventions almost five centuries later, such as the ship's hull with watertight compartments to stop it from sinking.



"We are very proud to be associated with this exhibition," says Gavin Cormack, Beca's executive chairman. "Leonardo da Vinci was not only a great painter, but also an engineer of the highest class. He continues to be an inspiration to all of us who recognise that our future depends on our innovation."

Also part of the exhibition are the **Beca Lecture Series** starting from 29 November, and the **Beca Flying Machine Competition** on 12 February. Beca's Dale Turkington will join lateral thinker Dr Cris de Groot from Unitec to explore Leonardo's perceived ability to access both sides of the brain. Dale will also chair a lecture by Auckland artist and author John Lyall examining Leonardo's three-dimensional thinking ability. The **Beca Flying Machine Competition** aims to encourage people to create their own flying machines, with advice from Beca engineers.

Leonardo's forward-thinking designs and Beca's strive for innovative engineering work find a natural synergy. Beca's endeavour to achieve innovation saw it win six Innovate NZ 2005 awards from ACENZ (Association of Consulting Engineers) earlier this year. Beca's association with the Auckland Museum dates back to the 1920s when Beca were the structural engineers for the original museum building.



## ISRM Australasia VP Report

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### Website

The Suggested Methods published by the ISRM Commission on Testing Methods are available on the ISRM Website. These are freely available from the member's area of the site, so you need to be registered to obtain access.

### Rocha Medal

Our panel has selected the following two nominations to go forward to the final judging which will take place at the ISRM meeting to be held in January 2006.

- Elena Pasternak - Generalised Homogenisation Procedures for Granular and Layered Materials, School of Civil and Resource Engineering, University of Western Australia
- Sedat Esen - A non-ideal detonation model for commercial explosives, Julius Kruttschnitt Mineral Research Centre, University of Queensland.

### Müller Award

Robert Morphet from the Queensland Branch of the AGS has nominated Professor E T Brown for the 2007 Müller Award. This is the highest honour of the Society and I am sure we all wish him every success on his nomination.

### Commission

Joint Technical Commission – JTC-2 on the visualisation and presentation of geotechnical data has been established. The ISRM has put forward Dr G. Beer and Professor Tanimoto to represent our Society in the core group of the JTC. Dr P G Ranjith, University of Melbourne, is our representative on the Commission on Environment.

### Conferences

The 4th Asian Rock Mechanics Symposium ARMS 2006 will take place in Singapore at the Meritus Mandarin Hotel, from November 8-10 with the title - Rock Mechanics for Underground Construction. This is an ISRM sponsored event and there will be Board, Council and Commissions meetings. Regional Symposia approved for 2006 are:

- May 09-12, Liege Belgium Symposium on Multiphysics Coupling and Long Term Behaviour in Rock Mechanics (EUROCK'2006)
- June 19-21, Trondheim Norway, Symposium on In-situ Rock Stress

### Board Meeting

The next Board meeting is scheduled to take place on 20-21 January 2006 in Lisbon.

### John St George

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## NZGS BRANCH ACTIVITIES

### Auckland Branch Activity Report

We have now made it to the end of the year and can look back on a successful meetings programme. At the end of last year we set a goal to hold one meeting each month on a regular day, the last Tuesday of the month. We have achieved this - just - there were some hairy moments when I thought we may not make it. My thanks go to those who helped on those occasions.

I would remind members that we now hold pre-meeting drinks in the common room on the 12th floor. This is a much better venue than the foyer in front of the lecture theatre. My thanks to the various organisations who have sponsored the drinks through the year.

The meetings programme has been wide and varied and included a site visit and several special lecturers in addition to the regular presentations. We also had a seminar on the design of MSE walls.

Following on from the precedent set last year we again saw the year out with a drinks party at Old Government House. The venue is hard to beat for such events and provides an opportunity for members to get together on a purely social basis. All going well, we will turn it into an ongoing annual event!

I would like to think that the team, with considerable help from outside, has now introduced a degree of stability into the meetings programme. The programme for next year is provisionally fixed and, like this year, will provide a range of topics that should appeal to all members. I have been asked on several occasions if we can publish the programme in advance. This seems to me like tempting fate. However, there are also many advantages do doing this and so, with some trepidation, I attach a draft 2006 Meetings Programme to this report. There will be additional events introduced during the year, mainly special lectures from visiting lecturers as and when they are in Auckland.

Finally I would like to thank Yan Chan and Steve Crawford who, along with myself, make up the branch organising team. Without their input, the meetings programme would not have occurred.



**Rodney Hutchison**

Auckland Branch Coordinator

Phone (09) 478 6655

Rhutchison@kga.co.nz

Rodney Hutchinson is Principal with Keith Gillespie and Associates Ltd – a small specialist geotechnical practice on Auckland's North Shore. They act as a "house builder's and small developer's friend". He is a geotechnical engineer who studied in London and then worked in Honk Kong and the UK before returning to NZ.

### Provisional 2006 Auckland Branch Meetings Programme

Date	Topic
Feb 21	Liquefaction
March 28	Northern Gateway Alliance field trip / presentation
April (May2)	Manapouri tailrace tunnel
May 30	Behaviour of compacted fills
June 23	Natural disasters – EQC, Tauranga/ Matata/Manawatu
July 25	Tokaanu power station tailrace
Aug 22	Soil nail design
Sept 26	Designing for rock sockets
Oct 24	SH20 Mt Roskill
Nov 28	Student prize



# EARTHQUAKES AND URBAN DEVELOPMENT

A New Zealand Geotechnical Society Symposium  
17-18 FEBRUARY 2006, Rutherford Hotel, NELSON

This symposium will provide a forum for practitioners to meet and exchange ideas on a wide range of geotechnical engineering and engineering geological issues related to the effects of earthquakes on urban development and infrastructure.

The symposium will extend over two days at the Rutherford Hotel, with an option for undertaking field trips on Sunday 19 February 2006.

## PRELIMINARY CONFERENCE PROGRAMME

### Friday 17 February

7.30am - 9.00am Registration and Morning Coffee  
9.00am - 9.10am Symposium Opening  
9.10am - 10.30am Seismic Hazard Assessment  
10.30am - 11.00am Morning Tea  
11.00am - 12.30pm Geotechnical Aspects of Urban  
Development  
12.30pm - 1.30pm Lunch  
1.30pm - 3.00pm Seismic Design  
3.00pm - 3.30pm Afternoon Tea  
3.30pm - 5.00pm Paleoseismicity  
5.00pm - NZGS AGM  
6.45pm - Buses depart for Conference Dinner at  
Seifrieds Vineyard Restaurant

### Saturday 18 February

8.45am - 9.10am Registration and Morning Coffee  
9.10am - 10.30am Panel Discussion - Geotechnical  
Seismic Design Standards  
10.30am - 11.00am Morning Tea  
11.00am - 12.30pm Poster Presentations  
12.30pm - 1.30pm Lunch  
1.30pm - 3.00pm Geotechnical Aspects of Urban  
Development  
3.00pm - 3.30pm Afternoon Tea  
3.30pm - 5.00pm Seismic Design  
5.00pm - 7.00pm Field Demonstration and BBQ  
(sponsored by Hiway Stabilizers  
Environmental and Pacific  
Geotech)

### Sunday 19 February – Optional Field trips

**Field trip 1:** 8.00am - 4.00pm Full day field trip to Nelson Lakes National Park  
**Field trip 2:** 9.00am - 11.30am Morning site visit to Bishopdale Subdivision  
**Field trip 3:** 12noon - 2.30pm Afternoon site visit to Nelson Water Treatment Plant

## REGISTRATION INFORMATION

### Registration Fees – if paid before 15 December 2005

Full Registration NZGS members \$450  
Full Registration Non members \$500  
Daily Registration Fee \$275 per day  
Student Daily Registration Fee \$120 per day

**A late fee of \$50 applies for registrations received after 15 December 2005.**

**To view registration information and register on-line**

[www.nzgeotechnical.org.nz/](http://www.nzgeotechnical.org.nz/)

## CONTACT DETAILS

The Conference Office, University of Canterbury  
Private Bag 4800, Christchurch, New Zealand

**Tel:** +64 3 364 2534

**Fax:** +64 3 364 2057 or 364 2324

**Email:** [geotech2006@cont.canterbury.ac.nz](mailto:geotech2006@cont.canterbury.ac.nz)

**Website:** [www.nzgeotechnical.org.nz/](http://www.nzgeotechnical.org.nz/)

## Bay of Plenty Branch Activity Report

Thursday 27 July: Meeting (Joint with IPENZ) – Dave Dowrick, a locally based and semi-retired earthquake engineer, gave a talk on the attenuation effects of the Taupo Volcanic Zone on the Bay of Plenty. He demonstrated, using a variety of different historic earthquake events around NZ, how the magnitude of the earthquakes deteriorate more rapidly as they pass through the TVZ when compared to rates of attenuation around the outside of the TVZ. In effect, the TVZ is a buffer ensuring that the BOP is somewhat protected from large earthquake events of the Poverty Bay district. So we're all sleeping much more soundly in our beds now!

Thursday 11 August: Meeting (Joint with IPENZ) – “The Pickering Lecture: “Tsunami – impacts and Engineering?”. Several different speakers discussed the mechanics behind tsunami and touched on related engineering issues. A well attended talk which was also open to the public.

## Canterbury Branch Activity Report

The Canterbury Branch has been quite active during the second half of 2005, with three excellent talks, a spillway model demonstration and, in December, the Southern Student Prize.

In June, Don Macfarlane, Principal Engineering Geologist at URS in Christchurch presented a talk entitled “Seismic Hazard Evaluation at Aviemore Dam, A Marriage of Geology and Engineering”. This presentation described a detailed seismic hazard evaluation of the dam undertaken over several years by URS and GNS.

In early September, Jane Walbancke and Charlie Price presented a talk about the Ghazi Barotha hydropower scheme in Pakistan, on which both Jane and Charlie worked for Black and Veatch prior to moving to New Zealand for the design phase of Project Aqua. This was a really good presentation which drew interesting parallels with Project Aqua.

In Late September MWH demonstrated a large model spillway constructed to help with design of a dam in Fiji. This demonstration was conducted in the Engineering School fluids lab.

During October, Max Ervin, Principal at Golder, based in Melbourne, gave a talk on the Morwell River Diversion, Latrobe Valley, Victoria. This project was a challenging diversion of a river through a coal mine via a channel constructed in weak loosely dumped fill.

In early December, the Southern Area Student Prize competition will be held at the University of Canterbury, and we look forward to hearing from some of our student members.

2005 has been a good year for the Canterbury Branch,



**Sally Hargraves**

Bay of Plenty Branch Coordinator  
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*Sally is an Engineering geologist and director of Terrane Consultants Ltd, Tauranga. She studied geology in the UK, before joining CL Associates based in Birmingham, and began work as an engineering geologist. She moved to NZ and found work with Connell Wagner in Tauranga.*

*Three years later, she joined the Tonkin & Taylor Ltd in Tauranga and after a maternity leave break she co-founded Terrane Consultants Ltd, a new geotechnical consultancy, which started up in March 2005.*



**Tim McMorran**

Canterbury Branch Coordinator  
URS New Zealand Ltd  
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with a meeting being held most months. The speakers have been from local consulting companies and contractors reflecting the high calibre of work undertaken in the industry in New Zealand. The meetings were well supported by local members the members can look forward to a similar high standard of presentations in the new year.

*Tim McMorran was elected onto the NZGS management committee in 2003, and was offered the position of Canterbury Branch Facilitator in 2004.*

*Tim is an Engineering Geologist who leads the geotechnical group of the URS Christchurch office. He graduated from University of Canterbury in 1991 with an MSc in Engineering Geology and has worked in consulting since then. After graduating Tim lived in Sydney and worked for DJ Douglas and Partners, and has worked for URS (formerly Woodward-Clyde), based in Christchurch since 1995.*

*The Canterbury Branch of NZGS typically has 30 to 40 attendees at meetings, and has a large local geotechnical community to draw speakers from, both in engineering practice and at local universities. In 2005 Tim has commitment from many local practitioners to give talks at our monthly meetings.*

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## Nelson Branch Activity Report

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There has been no Nelson Branch activity for the last 6 months but Mike Johnston will be presenting a talk next week at the Nelson Club titled: "Geohazards in the Community - the Nelson Response". We hope to get a bit more activity going on in the New Year.



**Tim Coote**

Nelson Branch Coordinator  
Tonkin and Taylor Ltd  
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*Tim Coote is a senior engineering geologist with Tonkin & Taylor Ltd in their Nelson office. Tim recently spent four years living in Colorado (1999 to 2003) working with SRK Consulting Ltd on mining development projects throughout South and Central America. Tim's project experience also includes two multi-million dollar landslide investigation and remediation programs at Cromwell (The Clyde Power Project) and Waihi (The Golden Cross Project).*

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## Otago Branch Activity Report

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Phil Glassey gave a talk on his visit to Banda Aceh at the Geology Department of University of Otago in September. We hope to get presentations from other centres in the New Year. Your ideas and assistance in putting together a programme would be appreciated



**Phil Glassey**

Otago Branch Coordinator  
Geological & Nuclear Sciences  
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*Phil Glassey is currently the Manager of the Mapping section at the Institute of Geological & Nuclear Sciences Ltd. He is also on the GSNZ management committee and the current editor of Geomechanics News. Phil is an engineering geologist and has been involved in wide range of engineering geological investigations mostly involving slope stability, foundation conditions and groundwater studies. Phil was the reporting geologist the proposed Lower Clutha Hydro Power Development More recently, Phil's specialist research interest is in GIS applications and database management.*

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## Wellington Branch Activity Report

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The Wellington Branch has had no activity in this period.

### Grant Dellow

Wellington Branch Coordinator  
Geological & Nuclear Sciences  
PO Box 30-368, Lower Hutt  
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*Grant Dellow is an engineering geologist employed by the Institute of Geological and Nuclear Sciences Ltd (GNS). He has been primarily involved in three areas of work. The first of these is foundation investigations and repairs for hydropower structures and includes major work at Matahina, Arapuni, Whakamaru, Clyde, Waitaki, Aviemore, Benmore and Ohau C. A second area of work has been in the earthquake hazards, producing susceptibility models for ground shaking amplification, liquefaction and slope stability. The third area of work and now the most time consuming has been the study of landslides. This work started with the systematic compilation of an inventory of large landslides in New Zealand for GNS and is still ongoing. Since 1996 landslides have been catalogued for GNS using news media accounts and response missions. The landslide catalogue has allowed a more accurate quantification of the hazard and associated risk New Zealanders are exposed to from landslides.*

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## Waitako Branch Activity Report

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Alas we have had no 'official' meetings in this period. Do remember that the Branch activities will only succeed if you offer to contribute and share your experiences.



