

What Could Tailings Facility Engineering Look Like in 2030? Version 6.0



QR Code for Input from Audience

Andy Small

Senior Tailings Engineer, Klohn Crippen Berger, Canada
asmall@klohn.com



Annika Bjelkevik, TCS, Sweden

Andrew Witte, KCB, Canada

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► Tailings Facility Engineering

- Tailings milling and processing
- Design of tailings storage facilities
- Closure design
- Geotechnical engineering
- Hydrogeological engineering
- Hydrotechnical engineering
- Geology
- Geochemistry
- Environmental protection
- Construction
- Operations
- Surveillance
- Risk Assessment
- Governance

- Engineering and scientific studies
- Field work (drilling, construction)
- Lab analyses (testing and interpretation)
- Modelling (simple to advanced)

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▶ Future Mining

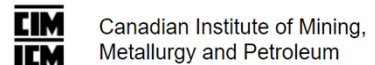
- ICOLD, TC L: world-wide registry with over 24,000 TSFs (Rana et al, 2024)
- Mining expected to increase by about 3%/year
- Grades of ore bodies are reducing
- Leads to more tailings
- Repurposing old facilities



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▶ Organizations Supporting T.F.E.



Universities, technical associations, etc.

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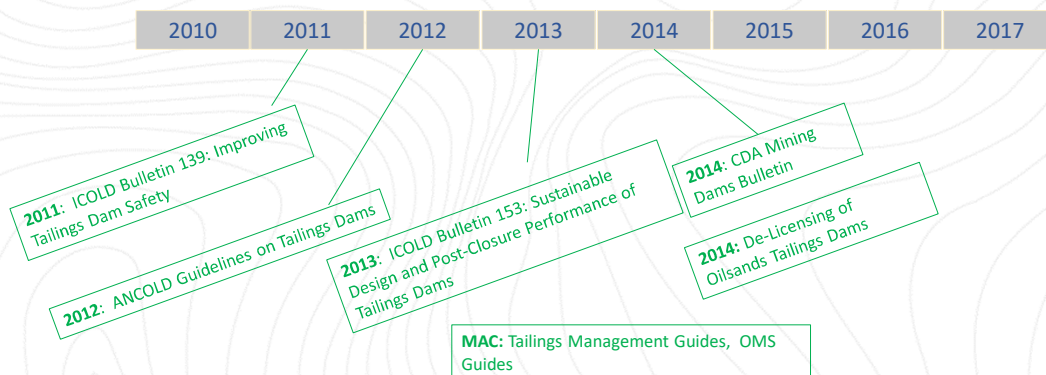
► Why 2030?

- Why not 2040 or 2050?
- “Next 6 years will go by in the blink of an eye”
- Reflect on some of what has happened in the past 6 years
- Start with guidance documents

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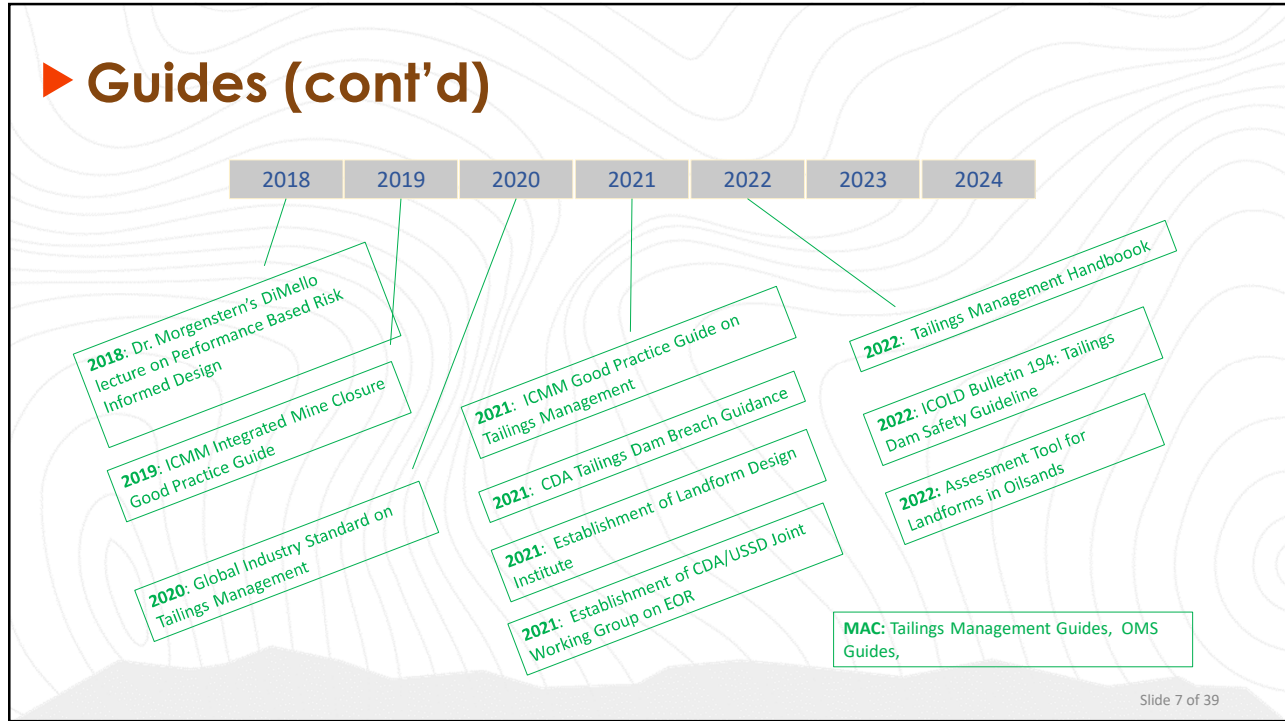
► Guides Supporting Tailings Facility Engineering



