

FRBC ENDOWED CHAIR IN RESOURCE GEOSCIENCE AND GEOTECHNICS

Dr. Sergio Sepúlveda
Report for the Period March 2022 to June 2023

1. Introduction

This report covers the period since the last Board meeting in March 2022, The main activities and developments from 2022 to mid-2023 are outlined.

2. Teaching

Dr. Sepúlveda undertook undergraduate teaching duties as instructor of EASC313 (*Introduction to Soil and Rock Engineering*) in Spring 2022 and Spring 2023, and of EASC413 (*Resource Geotechnics*) in Fall 2022. Additionally, a graduate one-off, concurrent version of EASC413, named EASC704 *Special Topics in Advanced Engineering Geology*, was also offered in Fall 2022. This course shared lectures and labs with the undergraduate course, plus a term project (including site investigation, rock mass assessment, and slope modelling) and seminar talks to be given by the graduate students to both classes.

Based on the experience of the latest courses and the expertise of the instructor, a revision of the contents of EASC413 (renamed *Engineering Geology and Resource Geotechnics*) was presented along with a proposal for a formal, permanent graduate course (EASC629 *Advanced Engineering Geology*), to be offered by-yearly. Both modified/new courses were approved by the Department, Faculty of Science and higher University administration at undergraduate and graduate levels, and will be offered since Fall 2024.

3. Research

During the 2022-23 informed period, the FRBC Chair obtained five new research grants (CFI-JELF and NSERC Discovery Grant as P.I.; Mitacs Accelerate and Fondecyt as Co-investigator, and Mitacs Globalink as Supervisor) and formed the new Engineering Geology and Resource Geotechnics research group with the arrival of five graduate students (2 Ph.D., 3 MSc.) under his supervision. An undergraduate Research Assistant (R. Jacobs) also carried out part-time work in January-May 2022. A new postdoctoral fellow supported by the FRBC chair started in April 2023 for a period of two years (J. Singh, supervisor: Sepúlveda), joining the research group.

Additionally, Dr. Sepúlveda as a part-time Associate Professor at Universidad de Chile continued supervising two MSc. students carried from his former position (one finished, second to be finished in Summer 2023) and took a new MSc student for a Fondecyt project in the Andes of central Chile. Dr. Sepúlveda was also invited as external examiner of an MSc student at the University of Auckland (A. Hammed), is forming part of the supervisory committee of SFU MSc student J. Carrigan (Supervisor: Ward), and formed part of another MSc student supervisory committee (Nickel, withdrawn, supervisors: Murphy, Ward).

During the Fall term of 2022, Dr. Sepúlveda supervised a visiting Ph.D. student (D. Groch, Universidad Nacional del Sur, Argentina, supported by a Mitacs Globalink grant), working on debris flow mitigation strategies in collaboration with the B.C Ministry of Transportation and BGC Engineering.

During this period, Dr. Sepúlveda worked on field research activities with his new graduate students in B.C., as well as doing collaborative work with Prof Williams-Jones and students applying new remote sensing instrumentation on volcanological studies in Mt Saint Helens and Tseax volcanoes. Dr. Sepúlveda also carried out a reconnaissance overflight of the Mosaic Creek slope deformation at Mt Meager in September 2022 supporting the B.C. Ministry of Forests, and started a collaboration with the Geological Survey of Canada to study earthquake-induced landslides in southern B.C.

3.1 Ongoing Research funding obtained before 2022

1. Pinto, L., Jara, P., Sepúlveda, S., De Pascale, G. **FONDECYT REGULAR 1200871**, 2020-2024: Quantification of mountain building in the Chilean High Andes (32°-33°S) using structural, geo- and thermo-chronological investigations, ca. \$110,000 per annum (Government of Chile).
2. Sepúlveda, S., **SFU Faculty Recruitment Grant** 2021-2026. Catastrophic rockslides - debris flows in paraglacial environments: British Columbia and Patagonia. \$20,000 per annum.

