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Oversight Board

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GMOB Workshop: Designing an Active Research Program for Managing Arsenic Trioxide.

Please find attached the summary report of the ***Giant Mine Oversight Board (GMOB) Workshop: Designing an Active Research Program for Managing Arsenic Trioxide*** as prepared by DPRA who facilitated the event. The workshop, held on October 19-20, 2017 in Ottawa, brought nine research experts together with the Directors and staff of the Giant Mine Oversight Board.

As background information, following the Environmental Assessment (EA) of the Giant Mine Remediation Project, the Mackenzie Valley Environmental Impact Review Board concluded that the Frozen Block Method was the most appropriate approach currently available for managing the underground arsenic trioxide at the mine site but stated that this was to be an interim solution. The 2015 Environmental Agreement led to the creation of the Giant Mine Oversight Board (GMOB) whose mandate included responsibility for the creation and management of a research program to lead to a more permanent solution for the underground arsenic trioxide.

As a first step, GMOB completed the ***Giant Mine State of Knowledge Review: Arsenic Dust Management Strategies*** in August 2017 and publicly presented the results of that review. The ***GMOB Workshop: Designing an Active Research Program for Managing Arsenic Trioxide*** is the second step in the development of the formal research program. As a result of the workshop, GMOB has seen progress on the Actions as outlined in Section 4.8 of the report.

The Board will continue to report on the development of its research program and is always open to input from the professional research community and the public in this regard.

Sincerely,

Dr. Kathleen Racher
Chair

GIANT MINE OVERSIGHT BOARD

DESIGNING AN ACTIVE RESEARCH PROGRAM FOR MANAGING ARSENIC TRIOXIDE

WORKSHOP SUMMARY REPORT

December 2017

SUBMITTED TO:

Giant Mine Oversight Board

Yellowknife, NT

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1.0 INTRODUCTION

The processing of gold-bearing ore for almost 50 years of operation of Giant Mine (GM) created the bi-product of arsenic trioxide (As_2O_3) dust. Approximately 237,000 tonnes of this dust are stored underground on-site, which is 5 km north of the city of Yellowknife. Because it is water soluble, the arsenic trioxide presents risks to the environment and the people of the area. Management of these risks fell to Indigenous and Northern Affairs Canada (INAC) and the Government of the Northwest Territories (GNWT) when Canada first assumed responsibility for the site in 1999. Assessing the remedial options for managing the arsenic trioxide dust, initiated in 2000 through a Technical Advisor hired by INAC / GNWT ("the Proponent"), led to the selection of what is known as the Frozen Block Method (FBM).

Following an Environmental Assessment (EA) of the Giant Mine Remediation Project, the Mackenzie Valley Environmental Impact Review Board (MVEIRB; "the Review Board") concluded that the Frozen Block Method was the most appropriate approach currently available for managing the As_2O_3 dust. The Review Board also suggested that this is an interim solution for a maximum of 100 years, and recommended some measures to help find a better long-term solution. A 2015 Environmental Agreement led to the creation of the Giant Mine Oversight Board (GMOB; "the Board") with the mandate, in part, to manage a research program to lead to a more permanent solution for dealing with arsenic trioxide on-site.

GMOB engaged DPRA to facilitate a workshop with the goal of designing a Research Program for the management of As_2O_3 dust located underground at Giant Mine. The result was a workshop of nine research experts with all GMOB directors and staff. It was facilitated and recorded by DPRA Canada in Ottawa on October 19 and 20, 2017. This report is a summary of that workshop.

2.0 THE GIANT MINE OVERSIGHT BOARD

2.1 THE ENVIRONMENTAL AGREEMENT

The *Giant Mine Remediation Project Environmental Agreement* (June 9, 2015; 41 pp.) provides for the establishment, roles and funding of an independent oversight body (the Giant Mine Oversight Board or GMOB) and gives effect to the rights and responsibilities of the Parties related to the independent oversight body.

GMOB functions under the direction of a six-member Board of Directors appointed individually by each of the Parties to the Environmental Agreement. The EA describes the roles of GMOB as follows:

1) Undertake communication activities to promote public awareness of the Project, disseminate information about the Project, and promote public engagement in processes related to the Project;
2) Provide such independent advice to the Co-Proponents on the management of the Project as the Oversight Body considers appropriate;

3) Provide such independent advice to regulatory authorities, the Parties, the public and to whomever else the Oversight Body considers appropriate, on the monitoring and management of the Project; and
4) Manage an active research program towards a permanent solution for dealing with arsenic trioxide dust at the Giant Mine site - as set out in EA Article 7 (Active Research Toward a Permanent Solution for Arsenic), Article 8.2 (Research Results) and Schedule A (Research Program Implementation Guidelines).

This project deals with role #4, highlighted above.

In its *Establishment Report of July 2015 to December 2016,* GMOB describes its vision, mission and responsibilities, including the GMOB Research Mandate:

GMOB VISION

The GMOB vision is that the remediation of the Giant Mine site, including the subsurface, is carried out in a manner that is environmentally sound, socially responsible and culturally appropriate.

GMOB MISSION

The GMOB mission is to independently monitor, promote, advise and broadly advocate for the responsible management of the remediation of the Giant Mine site, and manage a research program to seek a permanent solution to the arsenic trioxide stored underground at the site.

GMOB RESEARCH MANDATE

The GMOB research mandate is as follows: 'to research and administer funding for designated research to find a permanent solution to the arsenic trioxide stored underground at the site, by:

- Identifying priorities
- Conducting studies
- Making results available to the public.

It is important to determine the most effective way to use GMOB's limited time and implementation budget (approximately $200K/year) to meet this part of its mandate. The first step was to solicit a status report. This resulted in the *Giant Mine State of Knowledge Review: Arsenic Dust Management Strategies (Arcadis Design and Consulting, August 2017; 107 pp. plus Appendices).* The results were presented in a Yellowknife public meeting in October, 2017. The second step was to solicit the active involvement and advice of experienced researchers and research program managers, which was initiated through this workshop in Ottawa.

3.0 WORKSHOP METHODOLOGY

3.1 GOALS AND OBJECTIVES OF THE WORKSHOP

The Workshop was held in Ottawa over two days in October, 2017. There were 20 participants including nine research program experts from Canadian universities, Natural Resources Canada (NRCan), National Research Council (NRC), and other councils and associations. Also participating were all six (6) GMOB Directors, both GMOB staff members, and two people from DPRA Canada who acted as facilitator and recorder. See the list of workshop participants[1] attached to the Workshop Agenda (Appendix A).

WORKSHOP GOAL

The Workshop Goal was:

> To describe the main elements of a multi-year research program specifically designed to advance the state of knowledge towards a permanent solution for the management of arsenic trioxide (As2O3) dust which is currently stored underground at the Giant Mine Site.

WORKSHOP OBJECTIVES

The Workshop Objectives, as provided in the Agenda, were intended to support GMOB in developing a research program to explore technologies for the safe treatment, or removal and treatment, of arsenic trioxide stored underground at giant mine. Specifically, the workshop objectives were as follows:

- Consider all reasonable options for design of a GMOB arsenic trioxide research program and describe the elements of 2-3 of the best options for GMOB to pursue further; and
- Consider reasonable funding and administration options for the GMOB research program and describe the steps and planning needed for implementation of the best option(s).

4.0 WORKSHOP DISCUSSION

4.1 GIANT MINE OVERVIEW AND DISCUSSION

The presentation was led by the GMOB Chair, Dr. Kathy Racher. She used a PowerPoint presentation and aerial drone video of the mine site and surrounding area to describe the Giant Mine site, the arsenic trioxide issue and the roles and responsibilities of GMOB. She was supported by other Board members and particularly by Ken Hall and Tony Brown. This is a brief record of that presentation, questions and discussion. A number of workshop participants, while very familiar with mining and remediation research and research programs, were not familiar with the GM remediation project and had never visited the site; other participants had undertaken considerable research in the area. The presentation was considered

[1] Note - The following three experienced researchers and research program managers were unable to attend the workshop: Charles Dumaresq (Mining Association of Canada), Ron Layden (Aurora Research Institute), and Carl Weatherall (Canadian Mining Innovation Council)

important to establish some common level of understanding of the nature of the challenge before discussing a potential research program.

Giant Mine operated from 1944 until 1999, at which time the company (Royal Oak) declared bankruptcy, and responsibility and liability for the site fell to Canada. For two years early in the mine's operations, arsenic trioxide dust was sent up the smokestacks. In subsequent years, the dust was collected and deposited underground in 13 stopes and chambers, at a depth ranging from 30-200 ft. This was the depth of permafrost at the time and was considered suitable for long-term storage. Possibility of permafrost changing over time because of heat generated through mining, or global warming was apparently not considered.

