GN Online
www.geotechnicalnews.com

Volume 35 • Number 3• September 2017

GEOTECHNICAL news

New Walterdale Bridge in Edmonton will soar over the North Saskatchewan River

RST Instruments Ltd. offers 2 Wireless Data Collection Systems to quickly get you connected to your data: **RSTAR** and **DT LINK**. Both systems offer **minimum per channel cost, extra long battery life** and **long distance data transmission.**

WIRELESS DATA COLLECTION

for Geotechnical Monitoring Instrumentation

FULLY AUTOMATED COLLECTION (REMOTELY)

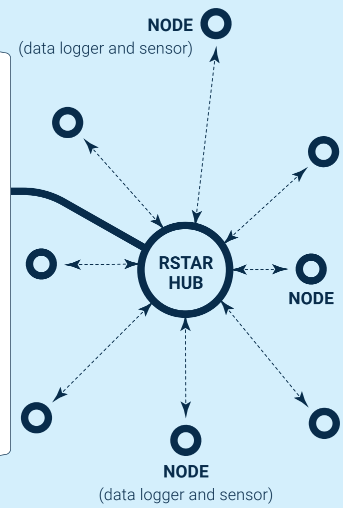
An RSTAR System uses data loggers (nodes) at the sensor level, deployed in a star topology from an active RSTAR Hub containing an RST flexDAQ Data Logger.

rstar ARRAY RADIO SERIES

FEATURES

- Up to 10 years of battery life from 1 lithium 'D' cell.
- Up to 14 km range from Hub to Node in open country. (depending on antenna type)
- Up to 255 nodes per RSTAR Hub.
- Based on 900 MHz , 868 MHz and 2.4 GHz spread spectrum band. (country dependent)

The RSTAR Hub shown left contains a flexDAQ Data Logger System with an antenna and battery. Collected data is saved to the flexDAQ memory where users can access it remotely, either on-site or off-site.



>>> Watch the video for both systems at: www.rstinstruments.com/Wireless-Data-Collection.html <<<

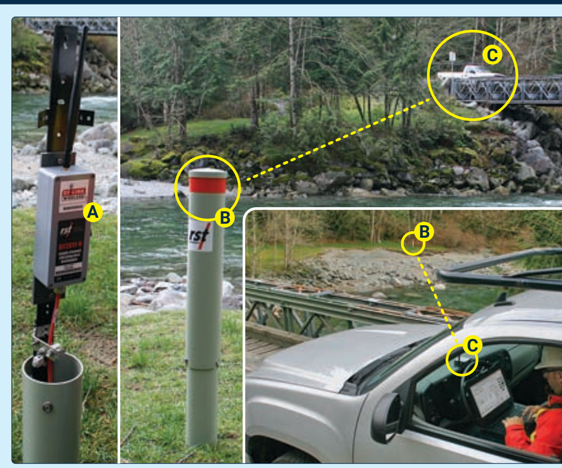
SEMI-AUTOMATED COLLECTION (ON-SITE)

DT LINK is an on-site wireless connection to RST data loggers for quick data collection. Ideal for hard to access areas where the data logger is within line of sight.

DT LINK WIRELESS

FEATURES

- Safely & easily collect data from data loggers that are in areas with poor access, trespass issues and hazardous obstacles.
- Years of battery life from 1 lithium 'D' cell.
- Range up to 800 m (900 MHz) and up to 500 m (2.4 GHz).
- Collect data in seconds with a laptop connected to DT LINK HUB.



Pictured: (A) DT LINK WIRELESS data logger, connected to a vibrating wire piezometer and housed in a (B) protective enclosure, has its data collected from a laptop connected to the (C) DT LINK HUB - all within seconds from the convenience of your vehicle.

DT SERIES DATA LOGGERS

RST's "DT Series" Data Loggers accommodate the RSTAR and DT LINK WIRELESS Systems. Compatible sensor types include:

Vibrating Wire, Potentiometers, MEMS Tilt Sensors, Strain Gauge (full bridge) Sensors, Digitally Bussed Sensors, 4-20 mA Sensors, and Thermistors.

rst INSTRUMENTS — innovation in geotechnical instrumentation

info@rstinstruments.com
www.rstinstruments.com

40 YEARS 1977-2017

CANADA: 604 540 1100
USA: 831 899 1632 or 303 993 9230
EUROPE / MIDDLE EAST / AFRICA: +44 7469 256642
RST Instruments Ltd., 11545 Kingston St., Maple Ridge, BC Canada V2X 0Z5

Certified System ISO 9001

YouTube www.youtube.com/user/RSTgeotechnical
LinkedIn www.linkedin.com/company/rst-instruments-ltd-

GEOTECHNICAL news

PUBLISHER John W. Gadsby

MANAGING EDITOR Lynn Pugh

Editors

Robert Chapuis
John Dunnicliff
Jonathan Fannin
Richard Guthrie
Paolo Gazzarrini
Don Lewycky
Ward Wilson

Managing Editors and Advertising

BiTech Publishers Ltd.
103 - 11951 Hammersmith Way
Richmond, British Columbia
Canada V7A 5H9
tel 604-277-4250 • fax 604-277-8125
email *gn@geotechnicalnews.com*
web *www.geotechnicalnews.com*

GEOTECHNICAL NEWS is published quarterly.

Paper subscription rates:

- within North America: $60.00 CDN per year
- overseas: $100.00 US per year through BiTech Publishers Ltd.

Electronic version:

GEOTECHNICAL NEWS is also available in electronic version.
For details,visit
www.geotechnicalnews.com

Canadian Editorial Office

Canadian Geotechnical Society

Don Lewycky, Editor, CGS News • email: *don.lewycky@edmonton.ca*

Membership Information : Canadian Geotechnical Society

Gibson Group Association Management

Wayne Gibson, 8828 Pigott Road • Richmond, BC V7A 2C4 • tel: 604-277-7527 • email: *cgs@cgs.ca*

Editors

Groundwater

Robert P. Chapuis, Dept. CGM, Ecole Polytechnique, PO Box 6079, Sta. CV Montréal, QC, H3T 1J4
tel: 514-340-4711 • fax: 514-340-4477, • email : *robert.chapuis@polymtl.ca*

Instrumentation

John Dunnicliff, Little Leat, Whisselwell, Bovey Tracey, Devon TQ13 9LA, England
tel: +44 1626-832919 • email: *john@dunnicliff.eclipse.co.uk*

Geosynthetics

Jonathan Fannin, Professor of Civil Engineering, University of British Columbia, 6250 Applied Science Lane, Vancouver, BC, V6T 1Z4 • tel: 604-822-3557 • email: jonathan.fannin@ubc.ca

The Grout Line

Paolo Gazzarrini, 11-2246 Folkestone Way, West Vancouver, BC, V7S 2X7 • tel: 604-913-1022
fax: 604-913-0106 • email: *paolo@paologaz.com*

Waste Geotechnics

G. Ward Wilson, Professor, Geotechnical and Geoenvironmental • University of Alberta, Dept. of Civil & Environmental Engineering, 3-069 NREF, Edmonton, AB T6G 2W2 • tel: 780-492-2534
fax: 780-492-8198 • email: *wwilson2@ualberta.ca*

Geohazards

Richard Guthrie, Senior Principal, Director, Geohazards and Geomorphology, Stantec,
200-325 25 Street SE, Calgary, AB T2A 7H8, • tel: 403-441-5133, •
email: *Richard.Guthrie@stantec.com*

Printed in Canada

CONTENTS

Cover *New Walterdale Bridge (photo by Donald M. Lewycky, P.Eng.*

GEOPIER IS GROUND IMPROVEMENT®

PROVIDING CUSTOMIZED SOLUTIONS FOR ALL SOIL TYPES

SEND US YOUR PROJECT DATA

Let our geotechnical engineers customize a solution that meets your needs. Submit your project details to receive a feasibility assessment and cost estimate at geopier.com/feasibilityrequest

For more information call 800-371-7470,
e-mail info@geopier.com or visit geopier.com.

Geopier's goal is to bring you advanced, innovative ground improvement technology in a way that is easy to use every day. Geopier Rammed Aggregate Pier® and rigid inclusion products enable you to:

- Improve variable fill soils in place
- Replace deep foundations
- Control settlement
- Increase soil bearing capacities

GEOPIER®
Tensar

Message from the President

Dharma Wijewickreme, President of Canadian Geotechnical Society

Hope you had an excellent summer period and are already getting back well into the usual Fall season schedules. I would like to use this opportunity to revisit a few highlighted points from my past messages and update you on the CGS accomplishments and ongoing activities.

As indicated earlier, member engagement and involvement is one of our key focus elements, and as per below, I would like to seek your input on some basic considerations related to this matter. After reading this message, I am hoping that you will return your thoughts by writing to us at *admin@cgs.ca;* alternatively, you could provide feedback in some of the member surveys that we are planning to conduct during the next CGS conference.

As a learned Society, we have adopted many different ways to provide services to our membership. Some examples are: the awards given for recognition of accomplishments and honors; dissemination of knowledge through the annual conference, lectures, and local section technical talks; production and publication of the *Canadian Foundation Engineering Manual (CFEM)*; our close relationship with the *Canadian Geotechnical Journal* available to all our members; the *Geotechnical News* magazine that you are now reading; our web site and social media provisions for communications. These traditional approaches are sound, and their excellent track-record serves as direct testimony to the value provided to the membership. I believe that it is also time for us to actively explore other creative ways to contribute to and serve the membership at large through further wide-spanning initiatives.

With the rapidly changing value systems globally, there may be a need to increase the visibility of our contributions outside the geotechnical realm. This would require bringing the value of our professional contributions to the attention of the society-at-large. I recognize that any new projects and initiatives along this thinking should be developed in due consideration of our volunteer-based frameworks and resource availabilities. It is important to observe that a number of other learned organizations have already recognized this need and are moving forward with initiatives to engage with the public.

I appreciate receiving your thoughts on the relevance (or need) of pursuing this avenue regarding an increased visibility, and how it can best be accomplished. Now, let me report on some of our accomplishments and ongoing activities.

It is my pleasure to announce that **Dr. Jean-Marie Konrad** (Laval University) will be the speaker for the 2017 Fall Cross Canada Lecture Tour (CCLT). As I have noted earlier, this is one of the most popular CGS events, and important to note the next Tour will be our 100th CCLT! The recently created CGS Colloquium Lecture Series (CLS) is also well underway. The CLS, developed in partnership with the Canadian Foundation for Geotechnique, is delivered across Canada by the Canadian Geotechnical Colloquium Speakers. My sincere thanks to our start up CLS presenters **Jasmin Raymond** and **Greg Siemens**.

We have now identified a geo-professional and long-time member of the Society to work on the Errata for the 4th Edition of the Canadian Foundation Engineering Manual (CFEM), with the intent of having the Errata finalized and delivered by the end of 2017.We are also actively working on the other important component – which is to work on the online English and French versions of the CFEM, so it can be delivered as early as possible. These initiatives are led and coordinated by our VP Technical **Suzanne Powell**; thank you Suzanne! If you are interested in contributing to these important CFEM-related activities, please contact us at *admin@cgs.ca.*

Our membership is the key to the Society's success. With this thinking in mind, **Jean Côté** (VP Communications & Member Services) and the CGS Executive is considering the possibility of reinstating the Membership Committee. On another note, if you have not already renewed your CGS membership, I encourage you to do so and continue receiving the benefits provided to all our members. I am also pleased to note that CGS still benefits from a sound financial situation, as it continues to be systematically managed under the leadership of our VP Finance, **Kent Bannister**.

The organizational work for the GeoOttawa 2017, the 70th CGS Conference is well underway with more than 400 papers already accepted. The event will be held at the Shaw Centre in Ottawa, Ontario, Canada from Sunday, October 1 to Wednesday, October 4, 2017. I would like to convey my sincere thanks to the Local Organizing Committee (LOC) - led by **Mamadou Fall** (as the Conference Chair) - for their tremendous teamwork. In addition to participating in the rich technical program presented by the LOC, please make sure to attend: the special luncheon event on Oct. 2nd to recognize the CGS Geotechnical Achievements; the Awards Banquet on Oct. 2nd where many of our colleagues will be recognized for their outstanding contributions to the profession and Society; and the Legget luncheon on Oct. 4th where our most prestigious prize will be given. I also invite all of you to attend the annual meetings of Divisions, Committees, and the Geotechnical Research Board (GRB) – where you will be able to volunteer and contribute to the numerous exciting activities of the Society. We are actively preparing for the annual Board meeting with Chairs of Divisions, Committees, and Sections; the main outcomes from this meeting will be presented during the Business meeting at the conference on October 3rd. Other information on the Conference are presented below; please visit the conference website (*http://www.geoottawa2017.ca)* for more information. I invite you to use the opportunity to engage, network, and connect with your colleagues while finding ways to contribute to our Society and the profession.

In conclusion, I would like to thank and recognize the contributions from our CGS volunteers involved in the Executive, Board, Sections, Divisions, Committees, and external representations along with the members of our CGS National office (**Michel Aubertin** - Executive Director; **Wayne Gibson** - Director, Administration and Finance; and **Lisa McJunkin** - Director, Communications and Member Services), and our CGS Corporate Sponsors.

Once again, thank you for reading this message and consider offering feedback. I look forward to meeting you in person at GeoOttawa!

Provided by Dharma Wijewickreme
CGS President 2017 - 2018

Message du président

J'espère que vous avez passé un bel été et que vous vous réajustez bien aux horaires automnaux habituels. Je souhaite profiter de l'occasion qui m'est offerte ici pour revenir sur certains points mentionnés dans mes messages antérieurs et pour vous informer des réalisations de la SCG et de ses activités en cours.

Comme indiqué précédemment, l'implication et la participation des membres constituent l'un des éléments les plus importants pour la SCG, et comme vous le verrez plus bas, j'aimerais obtenir votre avis sur certains points qui y sont reliés. Après avoir lu ce message, j'espère que vous nous ferez parvenir vos idées en nous écrivant à *admin@cgs.ca*. Vous pouvez également nous transmettre vos commentaires en répondant aux sondages à l'intention des membres qui seront menés durant la prochaine conférence de la SCG.

En tant que société savante, nous avons adopté de nombreuses approches différentes pour servir nos membres. Citons comme exemples : les prix accordés pour reconnaître les réalisations et les actions méritantes de nos membres; la diffusion de connaissances par le biais de la conférence annuelle, de conférences et de discussions techniques tenues dans les sections locales; la production et la publication du *Manuel canadien d'ingénierie des fondations* (*MCIF*); les liens étroits que nous entretenons avec la *Revue canadienne de géotechnique*, offerte à tous nos membres; le maga-

DGSI
Durham Geo Slope Indicator

Call Today To Learn More

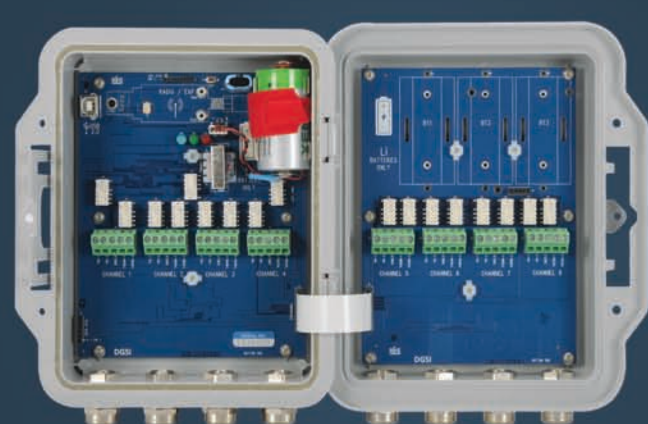
Call: 1-425-493-6200
Email: vlogger@dgeslope.com

V-Logger Series

Slope Indicator proudly introduces the V-Logger Series, our latest VW data logger product.

This flexible 4 or 8-channel data logger is IP 68 rated, CE certified, and has a battery life of up to 10 years. The optional radio uses the much less congested 860-930 MHz bands, which allows for better connectivity and longer range. Seamlessly connect to cellular modems and solar panels for fully remote stations.

- **Four or Eight Channel Vibrating Wire Loggers**
- **Extended Battery Life**
- **Expandable up to four D-cell lithium batteries**
- **Optional rechargeable lithium-ion polymer pack**
- **Expanded Memory**
- **Best in industry for VW logging accuracy**
- **Compatible with GSM or CDMA cellular modems**
- **Integrated 860-930 MHz radio option**



For more details, please call 425-593-6200 or visit www.slopeindicator.com

Durham Geo Slope Indicator
Tel: 425-493-6200 / 866-916-0541
Web: www.slopeindicator.com

Geotechnical and Structural Instrumentation

- Bridges
- Dams
- Embankments
- Excavations
- Foundations
- Geogrids
- Groundwater
- Landfills
- Mines
- Piles
- Pipelines
- Slope Stability
- Tunnels
- Waste Repositories
- Wind Turbines

- Strain Gages
- Crackmeters
- Jointmeters
- Strandmeters
- Convergence Meters
- Extensometers

- Piezometers
- Pressure Transducers
- Weir Monitors
- Settlement Sensors
- Pressure Cells
- DeAerators
- Temperature Gages
- Cables

- Load Cells
- Concrete Stress Cells
- B/H Deformation Gages
- Stressmeters
- Inclinometers
- Tiltmeters
- Pendulum Readouts

- Readouts
- Terminal Boxes
- Dataloggers
- Multiplexers
- Wireless Networks
- Software
- Custom Designs

GEOKON The World Leader in Vibrating Wire Technology®

www.geokon.com/projects

zine *Geotechnical News* que vous lisez actuellement; l'utilisation de notre site Web et des médias sociaux pour nos communications. Ces approches traditionnelles fonctionnent bien, et leur performance démontre la valeur qu'elles offrent aux membres. Je crois aussi qu'il est temps pour nous d'explorer activement de nouvelles avenues créatives afin de mieux servir nos membres et d'en augmenter le nombre grâce à des initiatives plus étendues.

Comme nos systèmes de valeurs globaux évoluent rapidement, il peut être nécessaire d'augmenter la visibilité de nos contributions en dehors du domaine de la géotechnique. Ceci nécessiterait de mettre en valeur nos contributions professionnelles au niveau de la société en général. Je reconnais que de nouveaux projets et initiatives en ce sens devraient être développés en prenant en compte nos structures basées sur le bénévolat et les ressources disponibles. Il est important de noter que de nombreuses autres sociétés savantes ont déjà reconnu ce besoin et qu'elles vont de l'avant avec des initiatives pour interagir avec le public.

J'aimerais recevoir vos idées sur l'importance (ou le besoin) de poursuivre cette avenue liée à une visibilité accrue et sur les façons d'y arriver. Permettez-moi maintenant de vous informer de quelques-unes de nos réalisations et activités en cours.

