# Giant Mine Oversight Board

Strategic Research Plan

# Executive Summary

The Giant Mine Oversight Board (GMOB) was established as a condition of the Giant Mine Remediation Project Environmental Agreement signed on June 9, 2015. It is an independent body whose mandate includes **managing a Research Program to seek a permanent solution to the arsenic trioxide dust stored underground at the former Giant Mine site**.

The arsenic dust's current storage situation is safe but temporary. It is currently stored underground in fourteen chambers. A "frozen block" method will be applied to freeze the ground around and inside the chambers that contain the dust, preventing water from entering them.

While the frozen block was considered the most appropriate technical solution available at the time of the Environmental Assessment, the Mackenzie Valley Environmental Impact Review Board identified the importance of studying emerging technologies to identify a permanent long-term solution. In 2015, GMOB was tasked with supporting and guiding this research.

The goal of the GMOB Research Program is to **identify and recommend a permanent solution for the underground arsenic trioxide dust** in a manner that will prevent the release of arsenic to the surrounding environment, minimize public and worker health and safety risks during implementation, and be cost-effective and robust over the long term. The solution should require minimal to no long-term maintenance and monitoring.

The Strategic Research Plan and accompanying Implementation Plan provides an approach and steps towards the goal of identifying and recommending a permanent solution to the arsenic dust. **This compendium provides details explaining how GMOB got here and where it is going.**

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# 1. Context

## 1.1 What is the Giant Mine Oversight Board (GMOB)?

The Giant Mine Oversight Board (GMOB) was established as a condition of the Giant Mine Remediation Project Environmental Agreement signed on June 9, 2015. It is an independent body with two primary purposes:

1. Independently monitor, promote, advise, and support the responsible management of the remediation of the former Giant Mine site; and,
2. Manage a Research Program to seek a permanent solution to the arsenic trioxide dust stored underground at the former Giant Mine site.

## 1.2 What is the Challenge Being Addressed through Research and Why is it Important?

Giant Mine is located at the north end of Yellowknife NWT, within the city limits. The mine produced gold from 1948 to 1999 by excavating and roasting arsenopyrite, a naturally occurring mineral that contains arsenic. The roasting process used to extract the gold produced arsenic trioxide dust ("arsenic dust") as a waste by-product in vast quantities. By the mine's closure in 1999, it had placed approximately 237,000 tons of arsenic dust in large underground chambers.

*Note: Arsenic contamination of the larger area through stack emissions prior to dust collection and storage, and arsenic contained in tailings ponds, are being addressed through the surface remediation and are not directly within the scope of GMOB's Research Program.*

### 1.2.1 The Circumstances at Giant Mine Make the Dust Hard to Manage

Arsenic dust can be a waste by-product of gold mining. However, the situation at Giant Mine is unique in several ways:

1. **There is a large amount of stored untreated dust**. Unlike other gold mines, Giant Mine stored the arsenic dust rather than transforming it to a more stable product progressively as it was produced. Any activity to extract, transport, treat and/or transform, and ultimately store the transformed dust over the long term, must be operationally realistic, safe and effective at a very large scale.
2. **The untreated dust is close to communities**. The proximity of the dust to the City of Yellowknife, Ndilo and Dettah means that extracting, handling and eventually storing the transformed dust must be conducted with extreme care to avoid exposure to the general public.

3. **The untreated dust is sealed underground**. Currently, the arsenic dust is stored underground and will be frozen for an interim period. While this measure keeps the communities safe, it adds a significant challenge for eventual extraction and treatment.

### 1.2.2 If Exposed to Air or Water, the Dust Poses a Risk

In addition to the challenges above, the arsenic dust has several properties that make it essential to ensure that no arsenic escapes into the environment.

- It is fine-textured, meaning it can blow away if exposed to the open air.
- It can dissolve in water, unlike some other kinds of minerals, presenting a risk to the environment and human health.

### 1.2.3 The Arsenic Dust's Current Storage Situation is Safe but Temporary

The arsenic dust is currently stored underground in fourteen chambers. A "frozen block" method will be applied to freeze the ground around and inside the chambers that contain the dust, preventing water from entering them. Chambers that have not yet been frozen are protected by continually pumping out mine water before it enters them.

The frozen block method was recommended in 2003 by a Technical Advisor and Independent Peer Review Panel to the Mackenzie Valley Environmental Impact Review Board. The recommendation followed three years of research and consultation, with input from several independent groups and the community.

As a result of the environmental assessment, the frozen block method was considered a **temporary solution**. It was recommended to be in place for no more than 100 years and is required to be reviewed every 20 years.

