GIANT MINE
Oversight Board

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Giant Mine Oversight Board Research Program

TERRE-NET 2021 (Year 3 Q1) Summary Report

2021 10 29

Year 3 Q1 Progress Report
Remediation Strategies for the Long-term Management of Arsenic-trioxide-bearing Roaster Wastes at the Giant Mine, Northwest Territories

This report was prepared by Toward Environmentally Responsible Resource Extraction Network (TERRE-NET) personnel to provide an update through to the end of Year 3 Q1 (to June 30, 2021) of the main aspects of the TERRE-NET-GMOB research project and to identify any research and budget challenges experienced to date. The research projects reviewed herein include:

Project 1: Examination of arsenic trioxide dust composition and solubility
Project 2: Sulfidation of As_2O_3 to low-solubility arsenic sulfide (As_2S_3)
Project 3: Incorporation of As_2O_3 into cemented-paste backfill
Project 4: Leaching behaviour and geochemical stability of vitrified arsenical glass

The overall goals of the four projects proposed within Phase 1 are to: provide an enhanced understanding of the physical and geochemical properties of the roaster waste; and screen for potentially viable remediation alternatives that may warrant additional research (*e.g.*, long-term laboratory experiments, pilot-scale trials).

The total combined budget of the proposed research activities within Phase 1 is $931,731 and Year 2 expenditures to end of Q2 are briefly summarized in the report (including for the Administrative portion of the project). Phase 1 projects will provide direct stipend support for the training of six highly-qualified personnel (HQP), including two MSc students, one PhD student, two Post-doctoral Fellows (PDFs), and one undergraduate summer student. HQP will be supported by the TERRE-NET co-investigators and administrative and technical staff, and academic collaborators.

Project 1: Examination of arsenic trioxide dust composition and solubility

Investigators:
Joyce McBeth (University of Saskatchewan)
Matthew Lindsay (University of Saskatchewan)
Heather Jamieson (Queen's University)
Valerie Schoepfer (University of Saskatchewan)

1.1 Research update

Since our last report, we have made progress toward meeting research objectives while managing transition in our research team. Dr. Jullieta Lum left the University of Saskatchewan in April 2021 to pursue a geoscience consulting career. We are pleased to report that Dr. Valerie Schoepfer is transitioning into the Postdoctoral Fellow role vacated by Dr. Lum's departure. Dr. Schoepfer is very familiar with the experimental methods and analytical techniques being employed in this research and has previously collaborated with Dr. Lum on associated data collection and analysis. Dr. Schoepfer will allocate 50% of her time to this project from September 1, 2021 through April 30, 2022, when she will fully transition to this project. We can also report that Dr. Schoepfer received supplemental funding through the NSERC CREATE INSPIRE training program, which provides $22,000 per year for up to 2 years. These funds will allow us to extend her involvement in this project without affecting project budgeting.

In terms of research progress, we have completed additional synchrotron measurements on archived arsenic trioxide roaster waste (ATRW) samples and on synthetic antimony-substituted arsenic trioxide. High-energy X-ray diffraction (HEXD) data collected on the Brockhouse beamline Canadian Light Source (CLS) is facilitating pair distribution function analysis. This approach allows us to probe antimony substitution mechanisms and corresponding impacts on the arsenic trioxide crystal lattice. Micro-X-ray fluorescence (μXRF) mapping of element distributions, coupled with micro-X-ray absorption spectroscopy (μXAS) measurements, is providing valuable insight into spatial relationships between arsenic, antimony, and other elements (e.g., iron) in archived ATRW samples. This approach also allows us to examine spatial variations in arsenic and antimony oxidation states, which may influence ATRW reactivity under environmental conditions.

We recently obtained electron microprobe analyzer (EPMA) results that demonstrate extensive quantitative antimony substitution for arsenic for archived ATRW samples. These results are currently being integrated into a manuscript describing the geochemical and mineralogical characteristics of archived ATRW samples. We anticipate submitting this manuscript to GMOB for review in November 2021.

1.2 Deviations from research plan

As outlined above, Dr. Jullieta Lum has left the project to take a consulting position; Dr. Valerie Schoepfer is transitioning into the project and will be a full-time member of the research team by May 2022.