### Stuart Finlan

Waikato Branch Coordinator  
MWH New Zealand  
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stuart.finlan@NZ.mwhglobal.com

*Stuart is a Senior Geotechnical Engineer at Tonkin & Taylor's Hamilton office, having joined T&T in August after almost six years with MWH, and Opus/Works Consultancy Services prior to that. Stuart came from the UK in 1996, where he worked for leading consultancies in the areas of contaminated land, landfill design, geotechnical engineering and highways where he was actively involved in setting geotechnical and geo-environmental standards for highway projects. Stuart was a committee member for the Engineering Group of the Royal Geological Society.*

*In New Zealand he led the design of Australasia's longest gabion structure and largest MSE walls (160 m long and 15 m high). In 2005 he was a co-recipient of the Transit New Zealand Innovation Award for work related to ground improvement by soil mixing. His key areas of interest are coastal protection, landfills, land instability, litigation and claims. Personal interests include tramping and he is also an international hot-air balloonist having flown in such diverse places as Norway (-25oC), Wadi Rum Jordan (+35oC), Australia, Hamilton and Carterton!*

## REVIEWS

### Soil Mechanics Concepts and Applications (Second Edition) 2004

Bill Powrie is Professor of Geotechnical Engineering and Head of the School of Civil Engineering and the Environment at the University of Southampton, UK. His book covers the topics typically included in university courses in Civil Engineering and is aimed in particular at the undergraduate or graduate student and university teachers. His aims are to encourage students of soil mechanics to develop an understanding of fundamental concepts and to build a framework of basic ideas that would be robust and adaptable enough to support and accommodate the more complex problems and analytical procedures which confront the practicing geotechnical engineer.

He illustrates, with reference to real case histories, that sensible application of simple ideas and methods can give perfectly acceptable engineering solutions to many classes of geotechnical problems. He avoids the unnecessary use of mathematics and tries to produce an uncluttered text book to cover typical first degree level soil mechanics and geotechnical engineering courses. He even suggests an undergraduate course structure.

Each chapter is set out with an introduction and objectives, so that the student may understand what he can expect to learn. In the main body of the chapter, each concept is backed up by a worked example or case history. This is followed by the key points that the reader should have gained from the chapter. To consolidate the lesson, there are a series of questions at the end of each chapter, some of which are taken from University of London examination papers. The eleven chapters cover:

- Origin and classification of soils
- Soil strength
- Groundwater, permeability and seepage
- One dimensional compression and consolidation
- The triaxial test and soil behaviour
- Calculation of soil settlements using elasticity methods
- The application of plasticity and limit equilibrium methods to retaining walls
- Foundations and slopes
- Calculation of bearing capacity factors and earth pressure coefficients for more difficult cases, using plasticity methods
- Particular types of earth retaining structures
- Modelling, in situ testing and ground improvement.

The progression of the text through each chapter clearly shows the lecture format and the language is very readable. Unfortunately the figures and sketches are not always of the same high standard, often small and cramped. Apart from a few topic areas, and in particular the section on consolidation, he keeps to his goal of limiting the mathematics. He covers both conventional and critical state soil models in his chapters on strength and in more detail in the section on soil behaviour.

The chapters are a good mix of theory with the more practical aspects. For example the chapter on groundwater not only covers the mathematics but has a useful section on construction dewatering. The photo of a failure caused by seepage from the toe of a slope, shown on the cover of the book, is an illustration of the importance of understanding groundwater.

As the book is written around the British universities courses, it does not cover a number of subjects close to the heart of the New Zealand geotechnical engineer. Earthquakes do not get a mention nor do volcanic soils. The updated second edition is aligned with design methods based on Eurocode 7, recent British Standards and CIRIA publications.

As an undergraduate text book, or for an engineer from another discipline, it is a book to be recommended as it puts over the concepts clearly. Also, the practicing geotechnical engineer may well like to dip into it to brush up on background theory and on the more modern topics.

**Reviewed by:** Jane Walbancke  
Beca Infrastructure Ltd

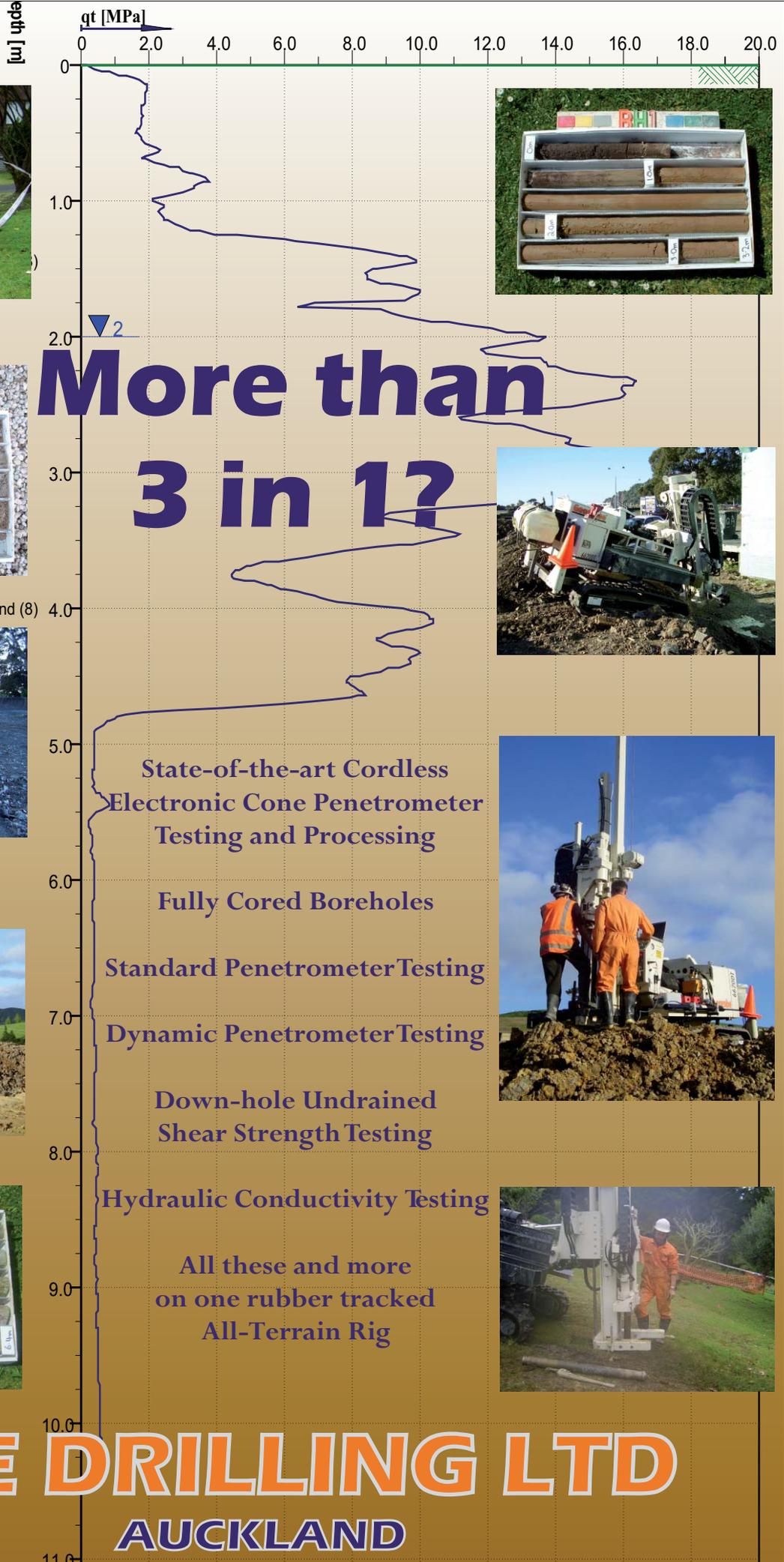
#### Soil Mechanics Concepts & Applications – Second Edition

<b>Author:</b>	William Powrie
<b>Publisher:</b>	Spon Press
<b>Year Published:</b>	2004
<b>ISBN:</b>	04 1531 156 x
<b>Web shopping at:</b>	www.sponpress.com
<b>Price:</b>	UK£29.99

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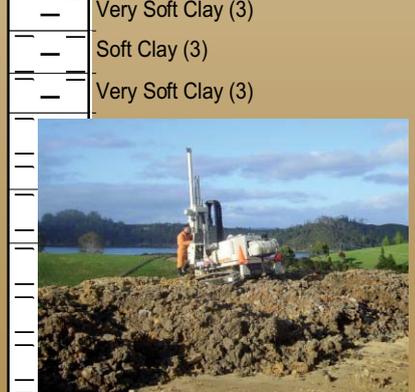


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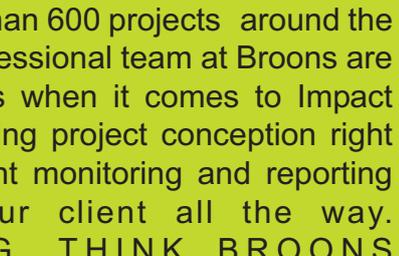
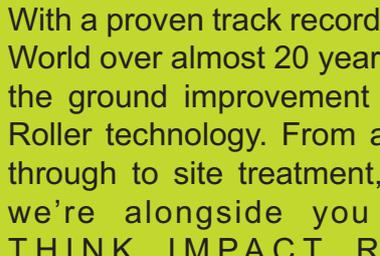
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## Numerical Modeling of Discrete Materials

In Geotechnical Engineering, Civil Engineering & Earth Sciences

This book contains 40 of the 50 papers presented at the 1st International UDEC/3DEC Symposium: Numerical Modeling of Discrete Materials in Geotechnical Engineering, Civil Engineering, and Earth Sciences, Bochum, Germany, 29 September -1 October 2001. The conference was organised by ITASCA Consultants and the proceedings edited by H. Konietzky.

ITASCA Consultants is an independent engineering consulting and software development firm that specialises in hydrogeological- and geomechanics-related problems in the fields of mining, civil, petroleum, waste, and environmental engineering. They have developed a total of six numerical modeling codes for solving problems in geomechanics and hydrology, with FLAC being the most widely known.

UDEC is a distinct element program for the 2D modelling of jointed rock subjected to quasi-static or dynamic loading conditions. It simulates large displacements (slip and opening) along distinct surfaces in discontinuous medium treated as an assemblage of discrete (convex or concave) polygonal blocks with rounded corners. Discontinuities are treated as boundaries between the blocks. Relative motion along the discontinuities are governed by linear and non-linear force-displacement relations for movement in both the normal and shear directions. It utilises an explicit solution scheme to give stable solutions to unstable physical problems, whether rigid or deformable blocks (or mixed). The built in library of material models for deformable blocks includes elastic, Mohr-Coulomb plastic, ubiquitous joint, double yield and strain softening models. Models for discontinuities include Coulomb slip, continuously yielding and Barton-Bandis. The program is capable of undertaking thermal and thermal-mechanical calculations and coupled fluid flow in joints and pressure in cavities. It has full dynamic capability with absorbing boundaries and wave input.

Structural elements can be modelled (including non-linear cables) with general coupling to continuum blocks or discontinuities. A programming interface enables users to define new variables and functions to customise a numerical model to suit their particular needs.

The contributors presented papers focussed on applications and new developments in the following fields;

- Rock slope stability, deformation and failure mechanisms
- Tunnels and caverns in fractured rock masses
- Application of DEM in underground and surface mining
- Reinforcement design (anchors, shotcrete, bolts)
- Dam analysis
- Earthquake, fault and rockburst modelling
- Mechanical behaviour of masonry structures (walls, bridges, towers, columns)
- Micromechanical particle behaviour
- Dynamic behaviour

I found the papers to be well written and made interesting reading, particular those relating to dynamic analysis of masonry structures, stability of dams on rock foundations and the stability of rock slopes. To the geotechnical practitioner those papers of greater interest would be those relating to the stability of rock slopes. Several papers were presented in this section outlining numerical methods to analysis flexural toppling, and link band slumping. The papers presented in this book however are aimed at specialist practitioners and academics and I therefore feel that it would only be of limited appeal.

**Reviewed By:** Michael J Laws,  
Sinclair Knight Merz, Fiji

### Numerical Modeling of Discrete Materials

**Author:** Heinz Konietzky  
**Publisher:** A.A. Balkema  
**Year Published:** 2004  
**ISBN:** 90 5809 6351  
**Web shopping at:** www.balkema.nl  
**Price:** UK£69.00

## STANDARDS, LAW AND INDUSTRY NEWS

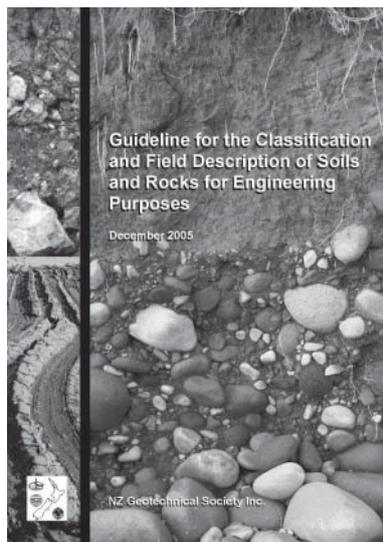
### Guideline for the Classification and Field Description of Soils and Rocks for Engineering Purposes

Revision of the 1988 Guidelines has been in progress since 2001, with a first revision being presented for discussion in 2002 and work-shopped at the NZGS Symposium in 2003. The revision was carried out with the objectives of providing:

- An industry document that is clear and uncomplicated;
- A Guideline that conforms to international practice while addressing issues particular to New Zealand soils and rocks;
- An emphasis on the description of soil and rock properties that are of engineering significance.

The soil description part of the Guidelines has been revised to emphasize the distinction between classification and description. This change is reflected in the revised title of the Guideline. Table 2.7 (USBR Unified Soil Classification Chart) has been omitted in keeping with the 3rd edition of the USBR Earth Manual and changes to presentation of the Unified Soil Classification System in ASTM standards.

The rock description part of the Guidelines has been modified to include standard terminology for the full description of a rock face. The section on weathering has been revised to be more directly relevant to the range of



rock types normally met in New Zealand.

It is planned that the document be “living” with the facility for updates to take place on a more regular basis. The 2005 revision will be available on the NZGS website from mid December 2005.

The NZGS wishes to acknowledge the commitment of the review team through the revision process: David Burns and Geoffrey Farquhar (Maunsell Ltd), Steve Crawford and Doug Johnson (Tonkin & Taylor Ltd), Dr Laurie Wesley (University of Auckland) and Ann Williams (Beca Infrastructure Ltd).

**Ann Williams**  
Beca Infrastructure

## COMPETITION

### PREDICTION OF PILE PERFORMANCE UNDER TEST LOAD

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You can enter either anonymously or nail your colours to the mast. All entries will be collated to report on the state of practice in NZ. The winner will be announced at the Nelson NZGS symposium dinner in February 2006.