The Frozen Block Method (FBM), an expensive but relatively cost-effective option, presented by the proponent in the EA and currently being pursued includes:

- Active and passive freezing of the chambers and
- Freezing the As_2O_3 dry dust underground.

Only one chamber is currently frozen, i.e., less than 5% of the As_2O_3 at the Giant Mine site; this was done recently as part of pilot tests for the FBM.

The EA process effectively began in the early 2000s, the formal review began in 2010 and the project was approved in 2014 with a number of measures. From the initial assessment of the FBM, the Project Team was convinced that this method was the method worth pursuing and considered it to be a permanent solution. However, much of the community did not accept this recommendation. The Review Board concluded that this plan is valid for no more than 100 years. The Review Board also stated that unless a new solution is actively sought, one will not be found.

The following is a summary of questions raised by the researchers/research managers, and the answers provided by GMOB members and, in some cases, other researchers. It is presented as questions under three key themes:

1. **Characteristics of Giant Mine contamination and arsenic trioxide, specifically**
2. **Considerations for arsenic trioxide treatment options**
3. **GMOB mandate and roles in the research program**

4.1.1 CHARACTERISTICS OF GIANT MINE CONTAMINATION AND ARSENIC TRIOXIDE

How extensive was the spread of arsenic caused by mining in the Yellowknife Area?

- AT dust is a by-product of the ore roasting process. While there is a very small amount of As_2O_3 aboveground, the vast majority of As_2O_3 is stored underground. There has been limited monitoring of the As_2O_3 dust dispersed through the smokestacks. One researcher noted she has collected about 900 soil samples, the results of which suggest that the roaster did spread As_2O_3 and other particulates widely, and the rate of dissolution is slow; and

- GMOB noted that another gold mine (Con Mine) operated from 1938 until 2004 and roasted ore until the 1970s. It had an estimated 2/3 production rate of GM, and arsenic dust was stored on surface and treated in the last 15 years of the mine's life.

How 'threatening' is water at the site and are there plans for de-watering?

- It is actually difficult to dissolve the As_2O_3 dust but, in spite of it being relatively insoluble, very little is needed in the water to render that water contaminated and so caution is important;
- Baker Creek runs through the Giant Mine site and was diverted from its original route. Water is getting into the underground chambers – partly because the bedrock is highly fractured. The risk of water going into the chambers is identified as a critical risk; and
- There is a gradual decline in slope towards the main shaft for water collection to keep the chambers dry. Dewatering will continue; there are also a number of proposed measures to reduce the interaction of the creek with the mine; as part of the mitigation.

What about other remediation issues such as fuel contamination?

- Generally, those areas impacted by fuel contamination are co-mingled with As_2O_3. It is the As_2O_3 contamination that will drive remediation. There are a few spots where bioremediation of soils is being considered but fuel contamination is not a major issue at the Giant site.

4.1.2 CONSIDERATIONS FOR ARSENIC TRIOXIDE TREATMENT OPTIONS

What is the current thinking on in-situ versus ex-situ treatment and storage of As_2O_3 dust?

- GMOB noted that getting the As_2O_3 out from underground for treatment was viewed during the EA as a very high-risk process – in terms of risks posed to the health and safety of workers as well as further contamination;
- The support for leaving and treating the 237,000 tonnes of As_2O_3 in situ is partly driven by the fact that bringing it up, treating or neutralizing it, and placing it on the surface for containment would occupy a significant amount of land; and
- The focus, and the preferred approach of Parties to the EA, will likely be on underground treatment of the As_2O_3 dust. Still, it is not appropriate to eliminate any option now and we should start discussing considerations for the research program such as land use required for a proposed treatment option, and the social acceptability of any such option(s).

How is integration of site remediation being considered in finding a solution for management of arsenic trioxide?

- There has been some discussion by the Giant project team of integration and GMOB members should pursue this matter. Aboveground infrastructure and future access to the site should be considered with respect to freezing and evaluating the permanent solution(s);
- We cannot predict what may be innovative in the future or valuable as an integrated component but GMOB is looking at long-term solutions. The evaluation process took 10 years to arrive at the FBM. The remediation of the site, including use of FBM, needs to happen now because the community wants it, and the risk of doing nothing is too high;

- The FBM is being pursued currently, but integration of the remediation with GMOB research is being considered. Surface remediation is moving ahead and GMOB can try to influence that process. No future potential treatment option should be foreclosed at this stage. By the time of the replacement of the FBM – hypothetically say 40-50 years from now – the rest of the site will have already been remediated;
- Parts of a remediation plan can direct an approach. For example, Gunnar Mine Site in Northern Saskatchewan has low tailings and extensive water, and waste rock is used as a working base for the remediation. It is important to integrate methods of infrastructure removal and contamination. As in Saskatchewan there are limitations in the availability of physical resources in Yellowknife. For example, GM obtained manure from farming and is using this for remediation as there is a lack of soil available locally; and
- GMOB provides oversight and will intervene in the water licensing process. By then, it will have a better idea of the more promising techniques available. GMOB can help ensure that the Land and Water Board reflects the needs we identify in its surface remediation plan.

How important is reversibility of the chosen As_2O_3 mitigation option?

- There is some concern that if we take something off the table by remediation of those components now, the options are limited later on. (For example, what if the tailings become key to managing As_2O_3?); and
- Reversibility was explicitly assessed in the EA and one of the key challenges with the FBM was the plan to wet the As_2O_3 dust. One of the reasons for not wetting the arsenic before it is frozen is so that the treatment can be reversible - so that a more permanent solution could later be carried forward with less difficulty. Whatever program is arrived at must have the option of reversibility.

In terms of the intersection of climate change impacts, how will the current solution of freezing (FBM) be limited as a result of climate change or climate change adaptations?

- Any long-term storage option will need to consider climate change and these environmental timeframes. A key criticism of the FBM has been climate change. It is modelled for 100 years but residents have raised the concern that 100 years is not a good enough insurance. Long-term viability under a range of scenarios needs to be considered.

What is the value of gold remaining in the As_2O_3 dust and could it incentivize recovery?

- It is estimated at approximately $200 M ($196, 000, 000) – so that is often brought up as a value-added component to remediation.

4.1.3 GMOB MANDATE AND ROLES IN THE RESEARCH PROGRAM

Does the GMOB Mandate extend beyond the As_2O_3 Research Program?

- GMOB has oversight of the entire project but it is that - an oversight board - not a decision-making body. GMOB's mandate extends to all remediation being undertaken by the Giant Project Team. However, this workshop is focussed on one part only of its mandate – A GMOB research program to manage As_2O_3 dust underground at GM (see Section 2 above); and

- The Proponent (INAC and GNWT in partnership) is responsible for remediating the GM site. Its Project Team is in the process of remediating all lands within the lease boundaries. Ownership of the site will stay with the federal government but there are ongoing discussions of who will have long-term governance of the site.

What is the extent of community involvement? Is there discussion of employment opportunities – training, capacity?

- Getting the community involved in mitigation is hugely important. There must be ways of mitigating risk and getting the community involved in treatment and risk mitigation efforts. There has not been much discussion to date on economic opportunities, such as employment and training and GMOB strongly encourages this; and
- The community is now quite actively involved in the project. The YKDFN, for example, is very engaged. But the feeling is that the community never accepted the FBM as a permanent solution, and the project team does not often hear and incorporate the community concerns as well as it should.

4.2 RESEARCH PROGRAM MODEL CONSIDERATIONS AND ELEMENTS

This section relays the key considerations and elements in the design/selection of the research program model, as first discussed at the workshop. These were revisited over the two days in an iterative process and should be read as such.

4.2.1 CONSIDERATIONS IN FRAMING A RESEARCH PROGRAM MODEL

The facilitator led a group discussion on potential considerations or **evaluative considerations** to design the GMOB Active Research Program for managing arsenic trioxide. A short list was provided to initiate the discussion which included designing a program that would: minimize administrative demands, attract partners and be responsive to shifts in policies, perspectives and funding.

