Introduction by John Dunnicliff, Editor

This is the seventy-fourth episode of GIN. Three articles this time. They're all self-explanatory, so there's no need for the editor to bore you with introductions. Here's a table of contents:

- A report on the US Society of Dams workshop in Arizona in February on state-of-the-art technologies for monitoring dams and levees, by Christopher Hill and Pierre Choquet.
- The second episode of Field Monitoring Challenges, by Marcelo Chuaqui and Wing Lam.
- An article by me on some on-line sources of information about geotechnical instrumentation.

Lessons learned. I need you

Nobody has responded to my plea for help with GIN, so here's a repeat of the plea:

> A significant number of articles in recent GINs have described new and emerging technologies. It's been exciting for me to learn about these, but I'd now like to take a step towards nuts-and-boltsy things, and lessons learned, primarily lessons learned from unexpected events in the field. All of us in this business have such stories to tell, and if we share them we can learn from each other. So – please – ask yourself whether you could contribute some of these stories for GIN. They don't need to be complex things, and you can refer to "Project X". I well understand that you may have difficulty with employer or client approval, in which case I'm happy to refer to you as "Anonymous", and promise not to disclose your name to anyone.

In the past, I've had very little response to pleas for contributions, and have usually had to rely on arm-twisting. **Please let me hear from you.**

PLEASE let me hear from you. The first step is an abstract – see "How to submit articles" on www.geotechnical-news.com/instrumentation_news.php. If I don't hear from you, GIN may die.

The April 2103 continuing education course in Florida

There were 64 registrants at the course, and 12 lecturers. 15 countries were represented. Thank you to all registrants and lecturers for participating.

I've decided that there will be no more of these courses in Florida, because age is taking its toll. Perhaps elsewhere. Watch this space!

Closure

Please send contributions to this column, or an abstract of an article for GIN, to me as an e-mail attachment in MSWord, to *john@dunnicliff.eclipse.co.uk, or by mail: Little Leat, Whisselwell, Bovey Tracey, Devon TQ13 9LA, England. Tel. +44-1626-832919.*

Sei Gsund! (Yiddish)

USSD presents workshop on state-of-the-art monitoring technologies

Christopher J. Hill and Pierre Choquet

At the USSD (US Society on Dams) Annual Meeting and Conference in Glendale, Arizona in February 2013, the Committee for Monitoring Dams and their Foundations hosted a workshop titled "State of the Art Technologies for Monitoring Dams and Levees." Fourteen speakers made short presentations about a wide variety of topics, followed by questions and discussion in the seven-hour event. Moderating the workshop were Pierre Choquet of RST Instruments and Christopher Hill of MWD of Southern California.

Two speakers came from Europe to describe the use of fiber optic cables for monitoring. Sam Johansson of HydroResearch in Sweden, and Daniele Inaudi of Smartec in Switzerland described use of fiber optic cables for temperature and strain monitoring, respectively. Johansson made the point that temperature monitoring for dams is a long-established practice to estimate seepage flows, especially in some European countries, and fiber optic is merely a newer technology for temperature measurements with the added advantage of distributed measurements. Inaudi gave a number of examples of strain measurement especially for dam and levee slope deformation monitoring and showed how the hardware has improved recently. Among these improvements are fiber optic cables designed especially for buried applications as well as improved software.

Four presenters described several geophysical techniques that can be used for dam monitoring. Gordon Anderlini of BC Hydro uses crosshole seismic shear wave tomography to characterize and confirm the remediation of a past sinkhole. Continued monitoring of the sinkhole repairs and embankment dam is done using the simplified common elevation method which has proven to be very repeatable. By monitoring changes in patterns of seismic wave velocity between boreholes, Anderlini monitors changes in void ratio and/or stress with time and expects to get early warning of future sinkhole or internal erosion development.

Phil Sirles of Zonge International, a geophysics company, described how traditional geophysical methods, especially seismic, resistivity and self-potential are used beneficially for assessment of internal erosion, seepage mapping and soil composition in dam embankments and foundations. He also discussed a project that is underway deploying wireless solar-powered self-potential and resistivity instrumentation for early detection of seepage and internal erosion using buried electrodes and passive sensors, thereby enabling "4D" monitoring, i.e., geophysical measurements through time.

William Doll of Battelle presented the background and the current status of an airborne electromagnetic survey system using a low-flying helicopter. This system was tested on a levee segment and showed good correlation with areas that are dominated by clays or sands as well as known sand boil locations.