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ANY QUERIES TO: Steve Crawford, [scrawford@tonkin.co.nz](mailto:scrawford@tonkin.co.nz)

## PROJECT NEWS

### And the rain came .... (and again .... and again)

Grant Dellow - GeoNet



**Top:** Landslides on the Matata Cliffs were caused by the rainstorm and earthquakes of July 2004.

**Above:** Landslides on the same face after the May 2005 storm (at this locality this later storm was a more severe event)

The last twelve months have been a busy time for GeoNet Landslide Response teams with three rainstorms causing enough damage to meet the criteria for mounting a response. The Bay of Plenty region was hit twice by rainstorms intense enough to cause widespread or significant landslides in July 2004 and May 2005. The Wellington region was hit by a rainstorm in late March 2005 that contained cells of very intense rainfall that affected the lower Orongorongo valley and parts of the eastern coastline between Palliser and Castlepoint.

#### Eastern Bay of Plenty, July 2004

During July 2004 landslides affected the coastal strip of the eastern Bay of Plenty from Te Puke to Te Kaha with the most severe damage occurring between Ohope and Opotiki. The small settlements at Bryans Beach and Ohiwa were particularly badly affected when landslides damaged houses in the settlements and killed a local resident.

The impacts of this storm on the region were compounded by a shallow magnitude 5.3 earthquake centred near Lake Rotoehu that occurred less than 48 hours after the height of the storm. The earthquake caused



**Above:** The settlement of Bryans Beach where two houses were destroyed by landslides and several others suffered moderate to severe damage.



**Left:** Landslide damage at Ohiwa

**Below:** Houses undermined by landslides on the eastern side of Ohiwa Harbour.



several landslides in the Lake Rotoehu area, blocking SH30 between Rotorua and Kawerau in several places and severing the only remaining road link into the region after SH2 had been blocked by landslides caused by the storm along the Matata straights.

With several of the criteria used to assess the need for a response to a landslide event being met GeoNet staff made contact with Environment Bay of Plenty with an offer of assistance. The GeoNet offer was passed on to the local authorities and resulted in Opotiki District making a request for assistance. The GeoNet team was on site in Opotiki within 24 hours of the request from Opotiki District and made contact with the Civil Defence controller.

At the request of the local civil defence controller the GeoNet team was first asked to make an assessment of cracks that had appeared in the Pacific Highway (SH35) on the bluffs south of the mouth of the Motu River. The GeoNet team were able to confirm that local roading

consultants and contractors had made the right decision to close the road as they could demonstrate that the block was still moving several millimetres per day. Over the next three days the GeoNet team inspected landslide damage at Bryans Beach and Ohiwa to assist the local authorities with assessing the risk to public safety.

GeoNet staff (including a technician from Victoria University's School of Earth Sciences) conducted an aerial reconnaissance to record the landslide damage, taking several hundred oblique aerial photographs. These photographs have proved invaluable as a record of the landslide damage and enabled damage recorded during this event to be compared with damage from the May 2005 rainstorm that affected the parts of the same area (see photos).

**Below:** A large gravel fan was built by landslide debris coming out of Boundary Creek that dammed the Orongorongo River (bottom centre). The dam lasted for 4-6 weeks before head-ward re-incision of the Orongorongo River led to the dam being breached and draining of the lake (visible bottom left).

### Wellington and Wairarapa, March 2005

At the end of March widespread rain over Wellington region produced cells of more intense rainfall that caused significant localised landsliding. These more intense cells caused landslides in the Catchpool valley and the lower reaches of the Orongorongo River in the Rimutaka Ranges east of Wellington and pockets of landslide damage along the eastern Wairarapa coastline from Cape Palliser to Castlepoint.

A GeoNet landslide response was not initially mounted for this event as it appeared that the landslide damage was relatively minor. It was only after several days reports trickled in from the more remote areas, that it became apparent that a response was warranted. This included notification from Greater Wellington (Regional Council) that the Orongorongo River had been dammed. GeoNet staff undertook a ground reconnaissance in the Orongorongo River valley to inspect the dam and an aerial reconnaissance of the wider area recording the landslide damage using oblique aerial photography.

Landslides in the head of small valleys on the eastern side of the Orongorongo River valley from Pakuratahi (Boulder Creek and North Boulder Creek) to Greens Stream resulted in the building of extensive debris fans over the Orongorongo River bed. The landslides were in





**Above:** Manurewa Point on the eastern Wairarapa coast was affected by shallow-regolith derived soil and debris flows.



**Above:** Debris flows coming down Browns Stream in the Orongorongo River valley undermined the foundations to Waeranga Hut.

many cases reactivations of old landslide scars dating to the 1855 Wairarapa earthquake. Two private huts in the Orongorongo River valley were destroyed (Goat Stream) and several others damaged (including Wairenga Hut adjacent to Browns Stream) by the landslide debris as it travelled down the small stream valleys. At Boulder Creek and North Boulder Creek the new debris fan completely blocked the Orongorongo River valley and led to the formation of a small lake 4-5 metres deep. The lake lasted for 4-6 weeks before head-ward erosion through the debris fan resulted in a breach developing through the debris fan and draining the lake.

On the Wairarapa coast landslides caused significant localised damage. An example of the sort of damage that occurred can be seen at Manurewa Point (see photo).

## Coromandel and the Bay of Plenty, May 2005

In May 2005 widespread rain in the Coromandel and Bay of Plenty again produced localised cells of more intense rainfall that resulted in significant to severe localised landsliding. It quickly became apparent as news reports filtered in that a GeoNet landslide response was warranted by the damage that had been caused. The GeoNet landslide team responded by dispatching a ground reconnaissance team and an aerial reconnaissance of the affected areas.

The heavy rain caused disruption to many communities with flooding and landslides creating significant problems that resulted in a state of emergency being declared by the Tauranga City Council and the Whakatane District Council for the Matata area. The wider region was affected by heavy rainfall with flooding reported along the Bay of Plenty coast from the Coromandel Peninsula to the Rangitikei Plains. The landslide damage was severe in two urban areas of the Bay of Plenty (Tauranga and Matata) where extreme rainfall was recorded.

In response to this event the Institute of Geological and Nuclear Sciences organised a landslide response through the Earthquake Commission funded GeoNet programme. Two landslide experts went to the area to

**Below:** Landslide damage in Otumoetai, Tauranga.

**Bottom:** Houses damaged by landslides in the suburb of Otumoetai in Tauranga.





A house destroyed by the debris flows that came down the Awatarariki Stream on the western side of Matata.

**Opposite top:** The Waitepuru Stream debris flow on the eastern side of Matata: **below:** The Awatarariki Stream debris flow on the western side of Matata

inspect the damage and provide support to the local emergency management effort as required. Flying to obtain oblique aerial photographs of the affected areas was also undertaken to document the damage.

In Tauranga multiple landslides occurred in Otumoetai, at Welcome Bay and on Mt Maunganui (Mouao). The landslides in Otumoetai undermined houses at the top of slopes and the debris damaged houses at the toe of the slopes. The local geotechnical community played a significant role in managing the emergency with experts advising on the landslide damage in Tauranga and instigating immediate mitigation measures to divert stormwater away from landslides and other potentially susceptible areas. An Urban Search and Rescue (USAR) team was deployed by the New Zealand Fire Service to Tauranga to assist in the recovery operations by shoring up severely damaged homes so residents could return to retrieve valuable possessions.

Landslides from the steep valley walls of the small catchments around Matata resulted in debris flows forming in the streams and depositing material on the debris flow/debris flood fans at the exits of the stream valleys onto the Rangitakei Plains and the coastal platform west at Matata. The debris flows from Awatarariki Stream caused structural damage to buildings on at least thirty properties and caused flooding damage to another twenty. The debris flows from the Waitepuru Stream catchment caused structural damage to nine properties with at least another forty affected by flood damage.

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## Terrace Tunnel (SH1) Approach Wall Anchors Maintenance

Beverley Curly - Opus



### Introduction

The Wellington Urban Motorway State Highway 1 (SH1) is a vital lifeline into Wellington City and the highway needs to remain usable (after clearance and temporary repairs to the walls) by emergency traffic after an earthquake event.

The tunnel and motorway approaches generally follow the Terrace Fault Zone. This zone consists of intensely fractured and crushed rock and fault gouge materials that were encountered during the original investigations and excavation for the construction of the southwest wall. The northern motorway approach to the tunnel follows the in-filled line of the Kumototo Stream Gully.

The past maintenance and inspection of the walls has been carried out on an irregular basis. A maintenance strategy for the Terrace Tunnel Approach Wall Anchors was developed by Opus International Consultants for Transit New Zealand. The maintenance strategy was developed to ensure that the approach walls are satisfactorily maintained during their design life, and the

strategy is presently being implemented.

The Terrace Tunnel approach walls and anchors were designed in the early 1970s and constructed during the mid to late 1970s and were completed in the summer of 1977-1978. The approach walls on the north-western and south-western sides are tied back and tied down concrete walls. The tied-back walls are anchored to a concrete beam in anchor drive tunnels. A section of wall on top of the tied back wall is supported by rock anchors.

### Drainage Maintenance

In the southwest and northwest anchor drive tunnels improvement and maintenance has been carried out to the drainage holes in the drives. The holes provide drainage of the bedrock behind the walls.

Drainage holes in the walls of the anchor drive tunnels were indicated to be 7.6 m in length, and in the roof 4.5 m from the ground surface (equivalent to 21.5 m in length for a portion of the holes). Before the maintenance work

began all of the drainage holes (a total of 492) in the anchor drive tunnels were measured. All of the drainage holes in both anchor drive tunnels were found to be shorter and were essentially mostly weep holes through the lining.

- The works undertaken in the anchor drive tunnels included;
- High pressure water cleaning of the walls and drainage holes,
- Reaming of the drainage holes and drilling to increase the length of the holes to 7 m in the walls and between 10 m and 21.5 m for the roof holes.
- Over 540 m of drilling and reaming was carried out.
- Drainage holes prone to collapse were lined with slotted PVC pipe, and others were left unlined.

### Instrumentation & Monitoring

As part of the maintenance strategy instrumentation comprising standpipe piezometers were installed to enable monitoring of the groundwater levels behind the retaining walls and to check the effectiveness of the drainage measures. Groundwater levels are being monitored by the piezometers installed in the hillside behind the southwest approach wall and the northwest approach wall. Groundwater levels showed an immediately drop after high pressure water cleaning of the drainage holes. This trend of dropping water levels has continued.

Seepage monitoring of the drainage holes in both the northwest and southwest anchor drives is being carried

out to assess whether flow of water from the drainage holes increased after decalcification, reaming and drilling. Generally for both anchor drive tunnels, the flow of water from the drainage holes has increased, although some small portions of the drive tunnels have remained relatively dry.

The instrumentation, monitoring and drainage maintenance was carried out between May and October 2005 by Webster Drilling & Exploration Ltd with high pressure water cleaning by sub-contractors Jet-Vac NZ Ltd.

### Anchor Maintenance

The next step in the maintenance strategy involves;

- Removal and inspection of a number of anchor bars
- Checking pre-stress and load capacity of a number of anchor bars
- Anchor head improvements
- Drainage and corrosion protection.

This tender will be let shortly.

### Beverley Curley

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**Left:** Inside the northwest anchor drive tunnel

**Above:** Stalactites inside anchor drive tunnel

**Opposite:** SH1 Terrace Tunnel northwest approach wall

## TECHNICAL ARTICLES

### The Physics, Formation, and Mitigation of Tsunamis

Assem Elsayed, Tufts University, USA

#### Abstract

Tsunamis are large water waves, typically generated by seismic activity. This paper contains background information that is including information about the mechanisms of tsunami generation and propagation, the impact of tsunamis on humankind. Tsunami is a Japanese word with the English translation, “harbor wave.” Represented by two characters, the top character, “tsu,” means harbour, while the bottom character, “nami,” means, “wave.” In the past, tsunamis were sometimes referred to as “tidal waves” by the general public and as “seismic sea waves” by the scientific community. The term “tidal wave” is misleading; although a tsunami’s impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, gravitational influences of the moon, sun, and planets. The term “seismic sea wave” is also misleading. “Seismic” implies an earthquake-related generation mechanism, but a tsunami can also be caused by a non-seismic event, such as a landslide.

#### Introduction

Tsunamis are unlike wind-generated waves, which many of us may have observed on a local lake or at a coastal beach, in that they are characterized as shallow-water waves, with long periods and wavelengths. As a result of this long wavelength, tsunamis behave as shallow-water waves. A wave becomes a shallow-water wave when the ratio between the water depth and its wavelength gets very small. Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity ( $9.8 \text{ m/s}^2$ ) and the water depth; let’s see what this implies: In the Pacific Ocean, where the typical water depth is about 4000 m, a tsunami travels at about 200 m/s, or over 700 km/hr. Because the rate at which a wave loses its energy is inversely related to its wavelength, tsunamis not only propagate at high speeds, they can also travel great, transoceanic distances with limited energy losses.

#### The Physics of Tsunamis

As the tsunami crosses the deep ocean, its length from crest to crest may be a hundred miles or more, and its height from crest will only be a few feet or less. In the deepest oceans, the waves will reach speeds exceeding 970 km/h (600 mph). When the tsunami enters the shallow water of coastlines in its path, the velocity of its waves diminishes and the wave height increases. The main factor, which

determines the initial size of a tsunami, is the amount of vertical sea floor deformation. This is controlled by the earthquake’s magnitude, depth, fault characteristics and coincident slumping of sediments or secondary faulting. Other features which influence the size of a tsunami the velocity of the sea floor deformation, the water depth near the earthquake source, and the efficiency which energy is transferred from the earth’s crust to the water column. A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. Submarine landslides, which often occur during a large earthquake, can also create a tsunami. During a submarine landslide, the equilibrium sea level is altered by sediment moving along the sea floor. Similarly, a violent marine volcanic eruption can create an impulsive force that displaces the water column and generates a tsunami. Unlike ocean-wide tsunamis caused by some earthquakes, tsunamis generated by non-seismic mechanisms usually dissipate quickly and rarely affect coastlines far from the source area.

#### The Formation of Tsunamis

Tsunamis are characterized as shallow-water waves. Shallow-water waves are different from wind-generated waves. Wind-generated waves usually have period of five to twenty seconds and a wavelength of about 100 to 200 meters (300 to 600 ft). A tsunami can have a period in the range of ten minutes to two hours and a wavelength in excess of 500 km (300 miles). A shallow-water wave is characterized by very small ratio between the water depth and the wavelength. The rate at which a wave loses its energy is inversely related to its wavelength. Since a tsunami has a very large wavelength, it will lose little energy as it propagates. Hence in very deep water, a tsunami will travel at high speeds and travel great transoceanic distances with limited energy loss. For example, when the ocean is 6100 m (20,000 ft) deep, unnoticed tsunami travel about 890 km/h (550 mph), the speed of a jet airplane. And they can move from one side of the Pacific Ocean to the other side in less than one day.