While the frozen block was considered in 2003 to be the most appropriate technical solution available, the Environmental Assessment identified the importance of studying emerging technologies to identify a permanent long-term solution. In 2015, GMOB was tasked with supporting and guiding this research.

## 1.3 Roles and Responsibilities

The roles of each party with regards to the Research Program were established by the Mackenzie Valley Environmental Impact Review Board in its *Report of Environmental Assessment and Reasons for Decision on the Giant Mine Remediation Project*. They were then formalized by the Giant Mine Remediation Project Environmental Agreement in 2015 (Table 1).

*Table 1. Roles and responsibilities of major parties related to the Research Program.*

| Members | Responsibilities - Research |
|---|---|
| **Giant Mine Remediation Project Team ("Project Team", also known as the "Co-Proponents")** | |
| ● Government of Canada (Indigenous and Northern Affairs Canada)<br>● Government of the Northwest Territories (Environment and Natural Resources) | ● Every 20 years in consultation with GMOB, commission an independent review of the Project to evaluate its effectiveness to date, and to decide if a better approach can be identified. |
| **Parties to the Giant Mine Remediation Project Environmental Agreement** | |
| ● Government of Canada<br>● Government of the Northwest Territories<br>● Yellowknives Dene First Nation<br>● North Slave Métis Alliance<br>● Alternatives North<br>● City of Yellowknife | ● Carry out their respective responsibilities under the Environmental Agreement in a manner that supports ongoing research and development into an inherently safe, economically viable, permanent and complete remediation alternative for the arsenic trioxide stored underground at the Giant Mine site. |
| **Giant Mine Oversight Board (GMOB)** | |
| ● Six-member independent Board of Directors appointed by the Parties to the Environmental Agreement<br>● Executive Director | ● Review, comment, and make recommendations on programs, research, and reports about the Project.<br>● Support and report on research into a permanent solution for the arsenic trioxide dust stored underground at the Giant Mine site.<br>● Communicate to the public and Parties to the Agreement about GMOB's activities.<br>● Evaluate the findings of the 20-year review. |

### 1.3.1 The 20-year Review and GMOB's Role

A key responsibility of the Co-Proponents (referred to in this document as the "Project Team") is to commission an independent review of the Project every 20 years from the start of Project implementation. The purpose of the review is to evaluate the effectiveness of the Project and explore any alternatives that may have arisen for the safe storage of the underground arsenic dust.

If the review identifies a better approach to the arsenic dust stored underground (e.g., through recent research) that is feasible and cost-effective, the Project Team will study it further and make the results public.

While not responsible for the independent review itself, GMOB has the following responsibilities as required under the *Giant Mine Remediation Project Environmental Agreement*:

- Provide the results of the Research Program to the independent review process.
    - Note: GMOB is to report publicly on research findings as they arise rather than waiting for the 20-year review cycles.
- Advise the Project Team in designing the independent review of the Project.
- Evaluate whether the independent review meets the requirements of the Environmental Assessment (Measure 2) and Environmental Agreement (Article 8.3(e)) and provide the results of its evaluation to the Project Team and the public.

The Project Team is responsible for replying to GMOB's evaluation, including:

- having the independent reviewer address any deficiencies found by GMOB,
- indicating agreement or disagreement with GMOB's recommendations and providing their reasoning, and
- making their reply to GMOB public.

# 2. Context for the Strategic Research Plan

The following section provides context to the GMOB Research Program that will inform a recommendation toward a permanent solution for the arsenic dust at Giant Mine.

A summary of the GMOB Research Program's history is provided in Appendix 1.

Steps toward achieving the GMOB Research Program is included as Appendix 3.

## 2.1 Overarching Goal of the Research Program

The GMOB Research Program has adopted a goal that mirrors the 2007 Giant Mine Remediation Plan, with the additional consideration around monitoring and maintenance as identified by the Environmental Assessment.

**GMOB will identify and recommend a solution for managing the underground arsenic trioxide dust in a manner that will prevent the release of arsenic to the surrounding environment, minimize public and worker health and safety risks during implementation, and be cost-effective and robust over the long term. The solution should require minimal to no long-term maintenance and monitoring.**

**The importance of communication**

While GMOB and the Project Team have clearly defined roles and are independent from one another, the work of each is impacted by, and impacts, the work of the other.

While GMOB must and will remain independent of the Project Team, a strong working relationship is necessary to ensure clear communication between them.

## 2.2 GMOB's Scope within the Larger Remediation Project

While GMOB is responsible for administering and overseeing the Research Program in pursuit of a permanent solution to the underground arsenic dust, its direct involvement ends upon making a recommendation to the Project Team (Figure 1).