Yogi Sookhu of Gotham Analytics talked about extensive data communication systems being used to transmit multiple streams of monitoring data along robust paths. One data stream he focused on is from long-wave infrared cameras that may be used to measure wet surfaces and provide notification in the event of sudden enlargement of wet areas.

There were four presentations focused on topics of "traditional" instrumentation. Jay Stateler of the US Bureau of Reclamation talked about anomalous readings and the process by which an anomalous reading is turned into an interpretation of how the dam is performing. Jim Hummert of URS showed results from DamSmart and related products that focus on helping the user manage and graph data. Pierre Choquet of RST Instruments and Christopher Hill of Metropolitan Water District of Southern California presented information about the progress of data acquisition systems focusing on changes in communication topology and energy usage. These improvements are gradually making automatic data acquisition systems more and more practical for users. Finally, in this section, Erik Mikkelsen of GeoMetron made a case for the value of fully-grouted piezometers and described how to install them for best effect.

The final section of the workshop was on deformation measurement. A rail-mounted system for accurate horizontal measurements using terrestrial inSar was presented by Larry Olson, of Olson Engineering. Pieter Bas Leezenbeg of Hansje Brinker, although unable to attend the workshop because of last minute commitments, had prepared slides on satellite-based InSAR applied to deformation monitoring of dams with millimeter accuracy. A 3-D laser scanning system being used for dam deformation measurements by the Metropolitan Water District was shown by Julio Castillo of MWD. Finally, Craig Hewes of Leica made a presentation on using differential GPS and total stations for deformation monitoring.

An abstract of the 14 presentations can be downloaded from the following link: http://mail.rstinstruments.com/DOWNLOADS/USSD2013.pdf . The email address of each presenter is included in the document for anyone who would be interested to obtain their PowerPoint presentation.

Additionally, a slightly modified program based on this workshop will be facilitated at the 81st Annual Meeting of ICOLD (International Commission on Large Dams) in Seattle, WA on August 16, 2014 (http://www.icold2013.org/workshops.html)

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Field monitoring challenges, Episode 2
Unforeseen movements (depth and magnitude)

Marcelo Chuaqui and Wing Lam

Introduction

Continuing our series on Field Monitoring Challenges from the perspective of a specialized monitoring contractor, we present situations where we could not execute a monitoring program as planned or where unexpected challenges arose. Typically the constraints consist of short schedules, limited budgets, no easy access to areas, damage to equipment or instrumentation, lack of understanding of roles and responsibilities, unexpected changes, and conflicting priorities/goals/experience amongst project stakeholders.

In these instances, the situation has to be evaluated and solutions must be implemented to continue providing the monitoring data. The data are valuable for assessing the performance of a design or structure, to verify assumptions and mitigate risk, as well as the safety of all those involved in the construction.

In describing these challenges, potential solutions and the results, we hopefully provide some lessons learned.

Challenge – Unforeseen Movements (Depth and Magnitude)

In the Greater Toronto Area, a roadway was being reconstructed that included widening the road into an adjacent wetland area in difficult ground conditions that included soft peat. The peat line was estimated to extend approximately 13 metres below grade at some points. The soft and variable wetland soils would not be able to provide adequate support and lateral confinement for the road and associated utilities. A permanent retaining wall was to be put in place to limit the potential road and underground utility deformation.

Within the proposed widened portion of the road, two sheet pile walls, approximately 13 metres apart, contained an area of 0.4 MPa filler caissons that were part of a drilled shaft peat removal plan. Within this area, slightly offset from the sheet pile walls, caisson walls would be installed with 20 MPa concrete for king piles and anchor piles and 2 MPa concrete for primary and secondary fillers. Anchor piles would contain double wide flange I-beams. The two caisson walls would be connected together with tie-rods and tiebacks would limit the wall movement. The length of the proposed road widening was approximately 110 metres. Sections of the proposed widening are shown in Figures 1 and 2.

The monitoring plan for the retaining wall system included 15 inclinometers, 68 to 108 feet in length, both attached to piles and borehole locations to measure below ground movements.

Twenty four deep monitoring points were installed in two rows along the length of the proposed road area to measure ground settlement. These were designed in order to be able to add a section to the monitoring point as fill material raised the grade. A base plate was welded to a steel rod section that was allowed to move freely vertically and surrounded by steel pipe sections. Centralizers kept the steel rod section correctly positioned as rods and pipe sections were added using couplers. When readings were required, the protective top cap was removed and a specially machined bar with a reflective target was coupled to the internal steel rod.

