NSERC/Rio Tinto Industrial Research Chair on Climate Change and Water Security

Annual Report – Year 5

(1 July 2023 – 30 June 2024)

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2023-2024 IRC Annual Report

Preamble

June 30th, 2024 marks the completion of the fifth year of the Natural Sciences and Engineering Research Council of Canada (NSERC)/Rio Tinto Industrial Research Chair (IRC) in Climate Change and Water Security at UNBC. The 5+1-year program of research started on July 1st, 2019 with the overarching objective to better understand and quantify the roles of climate variability, climate change, and water management on the long term water security of the Nechako Watershed. Among other research topics, we are elucidating some of the complex interactions between climate change and human interventions on flow volumes and water temperatures in the Nechako River using a combination of in situ observations and computer modelling. This annual report provides a progress update on personnel recruitment and training, program management, our field activities and research, communication strategy and community engagement, and the budget.

Tenure

In early 2024, UNBC applied to NSERC for a one-year, no-cost extension to the NSERC / Rio Tinto IRC in climate change and water security. This extension was indeed granted by NSERC and as such, the program of research has been extended by one year and will now end on June 30th, 2025. Sincere thanks to UNBC, NSERC and Rio Tinto in facilitating this extension to the IRC position so that we can complete several projects that were delayed due to the COVID-19 pandemic. While this extension comes with no additional funding, our field activities and research are well supported through a carry-over of funds from Year 5 (see Budget section) and through other efforts including an NSERC Alliance project and by the Nechako Environmental Enhancement Fund (NEEF). In this report, therefore, there are references to a sixth project year covering 1 July 2024 to 30 June 2025.

Personnel and Training

During the fifth year of activity, a number of highly-qualified personnel (HQP) were retained or recruited to support the IRC program of research. In supporting roles, Lisa Rickard (as of 4 March 2024) and Justin Kokoszka (as of 17 October 2022) acted as the (co-)research managers (RMs) for the group while Justin also took on the role of data manager. In January 2024, Kirsten Calder-Sutt transitioned from hydrometeorological technician to part-time data administrator in support of our data management efforts.

Training of graduate and undergraduate students remains central to the objectives of the IRC. Three undergraduate students from UNBC, Jade Reynolds, Laura-Anne Browning and Dylan Broeke, were recruited as field assistants to support our spring/summer 2023 field activities. While their positions ended in late August 2023, Dylan Broeke transitioned to a position of Research Skills Trainee in September 2023 to further support field work activities and hydrometeorological network development. During the spring of 2024, three UNBC undergraduate students, Kainen Parmar, Lynn Poeppelmann and Maria Tavares, were recruited as field and research assistants.

Their positions will run until the end of August 2024. They are responsible for conducting field work across the Nechako Watershed including site visits for data collection. Finally, each HQP has been trained on data management to enhance their skills and proficiency in handling and organizing data efficiently including: data entry, data validation, and general database operations.

Several graduate students have been recruited so far under the IRC umbrella. As of May 2020, a MSc student, Justin Kokoszka, leads a project on the naturalization of flows in the Nechako River using a flow translation approach. Meanwhile, Bruno Sobral began in 2020 his PhD program investigating atmospheric rivers affecting the Nechako Watershed. Two post-doctoral fellows (PDFs) worked for the IRC program of research over the past year. Dr. Jingwen Wu worked on hydrological modelling in the context of future climate projections (until early September 2023), and Dr. Mostafa Khorsandi (as of 1 February 2024) worked on station-based modelling of water temperature. As a part-time Research Skills Trainee, Dr. Tamar Richards-Thomas has continued exploring three atmospheric rivers that impacted the upper Nechako Watershed during the TRARE field campaign in autumn 2021. Finally, Meng Wang was recruited as an MSc student to explore spatio-temporal variability in water temperatures across the Nechako Watershed in September 2023 but has taken an extended leave of absence from UNBC as of February 2024.