The discussion led to a set of evaluative criteria as described in greater detail later in this report (Section 4.5 below). Workshop brainstorming also produced advice and caution that should be part of GMOB's thinking in the near-term, and sometimes for consideration in the future. This included:

- **IP:** The design of the funding program will affect matters of Intellectual Property (IP) rights which could greatly influence partnerships, marketability and program uptake;
- **Timeframe:** GMOB has the relative luxury of long-term funding (i.e., up to 100 years) and also should be able demonstrate some progress early in the program;
- **Scope:** It could be important to foster an 'incubator environment' to engage young minds, encourage "out of the box" ideas, and explore many different concepts and options;
- **Access to site and As_2O_3:** Researchers will need access to the Giant Mine site and to the As_2O_3 dust to conduct research and verify techniques. This requires early and good coordination of GMOB with the Giant Project Team so as not to limit such access;
- **Rollover of Funds:** GMOB receives approximately $200K annually, but has also been told that there will be the capacity to 'rollover' unused funds from one year to future fiscal years. However, this has not yet occurred and GMOB is anxious to have this confirmed by the project proponent;

- **Scope of Program:** To attract partners and match funding it will be important to select a funding program with a scope broader than the recovery, treatment and disposal of As_2O_3 dust;
- **Public Involvement:** There is a strong community interest in being kept informed and engaged in the Giant Mine Remediation Project and in the GMOB research program, particularly as there is a history of limited trust with Giant Mine. This legacy issue is fundamental to the success of the program, may be tied to the model selected, and must be carefully planned and implemented beyond this conceptual stage;
- **TK:** Similarly, the need to incorporate Indigenous Traditional Knowledge (TK) and Traditional Land Use (TLU) of the area could be important to the program model selected;
- **Permanence**: It is important to define the GMOB research program "end point or target" to understand the permanence of the solution being sought. This will provide a target, guide the program and manage expectations; e.g., is it "permanent" or is it "better and more permanent than the Frozen Block Method"? Is there a better term for a highly manageable long-term solution?
- **Monitoring:** Monitoring will be part of a long-term solution and the community will demand this;
- **Research Project Duration:** Consider how much research might be required to attract researchers and develop a viable model, i.e., Do we need 5 years of approved project funding?
- **Reversibility:** In the EA process reversibility was defined as avoiding the selection of an option that would close off the potential for future and better options. GMOB and the Giant Project Team should keep this concept top of mind; and
- **Adaptability:** The GMOB Research Program should be adaptable to new research and increased viability, and avoid a dead-end line of enquiry.

4.2.2 DESIGN AND ELEMENTS OF A RESEARCH PROGRAM MODEL

Through discussion of all of these research models in relation to GMOB needs, some of the **approach / methods and special considerations** for choosing and/or designing a research program were described. These considerations are summarized below:

Networking and Administration: The EA says GMOB's mandate is "to facilitate active research". One of the biggest obstacles discussed in respect of doing this alone is that GMOB is relatively isolated and doesn't have the connections of other research groups or networks. The Board also lacks the necessary infrastructure and administration resources. The start-up costs, both in funds and time, would be high. Some existing institutes have full-time staff that could be used.

Existing Research Programs: To avoid having the administrative burden, it was suggested that it may be possible to nest GMOB within an existing model. GMOB could search for an organization with a mandate that aligns with its own mandate. Sharing that administrative burden with another organization could also be helpful because it would already have rigour, an RFP process, evaluative criteria, etc. GMOB could start from scratch (not recommended) or connect with a credible body and become a partner with them.

Defining the Research Problem: Some participants expressed the need to clearly define the research program. The first question was: how do we describe the GMOB problem in a sufficiently broad way to attract partners and researchers, and not so narrowly as to unnecessarily restrict lines of enquiry and

scope of solutions? For example, is it a practical problem of removing dust rather than a technical or chemical problem related solely to As_2O_3 dust? Is it better defined as 'in situ treatment of heavy metals'. One participant noted that big mining companies also have arsenic issues and there may also be future potential; e.g., Miranda Gold Corp. may be looking to extract gold from refractory ore. So, there could be other applications for this technology other than simply recovering or neutralizing waste.

Need for Partners: In testing the viability of technology GMOB will need an industry partner, and/or government support to help 'de-risk' the technology. A challenge is that mining companies are no longer generating As_2O_3 dust, so there is a question of how new solutions will be driven. Therefore, there may be a need for 'new' research as well as scanning existing technologies. The GMOB SOK report is a start.

Industry Involvement: The industry lens is important for securing more funding, as is approaching the GM As_2O_3 issue as an area for applied research. However, existing programs like COSIA are trying to find solutions in the current context of operating projects, while Giant has a historic contaminants issue; we are talking about cleaning up an old mess. This raises the question of the relevancy to industry of a research program like this. One participant suggested that GMOB doesn't want to be limited only to the mining industry; other industries deal with buried waste and so it can be helpful to think more broadly. Neither is this necessarily a mining problem – it's a toxic waste problem. Another person cautioned that for community engagement and capacity building, an industry-driven model might be limiting.

Investigating Other Technologies: One participant suggested it is unlikely that GMOB will find a ground-up solution. Rather, it will likely be the application of another technology to the GM As_2O_3 problem. He said that the mining industry can be slow in adapting to new techniques and technologies, and it tends more to tinker with existing technologies. There would be greater support from industry to use applied research rather than to fund new research.

One participant suggested that "research" is perhaps too narrow a term – its also about investigating in other technologies or technology scanning to find pre-existing technologies. Much of this could be done in a desktop fashion by reviewing applicability to managing As_2O_3 at Giant Mine. Another cautioned that we should not get hung up on metals – we are looking for in situ or ex situ solutions to manage the materials over time.

Staged Approach: One suggestion was that GMOB consider a staged approach - one encompassing a preliminary phase of design development - without the need initially to commit to a research option. This would be a 'ramp-up' approach to arrive at a model. It was cautioned that stakeholders are expecting a product and GMOB needs to demonstrate some tangible progress in the relatively near term. One suggestion was to hire a consultant who is dedicated to this project. GMOB could quickly get an outcome such as a report with options for model architecture. However, GMOB needs someone to build the network and move the architecture forward as well as evaluate the different models for the next phases – to 'catalyze' a GMOB research program. GMOB does not "have the wheels" and may need to enable someone else to lead the charge. There was also a counter proposal expressed that GMOB doesn't need a consultant immediately to do this, but rather can set the process in motion and then have someone else flesh out and drive it.

Broker for GMOB: Participants discussed the potential for GMOB to hire an individual as a broker to help find the money, approach the VP (of a University for example) and negotiate the terms of what GMOB would bring to the institute and what the institute would provide to GMOB. One participant advised care that some institutions may push GMOB, consciously or subconsciously, towards an option that favours their own interests and expertise.

Governance: Fundamental questions related to governance of the Research Program included how RFPs will be managed, who will decide the content of requests for proposals (RFP) and who will evaluate proposals? It was agreed that GMOB itself is not resourced for this.

A Board member cautioned that GMOB cannot be removed from the decision-making process. Its membership originates from those Parties to the EA, with each board member having been nominated by one of the Parties (although each is not accountable on an individual basis to those organizations). GMOB reports back as a Board, and consultation is built into the entire process as an ongoing commitment. No one besides GMOB has the responsibility for As_2O_3management research and so farming out or delegating its responsibility to another committee was viewed as inappropriate.

GMOB Involvement: Researchers at the workshop noted that most existing models provide opportunities for GMOB to be directly involved in decision making. For example, if it were part of an institute, GMOB could sit on the Board of that institute. By using the approach of a University research chair this involvement may be more difficult. Nonetheless, there would be the opportunity to negotiate the role and involvement of GMOB.

Community Engagement and Benefits: There was a discussion of how GMOB will want to consider potential community benefits from each type of model, including training and economic opportunities. Several participants replied that universities do community engagement / scholarships / fieldwork so these can be pursued during the research & design phase of a program.

Interdisciplinary Approach: The GMOB As_2O_3 management project has a multidisciplinary nature, with elements of both technical and organizational development. These components don't typically exist together, so it calls for a consortium or network approach. The holism of the research model is really important as this GM As_2O_3 management problem is much more than an engineering science problem.

The response was that university research networks / institution mechanisms are not only amenable to such a cross-disciplinary approach, but there is little successful research done today within any one single discipline. There is an expectation of interdisciplinary research to make the project stronger.

Portfolio Management Approach: Participants discussed the possibility of establishing a research model that would allow GMOB to look at possibilities using an approach similar to an investment portfolio; one by which GMOB would 'hedge its bets' by funding a portfolio consisting of a mix of relatively certain treatment options and long shots (or "moon-shot") technologies. Through such an approach, decisions could be made on whether or not to invest in these options – through risk / investment management. One researcher described, for example, how technologies could be described in three categories:

- New and promising ('moon-shot') – applicability that is 20-30 years out, 10% probability of success
- Bench scale – 10 years out, 25% probability of success

- Applied, probable – more immediate and higher probability of success. This technology might also be used elsewhere in applications such as remediation of metals

The portfolio can include a process to call for seed funding on the various technology options in the portfolio – e.g., funding from a Water Institute or partnership with industry. One researcher used a tree diagram with drop-off points; trimming branches as you go along, and refining the options retained in the portfolio. At various points GMOB could choose to invest or not invest, and an option could also be dropped off after an investment had been made.

4.3 EXISTING RESEARCH PROGRAM MODELS

The facilitator led a discussion of **existing research programs and models** in which participants had experience, including their components and architectural frameworks. To initiate discussion, the Agenda included a short list of programs and models: NSERC Industrial Research Chair, X-Prize, research consortium, research council, and superclusters as incubators for innovation.