J'ai le plaisir d'annoncer que le **Dr Jean-Marie Konrad** (Université Laval) sera le conférencier de la Tournée de conférences transcanadienne (TCT) de l'automne 2017. Comme je l'ai mentionné précédemment, la TCT est une des activités les plus populaires de la SCG; il est aussi important de noter que la prochaine Tournée de conférences sera notre 100e ! La Série de conférences du Colloquium (SCC) de la SCG, récemment mise sur pied, se poursuit également. Cette nouvelle activité, créée en collaboration avec la Fondation canadienne de géotechnique (FCG), est offerte d'un bout à l'autre du Canada par les conférenciers du Colloquium canadien de géotechnique. Je remercie sincèrement les premiers présentateurs de la SCC, **Jasmin Raymond** et **Greg Siemens.**

Nous avons maintenant trouvé un professionnel en géotechnique et membre de longue date de la Société pour travailler sur l'Erratum de la 4e *édition du MCIF*; l'objectif est qu'il soit terminé et disponible d'ici la fin de 2017. Nous travaillons activement aussi sur les versions française et anglaise en ligne du *MCIF* pour qu'elles soient prêtes dans les plus brefs délais. Ces projets sont coordonnés par notre v.-p. technique, **Suzanne Powell**; merci Mme Powell! Si vous désirez contribuer à ces importantes activités liées au *MCIF*, veuillez nous écrire à *admin@cgs.ca.*

Les membres sont la clé du succès de la Société. En gardant ceci à l'esprit, **Jean Côté** (v.-p. aux communications et aux services aux membres) et le Comité exécutif de la SCG analysent la possibilité de rétablir le Comité des membres. Par ailleurs, je vous encourage à renouveler votre adhésion à la SCG, si ce n'est pas déjà fait, et à continuer ainsi à bénéficier des avantages offerts à tous nos membres. Je suis également heureux de souligner que la SCG est toujours dans une bonne santé financière, alors qu'elle continue d'être gérée rigoureusement sous la direction de notre v.-p. aux finances, **Kent Bannister.**

Le travail pour organiser la conférence GéoOttawa 2017, qui sera la 70e conférence de la SCG, progresse bien, avec plus de 400 articles déjà acceptés. L'évènement se tiendra au Centre Shaw, à Ottawa, en Ontario, au Canada, du dimanche 1er octobre au mercredi 4 octobre 2017. Je souhaite exprimer ma gratitude aux membres du comité organisateur local (COL), mené par **Mamadou Fall** (président de la conférence), pour leur excellent travail d'équipe. En plus de participer au programme technique diversifié élaboré par le COL, veuillez vous assurer d'assister aux divers évènements incluant le dîner spécial du 2 octobre visant à reconnaître les réalisations géotechniques marquantes de la SCG; le banquet de remise de prix de cette même journée où un grand nombre de nos collègues seront reconnus pour leurs contributions exceptionnelles à la profession et à la Société; et le dîner Legget le 4 octobre, où notre prix le plus prestigieux sera décerné. Je vous invite également à assister aux réunions annuelles des divisions, des comités et du Conseil de recherche en géotechnique (CRG); vous pourrez alors vous porter volontaire et contribuer aux nombreuses activités intéressantes de la Société. Nous préparons activement la réunion annuelle du Conseil avec les directeurs des divisions, des comités et des sections; le fruit de nos échanges sera présenté durant l'assemblée annuelle, à la Conférence, le 3 octobre. D'autres informations sur la conférence sont présentées ci-dessous. Pour en savoir plus, veuillez consulter le site Web de la Conférence *(http://www.geoottawa2017.ca/index.php?lang=fr)*. Je vous invite à profiter de cette occasion pour participer, réseauter et interagir avec vos collègues, tout en réfléchissant aux façons de contribuer à notre Société et à la profession.

En terminant, je désire reconnaître les contributions des bénévoles de la SCG qui sont membres du Comité exécutif, du Conseil, des sections, des divisions et des comités, et qui la représentent à l'extérieur de celle-ci, de même que les membres du Bureau national de la SCG (**Michel Aubertin** – directeur général; **Wayne Gibson** - directeur, Administration et finances; **Lisa McJunkin** – directrice, Communications et services aux membres), et les en remercier. Merci aussi aux commanditaires de la SCG.

Fourni par Dharma Wijewickreme
Président de la SCG 2017-2018

From the Society Canadian Foundation for Geotechnique

Brief history of the CGS Cross Canada Lecture Tour

The Cross Canada Lecture Tour was initiated in 1965 by the Associate Committee on Geotechnical Research (ACGR), a forerunner to the Canadian Geotechnical Society. The purpose of the lecture tour was to provide CGS members and other Canadian geotechnical professionals an opportunity to attend high quality technical presentations by prominent Canadian and international geotechnical professionals.

In September 1965, the ACGR organized and hosted the 6th International Conference on Soil Mechanics and Foundation Engineering in Montreal. The first CCLT was held shortly after that conference and may have been somehow associated with the conference.

The first CCLT presenter was **Ivan Rosenqvist** from the University of Oslo in Norway in the fall of 1965. The actual topic or topics of his presentations was not recorded, but Dr. Rosenqvist was at that time a professor of mineralogy and geology, whose specialty was marine sediments, specifically clays and clay minerals. It is likely his presentations were associated with his specialty related to the Norwegian quick clay, but that having been said, Dr. Rosenqvist attended the 6th ISCSMFE and presented a paper on the '*Fundamental Properties of Some Norwegian Magmatic and Metamorphic Rocks*'!

The second lecturer in the Spring of 1966 was **David Henkel** from Cornell University in Ithaca, NY, and the third lecturer in the Fall of 1966 was a young, Canadian-born lecturer from Imperial College in the UK, **Norbert Morgenstern**. Two years later, Dr. Morgenstern would return to Canada and join the faculty at the University of Alberta.

Since 1965, a CCLT has been presented at least once a year and in most years, twice a year. The intent was to have one Canadian lecturer and one international lecturer each year. For the most part, this intent has been met. On five occasions, two lecturers have split a single tour, with one lecturer covering eastern Canada and one lecturer covering western Canada. Five individuals have been 'Cross Canada Lecturers' more than once: **Geoffrey Meyerhof** (1967 and 1983); **Robert Quigley** (1969 and 1990); **Victor Milligan** (1972 and 1997); **Ralph Peck** (1972 and 2000); and **Liam Finn** (1991 and 2001). A list of all past lecturers can be found on the CGS website *http://cgs.ca/cross_canada.php*. It reads like a who's who of Canadian and international geotechnique.

In 1972, the CGS assumed the responsibility for selecting the lecturers, arranging the lectures through the 20 CGS sections across the country, and covering the lecturers' travel costs and honoraria.

In the late 1990s, due to funding issues, there was talk of reducing the frequency of the CCLTs. The Canadian Foundation for Geotechnique (or Geo Contributions as it was called until 2000), came to the rescue. By 2000, largely through the hard work of the Canadian Foundation for Geotechnique's President **Dr. Michael Bozozuk** and Geo Contributions members **Jack Clark** and **Ray Benson**, as well as through the generosity of CGS members **Jack Mollard** and **Ben Torchinsky**, sufficient funds were raised to retain the two CCLTs per year. Since 2000, a major activity of the Canadian Foundation for Geotechnique has been to solicit donations from Canadian corporations to sponsor the travel costs involved in the two CCLTs each year.

The 99th CCLT lecturer in the spring of 2017 was **Vaughn Griffiths** from the Colorado School of Mines, CO, and the 100th CCLT lecturer in the fall of 2017 will be **Jean-Marie Konrad** from Univérsité Laval, QC. With these two lecturers, there will have been 53 Canadian and 47 international lecturers (although some of the international lecturers were also Canadians), over the course of the history of CCLT's. There will have been 58 academics, 31 consultants or individuals from industry, and 11 from various levels of government.

The Cross Canada Lecture Tour has been, and continues to be, one of the 'flagship' activities of the CGS. These twice-a-year lecture tours are very highly anticipated by the many CGS local sections, members and Canadian geotechnical professionals. The CCLT has the distinction of being the longest such lecture tour anywhere in the world and is the envy of geotechnical organizations and geotechnical professionals in many countries.

Meet the 2017 Members for the Canadian Foundation for Geotechnique

The **Canadian Foundation for Geotechnique** is a registered charitable organization that works at arm's length from the Canadian Geotechnical Society. It funds the annual CGS' student awards and prizes, the annual Canadian Geotechnical Colloquium, the travel costs associated with the two Cross Canada Lecture Tours each year, and offers its own annual $5000 National Graduate Scholarship. On an annual basis the Foundation provides approximately $45,000 to recognize and foster excellence in the geotechnical field in Canada.

The Foundation is currently managed and overseen by 13 volunteer members who typically serve for one or more three-year terms. From the 13 members, 6 serve on the Board of Directors and run and manage the activities of the Foundation.

In the March 2012 issue of Geotechnical News, **Doug VanDine** (President of the Foundation at that time) initiated a quiz on the **Members of the Foundation**. It was all in good fun and was well received by the readers who undertook the quiz. As this is my last year as President of the Foundation, and following Doug's innovative and inimitable style, I invite the Canadian geotechnical community to take another quiz on the Members of the Foundation. The first list (numbered 1 to 13), lists the Members, their affiliation, location, and their position if they are on the Board of Directors. The second list (lettered A to O) lists a personal factoid about a member, but not in a matching order. In some cases, I provided the factoid on behalf of the individual. In many instances, the Member has also had executive positions in the CGS and other learned societies. Your task, should you wish to accept it, is to see how many members and factoids you can match up. The answers are given at the end of this CGS News column. So sit back, relax, and have a bit of fun!

2017 Canadian Foundation for Geotechnique Trustees (in alphabetical order):

1. **Dennis Becker** (Golder Associates, Calgary, AB) President
2. **Kevin Biggar** (K.W. Biggar Engineering, St. Albert, AB) Vice-President
3. **Robert Chapuis** (Ecole Polytechnique, Montreal, QC)
4. **Jean Hutchinson** (Queen's University, Kingston, ON) Director at Large
5. **Suzanne Lacasse Høeg** (Norwegian Geotechnical Institute, Oslo, Norway)
6. **Jorn Landva** (BGC Engineering, Halifax, NS)
7. **Harry Oussoren** (InSitu Contractors, Guelph, ON) Treasurer
8. **Bob Patrick** (Tetra Tech EBA, Nanaimo, BC)
9. **Lynden Penner** (JD Mollard Associates, Regina, SK)
10. **Ryan Phillips** (C-CORE, St. John's, NL) Director at Large
11. **Siva Sivathayalan** (Carleton University, Ottawa, ON)
12. **Jean-Pierre Tournier** (Hydro-Québec, Montreal, QC)
13. **Sai Vanapalli** (University of Ottawa, ON) Secretary

Personal factoids not in the same order as above. See if you can match the numbers with the letters!

A. Used elephants to move drill rigs in Sri Lanka and has delivered the Cross-Canada Lecture Tour.

B. Played against the Howe brothers at a midget hockey tournament and has an executive position in the Canadian Dam Association (CDA).

C. A former CGS VP Finance who plays pipe organ with four keyboards and 3,000 pipes, and in springtime is a 'twitcher'.

D. Survived a ride over a waterfall without a canoe or barrel.

E. Long-standing Foundation Member who taught mathematics at a Canadian university as a voluntary worker in lieu of military service.

F. Played the cello, turned wood, turned pots, quilted, designed and made stained glass, painted silk, developed photographs in a dark room, built a cedar strip canoe and refinished antique furniture.

G. Played a number of roles in a version of Jesus Christ Superstar in performing arts in High School.

H. Spent 5 weeks in China visiting many universities for collaborative research program.

I. Gave Prime Minister John Diefenbaker a tour of my high school that was renamed in his honour.

J. Former Secretary of the Foundation with interest in teaching and experimental research in fundamental sand behaviour.

K. Born in a small mining town in Canada, is fluent in many languages, has delivered the Rankine and Terzaghi Lectures, and has a Lecture named after them.

L. Worked in offshore geotechnics for many years and is a member of the CSA Offshore Foundations Code.

M. A former CGS VP Technical with research interest in groundwater and in-situ measurement of hydraulic conductivity.

Bonus Question:

Two Members who researched iceberg scour in Lake Agassiz Clay in Manitoba.

After having so some fun with this quiz, remember that in order to fulfill its mission, the Foundation relies on donations from individuals, corporations and donations and interest-free loans from the local sections and technical divisions of the CGS. To learn more about the Foundation and its activities visit *www.cfg-fcg.ca.*

Submitted by Dennis Becker
President of the Canadian Foundation for Geotechnique

La Tournée de conférences transcanadienne a été et continue d'être une des activités emblématiques de la SCG. Ces tournées de conférences offertes deux fois par an sont très attendues par les nombreuses sections locales de la SCG, ainsi que par de nombreux membres de la SCG et professionnels canadiens du domaine de la géotechnique. La TCT se distingue en étant la plus longue tournée de conférences du genre dans le monde et fait l'envie d'organisations géotechniques et de professionnels en géotechnique d'un grand nombre de pays.

Soumis par Dennis Becker
Président de la Fondation canadienne de géotechnique

Faites la connaissance des membres 2017 de la Fondation canadienne de géotechnique

La Fondation canadienne de géotechnique est un organisme de bienfaisance enregistré qui travaille de concert avec la **Société canadienne de géotechnique**. Elle finance les prix annuels de la SCG pour les étudiants, le Colloquium canadien de géotechnique annuel ainsi que les frais de déplacement associés aux deux Tournées de conférences transcanadiennes chaque année; elle offre aussi sa propre bourse nationale de 5 000 $ pour des études supérieures. Chaque année, la Fondation attribue environ 45 000 $ pour reconnaître et favoriser l'excellence dans le domaine de la géotechnique au Canada.

La Fondation est actuellement gérée et administrée par 13 membres bénévoles qui y siègent, habituellement pour un ou plusieurs mandats de trois ans. De ces 13 membres, six font partie du Conseil d'administration et gèrent les activités de la Fondation.

Dans le numéro de mars 2012 de *Geotechnical News*, **Doug VanDine** (président de la Fondation à l'époque) a créé un jeu-questionnaire sur les **membres de la Fondation**. Ce jeu a été proposé pour le plaisir et a été bien reçu par les lecteurs qui ont répondu au questionnaire. Comme il s'agit de ma dernière année à titre de président de la Fondation, et suivant le style novateur et inimitable de M. VanDine, j'invite la communauté géotechnique canadienne à participer à un autre jeu-questionnaire sur les membres de la Fondation. La première liste (dont les éléments sont numérotés de 1 à 13) répertorie les membres, leur affiliation, leur ville et le poste qu'ils occupent s'ils sont membres du Conseil d'administration. La deuxième liste (dont les éléments portent les lettres A à O) énumère un fait personnel sur chaque membre, mais pas dans le même ordre. Dans certains cas, j'ai fourni ce fait au nom de la personne. Dans de nombreux cas, le membre a également occupé un poste de direction au sein de la SCG et d'autres sociétés savantes. Votre tâche, si vous l'acceptez, consiste à voir combien de membres et de faits vous pouvez associer. Les réponses sont données à la fin de ce numéro de CGS News. Donc, détendez-vous et amusez-vous!

Administrateurs 2017 de la Fondation canadienne de géotechnique (en ordre alphabétique) :

1. **Dennis Becker** (Golder Associates, Calgary, AB), président
2. **Kevin Biggar** (K.W. Biggar Engineering, St. Albert, AB), vice-président
3. **Robert Chapuis** (École Polytechnique, Montréal, QC)
4. **Jean Hutchinson** (Université Queen's, Kingston, ON), administrateur
5. **Suzanne Lacasse Høeg** (Norwegian Geotechnical Institute, Oslo, Norvège)
6. **Jorn Landva** (BGC Engineering, Halifax, NS)
7. **Harry Oussoren** (InSitu Contractors, Guelph, ON), trésorier
8. **Bob Patrick** (Tetra Tech EBA, Nanaimo, BC)
9. **Lynden Penner** (JD Mollard Associates, Regina, SK)
10. **Ryan Phillips** (C-CORE, St. John's, NL), administrateur
11. **Siva Sivathayalan** (Université Carleton, Ottawa, ON)
12. **Jean-Pierre Tournier** (Hydro-Québec, Montréal, QC)
13. **Sai Vanapalli** (Université d'Ottawa, ON), secrétaire

Voici les faits personnels, qui ne sont pas dans le même ordre que ci-dessus. Voyons si vous pouvez associer les chiffres et les lettres!

A. A utilisé des éléphants pour déplacer des appareils de forage au Sri Lanka et a présenté la Tournée de conférences transcanadienne.

B. A joué contre les frères Howe à un tournoi de hockey de niveau midget et occupe un poste de direction à l'Association canadienne des barrages (ACB).

C. Ancien v.-p. aux finances de la SCG, il joue à un orgue comptant quatre claviers et 3 000 tuyaux, et il est aussi ornithologue le printemps.

D. A descendu une chute d'eau sans canot ni baril et y a survécu.

E. Membre de longue date de la Fondation qui a enseigné les mathématiques dans une université canadienne comme bénévole plutôt que de faire son service militaire.

F. A joué du violoncelle, a travaillé le bois, a fait de la poterie, a confectionné des courtepointes, a conçu et fabriqué des vitraux, a fait de la peinture sur soie, a développé des photographies dans une chambre noire, a construit un canot de cèdre et a restauré des meubles antiques.

G. A joué plusieurs rôles dans une version de Jésus Christ Superstar en arts dramatiques à l'école secondaire.

H. A passé cinq semaines en Chine pour visiter de nombreuses universités dans le cadre d'un programme de recherche collaboratif.

I. A fait visiter son école secondaire au premier ministre John Diefenbaker, qui a été renommée en son honneur.

J. Ancien secrétaire de la Fondation qui s'intéresse à l'enseignement du comportement général du sable et à la recherche expérimentale sur celui-ci.

K. Est originaire d'une petite ville canadienne, parle de nombreuses langues, a donné les conférences Rankine et Terzaghi, et une conférence porte son nom.

L. A travaillé pendant un grand nombre d'années dans le domaine de la géotechnique extracôtière et est membre du CSA Offshore Foundations Code.

M. Ancien v.-p. technique de la SCG dont les recherches portent sur les eaux souterraines et l'évaluation de la conductivité hydraulique in situ.

Question boni

Deux membres ont effectué des recherches sur l'affouillement des icebergs dans l'argile du lac Agassiz, au Manitoba.

Après avoir eu autant de plaisir avec ce jeu-questionnaire, n'oubliez pas que pour remplir sa mission, la Fondation se fie aux dons de particuliers et de sociétés, ainsi qu'aux dons et aux prêts sans intérêt de sections locales et de divisions techniques de la SCG. Pour en apprendre davantage sur la Fondation et ses activités, consultez le site www.cfg-fcg.ca.

Soumis par Dennis Becker
Président de la Fondation canadienne de géotechnique

Nouvelles de la Société

Fondation canadienne de géotechnique

Brève histoire de la Tournée de conférences transcanadienne de la SCG

La Tournée de conférences transcanadienne (TCT) a été lancée en 1965 par le Comité associé de recherches en géotechnique (CARG), un ancêtre de la Société canadienne de géotechnique. La Tournée de conférences visait à offrir aux membres de la SCG et à d'autres professionnels canadiens une occasion d'assister à des présentations techniques de haute qualité données par des experts en géotechnique canadiens et internationaux renommés.

En septembre 1965, le CARG a organisé la 6th International Conference on Soil Mechanics and Foundation Engineering (ICSMFE) à Montréal. La première TCT a eu lieu peu après cette conférence; elle peut avoir été associée en quelque sorte à celle-ci.