After making a recommendation to the Project Team, GMOB will return to an oversight role as relates to the permanent solution for the arsenic dust. The Board will review the reports and studies produced by the Project Team (e.g., engineering studies) and provide feedback and recommendations. As remediation is completed, the Giant Mine Perpetual Care Plan will be implemented; however, the details of this Plan (including each party's respective responsibilities) are unclear as the Plan has not yet been developed.

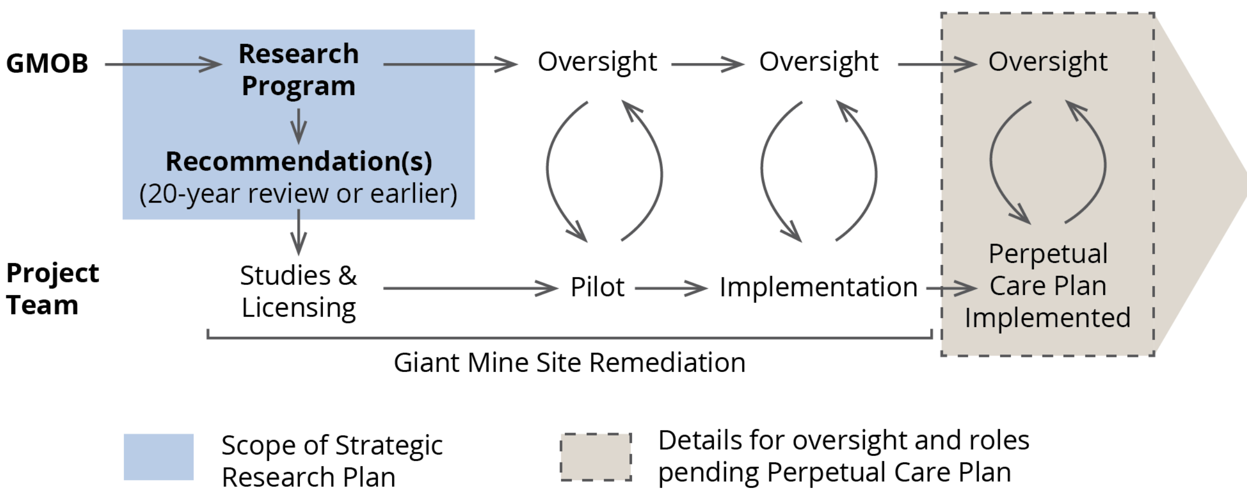


*Figure 1. Steps and respective roles of the Giant Mine Remediation Project, with the scope of the Strategic Research Plan indicated in blue.*

**The following steps describe actions for which GMOB is directly responsible as part of administering the Research Program. Actions that fall to the Project Team are outside the scope of the Research Program and Strategic Research Plan. If responsibilities are unclear for key steps, GMOB expects to be involved in discussions to clarify roles but does not expect to be directly responsible for the decision.**

## 2.3 Components of a Permanent Solution: Objectives, Considerations and Timelines

There are four key components of a permanent solution:

1. Dust extraction
2. Dust stabilization
3. Storage of the stabilized product
4. Management of the residual

Each of these components is described in more detail below, including an explanation of their importance, the high-level objective of the Research Program for addressing the component, and important considerations. A roadmap of key actions and their status is available in Appendix 3 of this document (Implementation Plan); this Appendix will be updated periodically as the Board continues to advance the Research Program.

### 2.3.1 Dust Extraction

For any activity that involves processing or treating the dust, the dust must first be safely extracted from the underground chambers.

*Objective*

One or more methods are identified that will extract the arsenic dust safely, cost-effectively, and as completely as possible.

*Key considerations*

Given the challenging properties of the dust, extreme care must be taken to ensure worker safety and prevent the possibility of dust being released into the environment.

A State of Knowledge assessment commissioned by the GMOB in 2017 concluded that of the challenges at hand, identifying a suitable method for stabilizing the dust presented a much greater challenge than safely extracting it.

*Timelines and progress*

Two preliminary studies examined dust extraction, namely the State of Knowledge assessment (2017) and a review of extraction technologies in 2021. Extraction is one of the first steps needed before a stabilization process can occur. Engineering studies and infrastructure development must occur before any extraction can take place.

### 2.3.2 Dust Stabilization

The underground arsenic dust is currently in a form and location that needs to be actively managed by pumping out underground mine water. This is needed to prevent arsenic dissolving and moving into the groundwater (e.g., through leaching).

The primary focus of the GMOB Research Program to date is researching methods for transforming the arsenic dust into a substance that is much more stable. The Research Program is investigating both physical methods (i.e., trapping the dust in something more stable) and chemical methods (i.e., chemically transforming the arsenic dust into something more stable).