As a tsunami leaves the deep water of the open sea and propagates into the more shallow waters near the coast, it undergoes a transformation. Since the speed of the tsunami is related to the water depth, as the depth of the water decreases, the speed of the tsunami diminishes. The change of total energy of the tsunami remains constant. Therefore, the speed of the tsunami decreases as it enters

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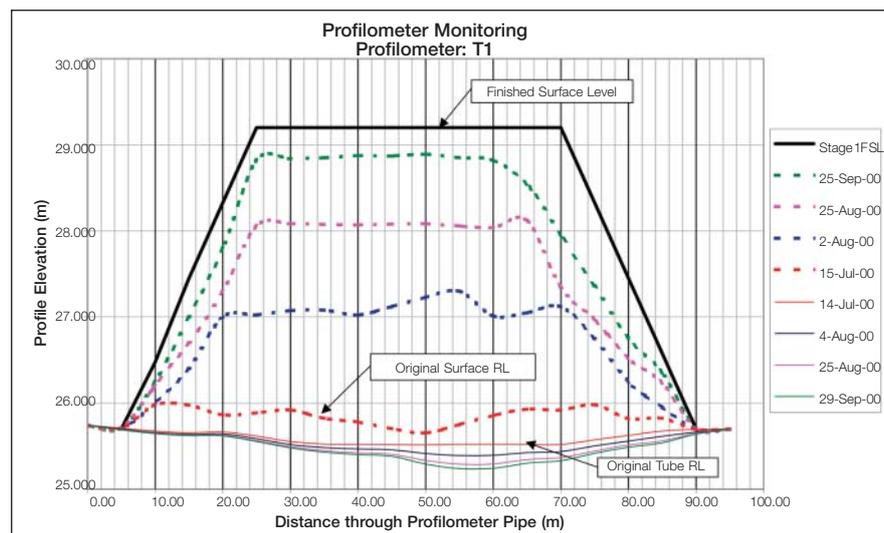
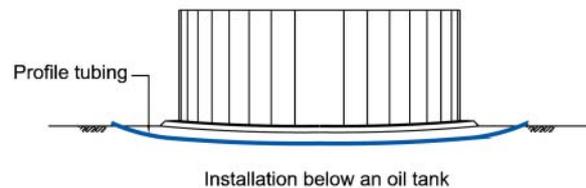
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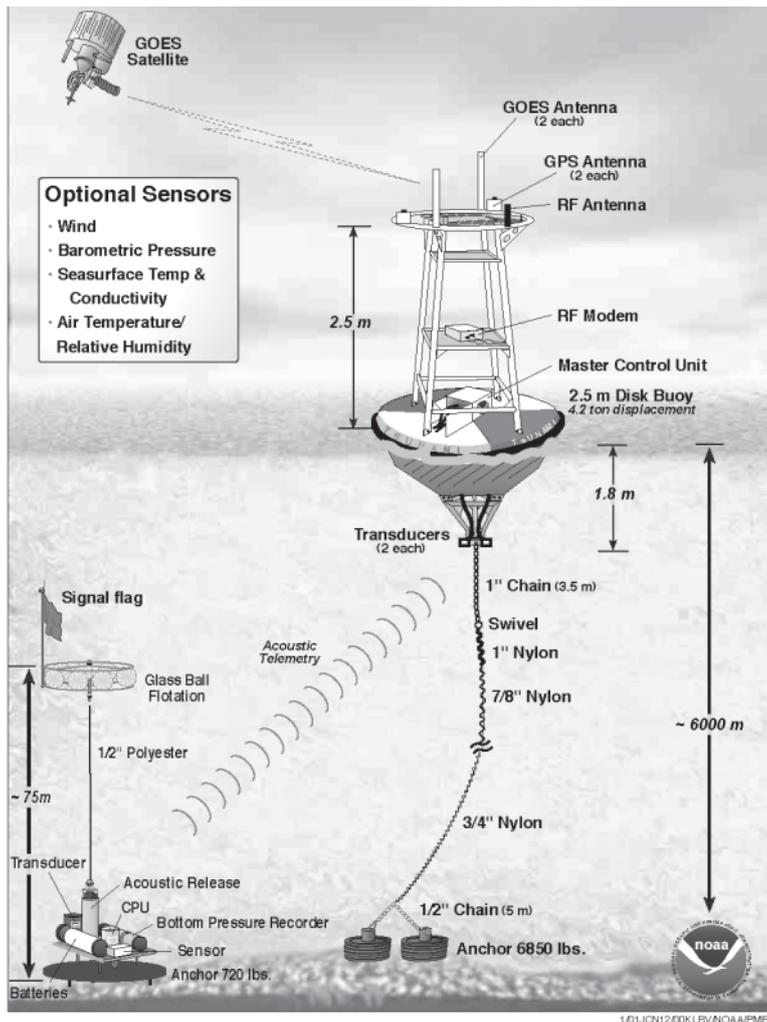


Figure 2 DART Buoy Photograph

Figure 1 DART Mooring System

shallower water, and the height of the wave grows. Because of this “shoaling” effect, a tsunami that was imperceptible in deep water may grow to be several feet or more in height when it reaches shore.

**The Effects of Tsunamis**

When a tsunami finally reaches the shore, it may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore. Tsunamis rarely become great, towering breaking waves. Sometimes the tsunami may break far offshore, or it may form into a bore: a step-like wave with a steep breaking front. A bore can happen if the tsunami moves from deep water into a shallow bay or river.

The water level on shore can rise many feet. In extreme cases, water level can rise to more than 15 m (50 ft) for tsunamis of distant origin and over 30 m (100 ft) for tsunami generated near the earthquake’s epicenter. The first wave may not be the largest in the series of waves. One coastal area may see no damaging wave activity while in another area destructive waves can be large and violent. The flooding of an area can extend inland by 300 m (1000 ft) or more, covering large expanses of land with water and

debris. Flooding tsunami waves tend to carry loose objects and people out to sea when they retreat. Tsunamis may reach a maximum vertical height onshore above sea level, called a run-up height, of 30 m (98 ft). A notable exception is the landslide-generated tsunami in Lituya Bay, Alaska in 1958, which produced a 525 m (1722 ft) wave.

**Tsunami Mitigation**

Since science cannot predict when earthquakes will occur, they cannot determine exactly when a tsunami will be generated. But, with the aid of historical records of tsunamis and numerical models, science can get an idea as to where they are most likely to be generated. Past tsunami height measurements and computer modeling help to forecast future tsunami impact and flooding limits at specific coastal areas. There is an average of two destructive tsunamis per year in the Pacific basin. Pacific-wide tsunamis are a rare phenomenon, occurring every 10-12 years.

As part of the U.S. National Tsunami Hazard Mitigation Program (NTHMP), the Deep-ocean Assessment and Reporting of Tsunamis (DART Project) is an ongoing

effort to develop and implement a capability for the early detection and real-time reporting of tsunamis in the open ocean. DART is essential to fulfilling NOAA's national responsibility for tsunami hazard mitigation and warnings. The goals of this initiative are:

- 1) Reduce the loss of life and property in coastal communities.
- 2) Eliminate false alarms and the high economic cost of unnecessary evacuations.

DART stations are sited in regions with a history of generating destructive tsunamis to ensure early detection of tsunamis and to acquire data critical to real-time forecasts. A DART system consists of a seafloor bottom pressure recording (BPR) system capable of detecting tsunamis as small as 1 cm, and a moored surface buoy for real-time communications. An acoustic link is used to transmit data from the BPR on the seafloor to the surface buoy. The data are then relayed via a GOES satellite link to ground stations, which demodulate the signals for immediate dissemination to NOAA's Tsunami Warning Centers as in Figure 1.

The surface mooring uses a 2.5 m diameter fiberglass-over-foam, disk buoy with a gross displacement of 4000 kg. The mooring line is 19 mm, 8-strand plaited nylon with a rated breaking strength of 7100 kg and is deployed with a scope of 0.985. This maintains a tight watch circle to keep the buoy positioned within the narrow cone of the acoustic transmission. Two downward looking transducers are mounted on the buoy bridle at a depth of 1.5 m below the sea surface. A multi-layered baffle system of steel lead, and syntactic foam shields the transducers and cushions them with rubber pads for a soft mount.

A typical tsunami DART bottom package mooring consists of a Bottom Pressure Recorder, an acoustic modem, acoustic release unit and battery pack bolted to a platform, to which a disposable anchor, flotation, and recovery aids are attached. Moorings are designed to free-fall to the bottom and are deployable for 24 months at depths of 6000 m; recovery is initiated by triggering the acoustic release to separate from the anchor, at which point the flotation brings the unit to the surface. These systems have measured tsunamis characterized by amplitudes less than 1 cm in the deep ocean, using a quartz crystal pressure transducer that is sensitive to changes corresponding to less than a millimeter of equivalent sea level change in the tsunami frequency band. Testing and prototype development was begun in 1995 and the first four DART stations were in place by August 2000. The standard DART surface buoy has a current design life of 1 year and the seafloor BPR package has a life of 2 years. The system has proven to be robust and reliable with a cumulative data return since 1998 of larger than 96%.

## International Warning System

The Tsunami Warning System (TWS) in the Pacific comprised of 26 participating international member states (Table 1), where they have the functions of monitoring seismological and tidal stations throughout the Pacific Basin to evaluate potentially tsunamigenic earthquakes and disseminating tsunami warning information. The Pacific Tsunami Warning Center (PTWC) is the operational center of the Pacific TWS. Located near Honolulu, Hawaii, PTWC provides tsunami warning information to national authorities in the Pacific Basin. As part of an international cooperative effort to save lives and protect property, The National Oceanic and Atmospheric Administration (NOAA) and National Weather Service operate two tsunami-warning centers. The Alaska Tsunami Warning Center (ATWC) in Palmer, Alaska, serves as the regional Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California. The Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii, serves as the regional Tsunami Warning Center for Hawaii and as a national/international warning center for tsunamis that pose a Pacific-wide threat. This international warning effort became a formal arrangement in 1965.

The objective of the PTWC is to detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Pacific Basin or its immediate margins. Earthquake information is provided by seismic stations operated by PTWC, ATWC, the U.S. Geological Survey's, and international sources. If the location and magnitude of an earthquake meet the known criteria for generation of a tsunami, a tsunami warning is issued to warn of an imminent tsunami hazard. The warning includes predicted tsunami arrival times at selected coastal communities within the geographic area defined by the maximum distance the tsunami could travel in a few hours. A tsunami watch with additional predicted tsunami arrival times is issued for a geographic area defined by the distance the tsunami could travel in a subsequent time period.

continued page 40 >

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**Table 1:** The Participating Countries in the Tsunami Warning System

• Australia	• Canada
• Chile	• China
• Columbia	• Russia
• Cook Islands	• Costa Rica
• North Korea	• Ecuador
• Fiji	• France
• Guatemala	• Indonesia
• Japan	• Mexico
• New Zealand	• Nicaragua
• Peru	• Philippines
• South Korea	• Singapore
• Thailand	• U.K (Hong Kong)
• USA	• Western Samoa

### Rare Reasons for Tsunamis

Although, for a given location on the Earth's surface, the risk of a "direct" hit from an asteroid is slight, researchers realized that an ocean impact had the potential to be much more destructive due to the effects of tsunami. An airburst explosion is a three dimensional event and energy decreases according to the square of the distance but a radiating ocean wave is a two-dimensional phenomenon and, in theory, energy decreases in proportion to distance. Since the early 1990s some advanced computer simulations have been conducted to estimate the effects of asteroid impacts above deep oceans. The dramatic picture by Don Davis is a little misleading, Figure 3. When an asteroid hits the ocean at 70,000 km/h there is a gigantic explosion. The asteroid and water vaporize and leave a huge crater - typically 20 times the diameter of the asteroid (that is, a 100 m asteroid will create a 2 km diameter crater). The water rushes back in, overshoots to create a mountain of water at the middle and this spreads out as a massive wave "i.e. tsunami".

### Case History - The 1964 Alaska Earthquake

More than 90% of the deaths in Alaska during the 1964 earthquake and subsequent tsunamis were due to the tsunami. The 1964 earthquake and tsunami deaths alerted State and Federal officials to the need for a facility to respond to the need for timely and effective tsunami warnings and earthquake information for Alaska and the northern Pacific. In 1967 and as a result of the earthquake and tsunamis, the West Coast & Alaska Tsunami Warning System (WC&ATWC) was established in Palmer to mitigate the tsunami hazard. The primary mission of the WC&ATWC is to provide tsunami warnings for Alaska, California, Oregon, Washington, and British Columbia in Canada. A secondary mission of the Center is to provide

immediate earthquake information to the general public, media, National and International agencies, and to many other recipients including both State and Federal disaster preparedness agencies. The Center is highly automated with state-of-the-art computers and techniques, which make the information immediately available.

Although Alaska's seismic and tsunamigenic history is only about 200 years or so, it is extremely seismic with the Pacific plate subducting under the North American plate. This subduction zone is referred to as the Aleutian-Alaska megathrust zone and makes the coastal areas very dangerous with regard to tsunami generation (tsunamigenesis). The vertical crustal movements in this area result in vertical sea floor displacements, thus highly tsunamigenic. Tsunamigenic events occurring about the Alaskan Peninsula, Aleutians, and Gulf of Alaska have a very high potential for generating local and Pacific wide tsunamis. Three past tsunamis that were generated in Alaska have resulted in Pacific wide death and destruction. In the southeast, the major fault is the Fairweather fault, which does have a history of vertical displacements (>12 meters), but is inland. This fault has not caused large tectonic tsunamis as the other Alaskan areas. However, events occurring in this region have induced large subareal and submarine landslides, which in turn, have generated massive local tsunamis. Subareal and submarine landslides, with induced massive local tsunamis, can and have occurred in this area without an earthquake

The great Alaskan earthquake of 1964 was the largest earthquake in North America and the second largest ever recorded (largest occurred in Chile in 1960). The earthquake occurred at 5:36 pm on March 27, 1964, Alaska Standard Time (or, at 03:36 Universal Time code on March 28, 1964). The epicenter was in the Northern Prince William Sound (61.1N 147.5W) about 75 miles E of Anchorage, or about 55 miles west of Valdez. The reported Richter magnitudes (Ms) for this earthquake ranged from 8.4 to 8.6. The moment magnitude (Mw) is reported as 9.2. The depth or point where the rupture began was about 14 miles within the earth's crust. The strong ground motion reported in the Anchorage area lasted about 4-5 minutes which triggered many avalanches and landslides - some being tsunamigenic. Ground deformations were extensive with some areas east of Kodiak being raised by 30 ft and areas about Portage being dropped by 8 ft. The rise is estimated to come in two thrusts of about 5 m each. The maximum intensity reported was XI on the modified Mercalli Intensity scale, indicating major structural damage, and ground fissures and failures. From this event, significant damage covered an area of about 50,000 square miles. Intensities of IV-V (felt by most people/minor damage) were reported as far away as Cold Bay, Bethel, McGrath, Kotzebue, Deadhorse, Ft. Yukon, Eagle and Skagway.