1.3 Budget update

The total proposed budget for research in Year 3 is $5,406 plus additional funds carried over from Year 2 of $128,560 for total available funds of $133,966 in Year 3. This amount includes $107,173 for direct research costs plus 25% overhead ($26,793) charged by the University of Saskatchewan (Table 1).

Table 1. Summary of budget proposed and actuals for Year 3.

	Year 3 Budget	Year 2 C'fwd	Total available Year 3	Y3 Q1 Actuals Apr1-Jun30	Y3 Q2 Actuals Jul1-Sep30	Y3 Q3 Actuals Oct1-Dec31	Y3 Q4 Actuals Jan1-Mar31	Year 3 Actuals Total	Total unspent Year 3
Salaries and Benefits	**$ -**	**$ 33,611**	**$ 33,611**	**$ 4,022**	**$ -**	**$ -**	**$ -**	**$ 4,022**	**$ 29,589**
a) PhD students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Master's students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) Undergraduate students	$ -	$ 12,163	$ 12,163	$ -	$ -	$ -	$ -	$ -	$ 12,163
d) Postdoctoral fellows	$ -	$ 10,198	$ 10,198	$ 4,022	$ -	$ -	$ -	$ 4,022	$ 6,176
e) Technical/Professional Assistants	$ -	$ 11,250	$ 11,250	$ -	$ -	$ -	$ -	$ -	$ 11,250
Equipment	**$ -**	**$ 47,446**	**$ 47,446**	**$ 144**	**$ -**	**$ -**	**$ -**	**$ 144**	**$ 47,303**
a) Purchase or rental	$ -	$ 4,768	$ 4,768	$ -	$ -	$ -	$ -	$ -	$ 4,768
b) Operation and maintenance costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) User Fees	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Analytical Costs	$ -	$ 42,679	$ 42,679	$ 144	$ -	$ -	$ -	$ 144	$ 42,535
Materials and Supplies	**$ -**	**$ 4,376**	**$ 4,376**	**$ 1,233**	**$ -**	**$ -**	**$ -**	**$ 1,233**	**$ 3,143**
a) Laboratory supplies, reagents	$ -	$ 4,376	$ 4,376	$ 1,233	$ -	$ -	$ -	$ 1,233	$ 3,143
b) Machining costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travel	**$ 4,325**	**$ 17,415**	**$ 21,740**	**$ 131**	**$ -**	**$ -**	**$ -**	**$ 131**	**$ 21,608**
a) Conferences and Workshops	$ 4,325	$ 13,415	$ 17,740	$ 131	$ -	$ -	$ -	$ 131	$ 17,608
b) Field Work	$ -	$ 4,000	$ 4,000	$ -	$ -	$ -	$ -	$ -	$ 4,000
Dissemination	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
a) Publication costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Communication costs (teleconference)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	**$ 4,325**	**$ 102,848**	**$ 107,173**	**$ 5,530**	**$ -**	**$ -**	**$ -**	**$ 5,530**	**$ 101,643**
University Overhead (25%)	**$ 1,081**	**$ 25,712**	**$ 26,793**	**$ 1,382**	**$ -**	**$ -**	**$ -**	**$ 1,382**	**$ 25,411**
Grand Total	**$ 5,406**	**$ 128,560**	**$ 133,966**	**$ 6,912**	**$ -**	**$ -**	**$ -**	**$ 6,912**	**$ 127,054**

1.4 Deviations from budget

Primary deviations from the budget include a lower level of salary and equipment disbursements due to the slightly delayed start of the project and a change in research personnel. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 2: Sulfidation of As_2O_3 to form low-solubility As_2S_3

Investigator:
Tom Al (University of Ottawa)

2.1 Research update

The purpose of this project is to explore methods to transform As_2O_3-rich dust to a low-solubility As_2S_3 material that is stable in an anaerobic environment such as deep in the mine.