ICOLD – International Commission on Large Dams
 ANCOLD – Australia National Commission on Large Dams
 CDA – Canadian Dam Association
 MAC - Mining Association of Canada

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▶ Why 2030?

- Reflect on some of what has happened in the past 6 years:

| Topic | 2018 | 2024 |
|-------------------------|-------------------------|--|
| Engineer of Record | Significant trepidation | Young engineers are viewing this as a viable career path |
| Surveillance | Some automation | Extensive automation and innovative technologies |
| Artificial Intelligence | Not prevalent | Playing a bigger role |

- Opportunity to maintain the momentum that has been built
- Opportunity for more than "continuous improvement"
- We believe the next 6 years could see continued significant advancements

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► Context

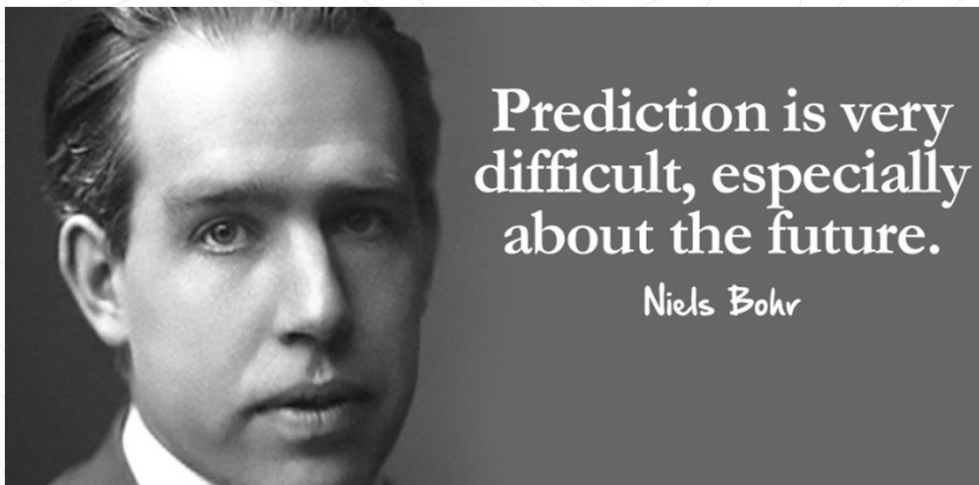
- Positive:
 - Many risk reduction initiatives underway
 - Moving in a good direction
 - Reducing likelihood of catastrophic failures
 - Owners and Consultants have created safe environments for young engineers
 - Training programs
 - Gain in computing power
 - Artificial Intelligence
 - TSF Registry (>21,000 TSFs catalogued)
- Challenges:
 - Water scarcity
 - Investors and insurance companies are paying a great deal of attention
 - Significant demand for EORs, RTFEs, ITRBs
 - Lack of engineers
 - Loss of senior engineers
 - Need to attract and retain talent
 - Dealing with classic upstream facilities

How do we get ahead of some of these challenges?