Le premier présentateur de la TCT a été **Ivan Rosenqvist** de l'Université d'Oslo, en Norvège, à l'automne 1965. Le ou les sujets de ses présentations n'ont pas été rapportés, mais le Dr Rosenqvist était à l'époque un professeur de minéralogie et de géologie, spécialiste des sédiments marins, particulièrement les argiles et les minéraux argileux. Ses présentations ont probablement été associées à sa spécialité liée à l'argile sensible norvégienne; cela dit, le Dr Rosenqvist a aussi participé à la 6th ICSMFE et y a présenté un article intitulé *Fundamental Properties of Some Norwegian Magmatic and Metamorphic Rocks* (Propriétés fondamentales de certaines roches magmatiques et métamorphiques)!

Au printemps 1966, le deuxième conférencier a été **David Henkel** de l'Université Cornell, à Ithaca, dans l'État de New York; à l'automne 1966, le troisième conférencier de la Tournée a été un jeune conférencier canadien de l'Imperial College, au R.-U., **Norbert Morgenstern.** Deux ans plus tard, le Dr Morgenstern est revenu au Canada et s'est joint au corps professoral de l'Université de l'Alberta.

Depuis 1965, une TCT est présentée au moins une fois par année; elle est offerte deux fois par an dans la majorité des cas.. Elle inclut habituellement un conférencier canadien et un conférencier international chaque année. À cinq occasions, deux conférenciers se sont séparé une tournée, l'un couvrant l'Est du Canada et l'autre, l'Ouest. Cinq conférenciers ont fait la Tournée de conférences transcanadienne plus d'une fois : **Geoffrey Meyerhof** (1967 et 1983); **Robert Quigley** (1969 et 1990); **Victor Milligan** (1972 et 1997); **Ralph Peck** (1972 et 2000); et **Liam Finn** (1991 et 2001). La liste de tous les conférenciers se trouve sur le site Web de la SCG, à *http://www.cgs.ca/cross_canada.php?lang=fr*. Elle se lit comme un répertoire des experts de la communauté géotechnique canadienne et internationale.

En 1972, la SCG a pris la responsabilité de la sélection des conférenciers, de l'organisation des conférences dans les 20 sections de la SCG au pays et du paiement des frais de déplacement et des honoraires des conférenciers.

À la fin des années 1990, en raison de problèmes de financement, on envisageait de réduire la fréquence des TCT. La Fondation canadienne de géotechnique (ou Geo Contributions, nom qu'elle portait jusqu'en 2000) est venue à la rescousse. En 2000, suffisamment de fonds avaient été recueillis pour conserver deux TCT par année, et ce, en grande partie grâce au travail acharné du **Dr Michael Bozozuk**, président de la Fondation canadienne de géotechnique à l'époque, et aux membres de Geo Contributions, **Jack Clark** et **Ray Benson**, ainsi qu'à la générosité des membres de la SCG Jack Mollard et Ben Torchinsky. Depuis 2000, une des activités importantes de la Fondation canadienne de géotechnique est de solliciter et amasser des dons pour financer les frais de déplacement liés aux deux TCT offertes chaque année.

Le 99e conférencier de la TCT au printemps 2017 a été **Vaughn Griffiths**, de la Colorado School of Mines, au Colorado, et le 100e sera **Jean-Marie Konrad**, de l'Université Laval, au Québec, à l'automne 2017. Avec ces deux conférenciers, il y aura eu 53 conférenciers canadiens et 47 conférenciers internationaux (bien que certains conférenciers internationaux fussent également canadiens) dans l'histoire de la TCT. Il y aura eu 58 universitaires, 31 experts-conseils ou personnes provenant de l'industrie et 11 autres des différents paliers gouvernementaux.

Members in the News

New Professor Emeritus Named at Polytechnique Montréal, Michel Aubertin

Congratulations to **Michel Aubertin**, CGS Executive Director, for his nomination as Professor Emeritus of Polytechnique Montréal. His exceptional achievements to research and teaching have contributed to transforming the practices of the mining industry, especially in terms of mine wastes management and site reclamation.

Nouveau professeur émérite de Polytechnique Montréal, Michel Aubertin

Félicitations à **Michel Aubertin**, directeur général de la SCG, pour avoir été nommé professeur émérite de Polytechnique Montréal. Ses réalisations exceptionnelles en recherche et en enseignement ont contribué à la transformation des pratiques utilisées dans l'industrie minière, particulièrement en matière de gestion des rejets miniers et en restauration de site.

Upcoming Conferences and Seminars

70th Canadian Geotechnical Conference and the 12th Joint CGS/IAH-CNC Groundwater Conference
October 1 to 4, 2017
Ottawa, Ontario
www.geoottawa2017.ca

GeoOttawa 2017 accepted over 400 papers. As this is the 70th *Canadian Geotechnical Conference* and the 12th Joint *CGS/IAH-CNC Groundwater Conference*, papers were submitted under either the **Geotechnical** or

Hydrogeological themes. GeoOttawa 2017 will also be recognizing the Best Case Study Papers and the Best Student Papers with awards. Up to three case study papers will be recognized at the conference and the lead authors of the Best Case Study Paper will come from consulting or industry (not academia).

The conference program will include daily plenary sessions, featuring keynote speakers of interest to all delegates, followed by technical and specialty, as well as poster sessions, to meet the diverse needs of attendees. Confirmed speakers currently include: Dr. Richard Bathurst (R. M. Hardy Lecture), Dr. Kamini Singha (Darcy Lecture), Dr. Greg Brooks (CGS Lecture), Mr. Robert Blair (Geotechnical Lecture), Mr. Mark Jensen (Hydrogeology Lecture) and Dr. Michael Hendry (CGS colloquium). Details on our confirmed speakers and their talks are available on the conference website. In addition to the oral and poster presentations, the conference's technical program will include local technical tours and industry presentations by our exhibitors.

There will be 75 booths at the trade show and 25+ confirmed sponsoring companies (as of press time) showcased before, during, and after the conference. An exciting addition to this year's conference will be the Monday lunch presentation of the Canadian Geotechnical Achievements Project that the CGS National Office has been busy organizing, under the leadership of **Doug VanDine** (CGS Past-President). This presentation will showcase 29 projects, introduced during the lunch on Monday, with full posters on display .

GEOpardy, the friendly student competition, will be back again this year at **GeoOttawa 2017**. Based on the popular quiz show, questions will challenge young participants' geotechnical engineering skills. Look for it during Tuesday afternoon coffee break in the main trade show space. Thanks again to Golder for sponsoring and supporting such a fun event!

GeoOttawa 2017 will be held at the **Shaw Centre** in downtown Ottawa. We have arranged accommodation for conference delegates at four surrounding hotels: **The Westin Ottawa**, **The Lord Elgin**, **Novotel**, and **Les Suites**. All hotels are just a short walk away from the Shaw Centre. Further information and online reservation links for each location can be found on the GeoOttawa 2017 website.

As this is the 70th Annual CGS conference and Ottawa will be the epicentre of Canada's 150th birthday celebration, this is one conference you don't want to miss! Join us October 1 – 4, 2017 at the Shaw Centre!

Please address any questions to the Conference Chair: **Mamadou Fall** at *mfall@uottawa.ca*

Based on a text submitted by
Mamadou Fall
Conference Chair – GeoOttawa 2017

Conférences et séminaires à venir

70e conférence canadienne de géotechnique et 12e conférence conjointe SCG/AIH-SNC sur les eaux souterraines
Du 1er au 4 octobre 2017
Ottawa, Ontario

GéoOttawa 2017 a accepté plus de 400 articles. Comme il s'agit de la *70e conférence canadienne de géotechnique* et de la *12e conférence conjointe SCG/AIH-SNC sur les eaux souterraines*, des articles ont été soumis sous le thème de la **géotechnique** ou de l'**hydrogéologie**. GéoOttawa 2017 reconnaîtra également les meilleures études de cas et le meilleur article d'un étudiant en octroyant des prix pour ceux-ci. Jusqu'à trois études de cas seront reconnues à la conférence; leurs auteurs principaux proviendront de sociétés d'experts-conseils ou de l'industrie (pas du milieu universitaire).

Le programme de la conférence comprendra des séances plénières quotidiennes, présentant des conférenciers qui intéresseront tous les délégués, suivies de sessions techniques et spécialisées, ainsi que de sessions de présentation d'affiches, pour répondre aux besoins diversifiés des participants. Voici les conférenciers actuellement confirmés : Dr Richard Bathurst (Conférence R. M. Hardy), Dr Kamini Singha (Conférence Darcy), Dr Greg Brooks (Conférence de la SCG), M. Robert Blair (Conférence sur la géotechnique), M. Mark Jensen (Conférence sur l'hydrogéologie) et Dr Michael Hendry (Colloquium de la SCG). Des renseignements sur nos conférenciers confirmés et leurs présentations sont disponibles sur le site Web de la conférence. En plus des présentations orales et d'affiches, le programme technique de la conférence comprendra des visites techniques locales et des présentations de l'industrie de nos exposants.

Il y a aura 75 kiosques au salon professionnel, et plus de 25 commanditaires (confirmés à ce jour) seront présentés avant, pendant et après la conférence. Un ajout prometteur à la conférence de cette année sera la présentation des réalisations géotechniques canadiennes marquantes que le Bureau national de la SCG s'est affairé à organiser, sous la direction de **Doug VanDine** (ancien président de la SCG). Cette présentation comportera 29 projets, qui seront présentés lors du dîner du lundi; dont les affiches seront aussi exposées durant la conférence.

GEOpardy, le concours amical pour les étudiants, sera de retour cette année à **GéoOttawa 2017**. Concours basé sur le principe du populaire jeu-questionnaire, les questions défieront les compétences en géotechnique des jeunes participants. Cette activité se déroulera le mardi, durant la pause-café de l'après-midi, dans l'espace réservé au salon professionnel. Merci à nouveau à Golder de commanditer et d'appuyer un évènement aussi amusant!

La conférence GéoOttawa 2017 aura lieu au **Centre Shaw**, au centre-ville d'Ottawa. Nous avons pris des dispositions pour que les délégués de la conférence soient hébergés dans quatre hôtels à proximité : le **Westin Ottawa**, le **Lord Elgin**, le **Novotel**, et **Les Suites**. Ces hôtels se trouvent tous à une courte distance de marche du Centre Shaw. De plus amples renseignements sur chaque hôtel et des liens pour y réserver une chambre en ligne se trouvent sur le site Web de **GéoOttawa 2017**.

Il s'agit de la 70^{e} conférence annuelle de la SCG, et Ottawa sera également l'épicentre des célébrations du 150^{e} anniversaire du Canada; c'est donc un rendez-vous à ne pas manquer! Joignez-vous à nous du 1er au 4 octobre 2017 au Centre Shaw.

Veuillez adresser toute question au président de la conférence, **Mamadou Fall**, à *mfall@uottawa.ca*.

Basé sur un texte soumis par
Mamadou Fall
Président de la conférence – GéoOttawa 2017

Division and Committee News

If you have thought about getting involved with the CGS as a volunteer at your local Section or at the national Division or Committee level, contact us for more information about some upcoming opportunities to participate. You will find it a rewarding and beneficial experience.

We will be looking for feedback on some important topics over the next few months. Please check out our website *www.cgs.ca*; email Lisa at *admin@cgs.ca* or check out the comment cards at the GeoOttawa conference. We are looking forward to hearing from you all!

Have an interesting Geotechnical related story or project that you would like to see profiled in an upcoming issue? Send your ideas to Lisa at *admin@cgs.ca*. We are looking for interesting material.

Nouvelles des divisions et des comités

Si vous avez envisagé de contribuer à la SCG en tant que bénévole de votre section locale ou au niveau d'une division ou d'un comité national, communiquez avec nous pour obtenir de plus amples renseignements sur les occasions de participation. Vous trouverez qu'il s'agit d'une expérience enrichissante et positive.

Nous voudrons obtenir des avis sur d'importants sujets au cours des prochains mois. Veuillez consulter notre site Web, www.cgs.ca, écrire à M^{me} McJunkin, à *admin@cgs.ca* ou utiliser les cartes de commentaires disponibles à la conférence GéoOttawa. Nous sommes impatients de connaître votre opinion!

Vous avez une histoire ou un projet intéressant lié à la géotechnique que vous aimeriez voir paraître dans un prochain numéro? Envoyez vos idées à M^{me} McJunkin, à *admin@cgs.ca*. Nous sommes à la recherche d'éléments intéressants.

GEO OTTAWA 2017

70TH CANADIAN GEOTECHNICAL CONFERENCE
70E CONFÉRENCE GÉOTECHNIQUE CANADIENNE

October 1-4 / 1-4 octobre

Ottawa, Ontario

www.geoottawa2017.ca

Join us in Ottawa this October for the Canadian Geotechnical Society's 70th annual conference. In 2017 we are collaborating with the International Association of Hydrogeologists (IAH/CNC) to also present the 12th Joint CGS/IAH-CNC Groundwater Conference.

*The GeoOttawa 2017 theme **70 Years of Canadian Geotechnics and Geoscience** will build on the extensive contributions of geotechnical and hydrogeological practitioners to Canada's built form since the Canadian Geotechnical Society was founded 70 years ago.*

GeoOttawa 2017 conference program highlights will include:

R.M. Hardy Address presented by Dr. Richard Bathurst (Royal Military College)
Darcy Lecture presented by Dr. Kamini Singha (Colorado School of Mines)
Comprehensive Industry Trade Show with over 70 exhibitors
Over 750 delegates and more than 350 technical and special presentations over three days!

TENTATIVE TECHNICAL SESSIONS

PRIMARY GEOTECHNICAL
- Soil Mechanics and Foundations
- Rock Mechanics and Engineering Geology
- GeoHazards and Landslides
- Mining Geotechnics and Hydrogeology
- Geoenvironmental Engineering
- Transportation Geotechnics
- Geosynthetics
- Cold Regions
- Sustainable Geotechnics
- Professional Practice
- Innovative Foundation Systems
- Foundations for Renewable Energy
- Trenchless Technology
- Risk Management in Geotechnical Projects
- Reliability Analysis for Geotechnical Design
- Radioactive Waste Management
- Shallow Geothermal Energy Exchange
- Seismicity and Sensitive Clay

SPECIAL GEOTECHNICAL
- Tunnelling and Deep Excavations
- Geohazards in Linear Infrastructure
- Remote Sensing

PRIMARY HYDROGEOLOGICAL
- General Hydrogeology
- Source Water Protection (including implementation of policy)
- Groundwater and the Ecosystem
- Groundwater and Climate Change
- Groundwater Resources and Management
- Fractured Rock
- Hydraulic Fracturing
- Application of Geophysics to Hydrogeology in Fractured Rock
- Groundwater Contamination by Human Activities
- Quantitative Assessment and Performance of Contaminant Remediation
- Professional Practice
- Public Consultation of Groundwater Issues

SPECIAL HYDROGEOLOGICAL
- Mining
- Cold Regions
- Radioactive Waste Management
- Shallow Geothermal Energy Exchange

The conference will be held at the Shaw Centre in downtown Ottawa, Ontario. Come and enjoy Canada's 150th birthday in our nation's capital this fall!

Please see the conference web site at www.geoottawa2017.ca for detailed conference information and to register online. Be sure to register before July 31, 2017 to take advantage of early pricing discounts!

PLATINUM SPONSORS

BGC · DST consulting engineers · Stantec · AATech Scientific Inc. · 40th Anniversary NILEX · Golder Associates · ConeTec · TREK Geotechnical · Thurber Engineering Ltd. · Reinforced Earth · Klohn Crippen Berger · Clifton Associates · Menard

Engineering Geology Division

Soliciting input for an engineering geology monograph

As discussed at the highly successful GeoVancouver Engineering Geology Division Executive meeting, the CGS Engineering Geology Division will be pursuing the publication of an **Engineering Geology Monograph** based on the Canadian experience. We would like to solicit input in terms of the content to include as well as suggestions for topics, etc. It is envisioned that the monograph will capture the history, significant events, innovations and contributions of Canadians to the field of engineering geology. We would like to have as many people as possible to contribute to this active, living archive. As such, we are soliciting the CGS membership (and beyond) for their ideas in terms of topics, articles, papers, historical perspectives and people to include. If you would like to contribute to the monograph, please contact Nicholas Vlachopoulos, at *vlach@rmc.ca* or at (613) 541-6000 x 6398.

Committee News

Heritage Committee

Make sure to check out the CGS Heritage Virtual Archives on the website. You will be surprised by how much information is there! *http://www.cgs.ca/history_overview.php*

Canadian Geotechnical Society Virtual Archives

There are rich but rarely used resources in Canada that consist of files containing historical information on geotechnical laboratory and field research, geotechnical investigations, work of committees and geotechnical expertise. Ways to identify and use these resources have been developed by the Heritage Committee of the Canadian Geotechnical Society in the form of virtual archives on the CGS web site, where the location and content of accessible historical geotechnical material are given.

CGS members and others are invited to submit candidate material for consideration. The submission should give the location of the material, a description of its nature and content, its historical significance and the conditions under which it can be accessed. Do not submit physical archival material as the Society has no space to store it, however electronic copies of photographs or materials are welcome.

History of Local Sections of the Canadian Geotechnical Society

The Heritage Committee believes that the history of the local sections of the Canadian Geotechnical Society are a valuable part of the Society and its members. The CGS Heritage Committee would like to assemble if at all possible, a collection of historical summaries of all the sections. Hopefully every local chapter of the CGS will take the time to gather their archives and write their own history.

Your contribution to the CGS Virtual Archives web page should be sent to the Chair of the Heritage Committee, Heinrich Heinz, P.Eng. at *hheinz@thurber.ca*.

Answers To the CFG Quiz:

A: 10
B: 8
C: 7
D: 9
E: 12
F: 4
G: 2
H: 13
I: 1
J: 11
K: 5
L: 6
M: 3
Bonus Question: 1 and 6

Editor
Don Lewycky, P.Eng.
Tel.: 780-478-4156
Email: don.lewycky@gmail.com

Introduction by John Dunnicliff, Editor

This is the 90th episode of GIN. Two articles this time.

In red book Chapter 15, I put forward a "recipe for reliability of performance monitoring", and suggested that the ingredients in the recipe can be divided into two categories: *instrument ingredients* and *people ingredients*. Others have used the term *human factors* to mean the same as the second category. In my experience the two categories are of equal importance, but very often insufficient attention is given to the human factors, resulting in failure of the monitoring program. The first article in this episode of GIN is about human factors; the second is about instruments.

Human factors will be one of the symposium themes during the 10th International Symposium on Geomechanics (FMGM) in Rio de Janeiro, Brazil in July 2018: http://fmgm2018.com/2018. Because "very often insufficient attention is given to the human factors", please consider very carefully contributing a paper about these to the 10th FMGM: open the above website and click on the "Call for Papers" tab. Abstracts are due by November 4, 2017.

System checks

The first article, by Isabella Ramaccia and David Cook, describes "System Checks" to test whether installed instruments for displacement monitoring provide correct data. In my view this is a very important subject, and one that is too often overlooked.