As part of our committed engagement to education and training we have developed a comprehensive training program for new staff members. Over the last year, we collected and implemented feedback and suggestions from past staff to improve our workflow and required training. The result has been a structured, three-week training program covering the following topics: history of the Nechako River Basin and its local and regional significance, administration and communication practices, field safety, site and equipment management, and data management practices. The training also included several day trips focused on building a weather station, coding in the field, data collection, collecting robust field notes, and GPS training.

Research Management

The Science Advisory Board (SAB) formed in late 2019 oversees the progress of the IRC program of research and met on two occasions during the reporting period. The SAB comprises five members: Mr. Andy Lecuyer (Rio Tinto), Dr. Ellen Petticrew (UNBC), Mr. James Rakochy (Cheslatta Carrier Nation), Mr. Chelton van Geloven (Lheidli T'enneh First Nation, formerly of the BC Ministry of Forests), and Dr. Francis Zwiers (Scientist Emeritus, Pacific Climate Impacts Consortium). The SAB along with the Director of the UNBC Office of Research and Innovation, Mr. Mark Barnes, met on 29 November 2023 and on 27 May 2024, respectively, to evaluate progress thus far with the IRC program of research through online presentations by Dr. Déry and the IRC team. The SAB will continue meeting with the Chairholder and his personnel twice annually to ensure the IRC objectives are met, to provide feedback, and to assess progress. The SAB reports to the UNBC Vice-President of Research and Innovation, Dr. Paula Wood-Adams.

Theme 1: Hydrometeorological Monitoring and Data Collection

During our fifth year of activity, we maintained a network of 31 water temperature loggers, five tipping bucket rain gauges, and six complete meteorological stations across the entire Nechako Watershed (Figure 1). Improved monitoring of water temperatures and hydrometeorological conditions across the Nechako Watershed is central to Theme 1 of the IRC program of research. Not only are these data providing high-resolution information on the spatio-temporal variations in water temperatures and rainfall in the Nechako Watershed but are also assisting with modelling efforts (Themes 2 and 3).

Over the past year we have fine-tuned our field records collection software and continue to collect and maintain field notes that include: site visit details, data downloads, equipment deployments/ retrievals, and annotated field photos. These records are stored in a central database for quick reference allowing access to field records, equipment details, in addition to raw data collected in the field. Additionally, we have developed an in-house quality assurance/quality control (QAQC) procedure to enhance our data quality and maintain consistency across all sites. Currently, we are finalizing the QAQC of water temperature records and developing a reporting procedure to generate data reports and fulfil specific data requests with ease. In the coming months, we plan to extend our QAQC and data management strategy to our extensive meteorological data collection.

Servicing of the water temperature loggers, tipping bucket rain gauges and meteorological stations was once again generously supported by several First Nations and by Rio Tinto. Cheslatta Carrier Nation provided boat access to reach sites in the upper Nechako Watershed including streams flowing into Tahtsa Lake and to the south shore of the Nechako Reservoir. Tl’azt’en First Nation also provided boat support and staff time to reach Kazchek Creek and the Middle River where water temperature probes were also deployed. Nak’azdli Whut’en provided staff support when accessing streams near Fort St. James. Finally, two staff members from Stellat’en First Nation joined some of the field visits at the Endako and Stellako rivers.