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► Visioning to 2030



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▶ What Could Tailings Facility Engineering Look Like in 2030?

1. Technical:
 - a) Tailings technology and deposition strategies
 - b) Closure strategies
 - c) Characterization of tailings and foundation soils
 - d) Design
 - e) Surveillance
2. Competency and Capacity:
 - a) Guidance documents
 - b) Training and development of Tailings Facility Engineers
 - c) Regulatory competency and capacity
- Governance is a key item that is also evolving, but beyond our scope

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▶ Intended Audience

- Owners and Operators
- Consultants
- Academia
- Suppliers
- Regulators

- Geotechnical, geological, hydrotechnical, hydrogeological, and civil engineers
- Young engineers who are interested in tailings facility engineering, but would like to know where we are headed

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▶ Intended Audience

- South American tailings facility professionals (owners, consultants, etc.)
- Prepare an addendum to the paper.



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▶ Papers and Presentations

| Version | Forum | Location | Deliverable | Date (2024) | Presenter |
|---------|--|-------------|------------------------|-------------|-----------|
| 1.0 | Calgary Geotechnical Society | Calgary | Presentation | May 14 | Andy |
| 2.0 | Edmonton Geotechnical Society | Edmonton | Presentation | May 16 | Andy |
| 3.0 | Mining Society of Nova Scotia | Nova Scotia | Presentation | July | Andy |
| 4.0 | ICOLD | India | Presentation and paper | September | Annika |
| 5.0 | Tailings and Mine Waste | Denver | Presentation and paper | November | Andrew |
| 6.0 | International Society of Soil Mechanics and Geotechnical Engineering | Chile | Presentation and paper | November | Andy |

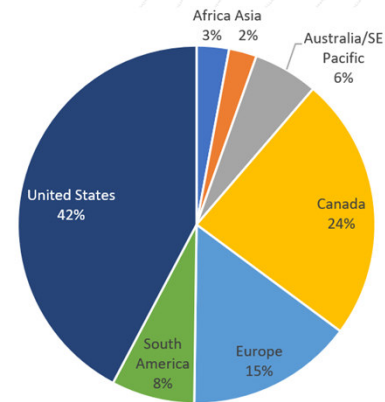
- Make presentations and papers available on publicly accessible drive

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▶ Questionnaire to Colleagues/Leaders

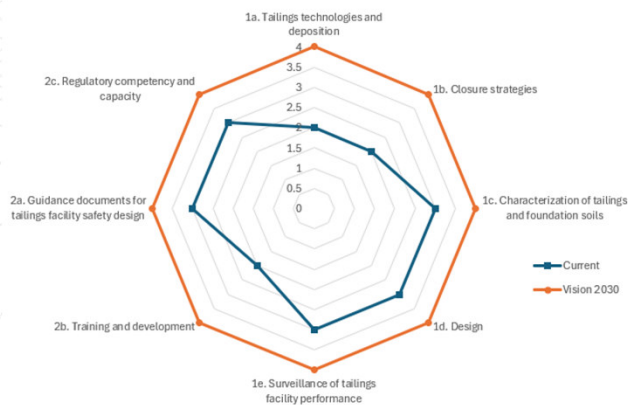
- To support development of the presentations and papers
- Issued to over 240 colleagues around the world
- Over 60 responses
- Lots is happening, this presentation provides some of the highlights
- South America:
 - Eduardo Marques, Brazil
 - João Pimenta Freire Neto, Brazil
 - Mauro Pio dos Santos Junior, Brazil
 - Emmanuel Pornillos, Peru
 - Fernando Schnaid, Brazil
 - Luis Valenzuela, Chile



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▶ Estimated situation for each topic



- 0** = not implemented / used / known
1 = implemented in research / regarded as future (pilot test) / known by few
2 = implemented in a few operations / used in a few places / known by few but regarded as an option
3 = implemented in most operations / used in most places / known by many
4 = implemented in many operations / used in many places / known by most
5 = implemented in "all" operations / best possible use / fully known

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 - c) Regulatory competency and capacity

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Part 2b – Training and Development



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▶ 2b – Tailings Management Professional

- Establish the discipline of Tailings Management Professional
- Tailings management includes the design, construction operation, and closure of systems that are used to produce tailings and the facilities that are constructed to store tailings
- Tailings structures include:
 - Conventional slurry, thickened, paste, filtered tailings stacks, etc.
 - Co-disposal with waste rock
 - Sludge and sediment containment facilities from process, water treatment plants, or runoff.