More on remote monitoring of displacement

In March 2017 GIN I summarized earlier GIN articles on this subject, and included an article about manual reflectorless total station monitoring (MRTS). Here's another one, this time about global navigation satellite system (GNSS) for landslide monitoring, by Zhangwei Ning and Marc Fish. The authors conclude that a GNSS system specially designed for geotechnical instrumentation and monitoring purposes is capable of achieving millimeter-scale precision at acceptable cost and low power needs.

"Deformation" or "displacement"?

If you're a regular reader of GIN (or of other scribblings by the editor), you may have noticed that I've now replaced the word "deformation" by "displacement". Since moving from USA to England nearly 20 years ago, my European colleagues have been encouraging me to make this change — they're right — it's a better word!

Fourth International Course on Geotechnical and Structural Monitoring

The fourth course was held in Rome, Italy in June this year. We had a record attendance: 140 from 31 different countries. The total attendance for the four courses to date (2013-2017) has been 440 from 49 different countries. We haven't yet decided on the venue and date for the 2108 course — watch this space!

One of the regular speakers at the courses wrote to me after Rome, as part of our discussion about what to do next time: "The course and FMGM [held once every four years] are the only two opportunities that monitoring people have to meet and discuss. We can have different opinions about the structure of the course or the location or the selected speakers, but *we have the course!* This is more important than the structure, the location, and the speakers". I like that!

Names of villages in England

There are many delightful ones: I've just returned from a visit to Upper Slaughter and Lower Slaughter in the Cotswolds, in the county of Gloucestershire (pronounced *Glostersheer*). The word 'Slaughter' stems from the Old English name for a wet land 'slough' or 'slothre' (Old English for muddy place).

Fascinating are the names of some villages in the county of Dorset, all within about five miles of each other: The most well-known one of the villages is Tolpuddle, famous for the "Tolpudle Martyrs", who were a group of 19th-century agricultural labourers who were arrested for and convicted of swearing a secret oath as members of the 'Friendly Society of Agricultural Labourers'. At that time 'Friendly Societies' had strong elements of what are now considered to be the predominant role of trade unions. In 1834 the Tolpuddle Martyrs were sentenced to 'penal transportation' (expatriation) to Australia. Names of nearby villages include:

- Puddletown (alternatively called Piddletown — I kid you not — it's on the river Piddle). The name Puddletown means 'farmstead on the River Piddle'. It derives from the Old English *pidele*, a river-name meaning fen or marsh, and *tūn*, meaning farmstead
- Briantspuddle
- Affpuddle
- Piddletrenthide
- Piddlehinton
- Turners Puddle

Closure

Please send an abstract of an article for GIN to john@dunnicliff.eclipse.co.uk—see the guidelines on www.geotechnicalnews.com/instrumentation_news.php

Yeghes da! (Cornish — Cornwall is most south-westerly county in England, neighboring Devon, where I live).

System Checks/Validations
A practical approach for displacement monitoring

Isabella Ramaccia and David K Cook

What?

When a monitoring system is installed a System Check should be undertaken on instruments to confirm that the data collected are correct, correctly identified and correctly transmitted to and received by those needing to review that data. Reference can be made to "*Monitoring Underground Construction, A best practice guide*" published by the British Tunnelling Society, where it is described as "a process for ensuring that the value obtained for a measurement is a true reflection of the actual change in the parameter being monitored". The most comprehensive form of System Checking is the whole System Check. This involves artificially inducing a known displacement to an instrument and testing whether the expected result is reported.

This differs from a pre-installation acceptance test undertaken to verify that the instrument is operating correctly and not, for example, damaged in transit.

The purpose of this article is to describe how System Checks have been undertaken for a number of instrument types so that methods can be determined for future implementation with these and other forms of instrumentation. This concept has developed over time, as instrumentation becomes more complex so that confidence can be established before the monitoring data is used for decision making.

Whilst this article uses displacement monitoring examples the general principles can be applied to all forms of instrumentation.

Other terms such as "Validation Check", "Verification Check", "Validation Process" and "Acceptance Tests" have also been used to describe this work element.

Why?

A System Check provides the necessary confidence that instrumentation is measuring parameters to the correct magnitude and direction.

When a monitoring system is specified it should be unnecessary for the specifying organisation to know how each component of the instrument, communications system and visualisation software operates and is interconnected. For example valid data production will be dependent on the following elements being correct:

- Instrument location
- Instrument orientation
- Wiring instrument to data logger
- Transmission to processing location
- Import to data management package
- Identification of instrument within the data management/visualisation package
- Calibration factors input
- Sign convention
- Use of environmental corrections (such as temperature and pressure)
- Instrument operation (at time of installation)

If a calibrated displacement is input at the instrument, the resulting data can be compared with the direction and magnitude of that displacement at the output software. If it doesn't match, within reasonable limits for the parameters being checked, then the system should not be considered as commissioned and therefore not accepted until the faults are clearly identified and all discrepancies satisfactorily resolved. Note this is not an accuracy check, it should be considered a reality check. This will provide an indication that the instrumentation system meets specification in terms of operation.

A common error with certain types of monitoring systems is that the combined response of instrumentation and software is not tested before the actual effect of the works is detected. This can result in erroneous readings and a need for corrective action. For example, more than one settlement monitoring system has initially reported heave, instead of settlement, simply because instruments had been connected the wrong way round or an incorrect sign convention programmed into the processing or visualisation software.

The System Check will ensure validity of the data (at the time of the check) and confirm the system configuration, which will depend on site constraints. As an example for instruments connected in a chain (i.e. electrolevel beams) validation of the system configuration is also based on the continuity of the chain installed along a structure.

If novel or unproven technologies are proposed then provision of a System Check will provide confidence to the parties involved.

When?

A System Check is most easily undertaken at the time of installation, as part of the commissioning process. If undertaken retrospectively the System Check is likely to disrupt the readings being recorded. As many projects require a period of background monitoring it is important to have confidence in data obtained from the beginning of that period or it may not be possible to use it for the project.

How the System Check is to be implemented must be considered prior to installation so that it is undertaken at an appropriate point in the process. The monitoring designer must consider how the behaviour of the system can be verified and any false alarms trapped as part of the specification requirements of the System Check. A system of testing should be considered to verify that the monitoring system (including data processing) correctly reports the nature of changes before critical works commence. The System Check process should be detailed in the Inspection and Test Plans (ITP) – see the Glossary at the end of this article.

If an Instrumentation and Monitoring system is altered it may be necessary to undertake at least a partial System Check to maintain confidence in the data output for those elements that have been replaced or repaired.

How?

System Checks are specific to instrument type and the requirement must be clearly defined in the specification regarding scope and inclusion as part of the commissioning process. The method used to undertake the System Check should be described in the Method Statement (see the Glossary at the end of this article) and agreed between all relevant parties with the system commissioning not considered as completed before satisfactory completion. This differs from a laboratory calibration test and may not achieve the same accuracy, but does provide a practical check.

Examples of System Checks

The following were undertaken when technologies were first being implemented but the need for System Checks may remain for future projects, for these instrumentation types.

Electrolevels

A System Check was carried out on electrolevel chains installed to structures predicted to be affected by a major tunnelling project. The system was designed so that a calibrated shim could be placed at one end of an installed electrolevel beam and the magnitude and direction of that displacement confirmed in the data visualisation software. This determined whether the entire monitoring system (including instrument, loggers, transmission elements and reporting software) correctly reported both the magnitude and direction of the change. It was used to confirm that electrolevels were correctly wired to the multiplexer/data logger, the data correctly referenced and processed and correct calibration factors used. Discrepancies found were investigated and remedied before commissioning was considered complete.

In-place Inclinometers (IPI)

Sometimes IPIs are installed but when construction influences occur the data indicates displacement in the opposite direction to that expected. At that point, usually at a particularly inconvenient time, it may be necessary to retrieve the IPIs to verify correct installation with consequent project delays.

On one project a calibrated frame was constructed and the fully wired up chain of inclinometers arranged so that each IPI was placed in the frame immediately prior to installation in the casing. Whilst in the frame the IPI was tilted in the plane of interest and displacements recorded (in both magnitude and direction) within the data management/visualisation software.

This provided confidence to the Project Owner regarding output from the IPI system before construction works commenced.

Automatic Total Stations (ATS)

In the early days of ATS, prior to major implementation (72 instruments) on a large infrastructure project, it was necessary to provide confidence to the Project Owner before committing to the major investment required that the instruments would perform as required. A trial was undertaken and an ATS installed (which would be required as part of the full installation) with reference targets and a number of the prisms to be monitored. The location of one prism was capable of adjustment by calibrated distances. This one instrument system was set up, the bugs sorted and a System Check undertaken. The adjustable prism was moved by known distances in x, y and z directions. The data visualisation software was then interrogated to determine the displacements the ATS was measuring relating to that prism displacement. Following successful completion of this trial and operation of this reduced system for a period of months the full ATS system was ordered and installed.

Reflectorless Automatic Total Station (RATS)

The use of RATS was proposed on the ATS project described above, as a replacement for manual levelling in trafficked areas along the centre line of each tunnel, to reduce risk to survey teams. There was a need to demonstrate the system capabilities prior to an investment in the number of RATS to supplement the ATS installation.

An RATS was installed to its proposed location and its reading circle on the ground determined at a number of locations, based on the angle of sight from instrument. At each of these locations discs approximating to the reading circle were applied and the changes in x, y and z for those thicknesses recorded by the RATS. Comparisons were undertaken in dry and wet conditions and on different materials to determine whether the reduced accuracy (compared to manual levelling) was acceptable to the project. Another part of the check was to determine the apparent horizontal displacement of the reflectorless monitored point (and its effect) due to the change in level of that point and mitigation methods implemented.

In addition the total time from reading to data availability including cycle time (the time taken for the instrument to physically take a round of readings from all the reference prisms and monitored reflectorless locations), data transmission, processing through to availability of data for review, was verified before project-wide implementation.

Following this successful trial, installation of the remaining RATS was undertaken, "double decking" with existing ATS locations along the trace, using a moving window approach to minimise the number of RATS to be procured.

Conclusions

Monitoring systems should be System Checked to demonstrably prove they meet design requirements and specifications. Dependent on the instrument type, criteria for testing can be based on the simulation of changes in instrument position/orientation and changes to parameters recorded.

Monitoring related problems can arise from:

- The implicit lack of past experience with proposed instrumentation and/or context in which it is being used
- Shortage of appropriately skilled resource
- Shortages of equipment leading to late supply and rushed installation
- Increased reliance on validation of results and background monitoring
- Erroneous results or unforeseen responses in use
- Potential for non-acceptance of system by third parties (i.e. re-assurance failure and resultant late deployment of conventional systems)

Undertaking a full System Check will assist in the minimisation of adverse effects from these problems. Omission or failure to specify or undertake System Checks on a monitoring system before construction activities commence can lead to inaccurate monitoring results to the detriment of a project.

System Checks provide information which will assist in preventing re-occurrences of issues on future projects.

Whilst a System Check will assist in providing confidence in the instrumentation operation, correct positioning of the instruments must be checked independently as they cannot directly form part of the process described above.

Bibliography

"Monitoring Underground Construction – A best practice guide" published by British Tunnelling Society ISBN 978-0-7277-4118-9. Information about this book is available on-line at www.geotechnicalnews.com/instrumentation_news.php . Scroll to December 2011.

Glossary

Inspection and Test Plan (ITP)

A standard quality assurance requirement, which requires that monitoring systems are supplied with calibration certificates, calibration checking arrangements and specific frequencies and protocols for such checks including any integral processing and reporting software.

Method Statement

A written document that details a safe system of work and identifies the conceivable hazards that may arise during the construction work. Method statements are usually provided to the Project Owner by the main contractor and/or to the main contractor by the sub-contractor(s). The Method Statement should explain in detail the work that is to be undertaken and the necessary measures that need to be in place in order to protect the site workforce and members of the public who may be affected by the work actions.

Isabella Ramaccia and David K Cook
Mott MacDonald
8 Sydenham Road
Croydon
CR0 2EE, England
Tel +44 (0208) 774 2000
isabella.ramaccia@mottmac.com
david.cook@mottmac.com

A case study of Global Navigation Satellite System (GNSS) in landslide ground movement monitoring

Zhangwei Ning and Marc Fish

Principles of GNSS positioning

GNSS was originally designed for precise navigation and positioning. In recent years GNSS applications have extended to civil and construction industries such as surveying, construction machine control as well as structural/ground movement monitoring. As positioning is the core for most GNSS applications, its underlying principle is similar to a very old surveying technique: trilateration. Both of them rely on the measurement of distances from an unknown point to a certain number of known points (control points). For trilateration these control points are fixed points on the earth surface, while for GNSS the control points are satellites orbiting the earth at a speed of several kilometers per second. As the instantaneous position of each moving satellite on the obit is precisely monitored and known by the GNSS ground control sector, the distance measurement (ranging) is derived from the travel time of the satellite signal transmitted from outer space to the receiver on the earth.

GNSS signals and ranging

GPS (Global Position System) was developed by the USA as the first global operational GNSS. It has been used as a synonym for GNSS until more global or regional GNSS such as

GLONASS (Russia), BeiDou (China) and Galileo (EU) have been developed. A GPS satellite is sending three legacy binary codes known as the Precise code (P (Y) code), the Coarse/Acquisition (C/A) code, and the Navigation (NAV) code. These codes are modulated into electromagnetic waves known as L1 at 1575.42 MHz and L2 at 1227.60 MHz. Both the code and the carrier signal can be used for ranging. The code based ranging is achieved by comparing the time shift between a section of code from the satellite and the same synchronized code generated at the receiver. The carrier-based ranging requires resolving the integer number of wavelengths included in the entire carrier signal from the satellite to the receiver (integer ambiguity), which involves more sophisticated algorithms and yields more accurate results.

GNSS errors and differential positioning

Errors exist in all kinds of measurements including GNSS. The main contributing sources of GNSS errors are: satellite clock error, satellite orbit error, ionospheric delay, tropospheric delay, multipath and receiver noise, causing errors in the orders of magnitude from a few decimeters to several meters. Without removing these errors, the accuracy of GNSS positioning would not satisfy many applications including geotechnical ground movement monitoring, for which sub-centimeter accuracy is expected. The solution to eliminate these errors is differential positioning, on which most, if not all, accurate GNSS positioning techniques rely. In differential positioning, the position of a fixed GNSS receiver (referred to as a base station) is determined to a high degree of accuracy using conventional surveying methods. The position of the base station is also calculated by using either code-base or carried-base ranging, which includes the errors listed above. Because most of the GNSS errors are spatially related, the difference between accurate and calculated position are nearly equal within a limited geographical area. Therefore, a spatially close receiver with its position in question (rover) can integrate the 'difference' received from base station via a wireless data link to 'correct' its calculated positon. The closer the rover is to the base station, the better the correction at base could match to the rover. DGPS (differential GPS) and RTK (Real-Time Kinematic) are the two common differential positioning techniques. The DGPS is code-base ranging with 100-200 km typical baseline (the distance between the base and the rover), providing approximately +/-1meter accuracy whereas RTK is carrier phase-based ranging with 10-20 km baseline, providing cm level accuracy even when positioning fast moving objects.

GNSS in geotechnical instrumentation and monitoring

Ground/earth structural surface deformation is one of the most crucial subjects in geotechnical instrumentation and monitoring (I&M), for which GNSS appears to be a perfect tool, as its direct output is the position of the object to which the receiver is attached. Also, there are some unique advantages of GNSS compared with other common monitoring methods, for example: the distance measurement range of GNSS is almost unlimited in 3D. The base station can be placed very far away on a stable zone from the active monitoring zone. However, GNSS it is still not commonly considered in geotechnical I&M, mainly due to the follow reasons:

- It is a less familiar technology to most geotechnical engineers;
- Its high hardware cost per monitored point (e.g. using high-end geodetic GNSS receiver);
- Many of the GNSS products are not capable of delivering millimeter scale precision;
- Relatively high power needs of the system to provide near-real time data (meaning bulky power supply equipment).

Although there are certain demanding requirements by geotechnical I&M, we shouldn't neglect there are also some very 'favorable' conditions compared with other GNSS applications when designing a GNSS-based monitoring system:

- Although a moving rate of centimeters per day is quite significant to geotechnical engineers, it is still considered 'static' positioning for GNSS which was originally designed to track fast moving objects;
- The area of the monitoring zone is usually not large, so the base station can be located closely to the rover (< 5km), which will help to improve the accuracy of differential positioning;
- The monitoring data is usually only required to be updated every few hours or even less frequently, while the sampling rate of GNSS is usually in 'Hz'.

Implementation of GNSS to monitor landslide movement

A recent pilot project performed by Sixense and Washington State Department of Transportation (WSDOT) geotechnical office has implemented a GNSS system in a small landslide site in Washington State. The project site is located along a short section of a notoriously unstable 40 km long stretch of US Highway 101, between the cities of Aberdeen and Raymond, which is about 170 km to the south east of Seattle (Site photos are shown in Fig. 1 and Fig. 2). This site suffers from frequent small-scale landslide movement, especially during the Pacific Northwest rainy season (November – April). The active landslide head scarp is estimated to be about 100 meters in length and the presumed landslide toe is around 175 meters downslope (~2H:1V slope), near an un-named creek. Over the last decade, WSDOT maintenance crews have had to resurface the highway on an annual basis

Figure 1. Site photo 1.

Figure 2. Site photo 2.

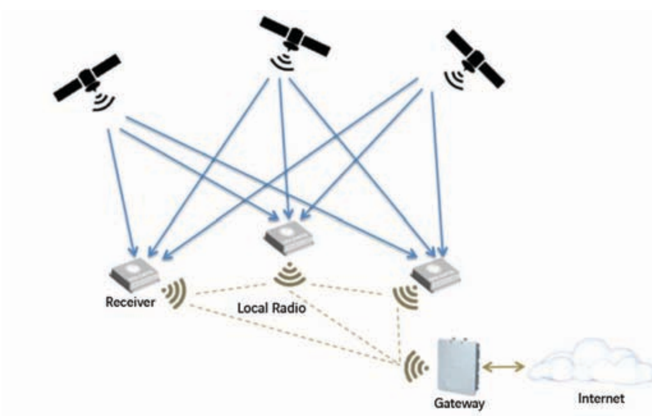


Figure 3. Schematic of GNSS monitoring system.

and have placed nearly 2-3 meters of asphalt over the down sliden block in order to keep the highway level. Since January 2016, recently installed inclinometers and piezometers have been actively monitoring ground movement and groundwater elevations to help develop a landslide response rate to precipitation. This instrumentation has measured ground movement at depths as deep as 34 meters below ground surface, with movement rates approaching 2.5 cm/month during the rainy season. The groundwater elevation appears to rise by as much as 4 to 5 meters between the dry (summer) and wet (winter) seasons, with ground movement accelerating when the groundwater elevation stays elevated over extended time periods.

Figure 4. Layout of GNSS receivers on site (red line shows the outline of the landslide).