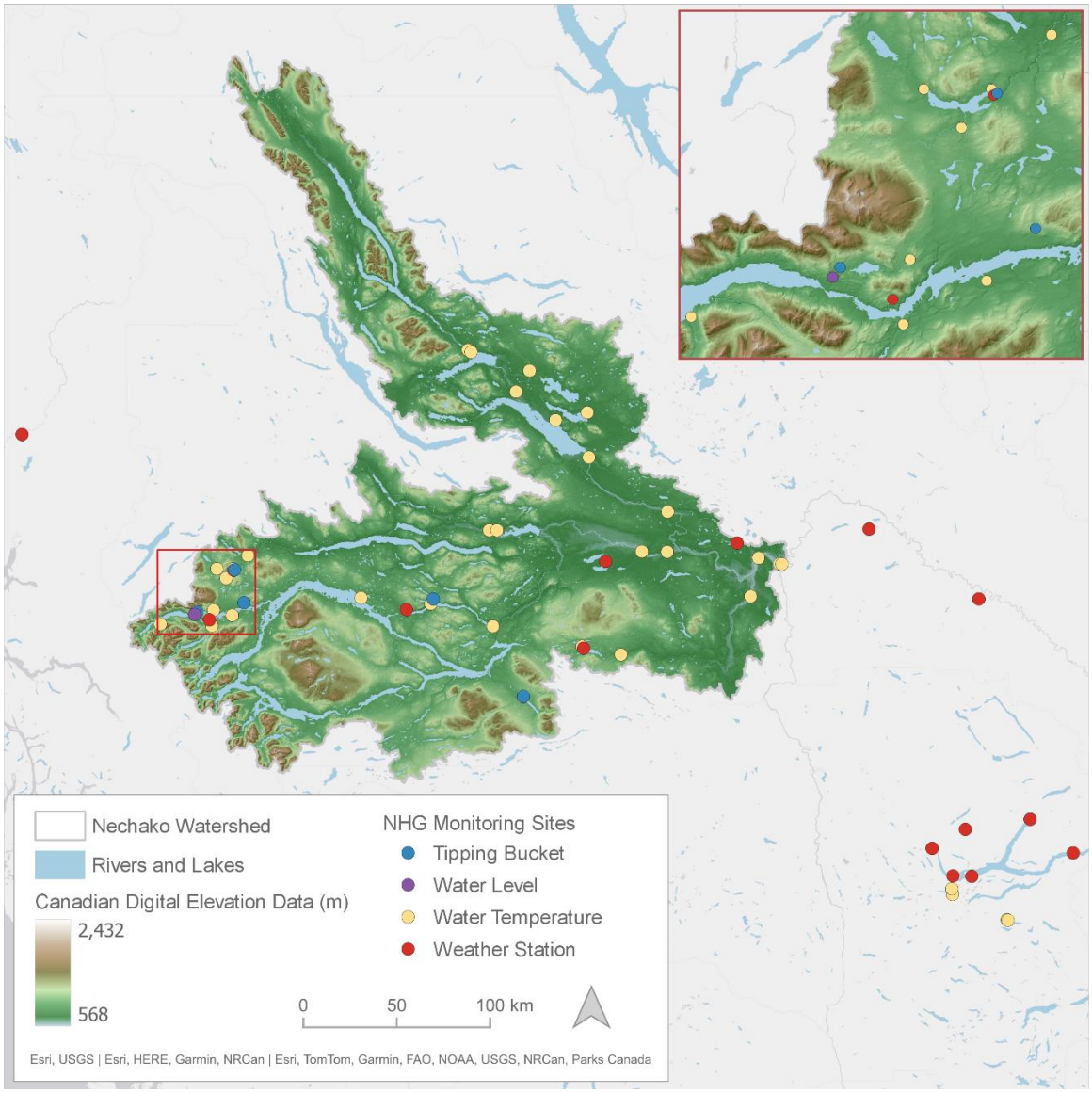

Figure 1: Map of active (as of 30 June 2024) tipping bucket rain gauge station, water level gauge, water temperature logger, and weather station sites across the Nechako Watershed and surrounding areas.