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▶ 2b – Tailings Management Prof. (cont'd)

- Tailings milling and processing
- Design of tailings storage facilities
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- Geotechnical engineering
- Hydrogeological engineering
- Hydrotechnical engineering
- Geology
- Geochemistry
- Environmental protection
- Construction
- Operations
- Surveillance
- Risk Assessment
- Governance

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► 2b –Training and Dev. - Path Forward

| Vision for 2030 | Action | Organizations | Role |
|---|--|---------------------------|--|
| Tailings Management Professional | Develop scope for this discipline and embrace usage | ICOLD | Lead development, work with ICMM, SME, CDA, ANCOLD, universities, etc. |
| Decision w.r.t. certification of Tailings Management Professional | Study this issue and land on a decision | ICOLD | Form working group to explore this issue. Work with ICMM, SME, CDA, ANCOLD, universities, etc. |
| Coordinated training | Develop Tailings Training Portal that reflects available training in the world. Use the Portal to support developing a coordinated training program. | SME | Host for the portal, supported by several organizations |
| Tailings cohorts in post graduate programs | Develop Masters-level program focused on training engineers to enter the tailings profession | Colorado State University | Lead development of this initiative, supported by other universities |
| Tailings Management Professional | Develop scope for this discipline and embrace usage | ICOLD | Lead development, work with ICMM, SME, CDA, ANCOLD, universities, etc. |

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Part 1 – Technical Topics



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► 1a - Tailings Technology – 2030?

- Conventional/slurried tailings:
 - Still will be the majority of tailings systems with focus on centerline and downstream dams
 - No more classical upstream dams being constructed in the world
 - High degree of confidence in slurry tailings facilities
- Filtered tailings will play a larger role



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► 1a - Tailings Technology - Path Forward

| Vision for 2030 | Action | Organizations | Role |
|--|---|----------------------------|--|
| Guidance on Filtered Tailings | Comprehensive, publicly available guidance document that addresses process and geotechnical aspects, but also, possibly enhanced financial models | Filtered tailings industry | To lead the development of the guidance. Supported by ICOLD and other organizations. |
| MAA that considers the whole mine, not just the tailings. Includes the mining plan, water restrictions, closure, circular economy. | Work with mining companies and MAC/ICMM to promote this concept. Also, develop financial models that can support better closure decisions. | Lead to be determined | To be determined |
| Co-disposal of tailings and waste rock more prominent | To develop | | |
| High level of confidence in safety of conventional/ slurried tailings systems | Continue training and development | All | Continue solid engineering |

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► 1b – Closure Strategies – 2030?

- Consensus between all parties of an effective definition of Safe closure/ Responsible closure
- Defined and standardized design criteria for closure, incl. transfer of ownership
- Less water in the tailings and impoundments
- Financial models that benefit good practices
- Long-term monitoring with remote methods and AI
- Established the role of reclamation designer of record (RDR) working in parallel with EOR.



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► 1b – Closure Strategies – Path Forward

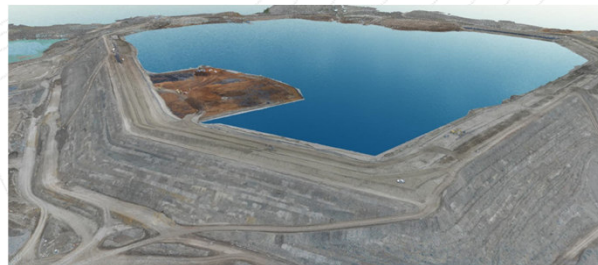
| Vision for 2030 | Action | Organizations | Role |
|------------------------------|--|---------------|--|
| Tailings Closure Handbook | <p>“Begin with the end in mind. Closure should not be an afterthought.</p> <ul style="list-style-type: none"> - closure design considerations/ criteria, - safe closure - landform design - governance - relinquishment - cost estimating / bonding” | SME | SME to lead development of handbook. The book editors are engaging with other organizations (e.g., USSD, CDA). |
| Risk Informed Closure Design | Develop guidance on “safe” or “responsible” closure. | CDA | CDA to lead with input from ICOLD, USSD, SME, ICMM, etc. |

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► 1c – Char. Tailings and Found. Soils – 2030?