The GNSS system deployed at the site includes one base station receiver, four rover receivers and a post-processing gateway. The raw GNSS data is first logged at all rover and base receivers and then transmitted to the gateway via local radio network. The data are then post-processed using carrier-phase ranging algorithms with network adjustment at the gateway to produce high accuracy geographical positions of each rover receiver. From the gateway, which is connected to the Internet via a cellular network, the calculated results are sent to the remote server and accessible to end users via a web-portal. Because the calculating module is removed from the receiver and the antenna is integrated into the receiver, both the hardware cost (per monitor point) and power consumption (0.5 w in this case) are effectively reduced. In addition, by combining public Internet connection and local radio network with mesh topology, it allows for a highly flexible deployment of GNSS node and the gateway (as shown in the schematic of Fig.3).

In April 2016 two rover receivers were installed in the sliding zone (#2 and

Figure 5. GNSS receiver and its power supply.

#3) while one rover receiver (#4) was installed outside the sliding zone. The base station receiver (#1) was installed at about 80 m away from the head scarp which was assumed to be relatively stable (as shown in Fig. 4). The gateway was installed near the base receiver. The entire system was powered by solar panels. Fig. 5 shows one of GNSS receivers installed on site.

Learned from the monitoring data

During the pilot project, this GNSS monitoring system had continuously been collecting data for nearly a month, delivering the post-processed results every minute. Although the test duration is not very long and the active landslide season had passed, the results show very promising repeatability (precision) as well as capture small anticipated ground movement.

Fig. 6 shows the time-series graphs of the relative ground movements of receiver #2 and #4 in horizontal E/W (East is positive in Y-axis) and vertical directions (upwards is positive in Y-axis). The following observations can be drawn from Fig. 6:

- The precision in both horizontal and vertical directions of the two receivers are in millimeter-scale while the horizontal precision is better than vertical precision.
- Receiver # 2 which is inside the slide zone shows almost zero movement in E/W direction and 3 mm vertical movement downwards while receiver # 4 which is outside the slide zone shows about 5mm movement towards the west (upslope direction) and about 10 mm movement upwards (all relative to the base station). From the relative moving direction shown in receiver #4, it seems plausible that the base station is still located within the influence zone of the landslide, and it moves in the opposite direction as to what receiver #4 shows. If this is the case and we assume receiver #4 to be the stable point instead, the actual movements of receiver # 2 would become approximately 12 mm downwards and 5 mm towards the downslope direction (west).

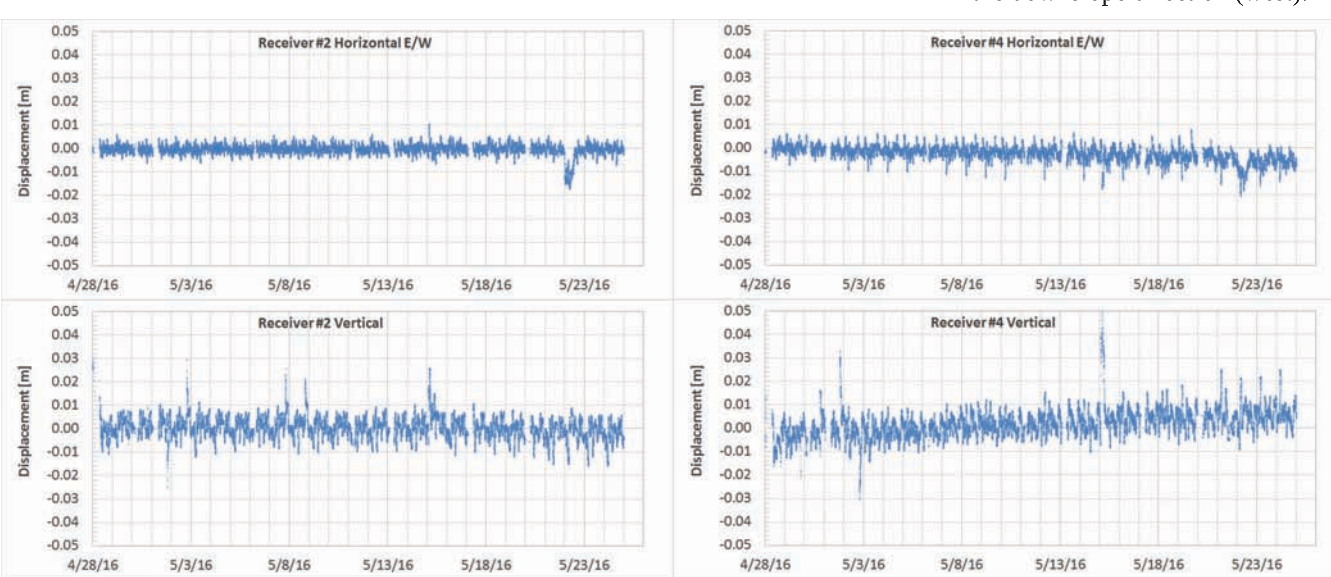


Figure 6. GNSS monitoring data.

This coincides with the horizontal movement measured by a nearby inclinometer during the same period.

- There is a clear daily cyclical pattern shown in the monitoring data. This is related to the residual of atmospheric errors after the majority of them have been removed by differential positioning. Thus applying a 24-hour averaging on the detailed one-minute interval data would further improve the precision of the results.
- There are a few major spikes shown in the data, which is due to the rainy weather as recorded by a local weather station.

Final words

The pilot project demonstrates that with today's developments in GNSS hardware and post-processing techniques, a GNSS system specially designed for geotechnical I&M purposes is capable of achieving millimeter-scale precision at acceptable cost and low power needs.

As more GNSS systems become globally operational by the end of this decade, the availability of GNSS satellites will be largely increased while the hardware cost will decrease. Using GNSS for high precision, near-real time monitoring is anticipated to become common in supplementing the existing conventional geotechnical I&M methods.

Zhangwei Ning
Sixense
11812 North Creek Parkway N, Suite 104B, Bothell WA 98011
Tel: (206) 588-1691
Email: zhangwei.ning@sixense-group.com

Marc Fish
WSDOT Geotechnical Office
1655 S. 2nd Ave, Tumwater WA 98512
Tel: (360) 709-5498
Email: FishM@wsdot.wa.gov

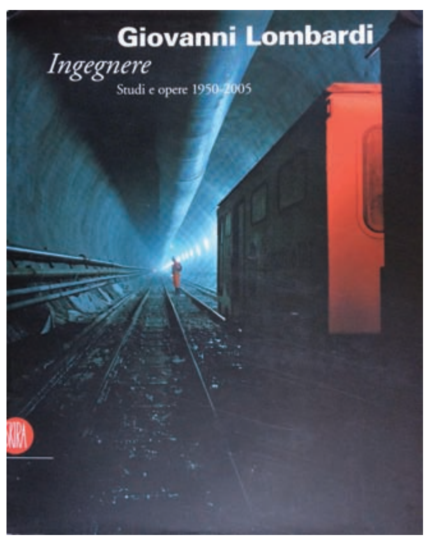
Paolo Gazzarrini

Overture

48th episode of the Grout Line, and we begin with some sad news for our grouting industry: Dott. Giovanni Lombardi passed away at the age of 90 on May 22 of this year. In commemoration, I would like to dedicate some words to him, followed by a personal remembrance by Maren Katterbach.

Giovanni Lombardi (1926-2017)

Picture from the book : Giovanni Lombardi-Ingegnere- Studi ed Opere 1950-2005 (SKIRA).



I had the pleasure to meet Dr. Lombardi ('ingegnere-engineer', as defined in a book prepared by the family to honor him in 2005) on several occasions due to our common passion of grouting.

Engineer, rock mechanic expert, dam designer, founder of Lombardi Ltd., one of the most important engineering firms in Switzerland, Dr. Lombardi is well known in our grouting industry for the development, along with Dr. Don Deere, of the GIN method for grouting in rock, and more importantly for me, contributor to our Grout Line.

Key note lecturer in 2003, at the 3rd Grouting International conference, and honored with GREATS (Grouters dedicated to Research, Education, Advancement of Technology, and Service) at the 2012, 4th Grouting conference.

I met him during several trips to Europe and it was always a pleasure to talk with him about our common interest. However, what I remember even better, was a situation before our 5th Grouting conference in 2012, a few months after he had some health problems. He was desperate because the doctors prohibited him from traveling, especially by plane, and consequently he was not able to receive in person the GREATS award. Instead, with the help of his employees, he prepared a video, to express his thanks. I don't enter here into the details and the time we lost in discovering the incompatibilities, sometimes experienced, between North American and European software. Only software? Or can we extend this incompatibility also to grouting?

Some of Dr. Lombardi's words, which, in my opinion we should never forget, referring to a colleague: "…who always kept in touch with the realities of the profession of builders without being seduced (unlike others) by flights of fancy toward virtual worlds created by computer processing technologies that are too easily available." Ref 1.

I would like to add some words of another colleague, Ugo Sadis, about Dr. Lombardi that I found perfect: "Polite and measured. Energetic and dynamic. Tolerant, creative and talented. It is no surprise that he has been awarded two honorary titles: in Lausanne in 1986 and Milan in 2004. Head high, he looks directly forward, and deeply, to the horizon. He gives over the (little) spare time he has to the family, to reading, study and reflection. And often to public, artistic and economic issues. A cocktail of professionalism and humanity". Ref. 1.

I should add a missing phrase, in my opinion: a "real gentleman" that sometimes, in the construction industry jungle, is missing.

For anyone who is interested, in the Grout Line web page (www.groutline.com) you can find the link to the movie that Dr. Lombardi recorded, due to the impossibility to travel, expressing his thanks, after receiving the GREATS award in 2012.

Ref. 1. Giovanni Lombardi - Ingegnere - Studi ed Opere 1950-2005 (SKIRA).

And now some personal words from Maren Katterbach, member of the GI Grouting Committee and instructor at the Grouting Fundamental Course in Austin, who started her engineering/grouting carrier with Dr. Lombardi.

Grazie Dottore!

Giovanni Lombardi is no longer with us, but his work and his memories will last. Countless are the good moments, the experiences and insights we are now taking with us. Apart from his excellence as an engineer it was his lively, open-minded and unbiased interest all around, and his mental vigor, that made a profound impact.

But there was so much more to and behind him!

To limit this article to a reasonable length, I would like to give you an idea about my personal impression of Dr. Lombardi and how our getting together positively influenced my future as an engineer – and above all, my passion for grouting.

I first met Dr. Lombardi about 8 years ago, when I started my career at Lombardi Engineering in Southern Switzerland. Highly motivated, full of ambition and admittedly quite sure of myself and the knowledge I had gained previously in my intensive studies, I had the chance to be, from the beginning, actively involved in major international projects. For me this was the big opportunity to get the final touch. Only afterwards I realized that what was to come was, of course, much more than that. And that the diplomas I had worked so hard to achieve, were actually nothing more than just pieces of paper.

As such, as not much more than a half-baked engineer, I remember I went with Dr. Lombardi in the first year to a dam site in Sardegna. I had studied this site in detail over the previous 3 months, including various geotechnical and dam stability analyses – trying to achieve, in accordance with the applicable standards, a safe and still economically feasible design. Considering the unfavorable foundation conditions, it was a task that caused quite a few headaches and additional working hours. Finally, on this day of joint inspection, I was standing there apparently well prepared in the brutal heat of the construction site, hoping to explain to the great Dr. Lombardi the outcome of my intensive previous evaluation. But where was he? I saw only later that the correct question here actually should have been "Where was I?". Because, the "wise, grey-haired Dottore" had meanwhile climbed high up on the abutment, visible just as a small grey dot, while I was still standing down there mentally preparing for any questions to come – however, the supposed question was not raised. After carefully listening to my information overloaded presentation, Giovanni Lombardi took in a very humble way, a crumbled piece of paper out of his pocket. And he outlined on less than half a page his idea and design proposal, based on what he saw and heard in 15 minutes and after climbing a 60 m height difference in this unbearable heat. Admittedly, in this moment my self-confidence was less than or equal to zero. Looking back on 3 months of complex evaluations with a final admittedly, quite compromised design suggestion, he arrived in a couple of minutes and by means of a simple hand calculation at the same foundation stresses and a completely consistent design. So, there I was – not more and not less than a graduate engineer, maybe able to correctly use standards and apply calculation methods, but still missing the main point: an engineering sense together with detached, critical thinking. In retrospect, this awareness and the self-assessment, even if sobering but still realistic, I largely owe to Giovanni Lombardi. I'm sure all of us can think of a similar experience starting our careers, which finally laid the foundation stone for improvement and for our professional development. For me personally, this particular situation represents the beginning of my immense admiration for Dr. Lombardi, his outstanding intelligence, the absolute dedication to work as well as his charisma, which altogether have enabled him to achieve the results that we all know.

In the following years, I had the chance to further learn and literally absorb Lombardi's great technical knowledge and also his engineering sensitivity, which I cannot put into words. In a very clear, and at the same time by no means presumptuous way, he managed to convey his fundamental philosophy of **engineering as being the search for the best solution to all intents and purposes, and this not only in civil engineering. This search starts with the questioning of the past and the willingness of a continuous improvement, from a deep conviction that nothing can be taken for granted and that every achieved result might be improved.** This philosophy characterized and hopefully always will be reflected in the engineering activities of the company Lombardi Ltd. which he founded more than 60 years ago.

His striving for continuous improvement together with his unstoppable

ambition, as well as the necessary creativity and imagination allowed Dr. Lombardi to make his name also by developing several internationally accepted engineering concepts. Here, just to mention the Grouting Intensity Number (GIN), well known to most of the grouting folks. His fundamental motivation for this: Introducing, next to the commonly considered maximum pressure, P_{max}, and maximum volume, V_{max}, a third limiting criterion, which is the combination of P and V, called GIN. With this additional parameter, higher grouting pressures can be safely applied without any unwanted hydrojacking and/or –fracturing. The result: A significant increase in the efficiency of the grouting works.

Fascinated by the simplicity and at the same time ingenuity of this concept, I finally made it in the field of grouting. Here, I appreciated the opportunity to work by Lombardi's side in a field, which he in his humble way considered just as his hobby. It was also he, who preached again and again the importance to fight against the "rules of thumb" in the grouting design, which unfortunately even today can still be found an ongoing struggle.

Looking back, I'm very glad, Dr. Lombardi still managed to pass in this way not only his unbiased and detached general way of thinking, but also his enthusiasm for grouting to the next generation – and with it he created the basis for any future success we are committing ourselves to, something that is nowadays in many companies too often forgotten.

Regrettably, we did not make it on time to conclude our book on grouting, that we planned to write together – an open issue that might be dealt with soon.

However, Dr. Lombardi did not just leave technical footsteps to be followed. Impressive also were his unfailing integrity and his modesty, which allowed him to remain always an open and down-to-earth person.

Many more positive memories will remain. Anecdotes about travel adventures, meetings, excursions – about shared moments. Undoubtedly, in 30 years from now I will still have his voice in my ear not only when dealing with challenging projects – and this is a good thing!

Finally, I'm unspeakably grateful to have had the chance to experience just two weeks before his death, a still cheerful and very charismatic, positive and joking Dr. Lombardi. During a breathtaking helicopter flight, the company organized for him, we had the chance to look together both, down and back to several projects he leaves behind.

Thank you, Giovanni, for far more experiences and stimuli generated! You exemplified the passion and enjoyment of work and we will try to keep this spirit in the future!

Faithfully,
Maren

GROUT 2017

The 5th International Grouting Conference was held July 9-12 in Honolulu, Hawaii and here are a few words from Mike Byle, conference chair.

Grouting 2017 was an amazing success. With over 330 attendees from 24 countries diversity of experience and culture gave the event its characteristic atmosphere. The sharing of technologies for grouting, deep mixing, and diaphragm walls was exciting and interesting. New developments in shaped jet grouting drew a lot of attention as did increased and novel uses of MWD. Newer bigger and deeper deep mixing applications also drew some attention.

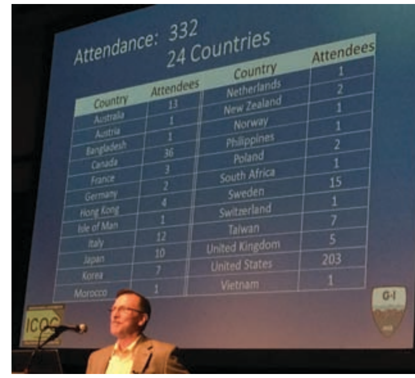
Keynotes lectures by Jim Warner, Dave Paul, Alessandro Flora, Rick Marshall, and Donald Bruce, provided exciting, entertaining and topical insights. Jim provided reminiscences from 65 years in grouting from the beginnings of mudjacking and compaction grouting and recollections of other grouting GREATS. Dave updated us on efforts to stabilize the Mosul Dam in Iraq, a fascinating and challenging project, which will be an ongoing concern for the foreseeable future. Alessandro provided news about the European experience and expectations for the future advances in control systems and shaped columns. Rick gave an enlightening talk on aspects of safety from design through to construction that we will all take to heart. Donald in classic fashion brought together heroes from David Bowie to Jim Bowie and Karl Terzaghi to highlight the exceptional and paradigm shifting outcomes of the Wolf Creek Dam remediation.

Thanks go to the planning committee and GI staff who made it all possible. Special thanks to Chadi El Mohtar for his work in bringing the student program to fruition. Students were involved in the sessions and a number of them received fellowships sponsored by Sea-to-Sky Geotech Inc., ICOG and Dave Paul. All expressed gratitude for the opportunity and encouragement they received.

The conference is a testimony to the character and passion of the grouting industry. Sessions were full right to the end; even when the beautiful beaches of Waikiki were beckoning, just outside. Aloha and Mahalo.

See you in New Orleans in 2022 for the 6th Grouting conference, Mardi Gras!

Please take note of the new dates for the Grouting Fundamentals 2018!



Michael J. Byle D.GE, F.ASCE Conference Chair.

And, please don't forget that in 8 months we will celebrate the 50th issue of the Grout Line with the same request, asking you to send me your grouting comments or grouting stories or case histories. My coordinates remain:
Paolo Gazzarrini, paolo@paologaz.com , paologaz@shaw.ca or paolo@groutline.com.

Ciao! Cheers!

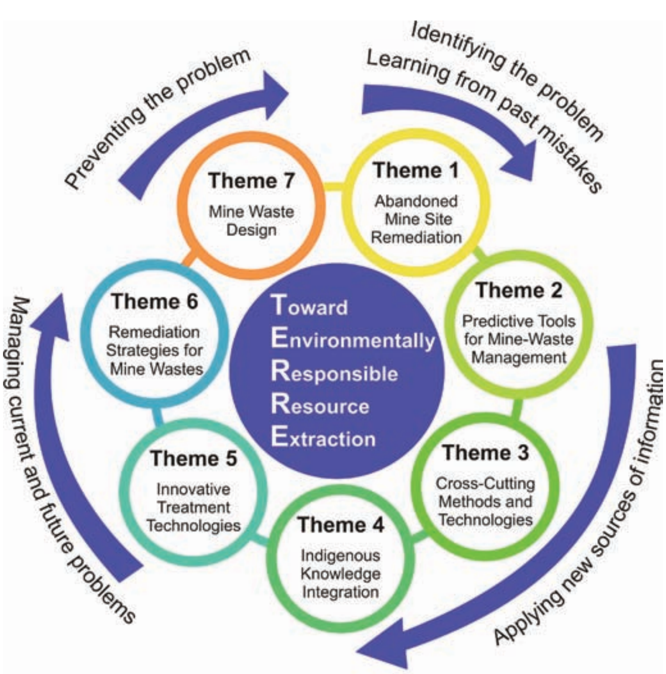
Canadian universities leading research toward environmentally responsible resource extraction

David Blowes, Carol Ptacek, Jeff Bain, Steve Holland, Julia Jamieson-Hanes, Krista Elena, and Vivian Giang

Researchers from seven of Canada's leading universities have established two major research and training programs with the Natural Sciences and Engineering Research Council of Canada (NSERC). Through these programs, the researchers aim to promote the broad collaboration and knowledge sharing necessary to address the technical and social challenges associated with responsible resource extraction.