One goal has been to identify a sulfide source for sulfidation; the following possibilities were considered:

- commercially available Na_2S
- H_2S gas; either recovered from oil & gas operations or *via* transformation of elemental sulfur (S^0) to H_2S

Commercially available $Na_2S{\cdot}9H_2O$ was rejected because a) the reagent cost would be extremely expensive to scale up, and b) the reaction with Na_2S requires acidification with a strong acid such as HCl, and again, scale-up costs and transportation risks would be prohibitively high - approximately 560,000 tonnes, or 28,000 truckloads of concentrated HCl would be required. Reaction of As_2O_3 with H_2S is therefore deemed the best option.

Transformation of S^0 to H_2S in a production facility constructed at the Giant Mine site is considered the best approach to provide the necessary reagent while minimizing transportation risks. There are massive amounts of S^0 stored as a waste at the Alberta oil sands operations, and transportation of this material presents a low health & safety risk. There are two general process options for transforming S^0 to H_2S; 1) reaction with natural gas (methane or CH_4) or 2) reaction with hydrogen gas (H_2). There is no available source of CH_4 in Yellowknife and transportation would come with a high cost and some considerable health & safety risk, so reaction of S^0 with H_2 appears to be the best approach. H_2 gas can be produced with commercially available electrolysis plants that are modular, and therefore scalable to meet the demand. The two requirements are clean water and electricity, both of which are available in Yellowknife. With S^0 transported to Yellowknife from Alberta and H_2 produced locally by electrolysis, the production of H_2S can be accomplished with a local production facility. There are several commercial suppliers of modular H_2S plants that could be consulted to meet the requirement. The recovery of H_2S from oil & gas operations was rejected because of the high health and safety risk of transporting the gas to the Northwest Territories from Saskatchewan and/or Alberta. The financial cost of this approach was not evaluated.

Given that As_2O_3 must first be dissolved prior to sulfidation, a second goal is to investigate the dissolution rate and temperature control on the solubility of As_2O_3. The dissolution rate and solubility of reagent grade As_2O_3 have now been determined up to 180 °C, and the data demonstrate that an industrial scale process requiring rapid throughput would benefit greatly by operating at temperatures in the range of 150 to 200 °C and corresponding pressures. Tests have been conducted on samples of ATRW from the Giant Mine to determine how much of the As_2O_3 can be dissolved in water at these elevated temperatures and pressures. Dust from sample B233-P9 was used because it contains the highest levels of impurities and is therefore thought to be the most difficult to dissolve. Results indicate ~80% of the arsenic is dissolved in a few minutes at temperatures ranging from 140 to 200 °C. Similar tests are now underway on dust from samples B235-P13 and B212-4 133-67 which have lower impurity contents. Work is also continuing with efforts to characterize the mineralogical hosts of arsenic in the extraction residues.

2.2 Deviations from research plan

There are no deviations from the research plan since the last report.

2.3 Budget update

The total proposed budget for research in Year 3 is $54,128 minus an overspend from Year 2 of $16,801 for total available funds of $37,327 in Year 3. This amount includes $26,662 for direct research costs plus 40% overhead ($10,665) charged by the University of Ottawa (Table 2).

Table 2. Summary of budget proposed and actuals for Year 3.