*Objective*

A safe, cost-effective, operationally feasible method for stabilizing the arsenic dust is identified and recommended to the Project Team.

*Key considerations*

A necessary first step in starting the dust stabilization program was to analyze dust samples to better understand their makeup and how their composition varied.

Testing will be completed with a range of dust samples. It is important to ensure that any selected stabilization process will work with dust compositions from all the chambers.

The research projects need to not only consider the stabilization method, but also the necessary storage conditions for the stabilized product. For example, does it need to be stored below ground or can it be stored above ground? What environmental conditions can it experience without leaching arsenic?

**The Importance of Communication**

The treatment of arsenic dust will require the construction of a facility and infrastructure (e.g., for transportation). Doing so cost-effectively will require communication and alignment with the Project Team, which is currently changing the site through remediation activities. There is an opportunity to ensure that remediation activities leave the door open for the construction of these facilities.

*Timelines and progress*

The Research Program is well underway, with several projects near completion and increasing clarity regarding the operational feasibility of the methods being tested.

Of the projects that have been funded to date, the most advanced stabilization method is physically transforming the arsenic dust into glass (“vitrification”). Chemically transforming the dust into a more stable mineral (“sulfidation”) may warrant further investigation to determine its feasibility.

### 2.3.3 Storage of the Stabilized Material

While the objective of transforming the arsenic dust is to produce a more stable substance, the safe storage of the stabilized material nevertheless needs to be considered.

*Objective*

Parameters for safe storage of the stabilized dust are identified such that storage requirements and associated infrastructure may be developed and implemented by the Project Team.

*Key considerations*

Whatever the selected stabilization process, the volume will be at least as large as (and more likely greater than) the current volume occupied by the 237,000 tons of arsenic dust currently stored underground. Any storage solution will need to accommodate the anticipated volume of stabilized material.

Different stabilization processes produce materials that may have different storage requirements to remain stable. For example, the arsenic transformation that creates a stable mineral using sulfidation is most stable when kept in an oxygen-free environment (e.g. under water). The results of the stabilization research phase will need to be considered when planning the storage solution.

Finally, the stabilized material must be stored in such a way that it can be appropriately monitored, with roles and responsibilities for long-term monitoring clearly defined.

**The Importance of Communication**

The above- or below-ground storage requirements needed for the stabilized dust need to be discussed with the Project Team. With this knowledge, the Project Team can plan to provide the needed conditions for safe storage (e.g., underground chambers remain accessible, or a large above-ground area remains available) as part of remediation activities.

*Timelines and progress*

Once the stabilization technique is selected, planning can begin in detail regarding the appropriate storage requirements.

The progress to date relates to individual research projects evaluating how well stabilized products resist leaching arsenic under a range of conditions. For example, dust that is transformed to glass performs best when stored under dry conditions, while dust that is transformed into a sulfide mineral performs best when stored deep underground and in water.

### 2.3.4 Managing the Residual Dust

While measures will be taken to ensure that the arsenic dust extraction is as complete as possible, there may be some residual dust that cannot be recovered and treated. The question of the residual is extremely important because it will determine how to manage the land and water on site.

While this question is of importance, it requires review after an extraction and stabilization approach have been determined, which will be developed at a later stage in the research program.

*What needs to be done?*

The critical gap at this stage is the lack of clarity around the effectiveness of the extraction and treatment process as well as the long-term management of surface water and groundwater on site.

The key considerations that must be examined include:

- Quantifying the expected amount of residual dust and its characteristics.
- Identifying treatment options that may be suitable for treating the residual in place in the underground chambers.
- Identifying whether continued water treatment is sufficient or necessary.
- Determining timelines for managing the residual.

# 3. Adaptive Management Framework for Research and Implementation

Adaptive management refers to a framework that explicitly collects, incorporates and applies learnings over time. In practice, this means that planned management steps may evolve as more is learned about what works and what does not. These planned feedback loops are a critical part of prolonged projects, as the amount of uncertainty increases into the future.

For example, the final storage of the stabilized dust will depend on how the site is remediated and what areas are set aside for storage, which stabilization technique (or techniques) is selected, and even how the environment may be different in 10 or 20 years (e.g., lower water levels or increased wildfire).

The GMOB Research Program has been designed using an adaptive management framework. In this context, research is being conducted in phases. Each phase scales up from the prior work and incorporates what has been learned.