The Challenge

Mining is an important sector of the global economy, because it provides the raw materials used in virtually all other industries around the world.



Canada is a world leader in the production of mined commodities, including base and precious metals, coal, diamonds, petroleum, and uranium. But the environmental and social impacts associated with mining remain an important issue. In particular, mines can release drainage contaminated by high concentrations acidity of dissolved metal(loid)s, sulfate, and acidity, all of which pose prominent threats to the environment. Effective methods are needed to predict, mitigate, and remedy these environmental threats.

New methods and technologies for managing and stabilizing mine wastes, treating contaminated mine water, and remediating decommissioned and abandoned mine sites have been developed and are being used throughout Canada. But more research is needed to enhance these methods and technologies and develop new ones. Concerns regarding past remediation strategies and the long-term effectiveness of current mine-waste management practices are the main focus of the NSERC Strategic Partnership Grants for Networks "NSERC Toward Environmentally Responsible Resource Extraction" (TERRE-NET). By addressing these concerns, this research network will help to bridge the gap between discovery and innovation in implementing better mine management and remediation technologies.

TERRE-NET builds on the strengths of the Training toward Environmentally Responsible Resource Extraction (TERRE) program funded through NSERC's Collaborative Research and Training Experience (CREATE) Program. TERRE-CREATE provides enhanced training opportunities for undergraduate and graduate students and postdoctoral fellows. Working together, TERRE-NET and TERRE-CREATE will forge close collaborative ties among world-class researchers and research facilities at top Canadian and international universities. These ties will enable TERRE-NET to prepare the next generation of scientists and engineers to address the pressing challenges of long-term environmental protection at active, decommissioned, and abandoned mine sites.

TERRE-NET

TERRE-NET unites leading experts from universities across Canada working in the fields of geochemistry, hydrogeology, mineralogy, biogeochemistry, waste-water processing, geotechnical engineering, nanotechnology, environmental microbiology, resource economics, environmental sociology, and Indigenous interactions. In a thoroughly integrated approach, the team will develop improved, cost-effective, socially acceptable strategies for managing mine wastes and mitigating contamination.

TERRE-NET brings together 15 leading researchers from seven universities across Canada (University of Waterloo, University of British Columbia, University of Alberta, University of Saskatchewan, University of Ottawa, Université du Québec en Abitibi-Témiscamingue, and Memorial University of Newfoundland) and numerous partner organizations and end-users, including provincial, territorial and federal government agencies, mining companies, and industry associations. This research network's members have extensive expertise in all areas of mine-waste management and remediation, as well as in interaction with First Nations, Métis, and Inuit communities. TERRE-NET collaboration with key industry partners, industry associations, government organizations and regulatory agencies in Canada, as well as with international partners, will ensure that this network provides real-world solutions for mine-waste management and remediation technologies both in Canada and around the world.

TERRE-NET's mission is to research and develop cutting-edge approaches and technologies for environmentally and socially responsible handling of the wastes generated during extraction of mineral and energy resources. TERRE-NET's research projects are organized under the following seven themes, each with a defined overall research objective that is directly relevant to the needs of the network's partner organizations.

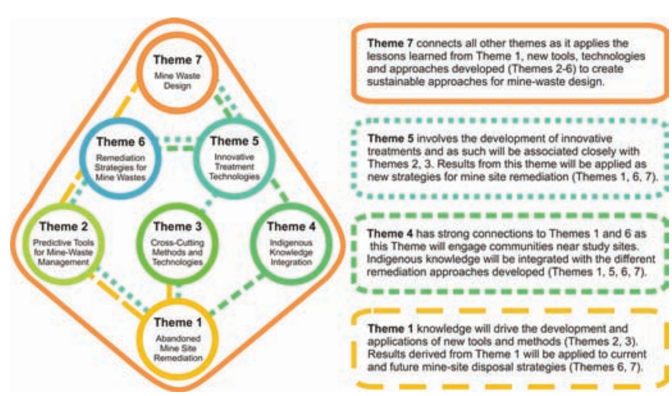
- **Abandoned Mine Site Remediation**: develop a comprehensive framework to assist in the optimization of remediation strategies for abandoned mine sites.
- **Predictive Tools for Mine-Waste Management**: develop novel, robust, efficient numerical models to predict the environmental impacts of mine wastes.
- **Cross-Cutting Methods and Technologies**: provide fundamental knowledge of the biogeochemical, mineralogical, and hydrological mechanisms and processes that control the physical and chemical stability of mine wastes.
- **Indigenous Knowledge Integration for Understanding Risks and Costs/Benefits of Resource Extraction**: integrate local and Indigenous knowledge indicators and monitoring practices, as well as cost/benefit analyses, into mine-waste management approaches.
- **Innovative Treatment Technologies for Mine-Impacted Water**: develop cost-effective strategies for treatment and remediation of mine wastewater.
- **Remediation Strategies for Mine Wastes**: develop and optimize the performance of remediation strategies for preventing the release of contaminated water at active and decommissioned mine sites.
- **Mine-Waste Design**: transform mine-waste management practices through the development of new methods for creating physically and chemically stable mine-waste structures that are easily remediated at the end of mine life.

The results that TERRE-NET achieves will help its partners to develop effective mine waste-management strategies in addition to:

- **securing Canadian leadership** in environmentally responsible resource extraction both in Canada and abroad;
- **developing, optimizing, and implementing new predictive tools, remediation strategies, and water-treatment technologies** in partnership with Canadian industry and government agencies; and
- **forging lasting relationships among partners from the private and public sector**, strengthening collaborations among academic researchers, the Canadian mining industry, government agencies, government researchers, First Nations, Métis and Inuit communities, and international partners.

TERRE CREATE

The TERRE CREATE program is designed to prepare exceptional science and engineering undergraduate and graduate students and postdoctoral researchers for impactful careers in the resource extraction sector. Through the adoption of a "Life of Mine" approach, this innovative training program will produce highly qualified personnel capable of addressing critical long-term issues related to mine waste management and mine site reclamation which arise throughout the various stages of mine site development – prospecting, design, construction, operation, closure, and post-closure. To accomplish this goal, the TERRE CREATE program offers a wide variety of courses to address



critical environmental, ecological, social and economic considerations surrounding resource extraction. In addition, TERRE CREATE trainees will have opportunities to participate in industry- or government-partnered internships and collaborative research exchanges between industry, government, and universities external to their home institutions; such exchanges will provide trainees not only with enhanced research experience, but also with substantial networking opportunities.

From its inception in April 2014, the TERRE CREATE program has strived to maintain a strong working relationship between affiliated university researchers and leading industry professionals. Its industry partners have been instrumental in helping to identify key areas of professional development and soft skill acquisition which would greatly benefit new scientists and engineers looking to enter industry positions in the resource extraction sector; these areas include communication and leadership, technical writing, and innovation, intellectual property, commercialization, and entrepreneurship. The TERRE CREATE program offers many unique courses which cover these important disciplines, and provides stipend funding to undergraduate and graduate students and postdoctoral researchers to facilitate course and research exchange participation.

Overall Impact

These two programs directly address NSERC's priority areas of natural resources and environmental science and technology. The benefits of TERRE-NET research to Canada in the short- and long-term will be multifaceted. TERRE-NET will develop advanced scientific tools and processes for mine-waste management for use by the mining industry. In addition, it is anticipated that government agencies responsible for the long-term management of abandoned mine sites, and for regulating active and decommissioned mining operations, will utilize TERRE-NET results to inform policy decisions to improve best practices for mine-waste management design and monitoring, and to minimize impacts to water quality, the environment, and human health. Further, TERRE CREATE will train a new generation of highly qualified personnel to pioneer new standards and technologies for protecting environmental quality. With their help, Canada can lead the world's drive towards environmentally responsible resource extraction.

David Blowes, PhD, Carol Ptacek, PhD, Jeff Bain, MSc, Steve Holland, MSc, Julia Jamieson-Hanes, MSc, and Krista Elena, MSc, are part of the University of Waterloo Groundwater Geochemistry & Remediation Research Group, University of Waterloo, EIT 5004, 200 University Avenue West, Waterloo, ON, N2L 3G1, ggr@uwaterloo.ca. and Vivian Giang email: viviang@ualberta.ca

Fully grouted piezometers in a soft Champlain clay deposit Part I: Piezometer installation

Vahid Marefat, François Duhaime, Robert P. Chapuis, and Vincent Le Borgne

Introduction

The fully grouted method has been used since the 1970s to install piezometers for several geotechnical and mining applications. The method has several advantages including ease in installing and reduced costs, especially when boreholes are shared with other geotechnical instruments. Several authors have noted that grout permeability is the most crucial factor influencing the piezometric error (Vaughan, 1969; McKenna, 1995; Contreras et al., 2008; Marefat et al., 2014). For steady-state seepage, Vaughan (1969) proposed that the error may be negligible for a grout with permeability up to two orders of magnitude greater than the adjacent formation permeability. Moreover, based on numerical modelling, Contreras et al. (2008) found a negligible error when the grout had a hydraulic conductivity within 3 orders of magnitude of the surrounding formation. Based on a new analytical solution and numerical modelling results, Marefat et al. (2014) found that pore pressure measurements are reliable when grout permeability is up to one order of magnitude greater than the adjacent clay permeability. Field measurements reported by McKenna (1995) indicated that the grout must be less permeable than the formation to reduce the piezometric error for most soil conditions. In addition to the results of McKenna (1995), there is very little published information on the field performance of fully grouted piezometers. It is worth noting that there is no consensus on the acceptable permeability contrast between the soil and the grout, which is only one of the parameters influencing the piezometric error. The grout physical stability also is an important parameter for successful piezometer installation. The main objective of the project was to appraise the performance of fully grouted piezometers under natural field conditions. The paper introduces a new field site that was equipped in collaboration with GKM Consultants for this purpose. The paper also presents preliminary results regarding pore pressure measurements.

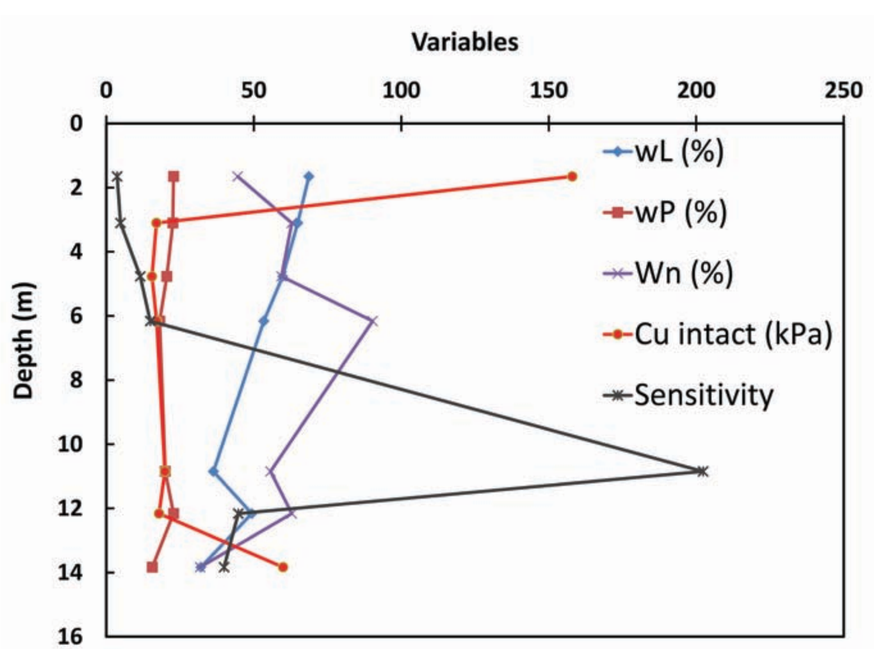


Figure 1: Geotechnical profile for the study site: w_L, liquid limit; w_p, plastic limit; w_n, natural water content; C_u, undrained shear strength.

Site description and stratigraphy

The study area is located in Sainte-Marthe, near Montreal, Canada. The intact Champlain clay is about 10 m thick. It is located under a layer of stiff clay, which is fractured and sometimes oxidized. The fractures can reach down to 6 m below ground surface. The intact clay deposit is soft and sensitive at depths between 6 and 12 m. Sensitivity can reach 200 at a depth of around 10 m (Figure 1). Falling-head laboratory tests provided an average hydraulic conductivity of 1.08×10^{-9} m/s for the intact clay. In the lower portion, the clay is mixed with sand, silt, and coarser material including erratic blocks. The silty layer is underlain by the bedrock. Figure 1 presents a preliminary geotechnical profile for the study site.

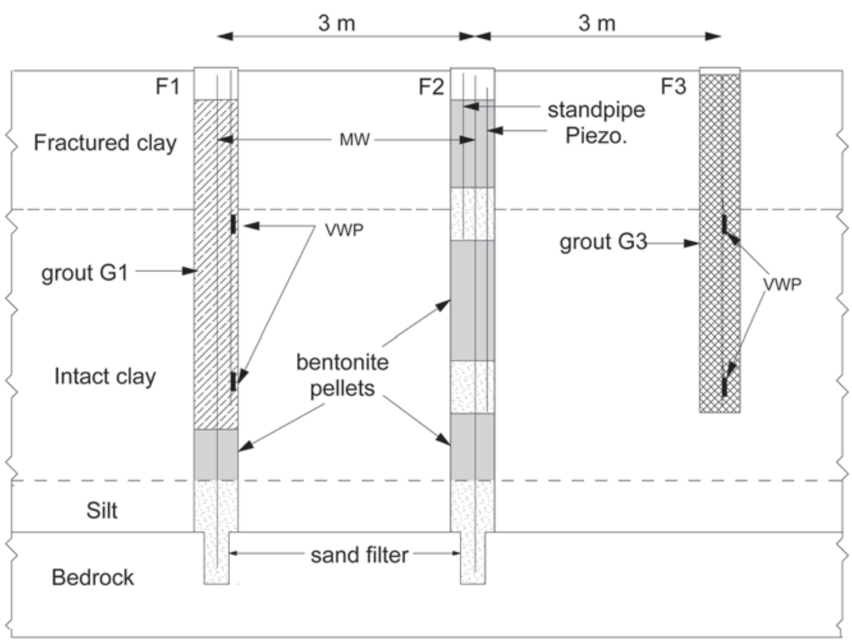


Figure 2: Cross-section of the piezometer installations.

Table 1: Grout recipes, permeability and compressibility for grouts G1 and G3				
	Borehole F1		Borehole F3	
Grout	G1		G3	
Material	M (kg)	Ratio	M (kg)	Ratio
Water	120	5	120	6.5
Cement	24	1	18.5	1
Bentonite	28	1.2	7.5	0.4
SP[1] (% of solid)	2.0		none	
permeability (m/s)	6.1×10^{-9}		1.2×10^{-6}	
compressibility (kPa^{-1})	4.15×10^{-5}		5.9×10^{-5}	
[1]SP = Superplasticizer				

Borehole drilling, grout recipes and piezometer installation

Boreholes F1, F2 and F3 were drilled in October 2016 using wash boring, with a flush-joint casing of diameter 114 mm. The boreholes are spaced 3 m apart. Borehole F3 was drilled to the lower third of the clay layer to a depth of 12.5 m from the ground surface while boreholes F1 and F2 were drilled into the bedrock down to a depth of 22 m. The clay layer was sampled using thin-walled tube samplers (3”) at 1.5-m intervals. Figure 2 shows a cross-section of the boreholes F1, F2 and F3. Two monitoring wells (MWs) were installed in F1 and F2. The MWs’ intake zones were located at the interface with the fractured bedrock and silty layers. In each borehole, two multilevel piezometers were installed approximately at the lower and upper third of the clay layer. The multilevel piezometers monitor pore pressure fluctuations within the clay layer. Boreholes F1 and F3 include two vibrating wire piezometers (VWPs), which were fully grouted at depths of 6.1 and 12.2 m below the ground surface. Borehole F2 contains two standpipe piezometers with a sand filter around their screen. The center of the intake zones for the standpipe piezometers was located at the same depth as the VWPs (Fig. 2).

The vibrating wire piezometers were calibrated before the installation. The piezometers were kept under water until their installation. Once the boreholes were drilled, the VWPs were attached to a ¾-inch grout pipe, which was lowered into the borehole to the appropriate depth. After having positioned the piezometer assembly in the borehole, grouting was started from the bottom up.

Two grout recipes were used to seal the VWPs in boreholes F1 and F3. The grout for F3, later referred to as G3, corresponds to the grout recipe suggested by Mikkelsen (2002). The weight proportions were 6.5 parts water: 1 part cement: 0.4 parts bentonite. Mikkelsen (2002) suggested adding more bentonite to this recipe for viscosity adjustments. Bentonite was not added in this case to obtain the properties for the exact recipe. A new grout recipe (G1) was designed for borehole F1 with a higher bentonite content. The weight proportions for the new recipe were 5 parts water: 1 part cement: 1.2 parts bentonite. The higher amount of bentonite made the grout more viscous. A viscous grout does not easily flow into narrow spaces, for example between the piezometer cord and grout pipe. Therefore, a liquid and chloride free superplasticizer (SP) was added in recipe G1 in order to increase the grout flowability. The concentration of SP was about 2.0% of the solid weight. The laboratory values for the Marsh funnel viscosity were 55 s and 29 s respectively for grouts G1 and G3.

All materials used in this work were produced in Canada. The cement was general use (GU) cement, and the sodium bentonite (Opta Minerals) was a powder. Tap water from the city of

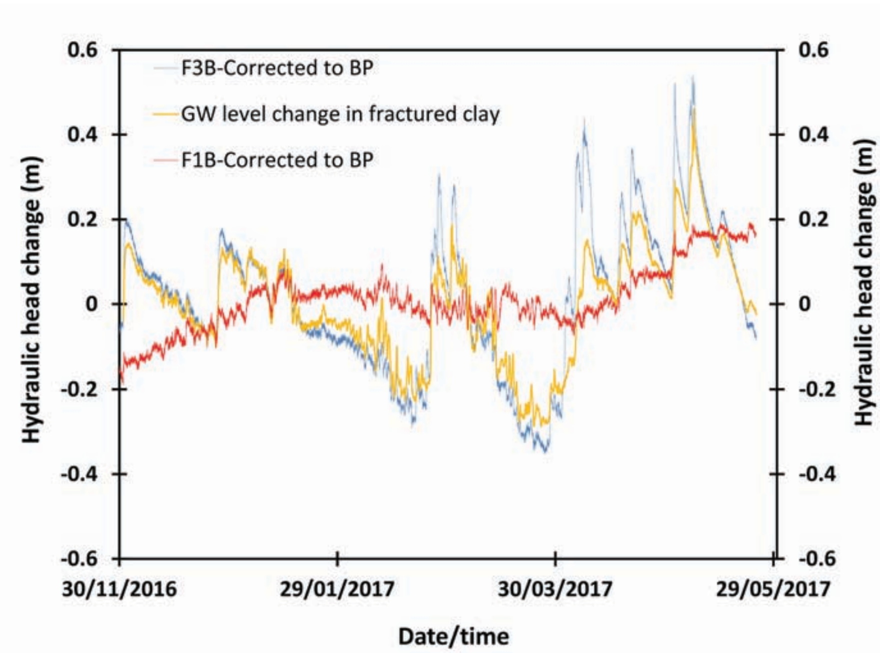


Figure 3. Groundwater level changes in the fractured clay and pore pressures registered in the lower portion of borehole F3 (high-permeability grout) and borehole F1 (low-permeability grout).