Workshop participants shared their knowledge and experience and brought forward a large number of existing research programs that may be applicable to Giant Mine's arsenic trioxide management issue. Key models discussed by the group are listed below. These fell under the following themes:

1. A call-for-bids approach whereby GMOB would frame the research problem and request, review and oversee the research and development of proposed treatment options;
2. Extrapolating from an existing program focused on an issue that is aligned with / similar to the GM As_2O_3 management issue; and
3. Tapping into an existing research network with a community of researchers predisposed to research of this kind to uncover potential solutions to the GM As_2O_3 management issue.

4.3.1 ADMINISTERING A BIDDING PROCESS

A call for technical solutions could be phased using a short list and seed money, or using X Prize which embodies a "winner-takes-all" approach. This approach would give GMOB the ability to solicit a spectrum of potential treatment solutions, but the evaluation and monitoring process may be administratively / financially burdensome.

> **X Prize** is one competition-based program that looks quite broadly at a problem, and awards a prize to the research team best able to address the problem. For example, CCEMC (Climate Change Emissions Management Corp.) has set up X Prizes to do carbon capping. Barrick Gold founded a $10 M prize for silver extraction and there was a prize for arsenic management for remediation of groundwater in Bangladesh. However, normally these prize type models require a lot of money, likely more than As_2O_3 management research is likely to generate.
>
> **Water Institute:** University of Waterloo has a loosely knit organization called the **Water Institute**. This is not a thinktank per se but it includes government, academics (from multiple disciplines), industry and communities (NGOs). Each year the Institute evaluates proposals and has a call for seed money. Certain criteria must be met. The proposals are evaluated and grants of 1 – 3 years

of funding are awarded. If GMOB wants to get something off the ground really quickly, that could be a way to go (another example is the **Arctic Institute**).

Montreal Centre for Excellence was described as a model successfully used for the review and evaluation of options, which identified priorities and called for technology demonstration. An oversight group looked at company or researcher proposals, evaluated the feasibility of doing the work, and went through a grading and project selection process.

CMIC (Canadian Mining Innovation Council) is membership driven. Members pay a fee to join and the research done/overseen by the council. It is demand-driven; members call for research on given topics – so, they are largely industry-led initiatives.

NRCan CANMET has a multi-stakeholder partnership fund and hosts a secretariat when there is a research question to be answered. NRCan prepares an RFP and this involves bringing together different partners with everyone putting a little money into the pot.

4.3.2 EXTRAPOLATING FROM AN EXISTING RESEARCH PROGRAM

GMOB could take advantage of the spectrum of existing programs to find one with a similar operating structure and purpose that would be capable of finding a solution to the GM As_2O_3 management issue. This work of reviewing 'best practice' research programs and developing recommendations for GMOB to build its own program could be contracted out to a consultant, an academic researcher, or undertaken by the Board. In Phase 1 of developing a research model, there could be the equivalent of one FT salary to pay out in organizing/laying groundwork for such a model.

Industrial research chair at a University or **Secondment**. This will normally be a 3 - 5-year commitment from an individual. GMOB could 'buy out' a faculty member and that Principal Investigator would no longer be required to focus on her teaching or research responsibilities. One participant stated they do a lot of this type of partnership and they tend to be negotiations. Typically, a faculty member may have 40% of their salary tied to teaching and can be untethered from that, but the other requirements are more difficult to untether. You also need to consider the Collective Agreement for that particular faculty. There was a caution expressed that by giving the lead to one University professor the program could take a personalized approach (as per the individual's research prerogative). One participant offered that the individual may be predisposed to an academic approach rather than to a more pragmatic path to a solution.

COSIA (Canadian Oil Sands Research Innovation Program) is one example of a research program focused on solutions to a specific issue: in this case the Alberta oil sands.

Wolf Creek Basin (Yukon) had a specific issue to be addressed with water hydrology in mountainous boreal forests. There was a small amount of seed money (from the National Hydrology Research Institute of Canada **NHRI**) that created a program in Yukon in 1993. It was successful and Universities from around the world continue to do research in that water basin.

Queens Institute for Energy and Environmental Policy is focused on Mining. This kind of model has its own architecture and is relatively flexible and open to partnerships.

4.3.3 TAPPING INTO A NETWORK

Several existing networks were seen as worth exploring, with the potential that GMOB could 'tap into' one of these networks and automatically be connected to a community of scientific researchers with expertise in mine / waste environmental management issues. Some discussed were:

CLEER (Clean, Low-energy, Effective, Engaged and Remediated) is an example of a 'supercluster' (part of CMIC). "The supercluster is an industry-led, multi-stakeholder consortium comprised of four existing clusters, which, combined, represent 11 large companies (including eight resource companies), 13 post-secondary institutions, 42 SMEs and 25 other support organizations."[2]

Alberta Innovates and Technology Futures: AI currently has a strong Director. Technology Futures split from Alberta Innovates and does similar work. Alberta Innovates is a research and innovation hub for the development of new ideas and technologies through the participation of innovators, businesses and researchers who bring "cross sectoral knowledge and expertise, funding, networks and research facilities."[3]

Horizon2020 (an EU Framework Programme for Research and Innovation). Internationally, Canada is seen as a global leader in mining with a lot of work in South America and around the globe. For example, someone in Brussels is exploring a model for Canadian-European cross-pollination of investment dollars. **Ernst and Young** is involved in the initiative. There may be an opportunity with GM because Ernst and Young is thinking about **joint research partnerships.**

I-Can (Innoventures Canada) has been around for 3-4 years. Saskatchewan Research Council (SRC) is a comparable research group, but I-CAN is a network of research groups across the country with a focus on innovation across a number of fields.

MEND (Mine Environment Neutral Drainage Program) is a multi-stakeholder institute/research model.

TERRE NET research network of 6 or 7 affiliate Canadian Universities, including the University of Waterloo, is NSERC-funded to look at environmental solutions to remediation in terms of mining. NRCan also works with them. TERRE NET already has an association with institutes and could, for example, reach a partnership agreement with GMOB for a 1, 3, 5, or 7-year term.

The discussion of existing models concluded with a synopsis: Some examples discussed above were at least temporarily taken off the table because they were seen as too focused, restricted or slow to construct. Others, such as X-Prize, seem to require too large a financial prize to be viable for the research subject of Giant Mine As_2O_3 dust. Some models, including an industry research consortium, may be too focussed and driven by industry, and finally there were qualifiers on using an academic approach such as

[2] Canadian Mining Innovation Council (CMIC). 2016. CLEER: Powering Clean Growth Through Mining Innovation. Online. Accessed November 8, 2017. Available: http://cmic-ccim.org/powering-clean-growth-mining-innovation/.
[3] Alberta Innovates. Online. Accessed November 8, 2017. Available: http://albertainnovates.ca/.

a research chair. As recommendation it was agreed that a more structured and systematic review, using a matrix approach, would be useful.

The concept of using an existing research network was favoured, and existing models such as TERRE NET were identified as potentially suitable for GMOB. This concept was carried forward to subsequent workshop agenda items.

4.4 ADVANTAGES AND DISADVANTAGES OF EXISTING MODELS

There was a facilitated discussion of the advantages and disadvantages of the various models - specifically for the potential application of these to GM As_2O_3 management. In order to understand the advantages and disadvantages, participants described the mandate, partnerships and approach of existing programs. Some of those are briefly described below.

4.4.1 OPTION 1: TAPPING INTO AN EXISTING GOVERNMENT RESEARCH INSTITUTE

The group turned to exploring the potential of tapping into existing government research institutes. A summary of this discussion with respect to 3 government research organizations is presented below. This summary has been presented in accordance with three criteria in order to draw attention to the distinctions between these government bodies:

1. Applicability / relevance of the research mandate of each organization to address an issue as specific as GM As_2O_3;
2. Availability of a broader research / funding network accessible through the government research organization;
3. Capacity and governance structure of the government organization.

NATIONAL RESEARCH COUNCIL (NRC):

- **RELEVANCE TO GM RESEARCH ISSUE:** NRCs mandate is to look at issues through separate institutes and portfolios and a series of programs in different areas.
- **NETWORKING:** Its work is very strongly linked to networking and can get things done faster than most government programs. It is linked for example to Canadian Mining Assets (CMA) and NRCan CANMET.
- **GOVERNANCE/CAPACITY**: NRC can both do the research and oversee it. The programs themselves have an internal budget but there are funding opportunities from other sources as well. The involvement of a Party such as GMOB could be described into an MOU.

SASKATCHEWAN RESEARCH COUNCIL (SRC):

- **RELEVANCE TO GM RESEARCH ISSUE:** Undertakes projects outside of Saskatchewan, including the north. Works about 80% in servicing the mining industry – with a focus on potash, gold, and uranium.
- **NETWORKING:** Does work with the NRC but generally, has less money and flexibility than NRC; it is a service-oriented organization and is not for profit.