Following collaborative planning efforts between the Northern Hydrometeorology Group and members of the Nulki-Tachick Lakes Stewardship Society (NTLSS) in addition to the Nechako Environment and Water Stewardship Society (NEWSS), a full weather station was successfully installed at Nulki Lake on 29-30 May 2024. The new weather station is located off the northeastern side of Nulki Lake, and it is now fully operational. This station consists of a variety of sensors, a data logger, and a solar panel installed on a 3 m tripod. Sensors include a snow depth sensor, two temperature probes, and a compact digital weather sensor (ClimaVUE50). Together, these instruments measure the following parameters: snow depth, soil, water and air temperature, incoming solar radiation, relative humidity, vapour pressure, barometric pressure, wind speed, wind direction, total precipitation, and lightning strikes. The new station will provide useful

meteorological data in an area where a data gap previously existed. It will also help us understand atmospheric drivers of water temperature fluctuations in the Stony Creek system. This project will also serve to promote continued data-sharing and collaboration with our partners at NTLSS and NEWSS. A similar weather station was then installed at the Nadina River Spawning Channel in late June 2024 in collaboration with the Department of Fisheries and Oceans Canada.

We continue our efforts to organize our monitoring data into a centralized database, promoting data shareability, and enhancing data quality. This initiative ensures easy access to information, facilitates collaborative research, enables efficient analysis, and ensures the longevity of data collected through the IRC program. Additionally, the database includes a system to track and maintain equipment, ensuring accurate and reliable data collection.

Theme 2: Atmospheric and Terrestrial Rivers

Over the past academic year (2023-2024), MSc student Justin Kokoszka has continued to work on his assessment of regulation and hydroclimate influences on historical streamflow within the Nechako River Basin. Naturalized streamflow has been reconstructed using a flow translation method with reservoir inflow data as a proxy for uninfluenced upstream flow. In summary, these proxy data were translated downstream to Vanderhoof and Isle Pierre while accounting for lake attenuation, water travel time, missing contributing area, and additional flows from gauged tributaries. Both the naturalized and observed streamflow time series were then evaluated for the principal indicators of change in terms of ecologically significant metrics using principal component analysis. These metrics were then evaluated for inter-annual variability in terms of long-term trends and significant change points. The results from these analyses were then used to estimate the relative contribution of change due to regulation and hydroclimate providing a unique insight into hydrological change along the Nechako River.

The project is in the writing phase with additional analyses underway. Moving forward, Justin will be evaluating the relationship between hydroclimate and streamflow in terms of time-frequency patterns using wavelet coherence analysis. This will provide an essential insight for the interaction between streamflow and large-scale hydroclimate patterns, such as the El Niño Southern Oscillation (ENSO). The completed project aims to provide insights valuable for water resource management that are linked to ecological significance within the Nechako River Basin. Justin aims to defend his thesis in the fall of 2024.

During the 2023-2024 academic year, PhD candidate Bruno Sobral continued his work on atmospheric river (AR) research with significant achievements and contributions. In September 2023, Chapter 2 of his dissertation was published in the *International Journal of Climatology* under the title "Spatiotemporal distribution and trend analyses of atmospheric rivers affecting British Columbia's Nechako Watershed." This publication marks the first significant milestone in his academic journey, showcasing his analysis and findings on AR activity in the region. In February

2024, he submitted Chapter 3 of his dissertation, titled "Variability and trends in the contributions of atmospheric rivers to the hydroclimatology of British Columbia's Nechako River Basin," to the journal *Hydrological Processes*. This manuscript is currently under review and, if accepted, will be part of a special issue focused on the Canadian Geophysical Union (CGU) 2023 Annual Meeting held in Banff in May 2023. Preliminary results of this work were presented as a poster at the event in May 2023.

Significant progress has been made in the past year, with Bruno dedicating a considerable portion of his studies to acquiring new literature on ARs, refining and updating extensive climate datasets, and programming scripts to display the results of Chapters 3 and 4. In early June 2024, he presented another poster with preliminary results of Chapter 4 at the Canadian Meteorological and Oceanographic Society (CMOS) 58th Congress. The poster, titled "Exploring the Climatology and Hydrological Response of Exceptional Atmospheric Rivers in British Columbia's Nechako River Basin," was presented online and awarded best student poster presentation at the congress. The results received positive feedback from attendees, providing external validation of the methods used to select exceptional ARs. This recognition from the academic community further underscores the significance of his ongoing work. A draft of the manuscript for Chapter 4 of his PhD dissertation is well underway and is planned to be submitted for publication later this year to another scientific outlet.