- Use of nuclear magnetic resonance well logging and other in-situ technologies on CPTs for water content estimation
- Ability to estimate in-situ void ratio
- Improved characterization of liquefaction potential and post liquefaction strength
- Initiatives underway by academia, industry, and suppliers

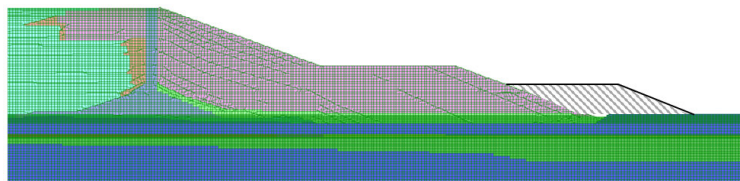


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► 1d – Design – 2030?

- Performance Based Design for Slope Stability Assessment:
 - PB design integrates advanced computer modelling with actual performance to reduce uncertainty and conservatism in design
 - From Dr. Morgenstern: “Further recognition of the value of Performance Based Design and significantly greater prominence in its use.”
 - Integration of complementary roles of PBD and classical approaches
 - Fully coupled deformation and seepage models
 - Regulatory capacity will still be a limitation to implementation
- Dam breach analysis that can be relied upon.



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► 1d - Design – Path Forward

| Vision for 2030 | Action | Organizations | Role |
|---|---|-------------------------|---|
| Greater use of Performance Based Design | Education, case studies | ICMM, CDA, and industry | ICMM and CDA – training Industry – case studies on PB design |
| Reduced uncertainty for dam breach analyses | Research to improve models and characterization and enhance guidance | CANBREACH CDA | CANBREACH – research CDA - guidance |
| No water covers required for geochemistry reasons | Desulphurization of tailings in the mill. Enhanced financial models. MAA for the mine, not just tailings. | MAC or ICMM? | ICOLD will monitor |

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► 1e – Surveillance– 2030?

- Increased use of “area” measurements (e.g., InSAR, fibre optics, “Smart” geofabrics, ERT cables, drones, etc.)
- Surveillance programs/systems developed based on risk assessment and failure modes
- Widespread automation with improved user interfaces
- Integration of collected data directly into engineering models
- Data scientists employed to manage the reams of data
- Increased use of AI for data review/screening
- Being implemented by owners and providers



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Part 2 – Competency and Capacity



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▶ 2a – Guidance Documents

- Some said: “We have enough guidance documents, use what we have!”
- Guidelines in review/being updated:
 - MAC
 - CDA
 - USSD (FEMA)
 - CDA/USSD EOR
 - ICOLD Bulletin 194
 - Others

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▶ 2a – Guidance – Path Forward

| Vision for 2030 | Action | Organizations | Role |
|--|---|---------------|--|
| Preferred definition of Credible Failure Modes | Objective guidance on thresholds for physical possibility and negligibility | CDA | Lead development of guidance, supported by other organizations |
| Landform Design Guidance | Develop comprehensive guidance for landform design | LDI | Lead development of guidance with support from other organizations |
| ICOLD Bulletin 194 Version 2 | Additional guidance on hydrogeology and hydrology, undrained stability analyses, brittleness stability, spillways, characterization | ICOLD | Lead preparation of guidance with input from other organizations |

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▶ 2c – Regulators - Current Situation

- From Dr. Morgenstern: "A major issue is the capacity of the regulatory community."
- Limited technical capacity among regulators
- Limited ability of external consultants to support regulators with reviews
- CDA providing training to regulators in Canada

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▶ 2c – Regulators – 2030?

- Enhanced competency and capacity
- Consistency of regulations
- Path is not clear
- Role of industry to support regulators?
- To be determined

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► Summary

- Fraction of the initiatives that are happening in the world
- Many other good initiatives are underway, pleased to include in our paper
- Let's maintain the momentum and go beyond just "continuous improvement"!

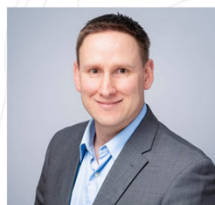
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► Being a Tailings Management Professional is and will be very interesting!