- **GOVERNANCE/CAPACITY**: Operates as arms' length from government and normally enters into MoUs. SRC does in part applied research in labs which can help fund other portions of the council's work. When competing for research monies, SRC puts in in-kind contributions. The Council has an independent board and reports like a business would report.

NATURAL RESOURCES CANADA (NRCAN):

- **RELEVANCE TO GM RESEARCH ISSUE:** Gets its mandate from the Minister of Natural Resources and therefore a challenge with GM As_2O_3 research is whether it meets the Minister's directives. The focus is applied research and NRCan typically does not take on projects and drive them for clients.
- **NETWORKING:** Has a lot of capacity and networks with academics as well as provincial representatives. NRCan tries to work on broad projects that have national application because its mandate is to respond to Canadian issues, rather than site-specific issues. In some instances (e.g., MEND) where there is a national interest, a multi-stakeholder approach can work, where Government provides the secretariat structure and in-kind research capacity.
- **GOVERNANCE/CAPACITY**: NRCan's research is done in house and on a cost-recovery basis. The stakeholders drive the research agenda and NRCan serves as the secretariat but it is arm's-length from the government. The administrative requirements which NRCan has imposed on it by government are high.

In summary, integration with NRC, SRC and NRCan each showed some potential as research model which GMOB could tap into.

4.4.2 OPTION 2: SECONDMENT OR INDUSTRIAL RESEARCH CHAIR

In reviewing the secondment or research chair option, there was a question on whether GMOB, if pursuing this approach, should focus on University individuals who are experienced as academics or program managers. From a **governance/capacity** perspective, there is a different skill set for someone in an academic role as compared with an individual in an administrative management position. In many ways it depends on the individual recruited - if they have knowledge of the science (technology), they may not have knowledge of the broader strategy to develop the program.

Another researcher noted that working with academia can be slow (others responded with humour, asking if they thought Government was fast!). The intention is that through a secondment or research chair position, an individual would be dedicated and focused to the GM As_2O_3 problem. However, the risk of the program becoming too personalized according to the interests and whims of that particular researcher was cautioned. Participants noted a risk of losing **relevancy and applicability** to the specificity of Giant Mine arsenic trioxide management can be high when there is one researcher steering the project. The nature of the GM research problem likely requires an interdisciplinary, targeted, and innovative approach that may likely prove difficult for one individual to successfully achieve.

Many University staff facilitate networks of research through mechanisms such as NSERC and those relationships persist beyond the funding grants. Its broader than the individual; it is about generating a research network. A key value which participants saw in pursuing a chair / secondment approach – as

opposed to working more broadly within the parameters of an existing program or organization – is the ability for GMOB **to link to a broader network or research and innovation**.

4.4.3 OPTION 3: TAPPING INTO AN EXISTING RESEARCH NETWORK / INSTITUTE

This brought the conversation back to a potentially viable existing University research network / institute which GMOB could tap into, thereby accessing a community of researchers working to address a common issue. They in turn would have their own personal research networks. There was agreement that multiple institutions together in a network would be beneficial. In this way, GMOB could act as a hub to connect individuals to ideas and stimulate research for GM As_2O_3 management.

NETWORKING THROUGH A RESEARCH INSTITUTE:

In response to how GMOB might select which universities should be involved, there was a discussion of how it could be a consortium of Universities through a research network like TERRE NET. With such a model, there would be industry, government and academic partners, which would add value. Other advantages include:

- Opportunities to leverage are key to institutes and they are typically focused on the development of a strategic research network;
- The approach need not be strictly a university-based organization, and could be opened up wide, to meld other industrial associations and institutes (MEND is on the board of TERRE NET and NRCan is also part of TERRE NET);
- A broad partnership model would also open GMOB up to broader funding sources
- Institutes promote interdisciplinary research:

  *In a discussion of the interdisciplinary nature of the As_2O_3 problem, a researcher said that the nice thing about a network like TERRE NET is how **interdisciplinary and connected** it is, and that includes access to funding. GMOB could tap into a network and delegate some of its work. For example, the research program could be expanded through collaboration, exploring in-situ opportunities like drilling into the cells, and pursuing questions across nanotech-geochemical-bio fields. Tapping into the network and its varied research expertise means that together you do better work than you can ever do alone.*

INSTITUTE GOVERNANCE/CAPACITY:

A question was raised regarding how GMOB should approach a network and whether the Board should first gather its own group of partners and funding. One research reiterated that the fact that GMOB's funding is "in perpetuity" (or at least for as much as 100 years) is a huge carrot – the surety of funding is a big incentive. Participants suggested that the network could help GMOB to leverage funds, connect to partners, and otherwise benefit from the network's capacity and structure:

- An institute is already leveraged to issue and administer a call for proposals and to receive matching funds from different institutions;
- The first phase of design of the GMOB program is development driven, and this would that be amendable to an institute;

- The research program would be multi-year and multi-phase but typically, there is annual (or sometimes quarterly) reporting on the research grants. Most research programs have a program coordinator to oversee those aspects. If the university is going to bring funding, they would expect a leveraging as well through other existing programs. That could work to GMOB's advantage, given that it has its own reporting commitments;
- In terms of the IP issue there could be an industrial agreement such that the institute is arm's-length from the group that develops a permanent solution. Each research office has its own rules around patenting and commercialization. NSERC, for example, has these rules very established and has measures around the divvying up of property rights and sharing of any profits.

RELEVANCE AND APPLICABILITY OF TERRE NET

If GMOB got involved in such a group, how much influence would GMOB have over the outcome of the research undertaken, and ensuring that it fits GMOB's needs/research mandate. Participants described how TERRE NET's mandate seems to align with the discussion. TERRE NET is driven to finding solutions and its research is very applied.

- Participants at the workshop representing Universities affiliated with TERRE NET said the network is working on issues very related to GM. They urged GMOB to find individuals whose institutions are already within TERRE NET. One researcher suggested that people involved in TERRE NET are probably looking for interesting research projects; another spoke to the ability of GMOB to incentivize the research through this network:

> *"You need money on the table but also a clear set of expectations. Every network, including TERRE NET, is a group of university faculties operating under one umbrella, and with money on the table people will respond to the issue of interest to their mandate. Tying into a network of researchers allows for opportunities to be matched with a researcher who has the time and availability to do the work. If there were a gap in what GMOB needs, the network could also bring someone else to the table. GMOB could pay for a PhD student, for example, to incentivize or catalyse that research."*

- Another participant said that NSERC funds these networks because they have value, and TERRE NET has a project at Giant Mine already.
- The mandate of TERRE NET and its research themes tie in very well to GMOB:

TERRE NET Research Themes as listed on www.terre-net.ca

THEME 1 - ABANDONED MINE SITE REMEDIATION	**Lead Carol Ptacek, UWaterloo**
THEME 2 - PREDICTIVE TOOLS FOR MINE-WASTE MANAGEMENT	**Lead Ulrich Mayer, UBC**
THEME 3 - CROSS-CUTTING METHODS AND TECHNOLOGIES	**Lead Tom Al, UOttawa**
THEME 4 - EXPLORING INDIGENOUS KNOWLEDGE FOR UNDERSTANDING RISKS AND COSTS/BENEFITS OF MINE RECLAMATION	**Lead Brenda Parlee, UAlberta**

THEME 5 - INNOVATIVE TREATMENT TECHNOLOGIES FOR MINE-IMPACTED WATER	**Lead Frank Gu, UWaterloo**
THEME 6 - REMEDIATION STRATEGIES FOR MINE WASTES	**Lead Bruno Bussière, UQAT**
THEME 7 - MINE WASTE DESIGN	**Lead Ward Wilson, UAlberta**

4.5 RESEARCH PROGRAM MODELS: EVALUATION

The DPRA facilitator began Day 2 of the Workshop by providing a draft list of what he had heard as criteria that GMOB could apply to evaluating a research program model. While preliminary, these criteria are aligned with, and give consideration to, GMOB's mandate and requirements to the public and account for a range of other administrative, economic, and human considerations that can be applied to vet potential options and guide the selection of a research program model.

4.5.1 EVALUATIVE CRITERIA – CONSOLIDATION FROM DAY 1

In applying these criteria to a potential option, GMOB should ask whether the design or structure of the particular research program would:

1. Permit GMOB to meet its mandate for research while maintaining some authority over the process e.g., GMOB board member serving on board of an institute?
2. Be able to demonstrate progress in the near-term and to generate / maintain momentum of the research process (that would be visible to GMOB and Giant partners/the Parties)?
3. Help to leverage significant funding from other sources including academia, government, and industry that would supplement the modest $200K annual seed funding?
4. Provide the necessary access/connections/network and connections to existing researchers, specialists, institutions and companies – without undue start-up time and costs (that GMOB does not have)?
5. Provide administrative and infrastructure (including the needed rigour, processes, network and credibility), at a reasonable cost, which is not available within GMOB. Tapping into an existing structure that has credibility and is already functioning (saves time, money)?
6. Have the ability to attract interest, ideas and research from beyond the narrow scope of arsenic trioxide. The GM problem is very specific, but generally is a toxic waste problem of broader application in and beyond mining - could the interest extend beyond mining to the problem of metals management, toxic waste management and both in situ and ex situ treatment of waste?
7. Respect and accommodate the principles (and demands of Giant partners) such as community involvement, use of TK, scholarships, jobs, training and other economic benefit opportunities for the community?