3.2 New Research funding obtained during March 2022-June 2023

1. Sepúlveda S. **NSERC DISCOVERY GRANT**, 2022-2027. Understanding rock slope failure and coseismic landslide hazard in deglaciated Cordilleran landscapes. \$31,000 per annum.
2. Sepúlveda, S. **CFI-JELF and BCKDF**, 2022-2027. The Landslide Field Laboratory: A Remote Sensing Suite for Multiscale Rock Mass and Slope Modelling. \$230,000 (acquisition and maintenance of a Geoslam ZEB handheld scanner, a Creaform Handyscan scanner, and a DJI Matrice 300 drone with Lidar, photogrammetry, and thermal camera payloads).
3. Williams-Jones, G., and Sepúlveda, S. **Mitacs Accelerate**, 2022-2024. Assessing the geohazards of Mount Meager, BC, Canada: Insights to advance green energy production on volcanoes. \$260,000 Partner organization: Meager Creek Development Corporation (geothermal energy).
4. Groch, D., Sepúlveda S. **Mitacs Globalink Research Award**, 2022. Mitigation measures against debris flows as an urgent response to Climate Change. \$6,000 (visiting Ph.D. Student from Argentina).
5. Fustos, I. Sepúlveda, S., Zambrano, M., Calderón, M. **FONDECYT REGULAR**, 2023-2027. Triggers of Rainfall-Induced Landslides in volcanic soils EXperiment: towards a full understanding of the water role in slope instability in the Southern Andes (TRILEX), ca. \$100,000 per annum (Government of Chile).

3.3 New SFU graduate students, Engineering Geology and Resource Geotechnics Group

Five graduate students started during this period. They have been completing their coursework, preparing their thesis proposals, and advancing in their research's first stages. They will all carry out extensive fieldwork during the 2023 Summer season.

MSc students **Jason Connelly** (started May 2022) and **Mariya Shintassova** (started January 2023), both supported by Mitacs Accelerate and FRBC Chair grants, are undertaking research on slope stability, remote sensing applications and geotechnical modelling in the Mt. Meager volcanic massif, with emphasis on the geothermal lease area in the south district. Connelly is developing a massif-scale landslide susceptibility map using statistical modelling, and will analyze a couple of slope stability case studies using RS2. He passed his MSc proposal in March 2023 and has a conference abstract accepted to be presented at the AEG meeting. Shintassova is performing geotechnical mapping of cores from the Meager Creek geothermal prospect, including the use of the Handyscan scanner, which data will be applied to generate a 3D geotechnical model in *Leapfrog*.

MSc student **Nicolas Jaimes** started in January 2023 to work on rainfall-induced rock slides related to atmospheric rivers with case studies in the Fraser Valley (November 2021 storms) and Patagonia (2020),

supported by the SFU FRG and FRBC Chair grants. He will develop photogrammetric models and *UDEC* models including fluid flow in rock for both case studies.

PhD. student ***Sina Fatolahzadeh*** started in May 2022 (though arrived in October due to visa issues), supported by FRBC and Discovery grants. He is undertaking research on the comparative assessment of rock mass parameters using different field remote sensing techniques and 2D-3D numerical modelling with application to rock slides and rock falls, with case studies in Squamish, Sea to Sky Highway, and the Chilliwack Valley. Sina will apply terrestrial and UAV-based Lidar and thermal scans at different scales using the research group's remote sensing equipment.

The newest Ph.D. student, ***Catalina Pino-Rivas*** (started May 2023) will work on earthquake-induced landslide susceptibility and modelling in Vancouver Island (area of the 1946 earthquake) and the BC Coast Mountains, supported on Discovery and FRBC grants and collaboration with the GSC.

3.4 Postdoctoral Fellow

A PDF in Geological Engineering, Dr. Jaspreet Singh (Ph.D. from IIT Roorkee, 2022) was hired in April 2023 (supported by residual FRBC funds) to undertake advanced research on 3D numerical modelling applied to slope stability, progressive failure, and remote sensing applications. He will follow up on previous research by Dr. Sepúlveda in Patagonia and work on different landslides in western Canada.