Figure 1. Section of proposed widened road showing wetlands.

Figure 2. Section of proposed widened road with piles.

In addition, at two locations 25 metre length multi-point borehole extensometers (MPBXs) were installed that were modified to measure convergence in the backfilled area and reflective pile targets were also placed at the top of sheet piles adjacent to the existing road for monitoring of horizontal and vertical movement of the wall.

A typical section of the monitoring plan is shown in Figure 3.

The ground conditions proved to be more challenging than initially foreseen with the initial assumptions with greater than predicted movements. It was anticipated that the bottoms of the inclinometer casings would be anchored in stable ground and used as a fixed reference point for calculation of movements as is usual practice. The lengths of the casing were determined by the engineer with the available data at the time. Review of the borehole inclinometer plots, in conjunction with the other monitoring data, particularly unexpected divergent movements in the MPBX data, suggested that the bottom of the casings were not in a fixed position but in ground that was experiencing significant movements.

In order to continue to provide valuable subsurface information at these inclinometer locations, the top of the casings were surveyed using a total station and a survey prism pole placed at a specific point on the casing. The survey determined the geodetic position of the top of the casing that was then used as the reference point from which movements were calculated. The resulting data showed a shift of the inclinometer profile adjusted for each reading with the changes in the x and y co-ordinates according to the survey at the top. An example of the adjusted inclinometer plot is shown on Figure 4 showing this shift in the profile.

Lessons Learned

Lesson learned 1: Benefits of a complete monitoring program.

This case history highlights the value

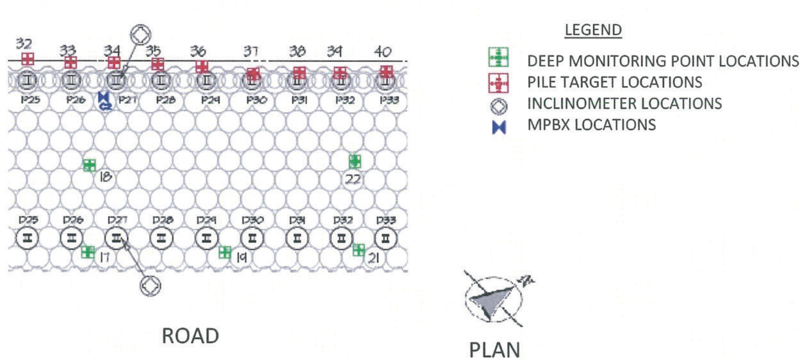

Figure 3. Typical section of monitoring plan.

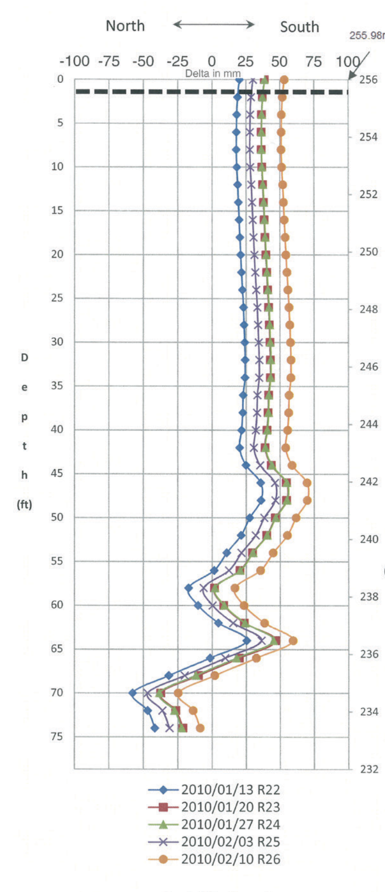

Figure 4. Sample of inclinometer plot.

of a complete instrumentation plan, with more than one instrument type. This permitted cross checking of critical readings across different instrument types that aided in determining a problem with the inclinometer data. The surveying of the top of casing allowed for combined readings to provide a more complete representation of what was happening above and below surface. The deep monitoring points and MPBXs also provided additional redundancy and means of correlation.

Lesson learned 2: Communication and education of needs.