The 1964 earthquake caused 115 deaths in Alaska alone, with 106 of these due to tsunamis, which were generated by tectonic uplift of the sea floor, and by localized subareal and submarine landslides. The earthquake shaking caused at least 5 local slide generated tsunamis within minutes after the shaking began. (In general, slide/slump induced tsunamis are generated within a few minutes after an earthquake starts.) These five occurred at Valdez (2), Seward, Whittier, and Kachemak Bay. As an example and in brief summary: In Seward, a section of the water front (1070 m) slid into the Resurrection Bay due to the earthquake shaking. This created a local tsunami causing much damage and the spreading of oil, which was on fire and floating on the water. About 20 minutes after this occurred, the first wave of the main tsunami arrived. The 11-13 fatalities in Seward were due to the local and the main tsunami.

Tsunamis generated by the 1964 earthquake (and their subsequent damage, loss of life, etc.) were recorded throughout the Pacific. This was the most disastrous tsunami to hit the U.S. West Coast and British Columbia in Canada. The largest wave height for this tsunami was reported at Shoup Bay, Valdez Inlet (67 m). Summary of lives lost and damage for Alaska, Canada, Washington, Oregon and California are: Alaska- 106 deaths and \$84 million; British Columbia- \$10 million; Washington-minor damage throughout the coast; Oregon- 4 deaths and \$0.7 million, with much of the damage away from the coast where rivers overflowed; California- 13 deaths and \$10 million damage. Many places that reported damage or lives lost are given below.

The tsunami-generating area covers an area of 700 km long by 150 km wide, a total of about out 105,000 km<sup>2</sup> (sq. km). The volume of the uplifted crust along the continental shelf is about out 96 km<sup>3</sup> (cubic km). The energy associated with the tsunami has been estimated by Van Dorn (1964) to be on the order of  $2.3 \times 10^{21}$  ergs. This estimate is based on the source dimensions of an area 240 nautical miles by 100 nautical miles and an uplift of 1.8 m (6 ft) at the northeastern end of this area and zero at the southwestern end. This estimate however, is considered low because the generating area had dimensions that were larger than those estimated by Van Dorn.

## Conclusion

Tsunamis that strike coastal locations in the Pacific Ocean Basin are most always caused by earthquakes. These earthquakes might occur far away or near where we live. Some tsunamis can be very large. In coastal areas their height can be as great as 30 ft or more (100 ft in extreme cases), and they can move inland several hundred feet.

- All low-lying coastal areas can be struck by tsunamis.
- A tsunami consists of a series of waves. Often the first wave may not be the largest. The danger from a tsunami can last

for several hours after the arrival of the first wave.

- Tsunamis can move faster than a person can run.
- Sometimes a tsunami causes the water near the shore to recede, exposing the ocean floor.
- The force of some tsunamis is enormous. Large rocks weighing several tons along with boats and other debris can be moved inland hundreds of feet by tsunami wave activity. Homes and other buildings are destroyed. All this material and water move with great force and can kill or injure people.
- Tsunamis can travel up rivers and streams that lead to the ocean.
- If someone at the beach or near the ocean and felt the earth shake, one should move immediately to higher ground.
- Tsunamis generated in distant locations will generally give people enough time to move to higher ground. For locally generated tsunamis, where someone might feel the ground shake, one may only have a few minutes to move to higher ground.
- High, multi-story, reinforced concrete hotels are located in many low-lying coastal areas. The upper floors of these hotels can provide a safe place to find refuge should there be a tsunami warning. Although, homes and small buildings located in low-lying coastal areas are not designed to withstand tsunami impacts.
- Offshore reefs and shallow areas may help break the force of tsunami waves, but large and dangerous wave can still be a threat to coastal residents in these areas. Staying away from all low-lying areas is the safest advice when there is a tsunami warning.
- Tsunamis can cause rapid changes in water level and unpredictable dangerous currents in harbors and ports.

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## TECHNICAL ARTICLES

### GEOMECHANICS AWARD 2005

# Rock mass defect patterns and the Hoek-Brown failure criterion

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The Hoek-Brown failure criterion is often applied to a wider range of rocks than the isotropic rock masses to which it is strictly applicable. This paper evaluates the patterns of defects in rock masses using spherical projection contour plots of samples of randomly-generated orientations and datasets from mapping of New Zealand closely-jointed greywacke rock masses. Two indices from the contour plots - the area within the 1% contour ( $A_{1\%}$ ) and maximum concentration ( $C_{\max}$ ) are introduced for distinguishing uniform (isotropic), random or regular defect patterns. The indices provide a potential extension to current guidelines on the use of the Hoek-Brown failure criterion. The paper also outlines kinematic checks to assess the influence of defect clusters on rock mass strength.

Das Hoek-Brown Bruchkriterium, das strikte nur fuer isotrope Gefuege gilt, findet oft einen viel weiteren Anwendungsbereich. Diese Arbeit bewertet diverse Dispersionsmuster der Defekte einer Gesteinsmasse. Wir vergleichen in sphaerischer Projektion (1) Beispiele zufaelliger Orientierung von Defekten und (2) Felddaten ueber neuseelaendisache engstaendig geklueftete Grauwacken. Die Projektionen werden durch die Indices  $A_{1\%}$  (Flaechenanteil des 1%-Bereichs) und  $C_{\max}$  (Hoechstkonzentration) gekennzeichnet, welche isotrope, zufaellige und regulaere Muster unterscheiden und die aktuellen Richtlinien zum Hoek-Brown Kriterium ergaenzen. Wir testen ferner Defektgruppen der Gesteine kinematisch auf ihren Einfluss auf Massfestigkeit.

Le critère de rupture de Hoek-Brown est souvent utilisé sur une variété de roches plus étendue que les masses rocheuses auxquelles il est strictement applicable. Ce travail évalue la distribution des défauts au sein d'une masse rocheuse en utilisant une projection sphérique des contours d'échantillons d'orientations générées aléatoirement et de données de cartographie provenant de greywackes à joints rapprochés de Nouvelle Zélande. Deux indices de cette projection - la zone des contours en dessous de 1 % ( $A_{1\%}$ ) et celle de concentration maximum ( $C_{\max}$ ) sont introduites pour distinguer les répartitions uniformes (isotropes), aléatoires ou régulières. Ces indices fournissent une extension potentielle aux règles d'utilisation du critère de rupture de Hoek-Brown. Ce travail utilise également les contrôles cinématiques pour évaluer l'influence des groupes de défauts sur la résistance de la masse rocheuse.

## Introduction

Rock defect patterns are an important attribute in rock mass strength. The Hoek-Brown failure criterion<sup>1</sup> is the commonly used method for assessing the strength of jointed rocks. Critical assumptions for the criterion are that the rock and the rock mass behaviour are isotropic and that the criterion *should only be applied to those rock masses in which there are a sufficient number of closely spaced discontinuities that isotropic behaviour involving failure on discontinuities can be assumed*<sup>1</sup>. Despite this clear warning about the limitation of the failure criterion, the procedure is often used fairly indiscriminately to assess the strength of rock masses with well ordered defect patterns.

Upper Paleozoic to Mesozoic-age greywacke rocks are widespread throughout New Zealand and these basement rocks form the foundations for many of the country's engineering projects. The rocks are commonly closely-jointed as a result of their complex tectonic and geological history. The impetus for this research has come from our less-than-satisfactory experience in using the Hoek-Brown failure criterion on unweathered New Zealand grey-

wackes<sup>2</sup>. Field mapping and laboratory strength testing indicate that these rocks have an unusual combination of high intact rock strength and close defect spacing<sup>2,3,4</sup>. In particular, this combination indicates the need for more detailed rock mass characterisation when assessing inputs for the Hoek-Brown failure criterion<sup>3,5</sup>.

Guidelines for the use of the Hoek-Brown failure criterion are based on the sample size and the number of defect sets in the rock mass<sup>1,6</sup>, as is shown in Figure 1. Geological input for the failure criterion is applied through the Geological Strength Index (GSI), which takes account of the structure and surface condition of rock mass defects. However, there is no specific provision for considering the orientation and pattern of the defects.

A defect pattern index would therefore be a useful adjunct for assessing the conditions under which the Hoek-Brown criterion can be used. In this paper, methods for describing defect orientation patterns are evaluated using spherical projections of data from artificial samples and field mapping of greywacke rock masses. The spherical projections are then used to assess the extent to which kinematic mechanisms will affect rock mass strength.

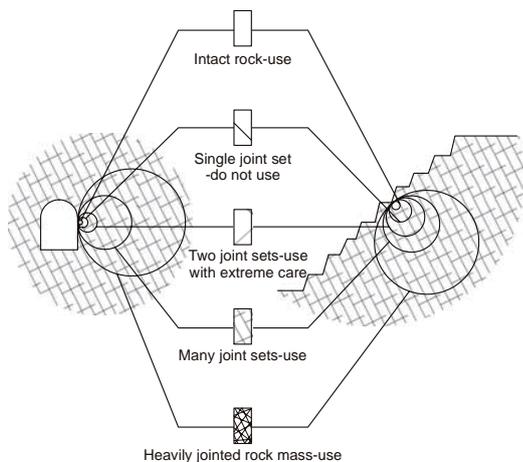


Figure 1: Rock mass conditions under which the Hoek-Brown failure criterion can be used (after <sup>16</sup>)

**Evaluation of defect patterns**

Spherical projections are the standard method for plotting defect orientations, which are measured in the field in terms of either their strike/dip or their dip direction/dip. When plotted in spherical projection, defect attitudes are most conveniently represented by poles, which are constructed from a line normal to a plane of the defect.

Defect patterns can be assessed using vector statistics or contour plots. Statistical tests <sup>7,8</sup> can provide information on the patterns, particularly where the defects are clustered or girdled. However, for multimodal datasets, tests such as spherical variance and uniformity cannot distinguish between random orientations and well-ordered patterns with multiple sets (e.g. three orthogonal defect sets).

Fisher et al. <sup>9</sup> note that clustering methods are of little practical use in finding multimodal distributions and that estimates using probability models are very tedious. They conclude that the most practicable method is to partition the data into groups visually with the aid of contour plots.

Contour plots on lower hemisphere equal area (Schmidt or Lambert) projections are used in this paper, rather than equal angle (stereographic) projections. The validity of the isotropic requirement for the Hoek-Brown failure criterion may be tested on the basis of contour patterns. The starting point for the approach in this paper is McMahon's Joint Dispersion Index <sup>10</sup>.

McMahon defined the Joint Dispersion Index (JDI) in 1968 as the area enclosed by a given concentration contour on an equal area projection of a joint pattern expressed as a percentage of the area covered by the same contour of a random sample from a uniform distribution, of the same number of points, contoured by the same method. This can be expressed as:

$$JDI = \frac{\text{Area of contour from field data}}{\text{Area of same contour from random sample}} \times 100 \%$$

McMahon suggested that regularly jointed rock masses have a JDI less than 60% where the index is based on the 1% contour. Figure 2 shows examples from McMahon of regular and irregular defect patterns.

**Evaluation of defect dispersion**

Calculation of JDI requires comparison of field data with random samples, and the same approach has been followed in this paper using:

- Random samples of defect orientations from a uniform (isotropic) distribution
- Greywacke defect data from three New Zealand sites at Belmont, Taotaoroa and Aviemore <sup>2,5</sup>.

**Random defects**

McMahon's analysis of random defect data was based on a probability approach <sup>11</sup> using non-overlapping counting cells. This showed that the most probable area of the 1% contour steadily decreased with increasing sample size. Current methods, which use denser counting techniques, have been used to check the McMahon trends.

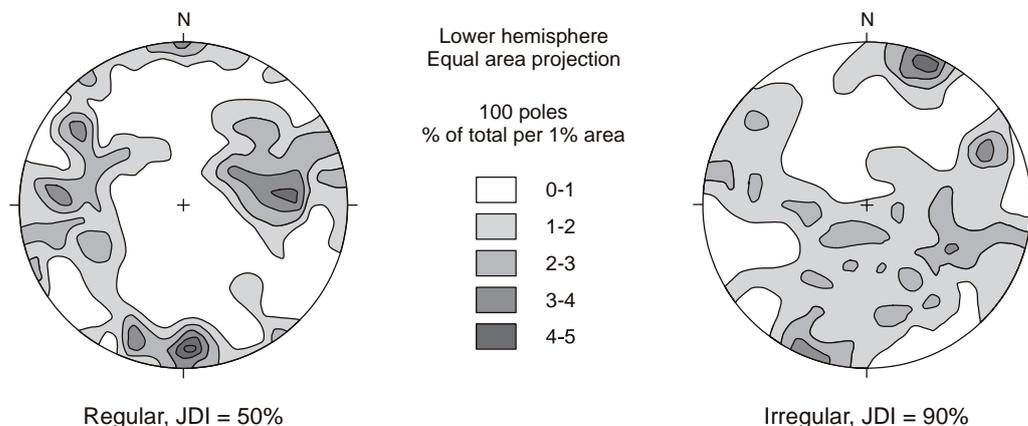


Figure 2: Joint Dispersion Indices for regular and irregular defect patterns (after <sup>10</sup>)

Random samples of 50 to 1000 defect orientations were generated with the *JTDist* utility in the *Dips* program<sup>12</sup>. These data have been plotted and contoured using the following spherical projection programs:

- *Dips*<sup>12</sup>
- *GEorient*<sup>13</sup>
- *QuickPlot*<sup>14</sup>
- *Stereonet*<sup>15</sup>

The circle used for counting was 1% of the area of the projection. The resulting contour shapes show variations related to the layout and density of the counting nodes (i.e. the shape and spacing of the grid over which the 1% count circle is moved) and the method of contouring. Figure 3 shows contours obtained for the same 100-point data sample using the four programs above. Following plotting of the contours, the area within the 1% contour ( $A_{1\%}$ ) has been measured with a digital planimeter.

In addition to variations in contour shape, the 1% contour area also varies among the programs (Figure 3). The largest area ( $A_{1\%} = 73\%$ ) results from the coarsest grid density setting in *GEorient* (approximately 300 nodes). This is the closest value to the McMahon result of 65% using 148 non-overlapping cells. The other three results, with more than 700 nodes, have similar  $A_{1\%}$  values of about 40% together with reasonably consistent values of the maximum concentration ( $C_{max}$ ) between 3.8 to 5%.