8. Have the ability to pursue practical applied solutions using a "portfolio" approach to research investment and hedge bets of various options – ranging from moon-shots to more technologically/economically risk adverse options?

9. Facilitate the involvement and network of multiple Universities/departments/companies in a truly multi-disciplinary approach – to be able to accommodate and encourage health, chemistry, geology, engineering, social, political and economic research continuums?

10. Encourage participation of a particular research group or company without limiting their intellectual property rights, or creating a conflict of interest on potential future work?

11. Embrace or reflect the GMOB focus on a practical and applied research solution – as a "permanent" solution – rather than a focus on research per se; to be able to arrive at a practical solution and not lose focus on related research programs that do not address the issue of As_2O_3?

12. Have the administrative infrastructure and ability to provide reports into GMOB on an annual or more frequent basis; to allow GMOB to meet its strong commitment to informing the partners and the public on GMOB research progress?

13. Be flexible and adaptable enough to allow relatively nimble changes in direction as more information and technical methods are available (e.g. 10 years or 20 years down the road) and to spur innovation – to be able to incorporate new and promising approaches and technologies to addressing with the problem of arsenic trioxide at Giant Mine?

14. Be capable of networking beyond the problem of arsenic trioxide, beyond metals management and beyond mining – for the program to have the potential for broader application to toxic waste problems in general?

The facilitator added a favourite quote from the previous day, which was in response to whether the GMOB As_2O_3 issue was likely to generate interest: "If money is on the table, enthusiasm will come" – meaning that the As_2O_3 problem can be generalized without too much problem. The floor was then opened to discussion to whether this captured the discussion or if anything was missed. The following section captures other considerations that emerged.

4.5.2 OTHER EVALUATIVE CRITERIA – EXPANDED ON DAY 2

- Must ensure that As_2O_3 dust remediation takes an approach that is integrated with the broader Giant Mine site remediation project. A complete solution means that the As_2O_3 research program considers all parts of the problem, e.g., in situ treatment as well as ex situ treatment with extraction and solidification. The program needs a **coordination and integration mechanism** to tie together the components.

- It is important to understand what else is mixed in with the As_2O_3 and study this further, e.g., perhaps conduct some kinetics in order to **better understand the contaminant material**(s), first.

- As the program advances, it will be important to continue community dialogue and take into consideration **concerns about health and safety and the long-term conditions of the area**. For now, however, all options are on the table.

With these and the evaluation criteria presented above, a more methodical evaluation could, and should, be done by creating a matrix to assess the options.

4.6 TECHNICAL CONTENT AND RESEARCH PROGRAM MODELS

There was a facilitated discussion to consider specific technical research approaches (i.e. research content vs. process) using the research plan models discussed above. There was clarity provided that there is no recommended option in the SOK report; it is a preliminary scan and no research decisions are based on it. Each option has a research technology component embedded in the SOK report.

The GMOB Chair noted that it will not just use the SOK report, but welcomes other ideas and technologies. There followed a discussion of the current approaches identified in the SOK report as well as creative development of new approaches and technology transfers from other fields. The public has stated that the main criteria for a treatment option is the stabilization of As_2O_3. There are branches of research problems/questions that come off of that – for example, transportation of the As_2O_3 dust. But it is of value to articulate as clearly as possible what GMOB needs done, and that can be adjusted as we move down the research plane.

The decision was made to use some of the limited time remaining to make best use of the researchers and research managers in attendance. This is what followed.

Dr. Scott Dunbar summarized his research focus on biotechnology applications, to decompose sulphides, and fundamentally to look at amino acids and peptides that bind to minerals. A student is doing research in this area using magnetics to separate particles from quartz – **polyelectrolytes**. He stated, scaling is difficult and peptides are expensive to create, as are nanoparticles. We are looking to do genetic engineering to pursue this research, but are currently in the "moonshot/ blue sky" stage of this research. He stated that potential applications of the research are tailings treatment and the removal of compounds. Bacteria can be used to decompose oxides, and if arsenic is in solution, the metal could be precipitated in a bioreactor cell. Some locations use this technology, for example, to produce power at wineries and breweries.

Using biological methods to cement As_2O_3 dust could also be used - such as **bio-silification**, i.e., bugs that create a silica material. These chemical and biological techniques are worth exploring for in situ treatment. This technology would also be of interest to mining companies with unstable tailings. This has been done in the lab but not in the field. One limitation is that there isn't a desire to put the As_2O_3 in solution, and that would be required through this treatment option. Unless you can actually control the As_2O_3 dust in a vacuum-type environment, ex-situ treatment could be risky. The stability of silification as a treatment method is still questionable.

Dr. Dunbar referenced a report from 2008 on using **biologically mimicked chemical compounds for treatment**. There is still no sense in the research community on the viability of that material but that could

for example form a research thesis. **Nanotechnologies** are used to clean up wastewater, but is still a 'moonshot' idea. Others offered that University of Alberta has a nanotech institute and that nanotechnologies are quite promising for heavy metal in-situ stabilization.

GMOB clarified that the attraction to in-situ treatment is that the material is all contained, whereas with ex-situ treatment, you cannot get all the material and some of it will remain underground. That remaining material would still require treatment/management. A technique that can negate the toxicity of the As_2O_3 becomes more 'permanent' and more 'manageable'. The challenge raised in the EA related to a potential failure of the monitoring and management program and the spectre that were government to dissolve, there would be huge environmental implications.

There was clarity provided that some GM chambers are relatively full, some are half-full. Adding polyelectrolytes would increase the volume – they are benign but they need space, a requirement for treatment. As such, the As_2O_3 may need to be pumped out, slurried, and reinjected into the stopes.

In terms of applicability of the unique GM As_2O_3 problem, one person noted that the most arsenic-rich tailings in Canada are 3-5% and As_2O_3 at Giant is about 50-60%. Solutions that work for As_2O_3 will work for tailings but not necessarily vice versa - because the scale and concentration of arsenic at GM is so much greater. Putting it in context could mean, "how do we deal with toxic metal by-products of mining?" It is a broader issue of dealing with toxic by-products, making them inert and managing them. That's the 'bigger than arsenic trioxide' piece.

In terms of working with industry and large mining companies, if it is packaged right, they should see the value for themselves. It would be smart to go beyond mining companies and look at biotech companies, and specifically companies that design and implement barrier systems. One researcher noted how mining companies have to see a way that research will affect their bottom line. Companies typically don't get involved in issues for which they do not need a solution. However, tech companies may have an appetite and researchers are working more and more with small and medium tech companies (such as KMX in Toronto area and BQE in Vancouver) and NSERC funding provides small grants, which are useful to such small companies. Some components of the SOK report, such as barrier systems, come out of landfill barrier system designs. There are technology companies that produce materials for toxic waste containment.

Patrick Chevalier noted that in his lab they do some work around the stabilization of effluent from the Chalk River plant. They are using cement as one option. The nuclear industry is looking at this issue as well. Some of the things GMOB is looking for are solutions that have been explored elsewhere. Perhaps this could be a case study of a bigger problem – a **pilot investigation project to address a bigger problem**.

Discussion returned to reversibility including the importance of access to the field site for research and testing and potentially leaving one of the stopes unfrozen as a project research site. It could be possible to start by working with surrogates, e.g., as NRCan uses surrogates first rather than Chalk River materials.

One researcher explained how in the GM stopes, there are incredible materials that have grown where water is dropping. She has discovered a new organism called GM 1 – a **cycrophyllic microbe** that seems to absorb arsenic. Researchers have found it on Giant bulkheads – which are concrete – and it neutralizes by dissolving parts of the bulkheads. It might be possible to take advantage of this energetics technology.

There may be some in-situ methods could involve injection – but you need to add something else, probably iron. The microbe would probably not be viable in frozen blocks; they need water and salt.

Researchers suggested having a really good description of the As_2O_3 dust, e.g., what are the chemical and physical characteristics? What other compounds are mixed in with the As_2O_3? What is the particle size? Is the chemistry affected over time or through freezing? This would serve an invaluable operating context.