	Year 3 Budget	Year 2 C'fwd	Total available Year 3	Y3 Q1 Actuals Apr1-Jun30	Y3 Q2 Actuals Jul1-Sep30	Y3 Q3 Actuals Oct1-Dec31	Y3 Q4 Actuals Jan1-Mar31	Year 3 Actuals Total	Total unspent Year 3
Salaries and Benefits	**$ 21,000**	**$ (13,783)**	**$ 7,217**	**$ 7,731**	**$ -**	**$ -**	**$ -**	**$ 7,731**	**$ (514)**
a) PhD students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Master's students	$ 21,000	$ 24,227	$ 45,227	$ 3,500	$ -	$ -	$ -	$ 3,500	$ 41,727
c) Undergraduate students	$ -	$ (8,722)	$ (8,722)		$ -	$ -	$ -	$ -	$ (8,722)
d) Postdoctoral fellows	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
e) Technical/Professional Assistants	$ -	$ (29,288)	$ (29,288)	$ 4,231	$ -	$ -	$ -	$ 4,231	$ (33,519)
Equipment	**$ 4,000**	**$ (18,989)**	**$ (14,989)**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ (14,989)**
a) Purchase or rental	$ -	$ (26,374)	$ (26,374)	$ -	$ -	$ -	$ -	$ -	$ (26,374)
b) Operation and maintenance costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) User Fees	$ 2,500	$ 5,000	$ 7,500	$ -	$ -	$ -	$ -	$ -	$ 7,500
d) Analytical Costs	$ 1,500	$ 2,385	$ 3,885	$ -	$ -	$ -	$ -	$ -	$ 3,885
Materials and Supplies	**$ 7,000**	**$ 10,599**	**$ 17,599**	**$ 195**	**$ -**	**$ -**	**$ -**	**$ 195**	**$ 17,404**
a) Laboratory supplies, reagents	$ 5,000	$ 6,599	$ 11,599	$ 195	$ -	$ -	$ -	$ 195	$ 11,404
b) Machining costs	$ 2,000	$ 4,000	$ 6,000	$ -	$ -	$ -	$ -	$ -	$ 6,000
Travel	**$ 4,663**	**$ 8,461**	**$ 13,124**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 13,124**
a) Conferences and Workshops	$ 4,663	$ 8,461	$ 13,124	$ -	$ -	$ -	$ -	$ -	$ 13,124
b) Field Work	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dissemination	**$ 2,000**	**$ 1,711**	**$ 3,711**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 3,711**
a) Publication costs	$ 2,000	$ 2,000	$ 4,000	$ -	$ -	$ -	$ -	$ -	$ 4,000
b) Communication costs (teleconference)	$ -	$ (289)	$ (289)	$ -	$ -	$ -	$ -	$ -	$ (289)
Subtotal	**$ 38,663**	**$ (12,001)**	**$ 26,662**	**$ 7,926**	**$ -**	**$ -**	**$ -**	**$ 7,926**	**$ 18,736**
University Overhead (40%)	**$ 15,465**	**$ (4,800)**	**$ 10,665**	**$ 3,170**	**$ -**	**$ -**	**$ -**	**$ 3,170**	**$ 7,494**
Grand Total	**$ 54,128**	**$ (16,801)**	**$ 37,327**	**$ 11,096**	**$ -**	**$ -**	**$ -**	**$ 11,096**	**$ 26,230**

2.4 Deviations from budget

This project is currently on budget in Year 3. Slight overspending in Equipment – User Fees has been off set by under-spending in other categories. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 3: Stabilization of As_2O_3 dust in cemented paste backfill

Investigators:
Isabelle Demers (UQAT)
Nick Beier (University of Alberta)
Mostafa Benzaazoua (UQAT; collaborator)

3.1 Research update

Characterisation of As_2O_3 dust and Giant mine tailings is complete. Cemented paste backfill (CPB) samples made with an inert material (silica), pure As_2O_3 and binders, as well as CPB samples made with Giant Mine tailings, pure As_2O_3 and binders, were tested for strength after 28 days and 96 days of curing. A significant reduction of strength acquisition was observed in samples containing As_2O_3, indicating lack of cement hydration and possible minimal As stabilisation. Further tests have been designed to investigate parameters that influence hydration and strength acquisition in the presence of As_2O_3, including water content, pore water composition, and mineral interactions. This investigation will identify the parameters to optimise stabilisation of As in the cemented matrix.

Amirhossein Mohammadi (PhD candidate) successfully completed his pre-doctoral exam. The University of Alberta components of this project are scheduled to start in 2024 (following to the associated NSERC Alliance timeline).

3.2 Deviations from research plan

It was expected to start working with ATRW earlier in the project; however, with unexpected results from exploratory tests (reduced strength in the presence of As_2O_3) and the limited amount of As_2O_3 dust available, it was decided to add more investigations on the cement hydration process and use laboratory grade As_2O_3 as a proxy for ATRW. Environmental assessment of CPB will be conducted once optimised recipes (with pure As_2O_3 and Giant mine dust) have been determined. The overall objectives of the project remain the same.

3.3 Budget update

The total proposed budget for research in Year 3 is $52,032 plus additional funds carried over from Year 2 of $67,221 for total available funds of $119,253 in Year 3. This amount includes $103,698 for direct research costs plus 15% overhead ($15,555) charged by UQAT (Table 3).