Annika Bjelkevik,
TCS Sweden



Andrew Witte,
KCB Vancouver



Andy Small,
KCB Fredericton

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▶ Contributors to Questionnaire

| First Name | Last Name | Affiliation | Country |
|---------------|--------------|--------------------------------|----------------|
| Elias | Baptista | AIB Consulting Services | Mozambique |
| Chris | Bareither | Colorado State | United States |
| Hector | Barriga | ICOLD | Peru |
| Nicholas | Beier | U of A | Canada |
| David | Brett | GHD | Australia |
| Karen | Chovan | Envirointegration | Canada |
| Dermot | Claffey | ICOLD | United Kingdom |
| Jarrad | Coffey | ICOLD | Australia |
| Andrew | Copeland | ICOLD | South Africa |
| Mike | Davies | Consultant | Canada |
| Norm | Eenkoren | Suncor | Canada |
| Fiona | Esford | WSP | Canada |
| Derek | Etherington | CNRL | Canada |
| Mason | Ghahghazi | University of Toronto | Canada |
| Duncan | Grant-Stuart | ICOLD | South Africa |
| Hans | Haggstrom | ICOLD | Sweden |
| Eric | Halpin | Consultant | United States |
| Christopher | Hatton | WSP | United States |
| Jiri | Herza | HATS Consulting | Australia |
| Dan | Hughes-Games | Klohn Crippen Berger | Canada |
| Modeste | Kamanda | CCGB | DRC |
| Dean | Korri | Cleveland-Cliffs Inc. | United States |
| Gareth Digges | La Touche | WSP | United Kingdom |
| Chad | LePoudre | BHP | Canada |
| Isabelle | Levesque | Government of QC | Canada |
| Peter | Lighthall | Consultant | Canada |
| Kevin | Lutes | Newfields | United States |
| Renato | Macciotti | U of A | Canada |
| Eduardo | Marques | Universidade Federal de Viçosa | Brazil |
| Scott | Martens | Teck Resources | United States |
| Gord | McKenna | Landform Design Inst. | Canada |
| Nordie | Morgenstern | University of Alberta | Canada |

| First Name | Last Name | Affiliation | Country |
|---------------|-----------------------|---|----------------------|
| Kim | Morrison | | United States |
| Len | Murray | KCB | Canada |
| Lindsay | Newland Bowker | WMTF | United States |
| João | Pimenta Freire Neto | Pimenta de Ávila Consulting | Brazil |
| Mauro | Pio dos Santos Junior | Pimenta De Avila | Brazil |
| Gord | Pollock | WSP | Canada |
| Emmanuel | Pornillos | WSP | Peru |
| Bob | Powell | GeoRDP | Canada |
| Caius | Priscu | ICOLD | Romania |
| Henny Dwi | Purnamasari | ICOLD | Australia/SE Pacific |
| Joe | Quinn | KCB | Canada |
| Nahyan | Rana | Klohn Crippen Berger | Canada |
| David | Reid | UWA | Australia/SE Pacific |
| Paul | Ridlen | Knight Piesold | United States |
| Chaitan | Sandhu | Tetra Tech | Canada |
| Marty | Sangster | O'Kane | Canada |
| Fernando | Schnaid | Universidade Federal do Rio Grande do Sul | Brazil |
| Rob | Schryburt | Government of ON | Canada |
| Ardy | Sharifabadi | ADEQ | United States |
| Clint | Strachan | Stantec | United States |
| Sara | Toyra | ICOLD | Sweden |
| Greta | Tresoldi | LSI Lastem | Italy |
| Aleksey | Vakulenko | ICOLD | Russia |
| Luis | Valenzuela | Consultant | South America |
| Ramon | Verdugo | Madrid | Spain |
| Hervé Kundulo | Wa Kitambo | WSP Africa | DRC |
| Mark Geoffrey | Walden | Newfields | United States |
| Bryan | Watts | Consultant | Canada |
| David | Williams | Queensland | Australia |
| Christina | Winckler | TailRiskReview LLC | United States |
| Krzysztof | Wrzosek | ICOLD | Poland |

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▶ Feedback welcome

- Prepare an addendum to the paper.



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Thank you!

Andy Small
Senior Tailings Engineer, Klohn Crippen Berger, Canada
asmall@klohn.com

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