Others asked whether ex-situ methods will even be socially acceptable. For example, if the cement encasing is at a 10:1 ratio, is the sheer size of the above-ground arsenic trioxide storage acceptable to stakeholders? One participant noted how many people are working on containment, suggesting an intersection between what the public wants and the research that needs to be done. The public has said containment is not good enough, but are looking ultimately towards stabilization and detoxification. One GMOB Director said the biggest challenge today is extraction, and specifically the residuals left underground. This led to discussing the notion to extract, retreat and reinject the material.

The transportation of pure As_2O_3 from the site was evaluated in the EA and was determined to be high risk (even though GM actually did this for 2 years). However, stabilizing the material on site and transporting elsewhere has not been investigated but the issue could be the volume.

There was a question of whether there is a market for As_2O_3 dust, if purified to a 99.9 % state. The response was that although there are other parts of the world where As_2O_3 has been produced (e.g., Dundee in Namibia), there is little likelihood of this providing a Giant solution.

4.7 RESEARCH PROGRAM IMPLEMENTATION STRATEGY

4.7.1 STRATEGY COMPONENTS

A facilitated exercise was used to describe some of the important components of an implementation strategy and workplan. Although this task will ultimately fall to GMOB, the workshop participants offered their experience and lessons learned from existing research programs.

One participant suggested that it was almost disconcerting how quickly all participants gravitated towards the network option and specifically TERRE NET - but there was indeed consensus on the potential benefits and rewards of this approach.

There was discussion of GMOB speak soon to TERRE NET, and better define the questions to be posed to the network. It could mean: describe the GMOB problem, provide the SOK report, speak to a portfolio approach and ask how the network can help. There was agreement that we need to be more rigorous by further defining GMOB specific option-related research questions.

Before closing with Actions Items, there was discussion on factors influencing the next steps:

- Timing
- Portfolio Approach
- GMOB Accountability and Role
- Program Progress Indicators and Evaluation

- Funding Strategy

TIMING

There was debate about the timing of different components of the research and which might come first; for example, looking at the feasibility of different technologies first - with risk assessment coming after those technological studies. GMOB explained that the work done in 2001-2002 and more recently the GMOB SOK in 2017 concluded that there are no permanent solutions - now. The FBM was determined to be the best temporary solution; it is not a permanent solution. In terms of a timeline, GMOB expressed hesitation to rush and we cannot be sure when the 'silver bullet' will come. The FBM is not due to be implemented until 2035 (~15 years from now). So, in some ways, a 20-year window is not a bad thing. The 10 years gives time to freeze and also allows time for the other work GMOB to move forward a potential solution, and planning around factors such as reversibility. Allowance could be given in the portfolio for a "backstop concept" or a plan 'B' to the FBM in case it was ever needed.

PORTFOLIO APPROACH

There was a return to the importance of using the portfolio option, and the distribution of funds across the range of promising to moonshot technologies.

The first speaker stated, "I would have some high risk (about 20%) but the low risk investment % would be higher." Another said that will be the call of GMOB, but she repeated, "a value of the portfolio approach is that it is adaptive; a moonshot can be pursued and, in a short timeframe when it proves not applicable, dropped." In a straw poll, participants suggested perhaps 20-30% of the portfolio could be moon-shots.

Moonshots could also emerge from other research projects, and subsequently brought to GMOB's attention. Or come from creating enhanced awareness by having researchers engaged in the problem and looking for solutions. The university has a greater network than GM, and by engaging them we can network out. This approach will, however, require management by GMOB.

Early on, this research program needs to start thinking about field testing and lab testing to 'trim the branches of the tree' of the portfolio of options (in reference to discussion and diagram presented in Day 1). In response to a question about how much money could it take to find a manageable solution to the As_2O_3 dust underground at Giant Mine, one participant stated that as a guide the freeze optimization study for the FBM at Giant cost $50 million dollars. Total cost of implementation of the FBM total cost is about $500 M (not including the R & D costs).

GMOB ACCOUNTABILITY AND ITS ROLE

One GMOB Director cautioned that GMOB does not want to close itself off to other options by pursuing one particular network. Several researchers noted that GMOB would retain flexibility and it is possible that a project could be carried forward over years and then evaluated. This could cause GMOB to change course and direction – that is a benefit of the longer timeframes for this research. One researcher suggested that the complexity and history of this issue seems to be really well understood by GMOB and speaks to the importance of continued GMOB involvement in remediation.

GMOB is accountable and needs to be at the table. It could mean inserting GMOB dollars and creating a sub-network at TERRE NET to meet GMOB's needs. GMOB could also second and/or fund a highly qualified person to sit within the network (i.e., on the TERRE NET board) as a 'coordinator' or 'lead' or 'surrogate' to design the research program within a network like TERRE NET.

Another option raised was an advisory board that typically meets a few times a year and is not too much of an administrative burden. In terms of what level of authority would GMOB have in terms of the decision-making, GMOB would need to negotiate a place. One Director said the Giant constituency needs to understand the technology options and where the research is going. They may be more accepting of GMOB not rushing to avoid selecting a solution that is not ideal. Another GMOB member put this into perspective by noting that Canada took over the issue 18 years ago and 20 years is a generation;" so, while we cannot rush, GMOB needs to demonstrate progress and we can't be passive about this."

PROGRAM PROGRESS INDICATORS AND EVALUATION

The Giant Mine As_2O_3 general research problem suits a long-term research program, and requires phased scheduling, monitoring and evaluation. It will be important to have an end target and evaluate progress every 5 years as the research program evolves. NRCan stated it works on a 5-year timeframe and develops logic models with intermediate outputs and goals. Having those performance indicators is important for the purpose of auditing by Treasury Board, but also the public. The Giant public is going to audit this work and GMOB must be able to map it out and show what progress you are making within your research program. You need to have those goals and objectives tied to timeframes to show accountability. There was agreement that 5 years is a manageable and workable timeframe.

FUNDING STRATEGY

One participant emphasised that the relationships within the network are valuable, but so is establishing connections with the universities themselves. He noted that Universities are also charitable organizations, so there is opportunity wherein an institution could find support to leverage research and funding. *Think of this as a potential priority research program rather than a project.*

Most universities obtain as much donor funding as they do research funding. The process of soliciting a donor – who gets a tax credit – highlights that story. There has to be a leverage opportunity and the donor wants to see it leveraged with other contributions. But its also the story they are intrigued by and how they want to be involved in addressing an important problem. Working with university partners, we could build some strategies around doing this fundraising work. With an issue like GM, if positioned right and aligned with university priorities the university would see the value in that and want to contribute. The fact that the Giant Mine As_2O_3 challenge is northern, aboriginal and about capacity building creates value from a donor perspective.

One participant stated that there is a desire from other project teams (e.g., Faro Mine in Yukon) to have a similar research program and this could be opportunity to work together. Given the substantial costs of maintenance alone – Canada should have an interest in financially supporting this research. Other participants countered that parts of government believe the FBM is a reasonable and even permanent

solution; it may not be so easy to open federal coffers towards an alternative, except perhaps through NSERC and other research channels.

One researcher suggested that if the research question is sufficiently enticing you can get more money. It is about a whole life cycle approach and characterizing the associated problem, risk, need to find technology solutions and the subsequent adoption of those. This whole life cycle lets people see the big picture and once that relevance and scale is clear, people will want to tap in. It was agreed there must be a strategy to support leveraging of funding from government and industry, and GMOB will need to demonstrate early on in its program the ability to create a return on the investment.

4.8 ACTIONS

The following is a list of key Actions resulting from this workshop:

Action #1: Using the evaluation criteria developed through this workshop, GMOB to complete a more *systematic and methodical evaluation* (using a matrix approach) to better substantiate selection of the preferred research model option.

Action #2: GMOB to pursue using *an existing research network* as the model for an Active Research Program for Managing Arsenic Trioxide.

Action #3: GMOB to select or design its research program to incorporate some of the *fundamental features* discussed and supported in this workshop including:

- Using a broad-based and integrated approach
- Using a funding portfolio approach to support research projects
- Negotiating a strong decision-making role for GMOB
- Using a funding strategy for universities, government and industry
- Developing goals, objectives and performance indicators
- Measuring and evaluating progress on a regular (e.g. 5 year) basis

Action #4: GMOB to pursue, as the best apparent fit, an existing research institute or *network such as TERRE NET* at University of Waterloo and six other Canadian Universities.

Action #5: GMOB to use this report to prepare a core *position and set of questions* to use in approaching an existing research network.

Action #6: GMOB to *contact TERRE NET* directly and soon - to discuss using the network to advance GMOB needs for an active research program for managing arsenic trioxide dust at Giant Mine.

APPENDIX A: WORKSHOP AGENDA AND LIST OF PARTICIPANTS

GIANT MINE REMEDIATION: DESIGNING AN ACTIVE RESEARCH PROGRAM FOR MANAGING ARSENIC TRIOXIDE

October 19 and 20th, 2017

Twilight Room, Novatel Hotel, Ottawa, Ontario

I. WORKSHOP GOAL: TO DESIGN AN ACTIVE ARSENIC TRIOXIDE RESEARCH PROGRAM

To describe the main elements of a multi-year active research program specifically designed to advance the state of knowledge towards a permanent solution for the management of arsenic trioxide (As_2O_3) currently stored underground at the Giant Mine site.