During installation of the borehole inclinometers, there was a lack of understanding of what was required for a successful installation. The field personnel and engineer should have a clear understanding that the instrument should be installed in a stable stratum and what to expect and look for during the drilling of the borehole. If the field conditions differ than expected, communication is important to modify procedures as required to ensure expectations are met.

Lesson learned 3: Be adaptable to the project and client needs.

This case history documents an example of a monitoring problem that occurred after installation and well into the construction project. However, some innovative thinking was able to provide a solution so that subsurface movement of the wall under construction and the ground in the area was available.

In would have been easy to simply stop monitoring the inclinometers when it was determined that the bottom of the casings were not anchored in stable ground but understanding their importance and providing the value added service of providing a solution is immeasurable to relationships among stakeholders.

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Some on-line sources of information about geotechnical instrumentation

John Dunnicliff

Introduction

This article is intended as a reference document, and includes the following on-line sources of information about geotechnical instrumentation:

- The U.K. Institution of Civil Engineers on-line manual, Manual of Geotechnical Engineering (MOGE)
- Websites of manufacturers of geotechnical instrumentation.
- Linkedin
- Geotechnical Instrumentation News (GIN)

The article is based on a paper presented during the Eighth Symposium on Field Measurements in GeoMechanics (FMGM), held in Berlin, Germany in September 2011.

The U.K. Institution of Civil Engineers on-line manual, Manual of Geotechnical Engineering (MOGE)

General description of the manual

MOGE consists of nearly 100 chapters, covering a wide spectrum of geotechnical engineering: www.icevirtuallibrary.com/icemanuals/MOGE. There are two chapters about geotechnical instrumentation and monitoring, which update parts of the red book:

- Chapter 94. Principles of geotechnical monitoring. There are three sections:
  - *Benefits of geotechnical monitoring*. The principal technical reasons for recommending a geotechnical monitoring program for a project are described. A common feature of these technical reasons is that monitoring programs generally save money. Allen Marr is the author of this section.
  - *Systematic approach to planning monitoring programs using geotechnical instrumentation*. This 20-step sermon will be familiar to many readers of GIN. It includes the vital topic of how to assign tasks for the construction phase such that high quality data are obtained. The sermon is followed by an example of planning a monitoring program for an embankment on soft ground.
  - *General guidelines on execution of monitoring programs*, including all tasks during the construction phase.

- Chapter 95. Types of geotechnical instrumentation and their usage. There are two sections:
  - *Types of geotechnical instrumentation*. Instruments are described for monitoring groundwater pressure, deformation, load and strain in structural members and total stress. The section includes applications, descriptions of how each instrument works, with schematic diagrams, and various other details intended to help the user.
  - *Usage of Instrumentation*. The section indicates the general role of instrumentation for 12 types of construction projects. For each project type a table summarizes the possible geotechnical questions that may lead to the use of instrumentation, and indicates some of the types of instruments that can be considered for helping to provide answers to those questions.

These two chapters can be downloaded for $30 each. As an alternative to ordering on the website, you can use e-mail, orders@pssc.com, or telephone (978) 829-2544.

Websites of manufacturers of geotechnical instrumentation

Table 1 lists websites of manufacturers with a wide range of products and Table 2 lists websites of manufacturers of specialized products, indicating the product types. I recognize that these tables are bound to be incomplete, despite efforts to be as comprehensive as possible. I've limited these lists to manufacturers, and have made no attempt to include service companies—to include them would be an unachievable challenge.

Table 1: Manufacturers with a wide range of products

Company Name and Country	Website
Ace Instrument Co., Ltd., Korea	www.aceco.co.kr
Dong-A Geovan, Korea	http://geovan.en.ec21.com
Durham Geo Slope Indicator, USA	www.slopeindicator.com
Encardiorite, India	www.encardio.com
Geodata, Austria	www.geodata.com
Geo-instrumentation, France	www.geo-instrumentation.fr
Geo-Instruments, USA	www.geo-instruments.com
Geostar, Taiwan	http://geostar.ueuo.com
Geokon, USA	www.geokon.com
Geonor, Norway	www.geonor.no
Geotechnical Systems, Australia	www.geotechsystems.com.au
Gloetzl, Germany	www.gloetzl.com
Huggenberger, Switzerland	www.huggenberger.com
itmsoil, England	www.soil.co.uk
itmsoil Interfels, Germany	www.interfels.com
Kyowa, Japan	www.kyowa-ei.co.jp
Marton Geotechnical Services, England	www.mgs.co.uk
Roctest, Canada	www.roctest-group.com
RST, Canada	www.rstinstruments.com
SimStrumenti, Italy	www.simstrumenti.com
Sisgeo, Italy	www.sisgeo.it
Solexperts, Switzerland	www.solexperts.com
Telemac, France	www.telemac.fr
Toyoko Elmes, Japan	www.elmes.co.jp/hp-en/E-index.html
Tokyo Sokki Kenkyjo, Japan	www.tml.jp/e/index.html