*Dips* has been used to look at possible trends in  $A_{1\%}$  and  $C_{max}$  for samples of 50 to 1000 orientations. The results in Figure 4, which include multiple samples of 100, 500 and 1000 orientations, show that:

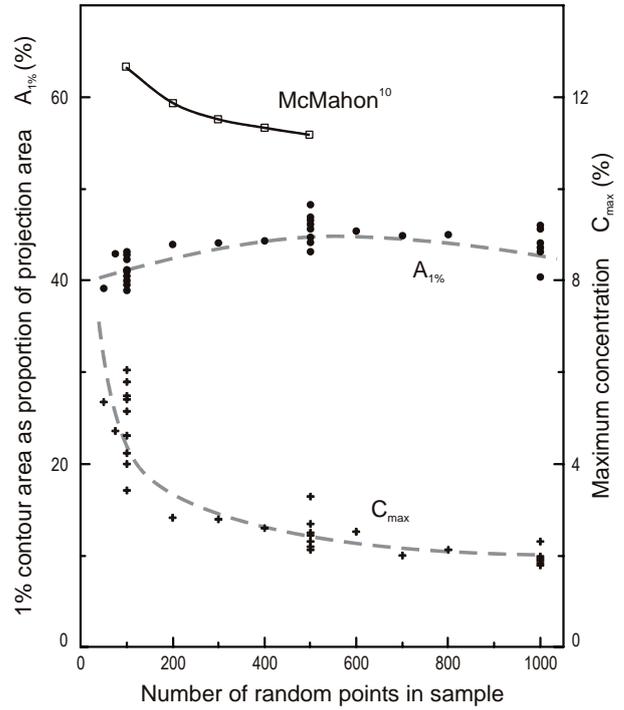


Figure 4: Summary data from contour plots of random defect samples using *Dips*<sup>12</sup>

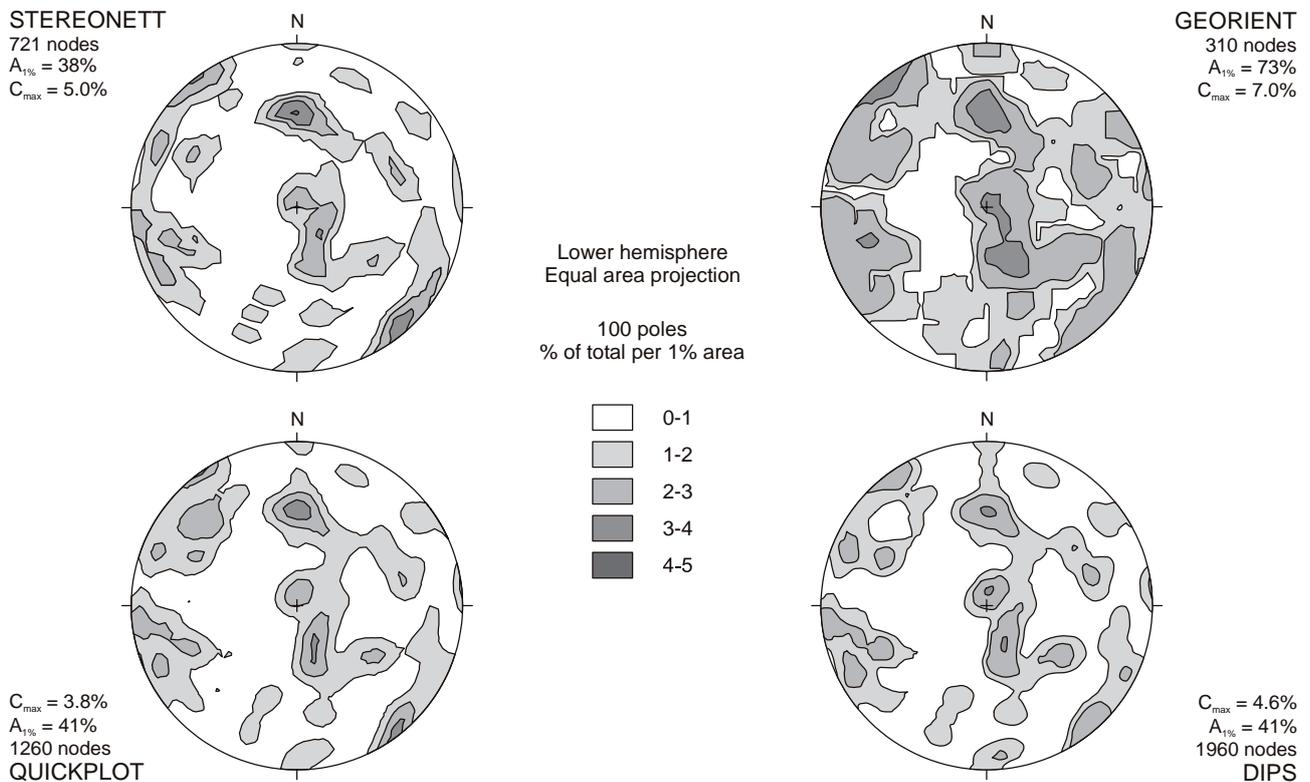


Figure 3: Contour plots of same 100-point random orientation sample by different programs

- $A_{1\%}$  values range from 38 to 48%. As shown in Figure 4, these are also lower than the values from McMahon<sup>10</sup> and are less influenced by sample size
- The variation in  $A_{1\%}$  for multiple sampling at a specific sample size is about 8%
- $C_{max}$  ranges from 6 to 2%, decreasing with increasing sample size
- The variation in  $C_{max}$  for multiple sampling at a specific sample size ranges from about 3 to 1%, again decreasing with increasing sample size.

**Greywacke sites**

Table 1 summarises data from contouring of greywacke defect data from the three New Zealand study sites, and Figure 5 gives contour plots for four of them. Sample sizes vary from 72 to 699 defect orientations, with  $A_{1\%}$  values ranging from 30 to 44% and  $C_{max}$  from 5 to 10%. The  $A_{1\%}$  values are smaller than those for random samples given in Figure 4, while the  $C_{max}$  values are noticeably higher.

**Suggested indices**

McMahon defined JDI as the ratio of  $A_{1\%}$  to the corresponding area for random samples of the same size. However, the procedures used in preparing our contour plots differ in detail from those used by McMahon. Because our results do not show a significant trend with sample size, the normalisation of  $A_{1\%}$  as in McMahon is not considered necessary. In addition, a uniform (isotropic) distribution will have  $A_{1\%}$  values greater than those for random samples. JDI in such cases could exceed 100%, which was probably not intended by McMahon.

Table 1: Summary of lower hemisphere equal area contour data for greywacke defects at New Zealand sites (after<sup>5</sup>).

Site	Number of defects	Area of 1% contour $A_{1\%}$ (%)	Maximum concentration $C_{max}$ (%)
Aviemore	183	37	7.0
Belmont I	168	37	8.0
Belmont II	72	36	9.6
Belmont III	169	44	5.3
Belmont IV	699	37	5.2
Belmont VI	144	33	9.2
Belmont West	216	30	10.3
Belmont South	216	33	8.0
Taotaoroa	331	37	4.9

Consequently, a more convenient way of describing the dispersion of defect patterns from contour plots of field data is direct use of the indices  $A_{1\%}$  and  $C_{max}$ .  $A_{1\%}$  is more useful and, based on data from random samples (Figure 4), can be used under the following guidelines:

- $A_{1\%} > 50\%$  Uniform (isotropic) pattern
- $A_{1\%} 40 - 50\%$  Random pattern
- $A_{1\%} 20 \text{ to } 40\%$  Moderately regular pattern
- $A_{1\%} < 20\%$  Highly regular pattern

$C_{max}$  should be used in a complementary manner, with increasing values for increasing regularity of defect pattern. Because of the trends with sample size in Figure 4, use of  $C_{max}$  is easier for larger sets (>200 points). Greater care is needed with smaller sample sizes because of the wider range of random sample values (Figure 4).

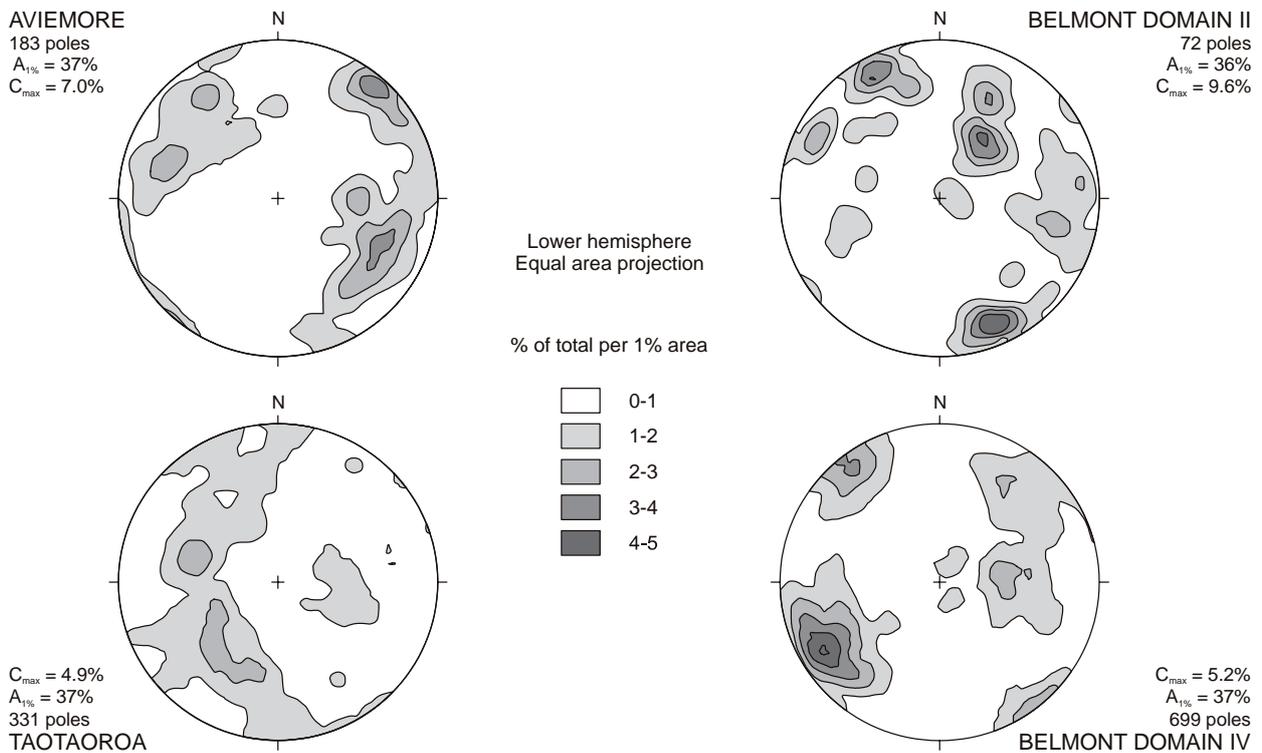


Figure 5: Contour plots of greywacke defects at New Zealand study sites by *Dips*.

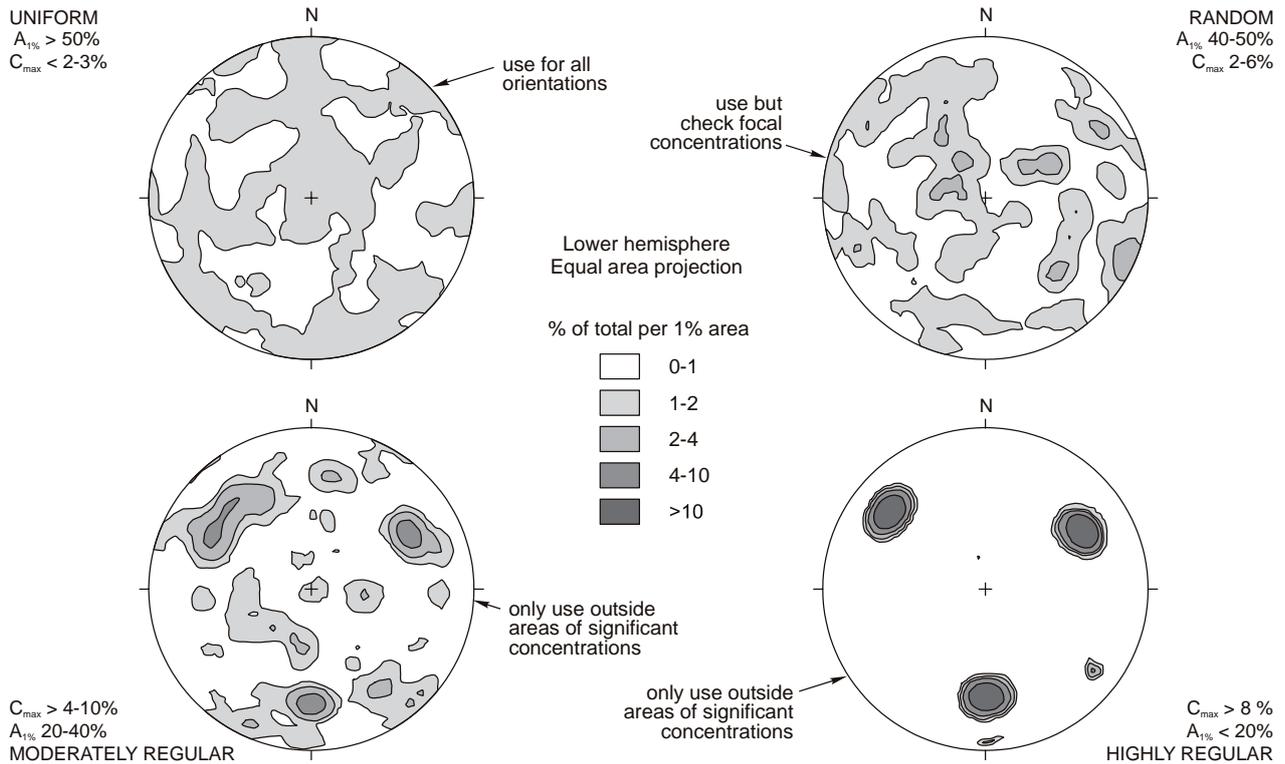


Figure 6: Guidelines for use of Hoek-Brown failure criterion based on defect patterns

Use of these guidelines with the data for the greywacke sites (Table 1, Figure 5) shows that the defect patterns are generally moderately regular. The exception is Belmont Domain III with higher  $A_{1\%}$  and lower  $C_{max}$  values that are more typical of a random pattern.

The contour plots in Figure 6 were prepared using *Dips* on generated data samples to represent defect patterns from uniform (isotropic) to highly regular (orthorhombic in plot). The trend for  $A_{1\%}$  to decrease as  $C_{max}$  increases with greater defect pattern regularity (i.e. less dispersion) is readily apparent, and typical index values are given on the plots. Figure 6 includes guidelines on the use of the Hoek-Brown failure criterion based on defect patterns, and these are considered a complementary extension to those in Figure 1.