II. WORKSHOP OBJECTIVES: BRAINSTORM RESEARCH PROGRAM MODELS

Overall, the Giant Mine Oversight Board (GMOB) shall develop a research program to explore technologies for the safe treatment, or removal and treatment, of arsenic trioxide stored underground at giant mine. This can include combining extraction, transportation, treatment and disposal and other technologies into a feasible solution for arsenic trioxide management. This workshop shall help this by:

- Considering all reasonable options for design of a GMOB arsenic trioxide research program;
- Describing the elements of 2-3 of the best options for GMOB to pursue further;
- Considering reasonable funding and administration options for the GMOB research program; and
- Describing the administrative steps and planning schedule needed for implementation of the best option(s) for a GMOB active arsenic trioxide research program.

III. WORKSHOP PARTICIPANTS

The workshop will include participants comprised of all GMOB Board members and staff, a DPRA Canada facilitator and recorder, and research program experts from Universities, NRC and other councils and associations. The full list of names with affiliation is provided as Attachment 1 to this Agenda.

AGENDA
GIANT MINE REMEDIATION:
DESIGNING AN ACTIVE RESEARCH PROGRAM FOR MANAGING ARSENIC TRIOXIDE

AGENDA – DAY 1

DAY 1	Thursday October 19th, 2017 (9:00 – 17:00)
TIME / FORMAT	**AGENDA ITEM**
9:00 AM	**1. SETTING THE STAGE**
Facilitator and GMOB presentation	1.1 WORKSHOP INTRODUCTION • Roundtable of introductions • Opening Remarks • Review of Workshop Goal, Objectives and Agenda
GMOB presentation	1.2 GIANT MINE OVERVIEW GMOB to provide a brief overview of the Giant Mine site, the extent of arsenic trioxide contamination, and the socio-cultural context for site remediation.
GMOB presentation	1.3 GMOB MANDATE AND RESEARCH PROGRAM GMOB to describe its mandate as contained in the Environmental Agreement, and in particular Articles 7, 8.2 and Schedule A; to set up an active research program towards a permanent solution for dealing with the arsenic trioxide stored underground at Giant Mine.
Facilitated Group Discussion	1.4 GIANT MINE REMEDIATION PROJECT PRELIMINARY QUESTIONS AND DISCUSSION

DAY 1	Thursday October 19th, 2017 (9:00 – 17:00)
TIME / FORMAT	**AGENDA ITEM**
	To address initial questions and encourage group dialogue on the Giant Mine Remediation Project and the challenge of arsenic trioxide management. Based on information shared through agenda item #1, other background material and previous experience of workshop participants
	2. EVALUATING RESEARCH PROGRAM MODELS
Facilitated Group Discussion	2.1 FACILITATOR AND GMOB TO INTRODUCE POTENTIAL CONSIDERATIONS TO GUIDE EVALUATION OF RESEARCH MODELS Facilitated group discussion to review and expand on the following list of evaluative considerations: o Design options for funding and attracting partners o Requirements for administering research under different models o Near-term, mid-term, and long term (2, 6, 10 + yrs.) considerations o Responsiveness: how to adapt to shifts in policies, perspectives or funding o How to best use research findings to influence the Giant Mine remediation plan o Others
	3. DISCUSS AND DESCRIBE EXISTING RESEARCH PROGRAMS
Facilitated Group Discussion	3.1 FACILITATED DISCUSSION OF RESEARCH PROGRAM STRUCTURES This will include the presentation and discussion by all participants of existing research program models, including: o NSERC Industrial Research Chair o X-Prize o Research consortium o Research council o University-based research chair (3 – 5-year funding cycle) o Others (not listed here, but brought forward at the workshop) Facilitated group discussion, but also encouraging expert(s) of a particular research program to provide a brief and informal introduction to their research program.
LUNCH BREAK	

	4. BRAINSTORM ELEMENTS OF RESEARCH MODELS
Facilitated Group Discussion (using 2 Breakout Groups only if considered an advantage)	4.1 FACILITATED DISCUSSION OF ADVANTAGES AND DISADVANTAGES Facilitated group(s) to discuss the advantages and disadvantages of the various models - specifically for Giant arsenic trioxide management. Participants will be encouraged to link the considerations developed in Agenda Item 2 to evaluate elements of existing research models (Agenda Item 3). This will require linking these to Giant Mine arsenic remediation in terms of project-specific considerations including technical, political, social, economic, and others.
4:45 PM	**5. CLOSING REMARKS FOR THE DAY – PLANS FOR TOMORROW**

AGENDA – DAY 2

DAY 2	Friday October 20th, 2017 (8:30 – 12:00)
TIME / FORMAT	**AGENDA ITEM**
8:30 AM	**6. OPENING REMARKS AND REVIEW OF AGENDA**
Led by Facilitator	• Introduction and overview of Day 2 expectations • Opening remarks (if any)
	7. DESCRIBING THE DESIGN AND MAIN ADMINISTRATIVE ELEMENTS OF ARSENIC TRIOXIDE RESEARCH PROGRAM MODEL(S)
Facilitated Group Discussion	7.1 SELECTING THE MAIN ELEMENTS OF RESEARCH PROGRAM MODEL(S) Use the results from Day 1 to collectively refine key evaluative considerations and program elements, and undertake a preliminary description and assessment of 1-3 research program options.
	8. TECHNICAL CONTENT OF AN ARSENIC TRIOXIDE RESEARCH PROGRAM MODEL(S)
Facilitated Group Discussion (using 2 Breakout Groups only if considered an advantage)	8.1 FACILITATED DISCUSSION OF POTENTIAL TECHNICAL RESEARCH SCENARIOS Facilitated discussion to consider specific technical research approaches (i.e. research content) and what these could look like using 1-3 top research plan models selected in agenda item 7 above. To include: • Iteration of current approaches as identified in the SOK Report; • Creative development of new approaches; and/or • Technology transfer from other fields that have potential application to Giant Mine.
	9. ARSENIC TRIOXIDE RESEARCH PROGRAM IMPLEMENTATION STRATEGY
Facilitated Group Discussion	9.1 PRELIMINARY DISCUSSION OF ELEMENTS OF A STRATEGY AND WORKPLAN A facilitated exercise to describe some of the important components of an implementation strategy and workplan for how to operationalize the best option(s). This task will ultimately fall to GMOB, but the workshop participants can offer their experience by describing essential components and lessons learned from existing research programs.

DAY 2	Friday October 20th, 2017 (8:30 – 12:00)
TIME / FORMAT	**AGENDA ITEM**
11:45 AM	**10. WORKSHOP CLOSURE**
Led by Facilitator and GMOB	10.1 SUMMARIZE WORKSHOP OUTCOMES
	10.2 DESCRIBE PLANNED FOLLOW-UP
	10.3 THANKS AND CLOSING COMMENTS

ATTACHMENT #1: WORKSHOP PARTICIPANTS LIST

WORKSHOP PARTICIPANTS		
Name	**Affiliate Organization**	**Position / Expertise**
Kathy Racher	GMOB	GMOB Chair
David Livingstone		GMOB Member
Kenneth Hall		GMOB Member
Ginger Stones		GMOB Member
Ken Froese		GMOB Member
Tony Brown		GMOB Member
Ben Nind		GMOB Executive Director
Letitia Pokiak		GMOB Office Administrator
Ricki Hurst	DPRA	DPRA Facilitator
Sophie Maksimowski		DPRA Recorder
Lianne Lefsrud	University of Alberta	Assistant Professor, Chemical and Materials Engineering
Scott Dunbar	University of British Columbia	Head and Professor, Mining Engineering
Charles Greer	National Research Council	Principal Research Officer, Group Leader, Biomonitoring, Energy, Mining and Environment
Heather Jamieson	Queen's University	Professor, Geological Sciences and Geological Engineering
Charles Dumaresq	Mining Association of Canada	Vice President, Science and Environmental Management
Bill Slater	Giant Mine Working Group	Principal Consultant, Bill Slater Environmental Consulting
Ron Layden	Aurora Research Institute (ARI)	Manager, North Slave Research Centre
Joe Muldoon	Saskatchewan Research Council	VP of Environment
Rob Gordon	Wilfrid Laurier University	VP Research
Carl Weatherall	Canadian Mining Innovation Council	Executive Director
Heidi Swanson	University of Waterloo	Assistant Professor / University Research Chair, Biology
Patrick Chevalier	Natural Resources Canada (Canmet)	Director, Green Mining Innovation - Environment, Canmet MINING, Lands and Minerals Sector