3.5 Conferences

A special emphasis on networking was given during Dr. Sepúlveda's first year in Canada after the Covid-19 pandemic. During the reported period Dr. Sepúlveda attended the Seismological Society of America Annual Meeting (Seattle, April 2022), the Canadian Geohazards Conference organized by the Canadian Geotechnical Society (Quebec City, June 2022), the Canadian Rock Engineering Conference (Kingston, August 2022), the Vancouver Geotechnical Society Symposium (Vancouver, September 2022) and the EGU Annual Meeting (Vienna, April 2023). Furthermore, Dr. Sepúlveda was invited to present at the Multi-hazard Risk and Resilience Workshop organized by the University of Western Ontario (London, November 2022). Dr. Sepúlveda has already submitted works to attend the Association of Engineering Geologists Annual Meeting (Portland, September 2023) and the Chilean Geological Congress (Santiago, November 2023), and is the Chair of the 2024 IAEG Latin-American Regional Conference.

4. FRBC Chair Publications (2022-23)

Completed /Accepted/Submitted Journal Papers, Book Chapters and Conference Proceedings (*HQP underlined*):

4.1 Journal Articles :

- Palma-Munita, S., Ochoa-Cornejo, F., Sepúlveda, S.A., Lara, M., Burgos, K., Duhart, P. 2023. Rock slides in paraglacial environments: Three-dimensional modeling of the Santa Lucia landslide in Chilean Patagonia. *Engineering Geology*, submitted.
- Hernández, M., De Pascale, G., Sepúlveda, S.A. 2023. Sackungen: deep-seated gravitational slope deformation in the postglacial Rio Volcan, Central High Andes, Chile. *Andean Geology*, submitted.
- Sepúlveda, S.A., Tobar, C., Rosales, V., Ochoa-Cornejo, F., Lara, M. 2023. Megalandslides and deglaciation: modelling of two case studies in the central Andes. *Natural Hazards*, accepted.

- Soto, M.V., Arriagada, J., Molina-Benavides, M., Cabello, M., Contreras, M., Ibarra, I. Guevara, G., Sepúlveda, S.A., Maerker, M. 2023. Geodynamic hotspots in a periglacial landscape: natural hazards and impacts on productive activities in Chilean fjordlands, Northern Patagonia. *Geosciences*, accepted.
- Carrasco, J., Sepúlveda, S.A., Lara, M., Rosales, V., 2023. Evidencias de expansión del deslizamiento activo de Yerba Loca, Andes centrales *Revista Asociación Geológica Argentina*, 80(2), in press.
- Sepúlveda, S.A., Ward, B.C., Cosman, S.B., Jacobs, R., 2023. Preliminary investigations of ground failures triggered during the mid-November 2021 atmospheric river event along the Southwestern British Columbia highway corridors. *Canadian Geotechnical Journal*, 60:580-586, dx.doi.org/10.1139/cgj-2022-0093
- Sepúlveda, S.A., Moreiras, S.M., Chacón, D., Villaseñor, T., Jeanneret, P., Poblete, F., 2022. The Pangal landslide complex, Cachapoal basin, central Chile (34°S): an example of a multi-temporal slope instability cluster in the Andes. *Journal of South American Earth Sciences* 115:103769.
- García-Delgado, H., Petley, D.N., Bermúdez, M.A., Sepúlveda, S.A., 2022. Fatal landslides in Colombia (from historical times to 2020) and their socio-economic impacts. *Landslides*, 19, 1689–1716, doi 10.1007/s10346-022-01870-2