More recently, he has started working on the introduction and conclusion sections of his PhD dissertation, marking the final stages of his research as a PhD student at UNBC. Looking ahead, a first draft of his PhD dissertation will be available for the PhD Committee in August 2024, with the defense scheduled for the upcoming Fall term. This approaching milestone will be a culmination of his extensive research and dedication to understanding the complexities of ARs and their impacts on the Nechako River Basin.

Theme 3: Water Temperature and Hydrological Modeling

Until September 2023, Dr. Jingwen Wu utilized various tools and datasets to examine the future hydrometeorological conditions in the Nechako River Basin (NRB) under two greenhouse gas emission scenarios. He assembled and prepared projected climate data from 17 climate models and two climate change scenarios for the hydrological simulations. The Variable Infiltration Capacity (VIC) hydrological model was implemented in the NRB using these climate projections. After calibration and validation, the model produced reliable simulations (1981—2100) of hydrological processes. The results indicate a 2.8% and 8.2% increase in annual mean streamflow for both periods (2041–2070 and 2071–2100) compared to historical streamflow (1981-2010) in the NRB under the high greenhouse gas emission scenario. Furthermore, the peak flow magnitude decreased by approximately 6% and 20% for both periods, mainly due to increased temperatures causing earlier snowmelt. The gradual release of water from snowmelt over an extended period leads to a reduction in peak flow.

In spring 2024, Mostafa Khorsandi completed his Ph.D. degree at the Institut National de Recherche Scientifique and joined the IRC team as a post-doctoral fellow. His work began by calibrating the Air2Stream model for multiple monitoring stations over the Nechako Watershed using measured water flows, temperatures, and climatic data from the ERA5-Land dataset. The calibrated models for each station can estimate water temperature for the past and the future. The first fulfilled goal was to fill missing records in the water temperature time series. Moreover, the historical water temperatures are successfully produced as hindcast modelling using the calibrated models for each station. On the other hand, by forcing the calibrated models with the naturalized flows at Vanderhoof and Isle Pierre stations, the water temperatures are simulated for the naturalized condition (e.g., the hypothetical scenario with absence of the Kenney Dam and Skins Lake Spillway in the watershed). Finally, Mostafa's work at this moment is focused on frequency analysis of water temperatures for the three scenarios: (1) observations, (2) simulations with regulated flow, and (3) simulations with naturalized flows.

Next, Mostafa's work involves simulating water temperatures for future climate change scenarios using naturalized flows (by implementing VIC model outputs) as well as regulated flows (by implementing CEQUEAU model outputs, the operation model under use by Rio Tinto). These results show the impacts of climate change and STMP on water temperature and produce outputs for possible modifications in flow release and water temperature management at crucial sites in the Nechako Watershed.

Communication Strategy

We maintain a comprehensive communication strategy to ensure information on the IRC program of research is disseminated widely and in a timely fashion. This includes a dedicated website, presence on social media (e.g. Twitter, ResearchGate and Rio Tinto's Facebook page), MS Teams and a Slack workspace to facilitate interactions between the IRC team members. Dr. Déry is also profiled on NSERC's online Chairholder database. The IRC team prepares a quarterly newsletter posted on the IRC website and emailed to our extensive distribution list (135 individuals and organizations) to disseminate further information on the IRC to the general public. Dr. Déry was interviewed at least 25 times over the past year by various media outlets including on his perspectives of recent drought and low streamflow conditions in northern BC.

Dr. Déry delivered several presentations over the past year to a wide range of stakeholders in the Nechako Watershed and beyond. For instance, he delivered a presentation on climate change projections at the Northern Health-UNBC climate and health knowledge exchange workshop held at UNBC in April 2024. In September 2023 and January 2024, Dr. Déry provided representatives from the German Research Foundation and from Rio Tinto, respectively, an update on IRC-related research. Dr. Déry also delivered two guest lectures in various courses at UNBC during which IRC-related research was profiled. Finally, he presented the findings of IRC-team research at the 2024 annual meeting of the Canadian Meteorological and Oceanographic Society (CMOS) in early June 2024 and at the Fifth International Atmospheric River Conference held in La Jolla, California

in late June 2024. Bruno Sobral also presented a poster at the 2024 CMOS congress.