Sainte-Marthe was used. The mixing was conducted within a barrel which had an effective capacity of around 150 liters. The ingredients were measured in the field with a portable balance. The water was first poured into the barrel. Then, the cement was slowly added to the water and mixed thoroughly. Next, bentonite powder was gradually added into the barrel to avoid forming clumps.

Grout samples were poured in cylindrical plastic moulds after grout mixing. The grout samples were left in the field to set for a week, and then transferred to a humid room for further curing. During setting, grout G3 was not stable and experienced significant segregation. This segregation was also observed in borehole F3, where grout G3 was used for piezometer sealing. The volume of grout G3 decreased by 25-30 % in both the mould and borehole F3 after the setting period. The low grout viscosity was most probably responsible for the segregation.

The 28-day permeability and compressibility tests were conducted on the hardened 4-inch grout specimens following standards ASTM D5084 and ASTM D4767 (Table 1). The average hydraulic conductivity values of grout G1 and G3 were respectively 6.1×10^{-9} and 1.2×10^{-6} m/s (Table 1). Because the clay hydraulic conductivity is 1.08×10^{-9} m/s, the permeability ratios are around 1100 and 6 for grouts G3 and G1 respectively and the surrounding clay.

Pore pressure response of fully grouted VWPs

Figure 3 presents the change in groundwater level in the fractured clay and hydraulic head in the lower portion of the intact clay. All data were plotted around their respective mean values observed during the study period (November 2016 - June 2017). The observed pore pressure and groundwater level data were corrected for barometric pressure (BP) effects using the multiple regression technique as described in Marefat et al. (2015). As shown in Fig. 3, the groundwater level in the fractured clay responded to several precipitation and snow melting events. Secondly, in the lower portion of the clay layer, the pore pressure response of fully grouted piezometers F1B and F3B differed significantly. The response of F3B, backfilled with high permeability grout (K=1.2×10^{-6} m/s, a permeability ratio of 1100), mimics the groundwater level change in the upper fractured clay, which is acting as an aquifer. This is a consequence of the hydraulic connection between the fully grouted piezometer and the upper aquifer due to the relatively high hydraulic conductivity of grout G3. On the other hand, piezometer F1B backfilled with the low permeability grout (K=6.1×10^{-9} m/s, a permeability ratio of 6) registered a smooth pore pressure response as expected for an intact clay layer.

Discussion

The viscosity of the grout mix and hydraulic conductivity of the hardened grout are very important parameters to register representative pore pressure with fully-grouted piezometers. There is no agreement on the acceptable permeability contrast between the soil and the grout. Furthermore, the current method to check the proper grout viscosity is qualitative. Our field observations have shown that using a grout with a hydraulic conductivity ratio of less than 10 resulted in pore pressure response that was smooth and dampened as expected for intact clay. However, a grout with a permeability ratio of around 1100 resulted in a totally differed response. A hydraulic conductivity ratio of 1100 created a hydraulic connection between the fully grouted piezometer in clay and the upper aquifer. As mentioned in Mikkelsen (2002) the current recipe for the installation of fully grouted piezometers in soft soil is only an initial guide to prepare a suitable grout. This study showed that following the proposed recipes by Mikkelsen (2002) without considering grout consistency or viscosity can result in an unstable grout. According to Mikkelsen (2002) the grout mix should be like "thick cream or pancake batter" to be physically stable and pumpable. However, it appears desirable to evaluate grout consistency quantitatively, using the Marsh Funnel for instance. Marsh Funnel tests can easily be conducted in the field. Further work is needed on the relationship between grout stability and permeability, and Marsh Funnel viscosity.

Conclusion

This paper investigated the field responses of fully-grouted piezometers sealed within a Champlain clay deposit using two grout recipes. The study showed that grout hydraulic conductivity and stability are key parameters for a successful fully-grouted installation. Baseline pore pressure monitoring demonstrated that a grout with a ratio of around 1100 between grout and surrounding clay permeability resulted in a hydraulic short-circuit between the piezometer and the upper aquifer. However, the piezometer that was sealed with a grout with a hydraulic conductivity ratio of less than 10 gave a smooth and dampened response as expected for an intact clay deposit. Our field and laboratory tests also indicate that the physical stability of grout is important and needs to be considered for fully-grouted installations.

Acknowledgment

The authors would like to acknowledge the funding of NSERC and GKM Consultants for this project.

References

Contreras, I. A., Grosser, A. T., and VerStrate, R. H. 2008. The use of the fully-grouted method for piezometer installation. Geotechnical News, 26: 30-37.

Marefat, V., Chapuis, R. P., and Duhaime, F. 2014. Piezometric error for fully grouted piezometers Installed in clay layers. Proceedings of the 67th Canadian Geotechnical Conference, Regina, Canada, October 2014. Canadian Geotechnical Society, 8 pages.

Marefat, V., Duhaime, F., and Chapuis, R. P. 2015. Pore pressure response to barometric pressure change in Champlain clay: prediction of the clay elastic properties," Engineering Geology, 198: 16-29.

McKenna, G. T. 1995. Grouted-in installation of piezometers in boreholes. Canadian Geotechnical Journal, 32(2): 355-363.

Mikkelsen, P. E. 2002. Cement-bentonite grout backfill for borehole instruments. Geotechnical News, 20(4): 38-42.

Vaughan, P. R. 1969. A note on sealing piezometers in boreholes. Géotechnique, 19(3): 405-413.

Vahid Marefat
Laboratory for Geotechnical and Geoenvironmental Engineering (LG2), École de technologie supérieure, 1100 Notre-Dame Ouest, Montreal, QC, H3C 1K3, Canada, vahid.marefat@polymtl.ca T; 1-438-931-9797

François Duhaime
Laboratory for Geotechnical and Geoenvironmental Engineering (LG2), École de technologie supérieure, 1100 Notre-Dame Ouest, Montreal, QC, H3C 1K3, Canada

Robert P. Chapuis
Department CGM, École Polytechnique de Montréal, P.O. Box 6079, Station CV, Montreal, QC, H3C 3A7, Canada

Vincent Le Borgne
GKM Consultants, 2141 Nobel, Suite 101, Sainte-Julie, QC, J3E 1Z9, Canada

Introduction by Richard Guthrie, Editor

Summer 2017

Mosquitoes, mud, hail storms and landslides! I hope your field season was as exciting as mine and you're safely back in the office compiling data and producing analysis.

If you are working on dams, planning for flood mitigation, or frankly, working any hazard that is affected by rainstorms, then you are frequently asked how to incorporate climate change into your design, models or analyses. This quarter I'm pleased to present to you the fantastic work of Slobodan Simonovic and the team at Western University. Together with the Canadian Water Network, they developed an online tool that downscales user-selected global climate model scenarios and provides Intensity-Duration-Frequency curves as an output.

It's free.

It's Canadian.

It's really, really useful.

Have a look (the link is in the paper) and think about how it might apply to your work.

Announcing

7th Canadian Geohazards Conference – Geohazards 7: Engineering Resiliency In A Changing Climate http://www.geohazards7.ca/

The Canadian Geotechnical Society (CGS) is pleased to announce the 7th Canadian Geohazards Conference – Geohazards 7 – to be held June 3-6, 2018 at the Coast Canmore Hotel & Conference Centre in Canmore, Alberta. The CGS's Geohazards conferences are the premiere forums in Canada for the sharing and dissemination of scientific and engineering knowledge related to geohazard assessment and risk management.

Canmore is ideally situated for hosting Geohazards 7. It is located within easy travel distance from the Calgary International Airport, and is less than a 30-minute drive from Banff National Park. Heavy rainfall in June 2013 resulted in the worst floods in Alberta's history. Landslides, debris floods and debris flows cut off highway and rail access to Banff and Canmore, and many homes constructed on alluvial fans were destroyed. Municipal governments, the Province and the engineering and geoscience community have since carried out aggressive programs to quantify geohazard risk, increase public awareness of hazards, and are constructing mitigation measures to reduce future risk. Canmore is a terrific venue to showcase the results of some of these initiatives, which will feature in the conference program and fieldtrip.

This conference will be of interest to engineering and geoscience students and consultants, industry, and government agency representatives who are involved in planning, approval, construction and operation of infrastructure and residential development in areas prone to geohazards. The conference will touch on the full gamut of hazards and risks associated with floods, debris flows, landslides, snow avalanche, earthquakes, volcanic eruptions, degrading permafrost and more. Arming participants with greater awareness of methods for quantifying geohazard magnitude and frequency for risk assessment and mitigation design, quantifying uncertainty in a changing climate, and communicating with the public about geohazard issues, are key objectives of the conference.

Closing Notes

Thank you for your letters! If you have a paper or project related to Geohazards that you think would be interesting to GN readers, please send me note at Richard.guthrie@stantec.com.

Until December,

Rick

Adapting to Climate Change: a Web Based Intensity-Duration-Frequency (IDF) Tool

Slobodan P. Simonovic

Introduction

Extreme rainfall events affect water quality, infrastructure management and public safety. Municipalities across Canada, including Thunder Bay, Sault Ste. Marie, Peterborough, Hamilton, Mississauga, London, Calgary, Edmonton, Moncton, Fredericton and Winnipeg have recently been affected by extreme rainfall related flooding. Together, these events have caused billions of dollars of damages and losses for homeowners, insurers and municipalities. The Canadian insurance industry has experienced a notable trend in disaster losses over the past thirty years. Three of the most expensive insurance industry disaster loss events from 1983 to 2014 were associated with flooding, including: $5.15 billion in southern Alberta (2013) and $1 billion (2013) and $732 million (2005) in the Greater Toronto Area.

Rainfall intensity-duration-frequency (IDF) curves are used for a number of water management applications in Canada, including the planning, design, operation and maintenance of stormwater management systems, wastewater systems, stormwater detention ponds, culverts, bridges, dams, pumping stations, roads and master drainage planning.

IDF curves have traditionally been developed based on the assumption that analysis of historical rainfall records can be used to predict future rainfall conditions. This is commonly referred to as stationarity; the assumption that the environment will behave as it always has. According to this assumption, historical data collected at rainfall monitoring stations are analyzed and used to develop statistics that give an indication of the likelihood of future extreme rainfall events. For example, municipal stormwater management systems are typically designed to accommodate flows associated with 2 to 100 year return period events lasting 10 minutes to 24 hours. However, it is now widely acknowledged that past climate conditions are no longer indicative of future climate.

Climate change will result in intensification of the global hydrologic cycle, causing increased intensity of wet and dry extremes and accompanying floods and droughts. One of the most significant expected impacts of climate change in Canada is an increase in the intensity and frequency of extreme weather events. While the impacts of climate change vary throughout Canada, an example from southern Ontario suggests an increase in the frequency of storms of equivalent size. A 1-in-100 year event, for example, may become a 1-in-30 year event in the next few decades (Peck et al, 2012). Consequently infrastructure built to manage 1-in-100 year rainfall events based on existing IDF curves will be grossly under-sized or under-designed for the job, not perform as intended and create considerable economic implications for existing and planned water management infrastructure across Canada.

A New IDF Tool

The process of updating and incorporating climate change impacts into local IDF curves is highly technical. The lack of locally relevant climate change impact information has been noted as a challenge that is difficult to overcome in many municipalities, including those with very high adaptive capacity (Sandink et al, 2016).

The intensity-duration-frequency under climate change tool (IDF_CC Tool) was designed to allow water managers, municipal infrastructure professionals, provincial and federal government agencies, researchers, consultants and non-profit groups to quickly develop estimates related to the impact of climate change on IDF curves for almost any local rain monitoring station in Canada.

How does the IDF_CC tool work?

The IDF_CC Tool was designed as a simple and generic decision support system to generate local IDF curve information that accounts for the impacts of climate change (Simonovic et al, 2016). It is publicly accessible online (www.idf-cc-uwo.ca), with a user-friendly Google Maps interface (Fig. 1). The tool provides precipitation accumulation depths for a variety of return periods (2, 5, 10, 25, 50 and 100 years) and durations (5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours), and allows users to generate IDF curve information based on historical data (Fig.2), as well as future climate conditions that can inform infrastructure decisions (Fig. 3).

The IDF_CC Tool allows users to select multiple future greenhouse gas concentration scenarios (RCPs) and apply results from a selection of 9 Global Climate Models (GCMs) downscaled using two downscaling methods that simulate various climate conditions to local rainfall data (Pacific Climate Impacts Consortium - PCIC, 2013). The tool also applies a novel downscaling method with localized temporal data (Srivastav et al, 2014).

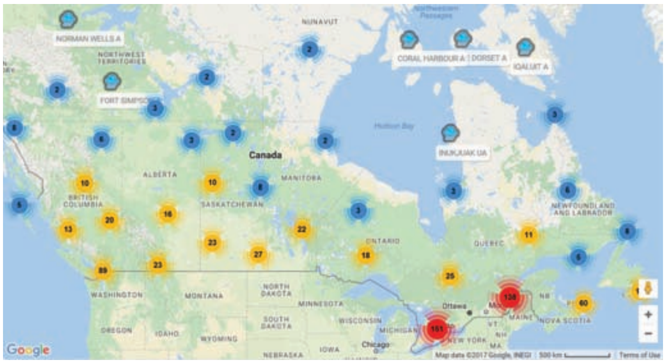
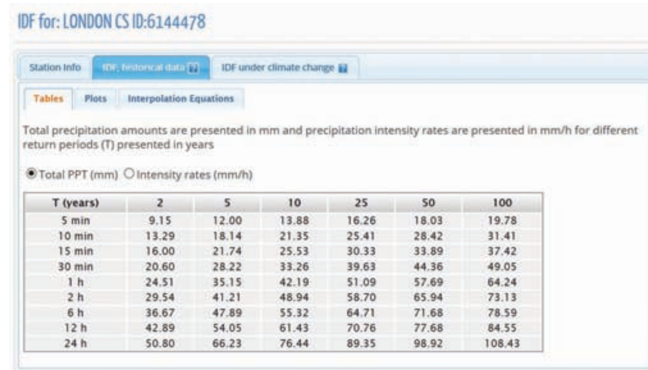


Figure 1: IDF_CC Tool GIS interface.


IDF for: LONDON CS ID:6144478

Station Info | IDF, historical data | IDF under climate change

Tables | Plots | Interpolation Equations

Total precipitation amounts are presented in mm and precipitation intensity rates are presented in mm/h for different return periods (T) presented in years

Total PPT (mm) Intensity rates (mm/h)

T (years)	2	5	10	25	50	100
5 min	9.15	12.00	13.88	16.26	18.03	19.78
10 min	13.29	18.14	21.35	25.41	28.42	31.41
15 min	16.00	21.74	25.53	30.33	33.89	37.42
30 min	20.60	28.22	33.26	39.63	44.36	49.05
1 h	24.51	35.15	42.19	51.09	57.69	64.24
2 h	29.54	41.21	48.94	58.70	65.94	73.13
6 h	36.67	47.89	55.32	64.71	71.68	78.59
12 h	42.89	54.05	61.43	70.76	77.68	84.55
24 h	50.80	66.23	76.44	89.35	98.92	108.43

Figure 2: Sample of IDF_CC Tool output – IDF curves based on the historical data. Users can display IDF curves in tabular form, plots and equations. Version 2 of the tool incorporates IDF curves fitted using Gumbel and General Extreme Value (GEV) distributions.

Global climate models and spatial downscaling

The IDF_CC Tool allows users to apply data generated from one (or a combination) of 9 GCMs downscaled using two different methods to adjust local IDF curves, based on the gridded data provided by PCIC (2013). The GCMs are designed to simulate climate variables on a coarse spatial scale – for example, 250 km by 250 km. To generate future conditions using GCMs, the key input is greenhouse gas emissions, but land-use, energy production, global and regional economies, and population growth also affect future climate scenarios and are incorporated into the GCMs. The GCM output is spatially downscaled to 10 km by 10 km grid using historical daily gridded climate data for Canada and two different downscaling methods: Bias-Correction Spatial Disaggregation (BCSD) and Bias Correction/Constructed Analogues with Quantile mapping reordering (BCCAQ).

Temporal downscaling

The GCM data is provided on daily time scale. That makes them insufficient for the development of IDF curves. To make daily GCM results usable for the update of IDF curves, they must be downscaled both temporally. A statistical downscaling method was applied to downscale GCM results for the creation of new IDF curves (Srivastav et al, 2014).

Representative concentration pathways

The international climate modeling community has adopted four RCPs through the Intergovernmental Panel on Climate Change (see Figure 4). These scenarios represent a range of climate change impacts, from low to high severity. These scenarios are measured by radiative forcing (i.e., the net change in the radiation balance at the tropopause, or top of the atmosphere — due to climate change or other external drivers) and measured in watts per square metre, as well as carbon dioxide equivalent concentration, a measure of radiative forcing potential caused by a given type of greenhouse gas (as represented by the equivalent amount of carbon dioxide). The most severe impacts are predicted if no climate policy is adopted, while the lowest risks are associated with stringent requirements for climate policy that limit and reduce greenhouse gas emissions.

Rain station information

The IDF_CC Tool stores data associated with 700 Environment Canada operated rain stations from across Canada. Roughly 500 of these stations have 10 years of data – the minimum time series used by Environment Canada to develop IDF curves for a specific location. Users can also create and share their own rain station information.

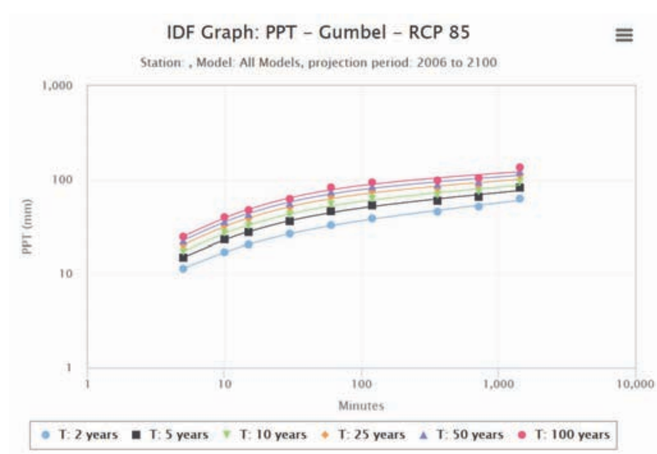


Figure 3: Sample IDF_CC Tool output – An IDF curve updated using the ensemble option and RCP 8.5. Users can compare historical IDF curves to curves that incorporate downscaled GCM outputs. Users can also click different tabs to compare outputs for different RCPs and rainfall return periods.