**Effect of defect patterns on rock mass strength**

**Kinematic considerations**

Random defect patterns are characterised by relatively large areas within the 1% contour ( $A_{1\%} > 40\%$ ). Where there are defect clusters, rock mass strength will be affected by defects or defect intersections where these are oriented subparallel to the shearing direction.

For wedge failures in slopes, kinematic analyses with spherical projections are generally carried out using great circles to define the lines of intersection of planes<sup>16 12</sup>. This process is tedious for large data sets and requires different daylighting criteria compared with those for planes. A simpler technique is to use the ‘pole’ to the line of intersection rather than the line of intersection itself<sup>17</sup>

(Figure 7). The ‘pole’ to the line of intersection ( $P_{AB}$ ) is the dip direction/dip angle of the great circle that passes through the normals to the two planes ( $P_A, P_B$ ) – the line of intersection ( $I_{AB}$ ) being normal to this great circle.

The Belmont Domain II data set in Figure 5 is used in this paper as an example. The intersection ‘poles’ for all the possible combinations of defects have been calculated from the formulae in Appendix A.5 of Priest<sup>18</sup>.

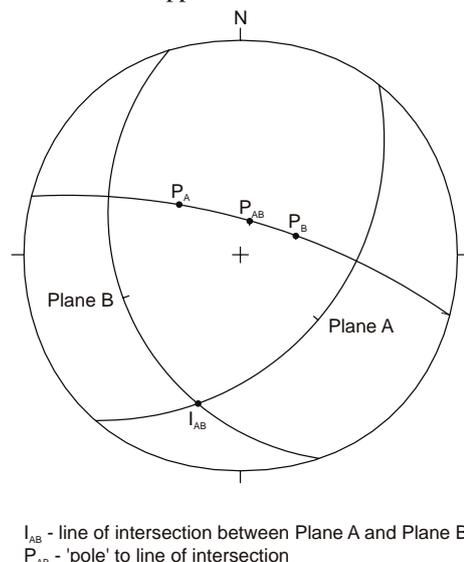


Figure 7: Definition of ‘pole’ to line of intersection of two planes

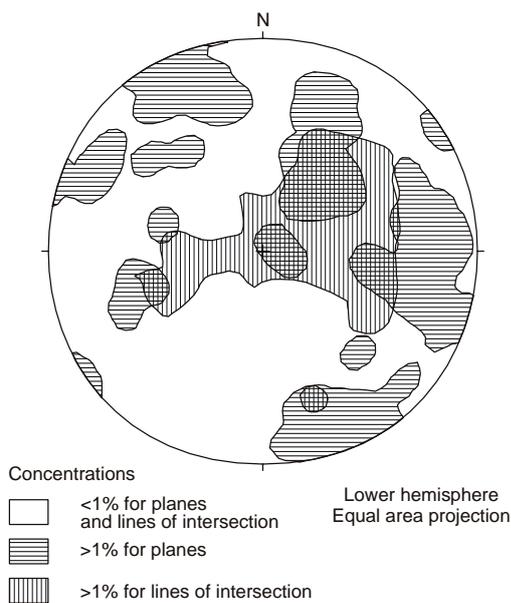


Figure 8: Extent of concentrations > 1% for planes and lines of intersection for Belmont Domain II

Figure 8 shows the extent of the 1% contours for the defects and intersection lines. The Hoek-Brown failure criterion is applicable to the blank areas on Figure 8 where defect orientations are not clustered (i.e. defect concentrations are less than 1%). Within the hatched areas representing concentrations of > 1%, kinematic checks for planar and wedge mechanisms must be considered.

The following description outlines how these checks can be applied to the slope stability situation illustrated in Figure 9. Figure 10 shows the attitudes of the slice bases on a spherical projection, together with the attitudes of the defects and their lines of intersection. For the purposes of this paper, defects within  $\pm 20^\circ$  of the dip or dip direction of a slice base are considered to influence rock mass strength. This range is similar to the zone within which the compressive strength of intact rock specimens is influenced by the presence of a defect<sup>19 20</sup> (Figure 11). This  $\pm 20^\circ$  window is illustrated for the base of one slice on Figure 10.

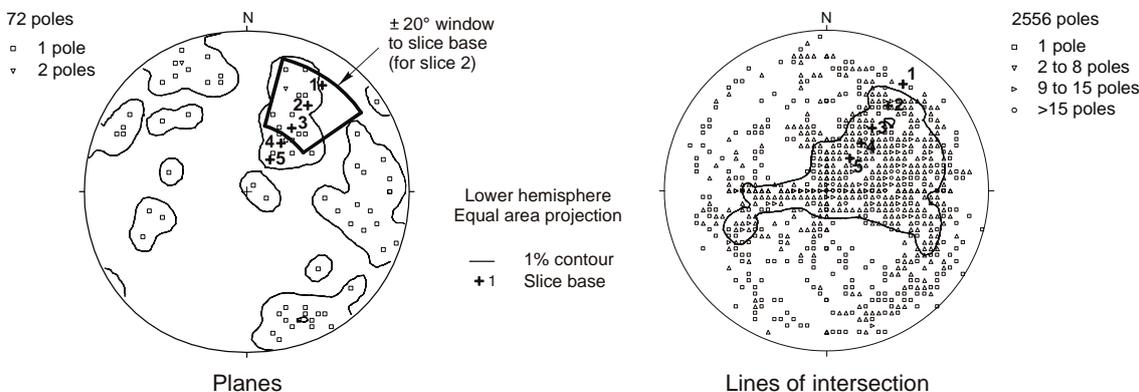


Figure 10: Slice base attitudes and Belmont Domain II defects and lines of intersection

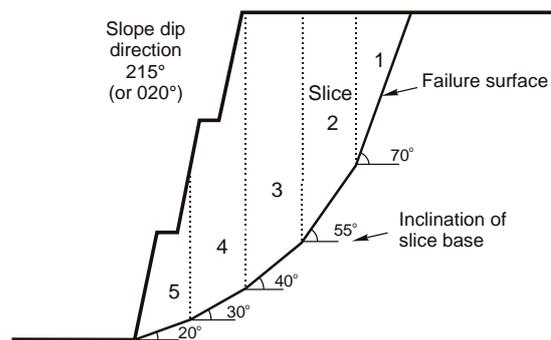


Figure 9: Section through slope showing failure surface geometry

There is only one planar defect cluster and one line of intersection cluster influencing the slice bases and Table 2 summarises the proportion of defects from each cluster within  $\pm 20^\circ$  of individual slice bases. There is a greater proportion (35 – 82%) for the planar cluster than for the lines of intersections (7 – 18%). If the slope were oriented in the opposite direction (e.g. 020°), Table 2 shows that there would be very few planes (0%) or lines of intersection (0 – 5%) close to the orientation of slice bases. The Hoek-Brown failure criterion is therefore directly applicable to the 020° slope, but not in the case of the 215° slope.

Table 2: Proportion of defect and lines of intersection oriented within  $\pm 20^\circ$  of individual slice bases

Slice		Proportion of defects within $\pm 20^\circ$ (%)			
		215° slope direction		020° slope direction	
Number	Inclination of base	Planes	Lines of intersection	Planes	Lines of intersection
1	70°	35	7	0	0
2	55°	71	13	0	0
3	40°	82	18	0	0
4	30°	59	15	0	1
5	20°	47	14	0	5

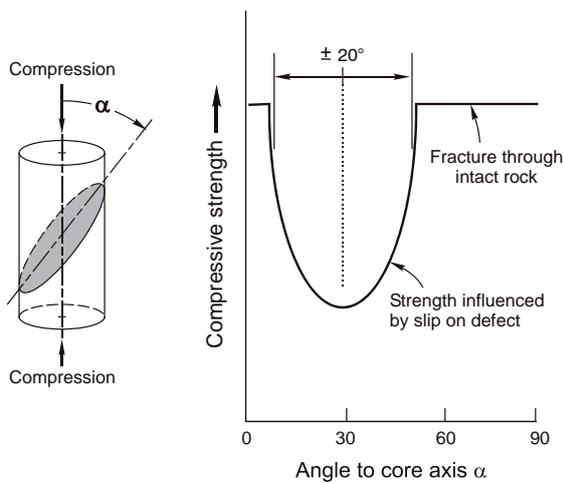


Figure 11: Influence of defect orientation on compressive strength

**Strength parameters**

Kinematic mechanisms involve failure along planes or lines of intersection. For planar mechanisms, strength is governed by the shear strength of the defect, whereas for wedge mechanisms, the strength will be greater than the defect shear strength by a factor of between 1 and 3 because of the wedging effect<sup>16</sup>. For the 215° slope (Figure 10 and Table 2), shear strengths for each slice base need to be assessed because their attitudes are close to the relevant clusters, in particular for planes.

The rocks at Belmont quarry are dominated by unweathered to slightly weathered sandstones with Geological Strength Index (GSI) values typically about 45. For the better quality sandstones in Domain II, the GSI is about 60<sup>5</sup>. Realistic estimates of the rock mass strength are obtained using a uniaxial compressive strength  $\sigma_{ci} = 80$  MPa and a Hoek-Brown intact rock parameter  $m_i = 13.5$ <sup>2,5</sup>. The rock mass strength envelope for these parameters is given in Figure 12, as well as the strength envelope for a rock to rock contact defect set with cohesion of 0 kPa and a friction angle of 35°. If the defect set selected was a sheared zone the strength would be correspondingly less.

Where the  $\pm 20^\circ$  window for a slice base falls entirely within the <1% contour area, the rock mass strength from the Hoek-Brown failure criterion can be used directly. Where the entire defect cluster lies within the  $\pm 20^\circ$  window the defect shear strength should be used. For intermediate situations, the strength can be estimated from the ratio of the number of defects belonging to that cluster within the  $\pm 20^\circ$  window to the total number of defects in the relevant cluster.

Figure 12 illustrates strength envelopes calculated using this approach, so that slice base 2, with influence from 71% of the defect cluster (Table 2), would have a strength close to the 75% line. Where the proportion of intersections is greater than for planes, strength envelopes would be higher than for planes alone, but this is not applicable in this example.

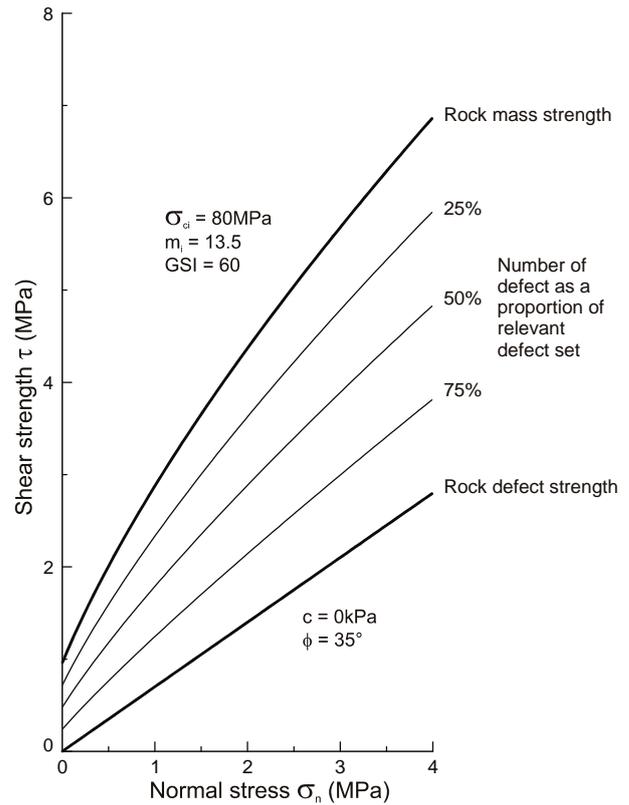


Figure 12: Effect of defect concentrations on rock mass strength

For the slope with a dip direction of 020°, there are insignificant numbers of planes and lines of intersection with orientations similar to those of the slice bases (Table 2). In these circumstances it would be appropriate to use the rock mass strength for the slice bases representing the failure surface.

**Conclusions**

Assessment of the conditions for the use of the Hoek-Brown failure criterion should include not only the number of defect sets but also their pattern. Using spherical projection contour plots, this paper has built on an approach of McMahon<sup>10</sup> to use a contour index to recognise rock mass defect patterns (dispersion). Simplified contour plot indices - the area within the 1% contour ( $A_{1\%}$ ) and maximum concentration ( $C_{max}$ ) - are introduced to distinguish uniform (isotropic), random or regular defect patterns. These indices ( $A_{1\%}$  and  $C_{max}$ ), which systematically change with increasing regularity of the defect patterns, provide a complementary extension to current guidelines on the use of the Hoek-Brown failure criterion based on sample size and number of defects.

Where defect patterns show clusters, kinematic checks should be carried out to assess the extent to which potential failure surfaces are affected by planes or lines of intersection. If there are few defects or intersection lines close to the orientation of failure surfaces (i.e. contours entirely <1%), then the use of rock mass shear strengths

based on the Hoek-Brown failure criterion is appropriate. Where a failure surface orientation is close to that of significant defect clusters, the strength is determined by the shear strength of the defect. For cases between these extremes, interpolation between rock mass and defect strength provides a pragmatic method of assessing the strength.

### Acknowledgements

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This paper has been judged the winner of the Geomechanics Award for 2005. Congratulations to the authors who are all members of the Geotechnical Society. The reference to the paper is Read, S.A.L., Richards, L.R., & Cook, G.K., (2003). Rock mass defect patterns and the Hoek-Brown failure criterion. Proc 10th ISRM International Congress on Rock Mechanics, Johannesburg : 2 947-954.

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## Presented at the 16th International Conference on Soil Mechanics and Geotechnical Engineering, Osaka, Japan

### Provision of Liquefaction Hazard Information: Building Resilient Communities La provision d'Information de Danger de Liquéfaction: Construisant des Communautés Élastiques

Steve Christensen

*Beca Infrastructure Ltd, Christchurch, New Zealand*

Peter Kingsbury

*Environment Canterbury and Ministry of Civil Defence and Emergency Management, Christchurch, New Zealand*

#### ABSTRACT

How effectively is knowledge of hazards disseminated throughout New Zealand in various communities? A brief introduction into New Zealand's regulatory planning and development for liquefaction risk evaluation and hazard mitigation is provided. The regulatory authorities have been surveyed on their perception of liquefaction and this showed that there is a wide variation in how liquefaction is perceived and dealt with. Finally, a discussion is provided on techniques that could be utilised to improve knowledge dispersion throughout our communities.