4.2 Book Chapters:

- Prakash, N., Santi, P., Dowling, C., Strouth, A. Sepúlveda, S.A. 2023. Fatalities from Debris Flow: Worldwide Distribution and Trends. In Jakob, M., Santi, P., McDougall, S. (Eds), *Debris-flow Hazards and Related Phenomena*, 2nd Edition, submitted.
- Sepúlveda, S.A., 2022. Earthquake-induced landslide susceptibility and hazard assessment approaches. In Towhata, G.Wang, Q. Xu, C. Massey (eds.), *Coseismic Landslides. Phenomena, Long-Term Effects and Mitigation*, Springer Nature Singapore, pp. 543-571.
- Sepúlveda, S.A., Ochoa-Cornejo, F., Serey, A., 2022. Earthquake-induced landslides and ground failure in Chile: The Aysen 2007 and Maule 2010 earthquakes. In Towhata, G.Wang, Q. Xu, C. Massey (eds.), *Coseismic Landslides. Phenomena, Long-Term Effects and Mitigation*, Springer Nature Singapore, pp. 41-57.
- Moreiras, S.M., Sepúlveda, S.A., 2022. Landslides in Arid and Semi-Arid Environments. *Treatise on Geomorphology* (2nd Edition), Elsevier, 5:322-337,

4.3 Conference Proceedings:

- Singh, J., Sepúlveda, S.A. 2023. Landslide failure surface and volume estimation using a Sloping Local Base Level (SLBL) method: A Case Study. *Indian Geotechnical Conference*, Roorkee, December 2023, submitted.
- Montanez-Munoz, S. Sepúlveda, S.A., Williams-Jones, G., Bahreyni, B., 2023. De la Tierra a la Luna: Escaneo láser y modelamiento 3D de tubos de lava para análisis de habitabilidad lunar. *Chilean Geological Congress*, Santiago, December 2023, submitted.
- Urrejola, J.T., Sepúlveda, S.A., Pinto, L., Moreiras, S.M., 2023. Análisis de megadeslizamientos y su relación con sismicidad cortical en el Sistema Estructural Pucuro, Región de Valparaíso. *Chilean Geological Congress*, Santiago, December 2023, submitted.
- Connelly, J.P., Sepúlveda, S.A., Williams-Jones, G., 2023. Statistical landslide susceptibility assessment in the Mount Meager Volcanic Complex, British Columbia: Results and lessons learned. *Association of Environmental and Engineering Geologists 66th Annual Meeting*, Portland, September 2023, accepted.
- Carrigan, J., Ward, B., Geertsema, M. Sepúlveda, S.A. 2023. The geology and evolution of the Brenot Creek landslide. *Association of Environmental and Engineering Geologists 66th Annual Meeting*, Portland, September 2023, accepted.