As results continue to emerge from the IRC program of research, conference presentations and peer-reviewed publications are in development. The following provides a list of recently submitted papers and others in preparation in addition to conference presentations from the past year.

Journal Articles

Cardinal, E., Thériault, J. M., Stewart, R. E., Thompson, H. D., and Déry, S. J., 2024: Climatology of and factors contributing to occurrences of near-freezing temperatures and associated precipitation near Terrace, British Columbia, Canada, *Atmosphere-Ocean*, **62**(2), 145-164, doi: 10.1080/07055900.2023.2270560.

Déry, S. J., Martins, E. G., Owens, P. N., and Petticrew, E. L., 2024: Extreme hydrometeorological events induce abrupt and widespread freshwater temperature changes across the Pacific Northwest of North America, *Communications Earth & Environment*, **5**, 228, doi: 10.1038/s43247-024-01407-6.

Gilbert, D. E., Morris, J. E., Kaveney, A. R., and Déry, S. J., 2022: Sub-hourly water temperature data collected across the Nechako Watershed, 2019-2021, *Data in Brief*, **43**, 108425.

Hurley, K. M., Morris, J. E., Cardinal, É., Gilbert, D. E., Kaveney, A. R., Sobral, B., Thompson, H. D., Thériault, J. M., and Déry, S. J., 2024: Hydrometeorological data collected during the Tahtsa Ranges Atmospheric River Experiment (TRARE), to be submitted to *Earth System Science Data*.

Sobral, B. S. and Déry, S. J., 2023: Spatiotemporal distribution and trend analysis of atmospheric rivers affecting British Columbia's Nechako Watershed, *International Journal of Climatology*, **43**(14), 6720-6732, doi: 10.1002/joc.8230.

Sobral, B. S. and Déry, S. J., 2024: Variability and trends in the contributions of atmospheric rivers to the hydroclimatology of British Columbia's Nechako River Basin, submitted to *Hydrological Processes*.

Conference Presentations

Richards-Thomas, T., Woyke, S., and Déry, S. J. 2024: Moisture fluxes during three atmospheric rivers in September and October 2021 in British Columbia’s Upper Nechako Watershed, 2024 annual congress of the Canadian Meteorological and Oceanographic Society, 4 June 2024.

Richards-Thomas, T., Woyke, S., and Déry, S. J. 2024: Moisture fluxes during three atmospheric rivers in September and October 2021 in British Columbia’s Upper Nechako Watershed, 2024

International Atmospheric River Conference, 27 June 2024.

Sobral, B. S. and Déry, S. J. 2024: Exploring the climatology and hydrological response of exceptional atmospheric rivers in British Columbia's Nechako River Basin, 2024 annual congress of the Canadian Meteorological and Oceanographic Society, 5 June 2024.

Community Engagement

The success of the IRC relies on a broad communication strategy and community engagement. To that end, efforts are routinely made to communicate with First Nations as to where field work and other research is being undertaken as part of the IRC. Over the past year, we maintained our engagement with four First Nations: Cheslatta Carrier Nation, Stellat'en, Nak'azdli Whut'en, and Tl'azt'en First Nations. Most of the IRC team travelled to Cheslatta Territory on 22 May 2024 to meet representatives from Cheslatta Carrier Nation. This included a presentation on the Nation's history and the geography their traditional territory covers.

We continued to entertain a wide range of discussions with many individuals and organizations across the Nechako Watershed during field work across the upper Nechako Watershed. This included several site visits in 2023 and 2024 at Huckleberry Mine for discussions with the mine's general manager, Mr. Marke Wong. We also connected with staff members of the Fisheries and Oceans Canada's Nadina River Spawning Channel where a new weather station is now installed. We anticipate continued interactions with members of the community this summer as we return to our field sites for data collection and as we finalize the commissioning of the MECHE observatory at Huckleberry Mine.