Table 2: Manufacturers of specialized products

Company Name and Country	Products	Website
Alert Solutions, the Netherlands	Systems for online monitoring based on micronano technology sensors	www.alertsolutions.nl
Amberg, Switzerland	3D laser scanning	www.amberg.ch
Applied Geomechanics, USA	Tiltmeters, vibrating wire sensors, dataloggers, fiber optics, GPS	www.geomechanics.com
Avongard, USA	Crack gages	www.avongard.com
BAT, Sweden	Piezometers	www.bat-gms.com
Campbell Scientific, USA	Dataloggers, time domain reflectometry readout units, vibrating wire noise filters	www.campbellsci.com
Canary Systems, USA	Web-based data management software, vibrating wire noise filters	www.canarysystems.com
Cautus Geo, Norway	Web-based data management software	www.cautusgeo.com
Consoil, Sweden	Liquid level settlement gages	www.consoil.se
CMCS, England	Load cells	www.cmcs.co.uk
C.S.G., Italy	Differential multiparametric systems (DMS): in-place inclinometers and multi-piezometers	www.csgsrl.eu
DataTaker, Australia	Dataloggers	www.datataker.com
Druck, USA	Pressure sensors, level meters, flowmeters	www.ge-mcs.com
Fibersensing, Portugal	Fiber-optic sensing systems	www.fibersensing.com
FOS&S, Belgium	Fiber-optic sensing systems	www.fos-s.be
Gage Technique, England	Strain gages	www.gage-technique.demon.co.uk
Gamma Remote Sensing, Switzerland	Gamma portable radar interferometer	www.gamma-rs.ch
Geocomp, USA	Web-based data management software, dataloggers	www.geocomp.com
Geodaq, USA	In-place inclinometers	www.geodaq.com
Geomation, USA	Dataloggers	www.geomation.com
Geotechnical Observations, England	Flushable piezometers	www.geo-observations.com
GeoSig, Switzerland	Earthquake/vibration monitoring	www.geosig.com
GeoTDR, USA	Time domain reflectometry	http://geotdr.com
Getec, England	Liquid level settlement gages, fiber-optic sensing systems	www.getec-uk.com
Gridpoint Solutions, Northern Ireland	3D laser scanning	http://gridpointsolutions.com
Hansje Brinker, the Netherlands	PS-Insar satellite monitoring	www.hansjebrinker.com
Heron Instruments, Canada	Groundwater products	www.heroninstruments.com
Hydroresearch, Sweden	Fiber-optic sensing system	www.hydroresearch.se
Idetec, France	Vibration monitoring	www.idetec.eu
Imetrum, England	Digital image correlation	www.imetrum.com
In Situ, USA	Groundwater products	http://www.in-situ.com