Table 3. Summary of budget proposed and actuals for Year 3.

	Year 3 Budget	Year 2 C'fwd	Total available Year 3	Y3 Q1 Actuals Apr1-Jun30	Y3 Q2 Actuals Jul1-Sep30	Y3 Q3 Actuals Oct1-Dec31	Y3 Q4 Actuals Jan1-Mar31	Year 3 Actuals Total	Total unspent Year 3
Salaries and Benefits	**$ 28,900**	**$ 24,906**	**$ 53,806**	**$ 8,500**	**$ -**	**$ -**	**$ -**	**$ 8,500**	**$ 45,306**
a) PhD students	$ 24,000	$ 20,006	$ 44,006	$ 7,200	$ -	$ -	$ -	$ 7,200	$ 36,806
b) Master's students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) Undergraduate students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Postdoctoral fellows	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
e) Technical/Professional Assistants	$ 4,900	$ 4,900	$ 9,800	$ 1,300	$ -	$ -	$ -	$ 1,300	$ 8,500
Equipment	**$ 10,000**	**$ 25,507**	**$ 35,507**	**$ 2,655**	**$ -**	**$ -**	**$ -**	**$ 2,655**	**$ 32,852**
a) Purchase or rental	$ -	$ 1,250	$ 1,250	$ -	$ -	$ -	$ -	$ -	$ 1,250
b) Operation and maintenance costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) User Fees	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Analytical Costs	$ 10,000	$ 24,257	$ 34,257	$ 2,655	$ -	$ -	$ -	$ 2,655	$ 31,602
Materials and Supplies	**$ 250**	**$ (600)**	**$ (350)**	**$ 48**	**$ -**	**$ -**	**$ -**	**$ 48**	**$ (398)**
a) Laboratory supplies, reagents	$ 250	$ (600)	$ (350)	$ 48	$ -	$ -	$ -	$ 48	$ (398)
b) Machining costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travel	**$ 5,595**	**$ 8,190**	**$ 13,785**	**$ 106**	**$ -**	**$ -**	**$ -**	**$ 106**	**$ 13,679**
a) Conferences and Workshops	$ 5,595	$ 8,190	$ 13,785	$ 106	$ -	$ -	$ -	$ 106	$ 13,679
b) Field Work	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dissemination	**$ 500**	**$ 450**	**$ 950**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 950**
a) Publication costs	$ 500	$ 450	$ 950	$ -	$ -	$ -	$ -	$ -	$ 950
b) Communication costs (teleconference)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	**$ 45,245**	**$ 58,453**	**$ 103,698**	**$ 11,309**	**$ -**	**$ -**	**$ -**	**$ 11,309**	**$ 92,389**
University Overhead (15%)	**$ 6,787**	**$ 8,768**	**$ 15,555**	**$ 1,696**	**$ -**	**$ -**	**$ -**	**$ 1,696**	**$ 13,858**
Grand Total	**$ 52,032**	**$ 67,221**	**$ 119,253**	**$ 13,005**	**$ -**	**$ -**	**$ -**	**$ 13,005**	**$ 106,247**

3.4 Deviations from budget

This project started January 1, 2020; it is anticipated that underspending in Year 1 will be corrected through the duration of the project. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Project 4: Geochemical and leaching characterization of vitrified arsenical glass

Investigators:
David Blowes (University of Waterloo)
Carol Ptacek (University of Waterloo)

4.1 Research update

The overall goals of this project include: 1) evaluate the physical and chemical characteristics of vitrified ATRW; 2) determine the leachability of the vitrified products under geochemically relevant conditions; and 3) evaluate the viability of long-term stability of vitrified ATRW. The current focus is on characterization of the vitrified products as well as leachability under different geochemically relevant conditions.

Three vitrified products (GMOB-G5, GMOB-G10, and GMOB-G15) were received from Dundee in March 2021. Standard operational procedures for working with the vitrified products, including procedures for general handling, crushing, non-sequential chemical extractions, and column leaching tests were established following guidance from the Safety Office in the University of Waterloo. Vitrified products were crushed in an aluminium cylinder using a hydraulic press inside a fume hood. Both uncrushed and crushed materials were separated for solid-phases characterizations, non-sequential extractions and then split for column experiments.