Dr. Déry remains fully engaged in Rio Tinto's Water Engagement Initiative (WEI) and participated in main table and technical working group meetings over the past year. The IRC quarterly newsletters are distributed to the entire WEI mailing list. Additional information on the IRC is posted on Rio Tinto's Get Involved website. Further, Dr. Déry and Bruno Sobral participated in and presented at the Nechako Watershed Roundtable's (NWR's) annual meeting on 7 November 2023 in Vanderhoof. Dr. Déry has also represented UNBC and the Integrated Watershed Research Group at several NWR Core Committee meetings starting in spring 2024. Dr. Déry has also engaged in the UNBC-Nechako Valley Working Group by attending its bi-monthly meeting and participating in an ad hoc group on weather stations in the Vanderhoof agricultural belt.

Industrial Partner Engagement

Dr. Déry interacts on a regular basis with Rio Tinto, the industrial partner via email, phone, online and in person meetings. The principal contact person at Rio Tinto for research is Andy Lecuyer, while for outreach, interactions are facilitated by Lianne Olson (Senior Advisor, Community

Social Performance) and Devrie Sanghera (Business Partner, Communities & Social Performance). Additional communication with Alec Mercier and Marco Latraverse on the water management team proceeds on a periodic basis for the exchange of data and metadata, information on Rio Tinto's operations and system in the Nechako Watershed, and to identify monitoring and information gaps in the basin. Dr. Déry travelled to Saguenay, Quebec in November 2023 to meet the entire Rio Tinto water resources team to discuss ongoing research and exchange recent findings. This trip also allowed a very informative site visit to Rio Tinto's Shipshaw generating station on the Saguenay River.

Over the past year we maintained close collaboration with Scott Klassen of Avison Management Services for periodic site visits of UNBC meteorological equipment at Chedakuz Creek, Eutsuk Narrows and at Mt. Sweeney. Alec Mercier also continued to provide up-to-date streamflow data at the Kemano Powerhouse and inflow data for the Nechako Reservoir that are being integrated into multiple IRC projects. Finally, Andy Lecuyer has provided continuous support by sharing his knowledge on Rio Tinto's operations across the Nechako Watershed.

Budget

The IRC program of research is supported equally by NSERC and Rio Tinto with a total budget of $1.5M over six years. Approximately one third of this budget is allocated to support Dr. Déry's salary and benefits. With the release of these funds and to fulfil the requirements of NSERC's IRC program, UNBC hired in September 2020 a new tenure-track faculty member (Dr. Siraj ul Islam) to build institutional capacity in hydrometeorology. As of 30 June 2024, available funds for Year 5 were disbursed mainly for the support of HQP (63.8%) with other expenses related to field work, materials and supplies, travel to conferences, etc. (14.5%). The remainder of available funds for Year 5 (21.7%) were used to purchase a new research vehicle (a 2023 Toyota Tundra) to support our intensifying field activities. As of 30 June 2024, we expended 91.6% of the overall allocated funds for Year 5 of the IRC with any year-end surplus or deficit of funds to be carried to Year 6. To date, we have expended 91.3% of the Years 1-5 proposed budget. The remaining 8.7% of the total budget will be expended by the end of Year 6 of the IRC program of research.

While NSERC and Rio Tinto provide the bulk of the funding for the IRC program of research, extra support was provided through EcoCanada (one successful applications totaling $15K in 2023/2024). Successful applications to the Nechako Environmental Enhancement Fund (NEEF) and to NSERC's Alliance program has secured additional funding that is partly supporting our field activities in the Nechako Watershed during the 2024 summer field season. In late spring 2024, we secured $17K through to the Partnering Fund of the Real Estate Foundation of BC to extend research on the atmospheric river phenomenon in the Fraser River Basin.