RCPS	DESCRIPTION	CO2 CONCENTRATION EQUIVALENT (PPM)	PATHWAY	SCENARIO SEVERITY
2.6	A peak in radiative forcing of approximately 3 watts per square metre (W/m^2) before 2100, declining to 2.6 W/m^2 by 2100 Also referred to as RCP3PD	Peak of ~490 and then decline by 2100	Peak and decline	Lowest
4.5	Stabilization at 4.5 W/m^2 by 2100 without overshoot	650 (stabilized after 2100)	Stabilization without overshoot	Medium-low
6.0	Stabilization at 6 W/m^2 by 2100 without overshoot	850 (stabilized after 2100)	Stabilization without overshoot	Medium-high
8.5	Rising pathway resulting in 8.5 W/m^2 by 2100. Radiative forcing continues to rise beyond 2100	>1,370 in 2100	Rising	Highest

Figure 4. Description of Representation Concentration Pathways (RCPs)

Using the IDF_CC Tool

After selecting a rain-station of interest, users can view information on that station, including the length of the data record. To create IDF curves for future climate change conditions, users can select a 20-year projection period for any time between 2006 to 2100, followed by one or multiple GCM or GCM ensemble options. After selecting these options, the tool will automatically downscale GCM results and apply GCM results to the local rain station data, providing future IDF curves in table or graphical format and allowing the user to compare the impacts of multiple RCP scenarios and rainfall return periods, and to compare historical IDF curves to these updated curves.

Implications for decision makers

Increasingly frequent extreme weather events due to a changing climate have profound implications for the planning, design and maintenance of stormwater management infrastructure across Canada. The IDF_CC Tool allows municipalities to more accurately forecast future rainfall events and make informed planning decisions that ensure stormwater infrastructure can handle increased stresses associated with climate change scenarios. This stormwater management infrastructure will help to mitigate the risk of urban flooding events, leading to more resilient and sustainable cities and long-term cost savings. Improved planning using this tool will help protect people, property and ecosystems from the negative impacts of extreme storms caused by climate change

References

PCIC, (2013) "Statistically downscaled climate scenarios", https://pacificclimate.org/data/statistically-downscaled-climate-scenarios last accessed July 12, 2017.

Peck, A., P. Prodanovic, and S.P. Simonovic, (2012) "Rainfall intensity duration frequency curves under climate change: City of London, Ontario, Canada", Canadian Water Resources Journal, 37(3):177-189.

Sandink, D., S.P. Simonovic, A. Schardong, and R. Srivastav, (2016) "A Decision Support System for Updating and Incorporating Climate Change Impacts into Rainfall Intensity-Duration-Frequency Curves: Review of the Stakeholder Involvement Process", Environmental Modelling & Software Journal, 84:193-209.

Simonovic, S.P., A. Schardong, D. Sandink, and R. Srivastav, (2016) "A Web-based Tool for the Development of Intensity Duration Frequency Curves under Changing Climate", Environmental Modelling & Software Journal, 81:136-153.

Srivastav, R.K., A. Schardong and S.P. Simonovic, (2014) "Equidistance Quantile Matching Method for Updating IDF Curves Under Climate Change", Water Resources Management: An International Journal, 28(9): 2539-2562.

Slobodan P. Simonovic,
Ph.D, P.Eng, Member CAE, Fellow CSCE, ASCE and IWRA
Professor, Department of Civil and Environmental Engineering
Director of Engineering Works, Institute for Catastrophic Loss Reduction
The University of Western Ontario, London, Ontario, Canada N6A 5B9
Tel: (519) 661-4075
Fax: (519) 661-3779
E: simonovic@uwo.ca

Don Welch

It is with great sadness that we share the passing of Don Welch on June 12, 2017. Don was a senior tailings engineering, Principal, and Senior Consultant in the Mississauga office of Golder for over 50 years.

Don was born and grew up in Ottawa, and went to McGill University in Montreal to study Civil Engineering. Part of his decision to choose McGill was his love of skiing—he was on the McGill ski team for four years. After graduation, he moved to Europe where he completed post-graduate studies in Soil Mechanics and Foundation Engineering. Upon his return to Montreal, a friend invited him to hear a lecture by Golder founder Victor Milligan and Don was inspired to join Golder's Toronto office in December 1964. He became an Associate in 1973 and a Principal in 1977. Initially, Don worked on many overseas projects for Golder including road projects in South Africa and Paraguay. In the early 1970s, as one of thirteen Golder expatriates, he was responsible for the geotechnical investigations, analyses and reporting on final engineering studies for three hydroelectric dams in northern Greece. While in Greece, Don met his future wife, Foula, who worked for the original SNC, with which Golder was carrying out the project on a joint basis. Greece was followed by work and living in Hong Kong and Egypt. With all the travel, Don acquired the nickname "the Wandering Welch".

Don became an acknowledged global expert in the management of mine tailings—from site selection studies through operation to decommissioning. Since the late 1970s, Don worked almost exclusively on the disposal of mine tailings and waste rock as a group leader, project manager, project director, advisor and review consultant.

He was the initial engineering manager for the 300 m high Antamina tailings facility situated in a high-seismic risk zone of the Peruvian Andes. Other major projects include the large Collahuasi copper tailings facility in Chile, feasibility studies for an 800 million ton copper basin in Argentina, the large Goro nickel project in New Caledonia and Inco's 150 million ton Voisey's Bay nickel project in Labrador. Don was heavily involved with the expansions and subsequent closures of the Rio Algom and Denison uranium tailings facilities in Elliot Lake, Ontario,

A prolific writer, Don authored or co-authored 38 technical papers on tailings and paste. He was one of only two consultants who participated with 17 staff from mining companies on the Mining Association of Canada committee that developed the 1998 "Guide to the Management of Tailings Facilities". He helped incorporate tailings dams into the Canadian Dam Safety Guidelines and also developed numerous internal Golder guides and tools for water balance modelling and mine waste management. For several years, Don was also heavily involved with the Association of Consulting Engineers of Canada (ACEC).

Renowned for his passion, experience, and development of junior staff, Don's leadership in Golder and in the mining world are well-recognized and will be deeply missed.

Oldrich Hungr

Dr. Oldrich Hungr, P.Eng./P.Geo., FGC and professor Emeritus in the department of Earth, Ocean and Atmospheric Sciences at UBC passed away at his son's home in Grenoble on August 10, 2017. Oldrich was one of Canada's foremost Geotechnical Engineers and ran the Landslide Hazards Research Geological Engineering Program at UBC. He developed or co-developed new techniques and applications for slope stability analysis and assessment including some of the earliest applications of magnitude-frequency assessment, to rock fall and debris flow runouts, to his many applications analyzing the behaviour of landslides. He is perhaps best known for his DAN suite of models that describe the dynamic behaviour of rapid landslides including entrainment, runout distance, and velocity. Those models continue to be used the world over. His tenure at UBC inspired cohorts of students and grad students to do some of their best work, and he authored or co-authored dozens of seminal papers on landslides and landslide mechanics. In his own words, he was interested in landslides, in the modelling of landslide behaviour, in applied geomorphology and terrain mapping, and in the engineering geology of excavations. His passing is a loss for the geotechnical community and will be deeply felt by many. Despite his extraordinary achievements, Oldrich continued to be active in the field (his most recent articles were on the Oso Landslide, numerical modelling, and rock avalanche case studies) and continued to nurture personal relationships with those around him. In the recent words of one of his long-time colleagues, "…he was always so empathic….". Perhaps that is what will be missed the most.

In 1982 members of the Canadian Geotechnical Society conceived the idea of a book recording the development of geotechnical engineering in Canada. Since a number of the early practitioners were still living at the time, foremost among them Bob Hardy and Bob Legget, the approach was intended to create "a living history ... through the eyes and recollections of living engineers, to show the humanity that underlies the development of major geotechnical projects in Canada."

As this book is now out-of-print, we will be publishing excerpts from it over the next few editions of Geotechnical News. Ultimately, a pdf copy will be available.

Geotechnical Engineering in Canada An Historical Overview

Cyril E. Leonoff

Terzaghi trained several other men who would go on to eminence in soil mechanics, and his tenure at MIT can logically be considered the birth of soil mechanics in America.

Terzaghi returned to Vienna in 1930 as a professor at the Technical University, where his department soon became a renowned centre of soil mechanics attracting students from many countries. And he continued to consult on important projects throughout Europe, North Africa, and the Soviet Union.

In 1936, as part of the Harvard Tercentenary celebrations, Arthur Casagrande, as Conference Secretary, convened the First International Conference on Soil Mechanics and Foundation Engineering, with Karl Terzaghi as Conference President. Despite Terzaghi's initial misgivings that it was premature, the conference was a great success, attracting 206 delegates from 20 countries. At this meeting, Terzaghi and Casagrande were commissioned to set up an executive committee to continue the work of the conference, an action which became the catalyst for establishment of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE).

In 1936 Terzaghi became a visiting lecturer at the Harvard Graduate School of Engineering. After Hitler occupied Austria in 1938, Terzaghi moved permanently to Harvard, becoming Professor of the Practice of Civil Engineering, where he taught courses on engineering geology and applied soil mechanics. He also lectured at the Imperial College of Science and Technology in London, England, at MIT, and at the University of Illinois. His 1948 book, *Soil Mechanics in Engineering Practice,* coauthored with Professor Ralph B. Peck of Illinois, became the seminal text for all engineers practicing in the field of soil mechanics. Terzaghi also produced more than 100 scientific papers during his career.

Terzaghi was never content to restrict his work to experimenting in the laboratory or theorizing at his desk. Early in his career he realized that soil mechanics could only be successfully applied as a tool in engineering practice through a capacity for judgment based on years of contact with actual field conditions. Whereas the designer of structures deals with steel and concrete, whose properties are constant when manufactured in accordance with standard specifications, the designer of earthwork engineering has to apply the laws of mechanics and hydraulics to an infinite variety of heterogeneous materials formed as a result of natural processes. Design assumptions have always to be verified or modified by observing, first hand, soil conditions as they are exposed and measured during construction. In his paper, "Soil Mechanics in Action," Terzaghi succinctly outlined his approach: "Soil mechanics will not consistently serve its purpose until practicing engineers come to realize that it is a supplement to, and not a substitute for, common sense combined with knowledge acquired by experience."

When Terzaghi's controversial theories began to circulate outside of university walls, they were first met with skepticism among American civil engineers. But, as their validity was consistently demonstrated in practice, Terzaghi's stature in the engineering profession became universally acclaimed, and his expertise as a consultant was avidly sought in many parts of the globe. But he carefully husbanded his time, accepting only those assignments that advanced the science and demanded artful, novel solutions.

Terzaghi's first exposure to the soils of the Pacific Northwest came during his visit to the United States in 1912-1913, when he had an opportunity to observe the instability of clay slopes in Washington and Oregon. In 1929, as Professor of Foundation Engineering at MIT, Terzaghi was engaged by the industrial engineers V.D. Simons Inc. of Chicago, designer of the Grays Harbor Pulp and Paper Mill in Hoquiam, Washington. Terzaghi was asked by this firm to analyze the cause of settlement which was occurring beneath the mill's foundation piles at tidewater. In a landmark report containing detailed computations, Terzaghi determined that the setttling was not, as previously believed, the result of "the weight of fill forcing the piles into the ground." In fact settlement occurred "as if the piles were non-existent." The settlement was due to the gradual consolidation of a soft clay layer, 30 to 50 feet thick, located at a depth of 120 feet below the surface of the tidal flat, later described by Terzaghi as "drowned valley clay."

The field engineer on the Grays Harbor job was the boss's son, Howard A. Simons. H.A. Simons later moved to Vancouver, British Columbia, where he established the international engineering company that bears his name. Faced with the design of a number of pulp mills on Vancouver Island, having similar tidewater conditions, in 1945 Simons brought Terzaghi to B.C. as a consultant. Terzaghi found British Columbia much to his liking, enjoyed its beautiful scenic landscape, and was attracted to the experience of participating in the development of a new country with many technical challenges. Here, during the last decade-and-a-half of his consulting practice, Terzaghi found many of his most challenging projects, on the foundations of pulp mills, and on hydroelectric and water supply dams.

Canadian Soil Mechanics Pioneers

Ibrahim Folinsbee (Ibe) Morrison (1889-1958) is regarded as the father of soil mechanics in Canada. Born near Boston, Massachusetts, he received his civil engineering degree from MIT in 1911. Morrison joined the University of Alberta as a lecturer in civil engineering in 1912, and was appointed Professor of Applied Mechanics in the civil engineering department in 1922. Commencing with the first graduation class, Professor Morrison, having a keen mind and a gift for sharp dialogue, taught and inspired virtually every engineering student at the university for over four decades.

I.F. Morrison was a perpetual student. Self-taught in German, he read Terzaghi's and other works, and began to introduce soil mechanics into his courses. By 1925 "Foundations" was recognized as a subject in the fourth year civil engineering curriculum. In 1930 an elementary soils laboratory was set up for classification tests, and by 1931 soil mechanics was recognized as a separate segment of the foundation course. In 1936 Morrison was one of eight Canadians to attend the First International Conference on Soil Mechanics and Foundation Engineering at Harvard. In 1937 his course was officially designated Soil Mechanics and Foundations. Active in professional practice and research, Morrison contributed extensively to technical discussions in Canada and the United States, and authored textbooks and papers. "The Fundamentals of Pile Foundations," published in 1939 in *The Engineering Journal*, was an early paper on the subject of foundations.

Robert M. (Bob) Hardy (1903-1985) graduated as a gold medallist in civil engineering from the University of Manitoba in 1929 and received his master's degree in 1930 from McGill University, specializing in structural engineering. In September 1930 he joined the Faculty of Engineering at the University of Alberta as a sessional lecturer. Professor I.F. Morrison encouraged his bright, younger colleague to take the soil mechanics courses at the Harvard Graduate School of Engineering taught by Casagrande and Terzaghi, which Bob Hardy did in 1939-1940.

When he returned to Alberta, Hardy established a state-of-the-art soil mechanics laboratory, and by September 1945, a graduate program. In 1946 he was appointed Professor, Head of the Department of Civil Engineering and Dean of Engineering. Thus, under the impetus of Morrison and Hardy, the University of Alberta became the first soil mechanics school in Canada, attracting large numbers of students from every province and from many countries abroad.

The beginning of applied soil mechanics in Canada dates as early as 1928, when Morrison and later Hardy commenced a long-lasting consulting association with Montreal Engineering Company and Calgary Power in the design and construction of several early power projects in Alberta. In 1942-43 Hardy carried out research studies on muskeg and permafrost for the US Army Corps. of Engineers, who were then hastily constructing the Alcan Military Highway—the first such studies conducted in North America. During the war Hardy also consulted on Canadian airports, then being built from Vancouver Island to Newfoundland.

In April 1951, Hardy, along with L.A. (Chick) Thorssen, a concrete specialist, established Engineering and Construction Services, a commercial soil and concrete testing laboratory in Edmonton—one of the first in Canada. After Thorssen left, in 1954 the company was renamed R.M. Hardy and

Associates. During the remainder of his long career, Hardy carried on an extensive consulting practice and was widely regarded as the eminent soil mechanics consultant in Canada.

Concurrent with Morrison's and Hardy's work, the other significant application of soil mechanics in Canada was initiated by the Prairie Farm rehabilitation Administration, a federal government agency that was building water conservation projects in Alberta, Saskatchewan, and Manitoba. Since its inception in 1935, the PFRA had been helping drought-stricken farmers to build small earth dams and reservoirs on their properties. By 1939 the agency was becoming involved in a few larger dams intended to provide reservoirs for entire communities, and the soil problems inherent in these structures were being encountered.

The catalyst in introducing soil mechanics to the PFRA was Dean C.J. (Chalmers Jack) Mackenzie (1888- 1984) of the University of Saskatchewan. Born in St. Stephen, New Brunswick, in 1909 Dr. Mackenzie had earned his engineering degree from Dalhousie University and in 1915 his master of civil engineering from Harvard University. In 1912 he joined the University of Saskatchewan as a sessional lecturer. After serving in the Canadian Expeditionary Force, 1916-1918, in World War I, and being awarded the Military Cross, he returned to the university, becoming first Dean of the College of Engineering in 1921. Mackenzie a structural engineer, was a consultant on civil engineering projects across Western Canada - among them in 1932 the design of the Broadway Bridge, a reinforced concrete arch structure in Saskatoon, and in 1935-1937 a reinforced concrete bridge across the North Saskatchewan River at Borden.

On these major projects, Dr. Mackenzie realized the need for the application of soil mechanics technology to the design of bridge foundations. One of Mackanzie's brightest graduate students was David Kirkbride, who worked on construction supervision of the Borden Bridge.

David Spencer Kirkbride (1913-1995) was born in Calgary. But at the age of four, when his lawyer father died, he came to Regina with his mother Isabelle Spencer) to live with her parents. David graduated from Central Collegiate, winning the Governor General's Bronze Medal, then attended the University of Saskatchewan, 1930-1937, where he earned a bachelor's degree in civil engineering and a master's degree majoring in structural.

Upon graduation, finding no employment in Saskatchewan, Kirkbride obtained work with Monsarret and Pratley, bridge engineers in Montreal, but when that job petered out, he moved on to Canadian Industries Limited in that city to work as a draftsman.

Through his contacts with Mackenzie and the bridge firm, Kirkbride became aware of the developments taking place in soil mechanics and foundation engineering. He approached the leading foundation firm in Canada, the Foundation Company in Montreal, proposing that they should employ him, sponsor his graduate training at Harvard, and thereby gain the benefit of soil mechanics knowledge on his return. But they were skeptical of the practical application of the new science, and nothing came of this. Nevertheless, Kirkbride applied to Harvard Graduate School, obtained a scholarship, and in 1938-1939 became the first Canadian to earn a master's degree in soil mechanics.

Upon graduation, Kirkbride tried to persuade the Dean of Engineering at McGill University to introduce soil mechanics into their teaching program, but at the time the Dean didn't appreciate that the subject was worthwhile. However the PFRA was planning some larger dam projects and Dr. Mackenzie was influential in persuading this organization that they should utilize the soil mechanics training. that Kirkbride had acquired at Harvard. He was hired on staff as a junior engineer. Kirkbride worked for the PFRA only from his graduation in June through October 1939. During this short period, he set up the first elementary wash-bore drilling equipment, used to augment the digging of test pits and the boring of auger holes, the methods heretofore used which were limited in depth. Kirkbride also recommended to management the need for laboratory facilities, and gave some preliminary soil mechanics advice on a few dam sites. War came in September 1939, and knowing that the PFRA activities would be curtailed during the war, Kirkbride returned to CIL to work in the war effort with its wartime counterpart Defence Industries Limited.

Kirkbride spent the remainder of his substantial career with DIL and CIL, first in the engineering department, which greatly expanded in the war, then as resident engineer on the Atomic Energy Plant at Chalk River, Ontario. After the war, Kirkbride took on senior management roles with CIL, ending his career in the late 1970s as Vice-President for Western Canada. Thus he never made his mark in soil mechanics. Yet David Kirkbride had introduced soil mechanics into the PFRA and opened the door for others.