Structural characterizations of the vitrified products were determined using pair distribution function and Fourier-transform infrared spectroscopy. Presence of aggregates within the vitrified products was examined using optical microscope. Grain size analysis was completed for both uncrushed and crushed materials to determine impacts of crushing on particle size distributions. Non-sequential extractions have been conducted in triplicate using both uncrushed and crushed materials targeting eight phases: 1) water-soluble; 2) exchangeable; 3) weakly-sorbed; 4) less-readily exchangeable and /or sorbed; 5) amorphous reducible; 6) amorphous to crystalline reducible; 7) sulfide; and 8) residual. Extractions 1-6 are complete, and extractions 7-8 are in progress. Concentrations of major and trace metals for extractants 1-6 were analyzed using inductively coupled plasma mass spectrometry and inductively coupled plasma optical emission spectrometry. Values of pH, Eh, alkalinity and concentrations of anions were also determined in water-soluble extractants. Solid residues from each extraction were stored for future analysis.

4.2 Deviations from research plan

Additional characterization and extractions were added to the research plan. Pair distribution function analysis provides structural information for amorphous materials. Grain size analysis shows impacts of crushing on particle size distributions, and the shifts in particle size distributions may further illustrate changes in reactivity and leachability of the vitrified products. Extractions targeting weakly-sorbed phases were modified following the procedure described by Wenzel et al. (2001). Extractions targeting residual phases were modified from the EPA method 3052 (EPA, 1996) to evaluate the leachability of the vitrified products under strong acidic conditions. These deviations provide a more comprehensive understanding of the vitrified products.

Wenzel, W. W., Kirchbaumer, N., Prohaska, T., Stingeder, G., Lombi, E., Adriano, D. C. (2001). Arsenic fractionation in soils using an improved sequential extraction procedure. *Analytica Chimica Acta*, *436*(2), 309–323.

US EPA, 1996. Method 3052: Microwave assisted acid digestion of siliceous and organically based matrices.

4.3 Budget update

The total proposed budget for research in Year 3 is $96,498 plus additional funds carried over from Year 1-2 of $78,221 for total available funds of $174,718 in Year 3. This amount includes $134,399 for direct research costs plus 30% overhead ($40,320) charged by the University of Waterloo (Table 4). Note: the original Year 2 budget was deferred to Year 3.

Table 4. Summary of budget proposed and actuals for Year 3.

	Year 3 Budget	Year 2 C'fwd	Total available Year 3	Y3 Q1 Actuals Apr1-Jun30	Y3 Q2 Actuals Jul1-Sep30	Y3 Q3 Actuals Oct1-Dec31	Y3 Q4 Actuals Jan1-Mar31	Year 3 Actuals Total	Total unspent Year 3
Salaries and Benefits	**$ 45,000**	**$ 40,441**	**$ 85,441**	**$ 16,115**	**$ -**	**$ -**	**$ -**	**$ 16,115**	**$ 69,325**
a) PhD students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Master's students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) Undergraduate students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Postdoctoral fellows	$ 40,000	$ 35,441	$ 75,441	$ 16,115	$ -	$ -	$ -	$ 16,115	$ 59,325
e) Technical/Professional Assistants	$ 5,000	$ 5,000	$ 10,000	$ -	$ -	$ -	$ -	$ -	$ 10,000
Equipment	**$ 18,000**	**$ 8,000**	**$ 26,000**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 26,000**
a) Purchase or rental	$ 2,000	$ 2,000	$ 4,000	$ -	$ -	$ -	$ -	$ -	$ 4,000
b) Operation and maintenance costs	$ 500	$ 500	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000
c) User Fees	$ 500	$ 500	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000
d) Analytical Costs	$ 15,000	$ 5,000	$ 20,000	$ -	$ -	$ -	$ -	$ -	$ 20,000
Materials and Supplies	**$ 5,000**	**$ 10,000**	**$ 15,000**	**$ 5,742**	**$ -**	**$ -**	**$ -**	**$ 5,742**	**$ 9,258**
a) Laboratory supplies, reagents	$ 5,000	$ 10,000	$ 15,000	$ 5,742	$ -	$ -	$ -	$ 5,742	$ 9,258
b) Machining costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travel	**$ 5,729**	**$ 1,729**	**$ 7,458**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 7,458**
a) Conferences and Workshops	$ 4,229	$ 1,729	$ 5,958	$ -	$ -	$ -	$ -	$ -	$ 5,958
b) Field Work	$ 1,500	$ -	$ 1,500	$ -	$ -	$ -	$ -	$ -	$ 1,500
Dissemination	**$ 500**	**$ -**	**$ 500**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 500**
a) Publication costs	$ 500	$ -	$ 500	$ -	$ -	$ -	$ -	$ -	$ 500
b) Communication costs (teleconference)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	**$ 74,229**	**$ 60,170**	**$ 134,399**	**$ 21,857**	**$ -**	**$ -**	**$ -**	**$ 21,857**	**$ 112,542**
University Overhead (30%)	**$ 22,269**	**$ 18,051**	**$ 40,320**	**$ 6,557**	**$ -**	**$ -**	**$ -**	**$ 6,557**	**$ 33,763**
Grand Total	**$ 96,498**	**$ 78,221**	**$ 174,718**	**$ 28,414**	**$ -**	**$ -**	**$ -**	**$ 28,414**	**$ 146,304**