- Sepúlveda, S.A. 2023. Earthquake-induced landslides in subduction zones: Insights from the Central-Southern Andes. *Association of Environmental and Engineering Geologists 66th Annual Meeting*, Portland, September 2023, accepted.
- Moreiras, S.M., Junquera-Torrado, S., Rodríguez-Peces, M., Sepúlveda, S.A. 2023. Linking Andean paleo-landslides to the probable triggering seismic source (31°–33°S). *XXI INQUA Congress*, Rome, June 2023, accepted.
- Ugalde, F., Sepúlveda, S.A., Marangunic, C. 2023. Susceptibility assessment for glacier hazards in the Rio Volcan basin, Central Andes of Chile. *IUGG 28th General Assembly*, Berlin, July 2023, accepted.
- Montanez, S., Williams-Jones, G., Sepúlveda, S.A., Bahreyni, B. 2023. Gravity modeling of lunar lava tubes: insights from Ape Cave as a terrestrial analogue, *2nd Canadian Lunar Workshop*, online, May 2023.
- Ugalde, F., Sepúlveda, S.A., Marangunic, C. 2023. Susceptibilidad ante remociones en masa de origen glacial en la cuenca del rio Volcan, Andes centrales de Chile. V Congreso Sociedad Chilena de la Criosfera, Valparaiso, May 2023.
- Sepúlveda, S.A., Moreiras, S.M., Jeanneret, P., Correas Gonzalez, M., Bravo, K., Azanero, J., Lara, M. 2023. Investigation of prehistoric landslide dams in the central Andes of Chile and Argentina. *European Geosciences Union Annual Meeting*, Vienna, April 2023, paper EGU23-8382.
- Piñero, L., Leyton, F., Sepúlveda, S.A., González-Mondaca, P., 2022. Soil dynamic response for seismic microzonation purposes: Rancagua-Machalí and Rengo cities, Chile. *83rd EAGE Annual Conference / Exhibition*, Madrid, España.
- Sepúlveda, S.A., Serey, A., 2022. Lessons from recent earthquake-induced landslides in Chile and some considerations applicable to British Columbia. *8th Canadian Conference on Geotechnique and Natural Hazards*, 155-161
- Sepúlveda, S.A., 2022. Rock slides induced by atmospheric rivers: A preliminary insight to recent cases in B.C. and Patagonia. *Program 28th Vancouver Geotechnical Society Symposium*, p. 7.
- Sepúlveda, S.A., Ochoa, F., Lara, M., Palma, S., Tobar, C., Burgos, K., 2022. Influencia de la desglaciación en grandes deslizamientos de roca en los Andes de Chile central y Patagonia. *Resúmenes 1er Simposio de la Asociación Chilena de Ingeniería Geológica*, p. 30.
- Sepúlveda, S.A., Junquera-Torrado, S., Moreiras, S.M., Pinto, L., Urrejola, J.T., 2022. Landslides as paleoseismological indicators: Experiences using geotechnical back-analyses in the Andes. *2022 Seismological Society of America Annual Meeting, Seismological Research Letters*, 93:2B, 1214-1215.
- Sepúlveda, S.A., 2022. Deslizamientos cosísmicos y su relación con los tipos de terremotos en los Andes chilenos. *Actas XXI Congreso Geológico Argentino*, Puerto Madryn. 1673-1674.
- Tobar, C., Lara, M. Sepúlveda, S.A., Ochoa, F., 2022. Modelamiento numérico 2D de estabilidad de laderas en ambientes paraglaciaros: caso del deslizamiento del Estero Parraguirre, San José de Maipo. *Actas XXI Congreso Geológico Argentino*, Puerto Madryn. 1700-1701.
- McCarte, L. Sepúlveda, S.A., Lara, M. 2022. Vulnerabilidad de estructuras y riesgo específico de flujo detríticos en la ciudad de Antofagasta, norte de Chile. *Actas XXI Congreso Geológico Argentino*, Puerto Madryn, 727-728.

5. Outside and Outreach Activities

- Associate Professor (part-time), Universidad de Chile
- Adjunct Researcher, Universidad de O'Higgins, Chile.
- Vice-President of the Chilean Association of Engineering Geology (2020-2023)
- Chair, 2nd *IAEG Latin-American Regional Conference* (La Serena, Chile, 2024)
- Guest Editor, Special Issue on Landslides in the Andes, *Revista de la Asociación Geológica Argentina* (April 2022-March 2023).
- Reviewer, Professional Practice Guidelines - Development and Use of Seismic Microzonation Maps in BC. *Engineers and Geoscientists BC* (April-May 2023).
- Invited talk at *ConocoPhillips-UAA Geological Sciences Seminar Series, University of Alaska – Anchorage, USA* (online). “Landslides and deglaciation: examples from Patagonia, central Chile and British Columbia” (March 2023).
- Invited talk “Landslide hazards in British Columbia: an overview and challenges”. *Third Western-ICLR Multi-hazard Risk and Resilience Workshop. Institute for Catastrophic Loss Reduction, University of Western Ontario, London, Canada* (November 2022)
- Interview on earthquake-induced landslides and cascading hazards for SFU News and participation in ShakeOut BC 2022 (October 2022).
- Invited talk at *Seminario Instituto de Ciencias de la Ingeniería, Universidad de O'Higgins, Rancagua, Chile*. “Grandes deslizamientos de roca en valles cordilleranos: mecanismos y peligros asociados” (August 2022).