Table 2: Manufacturers of specialized products, cont'd		
Company Name and Country	**Products**	**Website**
Instantel, USA	Vibration monitoring	www.instantel.com
Inventec, the Netherlands	Fiber-optic sensing systems	www.inventec.nl
Jauges Saugnac, France	Crack gages	www.jauges-saugnac.fr
Keynetix, England	Web-based data management software	www.keynetix.com
Kinemetrics, USA	Earthquake/vibration monitoring	www.kinemetrics.com
Laser Solutions, Russia	Fiber-optic sensing systems	www.lscom.ru
Leica Geosystems, USA	Robotic total stations, 3D laser scanning, GPS	www.leica-geosystems.com
Magellan, USA	GPS	www.magellangps.com
Marmota, Switzerland	Fiber-optic sensing systems	www.marmota.com
Maxwell Geosystems, Hong Kong	Web-based data management software	www.maxwellgeosystems.com
Mayes, England	Demec strain gages	www.mayes.co.uk
Measurand, Canada	ShapeAccelArray (SAA) in-place inclinometers	www.measurand.com
Micron Optics, USA	Fiber-optic sensing systems	www.micronoptics.com
Mitre, Canada	Inclinometer software	www.mitre.com
Omnisens, Switzerland	Fiber-optic sensing systems	www.omnisens.ch
Onset, USA	Dataloggers	www.onsetcomp.com
OpSens, Canada	Fiber-optic sensing systems	www.opsens.com
Penny and Giles, England	Displacement transducers	www.pennyandgiles.com
Profound, the Netherlands	Liquid level settlement gauges	www.profound.nl
Reflex, Sweden	Borehole survey equipment	www.reflexinstruments.com
Schlumberger, Canada	Westbay Multilevel Groundwater Monitoring Systems	www.swstechnology.com
Sensornet, England	Fiber-optic sensing systems	www.sensornet.co.uk
Sigra, Australia	Extensometers, stress cells, pressure transducers	www.sigra.com.au
Sireg, Italy	Inclinometer casing	www.sireg.it
Smartec, Switzerland	Fiber-optic sensing systems	www.roctest-group.com
Soilmoisture, USA	Tensiometers (soil suction)	www.soilmoisture.com
SolData, France	Web-based data management software	www.soldatagroup.com
Solinst, Canada	Piezometers	www.solinst.com
Strainstall, England	Load cells and crack gages	www.strainstall.com
Syscom, Switzerland	Earthquake/vibration monitoring	www.syscom.ch
Tektronix, USA	Time domain reflectometry readout units	www.tek.com
Tencate, The Netherlands	Fiber-optic sensing systems	www.tencate.com
Topcon Sokkia, Japan	Robotic total stations, GPS	www.topcon.com
Trimble, USA	Robotic total stations, GPS	www.trimble.com

Table 2: Manufacturers of specialized products, cont'd		
Company Name and Country	**Products**	**Website**
Turner Designs, USA	Fluorometers for flow monitoring	www.turnerdesigns.com
Vibrock, England	Vibration monitoring	www.vibrock.com
Vista Data Vision, Iceland	Web-based data management software	www.vistadatavision.com
VMT, Germany	Ring convergence measurement system for tunnels	www.vmt-gmbh.de/387.html?&L=

Linkedin

www.linkedin.com has numerous Facebook-type networking groups, allowing us to initiate discussions and to post comments. The following are the most relevant for us:

- Geotechnical and Structural Instrumentation & Monitoring
- Geotechnical & Structural Instrumentation
- M.I.T. Monitoring of Infrastructure & Terrain

The first of the three is the most active, and currently has several worthwhile topics.

Geotechnical Instrumentation News (GIN)

For completeness, I should include GIN in this article: www.geotechnicalnews.com/instrumentation_news.php. As you're likely to know by now, there's an index of articles that are on the web, more than 100 downloadable articles, and guidelines on how to submit articles to me for future GINs. As I keep saying—please help to keep this going by sending me an abstract—details are in the guidelines.

Klohn Crippen Berger establishes new graduate scholarship at the University of Alberta

Vivian Giang

(L to R): Ward Wilson, Nicholas Beier, Earle Klohn and Dave Sego. (Courtesy of Jen Stogowski Photography).

On May 6, 2013, the Geotechnical Centre at the University of Alberta celebrated the establishment of the Earle Klohn Graduate Scholarship in Geotechnical Engineering. Klohn Crippen Berger Ltd. (KCB) President & CEO Bryan Watts and scholarship namesake Earle J. Klohn presented the inaugural award to Nicholas Beier at the Fairmont Hotel Macdonald in Edmonton.

KCB donated $150,000 to create an endowment fund which will provide scholarships valued at a minimum of $5,000 annually to outstanding students pursuing graduate research in the field of geotechnical engineering specializing in the geotechnical behaviour or the environmental impact of mine tailings. Klohn is an international authority on the design and construction of tailings dams and has specialized in the design of embankments and the foundations for heavy industrial developments.

At the dinner, Watts made a surprise announcement of an additional donation of $100,000 to the endowment, now worth $250,000. "This scholarship is a testament to Klohn Crippen Berger's vision and commitment to building the next generation of geotechnical engineers," said Dr. Ward Wilson, Professor at the Department of Civil & Environmental Engineering. In his speech, Klohn, who graduated from the University of Alberta with Bachelor's and Master's Degrees in Civil Engineering, recognized the University's strong history of geotechnical education and training and mentoring of geotechnical engineers. "I am honoured that [KCB] would do something like this for me."