4.4 Deviations from budget

This project started later than anticipated due to delays in receiving vitrified material from Dundee; the project was started in March 2021. The end date for this project has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).

Administration

Investigators:
David Blowes (University of Waterloo)
Carol Ptacek (University of Waterloo)

5.1 Budget update

The total proposed budget for administration in Year 3 is $49,768 plus additional funds carried over from Year 1-2 of $43,068 for total available funds of $92,835 in Year 3. This amount includes $71,412 for direct administration costs plus 30% overhead ($21,424) charged by the University of Waterloo (Table 5).

Table 5. Summary of budget proposed and actuals for Year 3.

	Year 3 Budget	Year 2 C'fwd	Total available Year 3	Y3 Q1 Actuals Apr1-Jun30	Y3 Q2 Actuals Jul1-Sep30	Y3 Q3 Actuals Oct1-Dec31	Y3 Q4 Actuals Jan1-Mar31	Year 3 Actuals Total	Total unspent Year 3
Salaries and Benefits	**$ 32,960**	**$ 24,532**	**$ 57,492**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 57,492**
a) PhD students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Master's students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) Undergraduate students	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Postdoctoral fellows	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
e) Technical/Professional Assistants	$ 32,960	$ 24,532	$ 57,492	$ -	$ -	$ -	$ -	$ -	$ 57,492
Equipment	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
a) Purchase or rental	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Operation and maintenance costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
c) User Fees	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
d) Analytical Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Materials and Supplies	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
a) Laboratory supplies, reagents	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Machining costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travel	**$ 4,323**	**$ 7,597**	**$ 11,920**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 11,920**
a) Conferences and Workshops	$ 4,323	$ 7,781	$ 12,104	$ -	$ -	$ -	$ -	$ -	$ 12,104
b) Field Work	$ -	$ (184)	$ (184)	$ -	$ -	$ -	$ -	$ -	$ (184)
Dissemination	**$ 1,000**	**$ 1,000**	**$ 2,000**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 2,000**
a) Publication costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
b) Communication costs (teleconference)	$ 1,000	$ 1,000	$ 2,000	$ -	$ -	$ -	$ -	$ -	$ 2,000
Subtotal	**$ 38,283**	**$ 33,129**	**$ 71,412**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 71,412**
University Overhead (30%)	**$ 11,485**	**$ 9,939**	**$ 21,424**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 21,424**
Grand Total	**$ 49,768**	**$ 43,068**	**$ 92,835**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 92,835**

5.2 Deviations from budget

The administration portion of the project incurred some costs in Q3 (Year 1) but has not yet fully started and funding for Year 2 has been deferred by one year. The end date for the administration portion of the agreement has been revised to align with the NSERC Alliance portion of the research program (May 14, 2026).