#### RÉSUMÉ

Combien efficacement la connaissance des risques est-elle disséminée dans l'ensemble de la Nouvelle Zélande dans diverses communautés? Une brève introduction dans la planification de normalisation de la Nouvelle Zélande et le développement pour la liquéfaction risquent l'évaluation et la réduction de risque est fournie. Les autorités de normalisation ont été examinées sur leur perception de la liquéfaction et ceci a prouvé qu'il y a une grande variation dans la façon dont la liquéfaction est perçue et traitée. En conclusion, une discussion est fournie sur les techniques qui pourraient être utilisées pour améliorer la dispersion de la connaissance dans toutes nos communautés.

#### 1 INTRODUCTION

In the nineteenth and twentieth centuries we have put increasing pressure on coastal and riverside land as cities have built up and out around transportation hubs, none more so than in New Zealand where a new nation was in the process of being born. Furthermore, coastal properties have become more desirable and fashionable over the last 20 to 30 years. However, the soils in these areas are often prone to liquefaction. In these types of soils in New Zealand a number of earthquake induced liquefaction events have been recorded (Fairless and Berrill, 1984). Internationally prior to 1964 liquefaction was observed, but the understanding of its mechanisms was still developing (Housner, 1958; Florin & Ivanov, 1961). Following the 1964 Niigata (Kawasumi, 1968) and Alaskan Earthquakes (Scott & Zuckerman, 1973), where a significant amount of ground and infrastructure damage was caused by liquefaction, our understanding of the phenomena has grown dramatically. Nowadays, it is rare for a geotechnical conference, especially in a seismically active region, to pass without further knowledge being passed on in regards to liquefaction. But how well is that knowledge of liquefaction being passed from a knowledge centric technical community on to the wider community? Firstly in this paper we will briefly look at New Zealand's legislative framework, followed by a summary of liquefaction knowledge in New Zealand. Lastly, we will consider changes that could be made to present systems in order to create more resilient communities.

#### 2 NEW ZEALAND'S LEGISLATIVE FRAMEWORK

##### 2.1 *Resource Management Act 1991*

The Resource Management Act 1991 (RMA) is the principal Act for the management of land use, subdivision, the use of water and soil resources and several other functions. Its purpose is to promote the sustainable management of natural and physical resources. The RMA requires Regional Councils to collect information about natural hazards relevant to their communities.

##### 2.2 *Civil Defence and Emergency Management Act 2002*

In 2002, the Civil Defence and Emergency Management Act 2002 (CDEM Act) was enacted, which requires a risk management based approach to the sustainable management of hazards, both natural and man-made. The Act's purpose includes: improving sustainable hazard management; improving safety of the public and property; encouraging communities to achieve acceptable levels of risk; requiring local authorities to co-ordinate CDEM planning and other activities; ensuring integration of national and local CDEM planning; and encouraging CDEM co-ordination across a range of agencies.

Of particular relevance to the consequence of liquefaction, engineering lifeline operators and local authorities are required to be able to function to the fullest possible extent during and after an emergency.

#### 3 HISTORY OF LIQUEFACTION IN NEW ZEALAND

Liquefaction has been actively studied in New Zealand's Engineering Schools in the 1980's at an undergraduate and post-graduate level. Prior to this there were few 'champions of liquefaction' within academia. Lecturers at Canterbury University (NZ) published a liquefaction prediction methodology based on an energy dissipation approach in 1982 (Davis and Berrill, 1982). In addition, a few of the large national development projects (e.g. Motunui Gas to Gasoline Project) in the 1980's con-

sidered the hazard of liquefaction using 'state of the art' methods. But until the late 1980's and into the early 1990's the wider engineering community generally had a poor understanding of the hazard (and also the liquefaction process). From the 1980's, the main metropolitan Regional Councils commenced studies to identify the hazard of liquefaction in the more populous areas, resulting in the production of liquefaction hazard and damage maps and supporting technical reports. But still the knowledge of the hazard was restricted to a select community, and there are members of the engineering community, albeit in decreasing numbers, who deny that liquefaction is a hazard that needs addressing. But in general, our civil and geotechnical engineering communities are becoming more aware of the concept of liquefaction, its implications and potential mitigation techniques. But what is the knowledge base in the wider community?

#### 4 CURRENT STATE OF KNOWLEDGE

The authors conducted a telephone survey in 2004 of the Regional and District Councils within New Zealand to assess the level of awareness and understanding of liquefaction and the extent and use of liquefaction hazard information.

District Councils, also grouped with city councils and unitary authorities, are local government bodies used to administer the affairs of local communities in New Zealand, of which there are 74. Regional councils, of which there are 12, serve a collective of district councils and have a greater focus on environmental issues. Collectively the councils make land use planning and development decisions, including consenting, but also create and maintain statutory plans. Councils are responsible for issuing consents to allow development and therefore are an important check-point for an issue such as liquefaction.

Generally, the survey attempted to ask questions of the chief building officer, but often that person was unavailable and other officers within the council were able to respond to the questions posed. It is possible that the informal survey technique may have resulted in erroneous or incomplete answers in some instances as the responses often relied upon an officer's personal knowledge, rather than the council's collective knowledge. Notwithstanding this, these officers were responsible on a regular basis for providing advice on building consents. The survey had a 98% response rate. Some of the questions asked in the survey are provided in Table 1 (other more detailed questions on the specifics of liquefaction knowledge were also asked). A graphic representation of the perception of liquefaction as a hazard in New Zealand is shown in Figure 1.

The results demonstrated in Table 1 imply that the regional councils appear to have collectively a greater knowledge on liquefaction as a hazard in their region. This is not surprising given their functions, roles and responsibilities. However, the results recorded for the district councils in all likelihood do not accurately depict the liquefaction hazard present in New Zealand. It is probable that there are soils in every district of New Zealand that would be susceptible to liquefaction, albeit their percentage coverage of a region would vary greatly. Consequently the liquefaction risk, or perceived risk, to districts is under-recognized, and it is likely that this is reflected in the results. Surprisingly there were some regions that have suffered from the affects of liquefaction over the past century, which have responded during the survey that liquefaction is not perceived as a hazard in their region. Therefore, at least on an individual basis, the collective knowledge of these councils is not being adequately communicated within the council and to the community.

If we are to build resilient communities, then the knowledge that is possessed needs to be passed onto the community. Furthermore, that knowledge needs to be passed in a manner suitable to the recipients. The survey undertaken shows that for large parts of the country, liquefaction is identified as a hazard.

Table 1: Liquefaction Survey Summary for New Zealand Council's

	Regional Council	District Council
Is liquefaction considered a hazard in your region?	83 %	46%
Are liquefaction hazards noted on Land Information Memoranda (LIM's)?	n/a	32%
Are maps available showing liquefaction hazards?	75%	26%
Does the region have a liquefaction public hazard education programme?	25%	8%

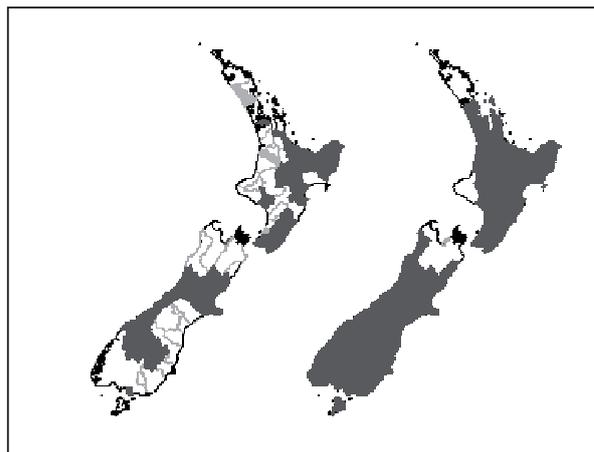


Figure 1: Distribution of Regional Council's (shown on the right) and District Council's (shown on the left), which have identified liquefaction as a hazard within their region. Dark areas show regions that identify liquefaction as a risk (light shading is for areas of no response in the survey).

Yet steps of quantifying the hazard and presenting hazard information to the community is not occurring on a systematic basis. Only one third of the district councils are presenting information that it holds on liquefaction to landowners (via Land Information Memoranda, or LIM's, which are available from council and provide information on land parcels). Moreover, only 26% have maps that depict liquefaction hazard zones. A small number of councils, typically the larger and better-funded councils (on a population basis), do have a considered programme of identifying liquefaction hazards and educating the community on the risk.

In November 2004 the Auckland City Council released information to the community on pesticide hazards, through a press release and notification on LIM's. Where market gardens were known to exist historically, the property files were tagged with the possibility that the land was contaminated from pesticide residue in the soil. A significant press and public backlash resulted, causing the council to back-step and remove the possibility of contamination from the property files (primarily due to peoples concerns over reduction in property values). This demonstrates that caution needs to be exercised when relaying technical risks to the community. However, where liquefaction has been listed as a potential risk item on a LIM, it has proved comparatively inert as a risk item to the community compared to this pesticide case.

With time, a greater range of projects in New Zealand are addressing liquefaction, not just those that have a major infrastructure or engineering lifeline utility function. Provided below are three examples of how liquefaction hazard has been addressed in New Zealand, including two regional studies to determine the risk and a case of liquefaction mitigation that has been completed.

4.1.1 *A Mapping Example – Christchurch Liquefaction Study*  
A geotechnical study was undertaken in 2002 (and updated in 2004) to evaluate the liquefaction hazard for Christchurch City (Beca, 2004). Liquefaction was recognised as a potential hazard for around one-third of Christchurch City (Brown & Weeber, 1992, and CAE, 1997). These published liquefaction maps showed the hazard as a function of distribution of soil types across the City, but did not take into account the soil strength data. A new study was completed which took into account the available soil strength and water table data.

The new desk-top study included: the collation of soil information from various organisations (both public and private); analysis of historical monitored bore water levels held by the regional and district councils; creation of geotechnical database with around 10,000 data points including bores, cone penetrometers, hand augers and test pits; creation of an algorithm to analyse liquefaction hazard based on actual soil strengths; estimation of liquefaction ground damage; and presentation of liquefaction hazard and ground damage on maps compiled at a scale of 1:25,000. The analysis was undertaken using three ground-shaking scenarios and two ground water elevation scenarios. This methodology provided a more robust and detailed means of identifying liquefaction trends across the city (it does not however eliminate the need for site specific studies to be undertaken).

The resultant study forms part of a greater earthquake hazard education package. The package includes a poster detailing the results of the liquefaction study and information booklets on liquefaction, earthquake hazards, and general natural hazards throughout the region. The liquefaction hazards are presented to the residents of Christchurch through information on LIM's available at Christchurch City Council.

4.1.2 *A Mapping Example – Wellington Liquefaction Study*  
A study of the liquefaction hazard, in addition to other hazards, was completed in 1993 (Works, 1993) for the Wellington Regional Council. The study published six different maps of the more populous localities within the Region at scales varying between 1:50,000 and 1:75,000.

The maps were compiled based on geological maps, ground water conditions, a small number of 'representative' boreholes and CPT's, and a few particle size distribution tests. The limited field-testing was used to establish typical profiles for select geological units, which in turn were used to describe the regional hazard. Sensitivity to liquefaction was demonstrated using two different earthquake scenarios. As with the Christchurch Study, the maps distinguished areas of liquefaction potential and liquefaction ground damage. This information has been presented to the local community through newspaper reports, available maps, and on LIM's.

#### 4.1.3 *A Mitigation Example – Christchurch Wastewater Treatment Plant*

The eastern side of Christchurch City is a low lying coastal margin that sits atop of Holocene sand deposits, i.e. a prime liquefaction candidate. The city's wastewater treatment plant is located beside a large estuary on these deposits. The plant services a community of around 330,000 people.

Aware that Christchurch was in a zone of potential liquefaction (CAE, 1997), the council decided that when constructing the new facilities in 1998 (required to improve effluent quality and expand plant capacity) that they would be designed especially to resist liquefaction. The major components of the upgrade included four 50m diameter, 5m deep in-ground concrete clarifier tanks. Specific seismic and field investigations were undertaken to determine the extent of the liquefiable soils. It was found that a layer of around 5m thickness located directly beneath the clarifiers had the potential to liquefy in a major earthquake (Beca, 1998). The design solution utilized vibro-compaction beneath the clarifier to densify the subgrade and

make the treatment plant more resilient to damage from liquefaction.

## 5 EDUCATION AND KNOWLEDGE DISPERSION

Fisher et al. (1991) conducted a survey of risks that most concerned people. Respondent's most frequent nominations for risks were for threat to life from accident, disease and crime, while only 10 per cent of respondents listed environmental, natural or technological risks as a concern. As expected we are primarily concerned about risks that have a high frequency, but typically low consequence (such as theft), as compared to those risks that have low frequency and high consequence (such as earthquakes). Furthermore risks are contextual, for example, most will perceive the risk of earthquake damage in Kobe (Japan) to be significantly greater than in Alice Springs (interior of Australia). Earthquake risks (including liquefaction) interest only a select group of professionals or those that have been recently affected by that risk. How then do we bring a suitable level of understanding and hazard mitigation to the community when peoples risk portfolio is probably already full with higher likelihood risks?

Firstly we need to understand the logic of people. Nathe (2000) suggests that people do not think in terms of probabilities, they are more likely to make decisions in a binary fashion. An example of such a logic process for an earthquake would be:

1. Earthquake: what is it?
2. What damage can it do?
3. Is it likely to happen?
4. What losses would there be?
5. Can I reduce the losses?
6. How complicated is the mitigation?
7. What is the cost?
8. Has anyone done it before?
9. Who can help me?
10. When shall I begin?

At any stage in the above process, if credible information is not available then we are unlikely to move to the next step, and a fatalistic attitude may prevail in relation to the risk. To create a successful education campaign we must firstly generate interest or a questioning attitude of our audiences. We then need to be available to provide credible answers to the questions in a simple manner and also reinforce a consistent message over time.

The first task in improving liquefaction awareness is to identify the target audience of our message. In New Zealand there is an ongoing campaign at national level to reinforce earthquake preparedness through the use of television advertisements using celebrities, the use of print media, and every telephone book in the country sets out useful information on emergencies and 'B-Ready Kits'. Furthermore, New Zealand is using a 4 R's concept – reduction, readiness, response and recovery. Reduction being the avoidance of liquefaction prone areas and designing structures to reduce damage and then lessening the need for readiness, response and recovery. And still after decades of earthquake preparedness campaigning, most individuals do not take a personal responsibility. How then are we to address more specific and technical aspects of liquefaction hazard awareness and mitigation to the wider community? The short answer is that we should not attempt to. We do not want to dilute a basic earthquake awareness campaign with technical issues, at least not until a minimum level of understanding is achieved for general earthquake concepts. We should instead focus our attentions on our building professionals (developers, owners, certifiers, engineers, planners), who at this stage appear to be receiving mixed messages. Nonetheless, we still need a consistent message to provide to the general public, when an interest is generated, so that we reinforce our message at multiple levels.

We need some simple and yet effective tools in order to further increase the awareness of our building professionals, developers, owners, certifiers, engineers, planners. These tools