The following list outlines phases of research and implementation as currently planned for all research components:

1. GMOB invites research proposal submissions for studying potential permanent solutions for the arsenic dust (ongoing).
2. GMOB-funded studies occur at the small scale using samples from underground chambers at the Giant Mine.
3. The highest-performing project(s) are funded for advanced research with a wider range of dust samples or reagents (e.g., “ingredients” needed for stabilization).
4. Learnings from the advanced research are incorporated into the GMOB recommendations to the project team.

Given the short timeframes and budget limitations, GMOB adopted a “fail-fast” approach, funding a wide range of initial projects with small investments to determine which areas show most promise. By capturing a wide breadth of options, GMOB has avoided investing too heavily in a single method that could ultimately fail to outperform the current frozen block method.

The most promising project(s) will receive funding for an additional phase of work to more closely examine 1) the risk of arsenic release from the transformed dust and 2) their feasibility for the Giant Mine site.

## 3.1 Proposed Criteria for Selecting the Method for the Permanent Solution

GMOB is responsible for evaluating the success of the methods tested by the Research Program and selecting which project(s) will continue at increasing scales. To do so, it is essential that GMOB clearly define the criteria by which "success" will be evaluated.

In 2017, the State of Knowledge report commissioned by GMOB adapted and expanded on the criteria used for the Giant Mine Remediation Plan to evaluate methods for a permanent solution. These criteria were weighed to ensure that the most important considerations (e.g., effectiveness) were weighted more strongly than others (e.g., time required for completion).

GMOB will use these structured criteria, which are summarized below, to evaluate the research projects that have been funded to date. This will allow both consistency and comparison with the current frozen block method, which was evaluated as part of the State of Knowledge report.

The full details of the criteria, including the weighting table, are included in Appendix 2.

### 3.1.1 Performance Criteria for Evaluating Stabilization Methods

- **Technical maturity**: How soon could the technology be implementable?
- **Effectiveness (long-term stability/permanence)**: How much more long-term stability will the stabilized dust have as compared with the stability of the frozen block method?
- **Technical independence**: Does the method require additional technical changes or invention to be implemented? If so, how many extra steps, and what is their associated cost and risk?
- **Confidence in predictive models**: Are the predictive models strong? Are they supported by robust field data and/or well validated?
- **Pilot testing/Design/Pre-installation requirements**: How much pilot, field and design work is needed before the method can be implemented?
- **Operation, maintenance and monitoring requirements**: How much active management will be required during and after implementation?
- **Short-term risk**: What is the risk of arsenic release during implementation in large enough amounts to affect ecological or human health?
- **Worker health and safety**: What is the risk to workers at each stage of implementation?
- **Practicality of contingency measures in case of failure**: Does the primary method constrain the ability to implement a secondary or backup method?
- **Time required for implementation**: How much lead time and implementation time are required to convert from the frozen block method?
- **Ease of implementation**: How hard will it be to transition the dust from the frozen block to the new method?

- **Compatibility with future land uses in Giant Mine area**: Does the method add any benefit to future land use or, conversely, disrupt or impact land use?
- **Cost - Initial and total lifecycle cost**: Does the method cost more or less than the frozen block method, and by how much?
- **Compatibility with cold climates**: What issues may arise from implementing the method in cold climates? Has it already been successfully used in cold climates?

# 4. Closing

Ultimately, GMOB's vision of the future is one in which the arsenic dust no longer weighs on the minds of the people of Yellowknife and nearby communities.

By developing and sharing this Strategic Research Plan, GMOB is taking an important step to provide clarity, transparency and consistency on the Board's approach to the Research Program toward a permanent solution to the arsenic dust stored underground at Giant Mine.

This Strategic Research Plan is a living document that will be updated as progress continues on research and implementation, within the context of the larger remediation activities taking place at Giant Mine. The Plan is additionally an opportunity for GMOB and all parties involved in the remediation of Giant Mine to engage, discuss and ultimately align their efforts.

# Appendix 1. History of Research and Decisions Relating to the Underground Arsenic Dust

## Introduction

This appendix summarizes key decisions that were made regarding the underground arsenic dust and the rationale for those decisions, leading up to and including the establishment of GMOB's Research Program.

The goal of this summary is to provide a high-level framework for understanding the choices that were made in the past and building on those learnings. External documents will be referenced as appropriate, and the reader is invited to refer to those for greater detail.

## Timeline of Events

In 1999, Giant Mine ended gold production. That year, the Government of NWT and the Government of Canada (Dept. of Indian Affairs and Northern Development (DIAND), now Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)) assumed responsibility for the mine's environmental liabilities.

From that point, key milestones related first to the selection of the frozen block method for freezing in the arsenic dust, followed by GMOB's formation and initiation of its Research Program (Fig. A1).

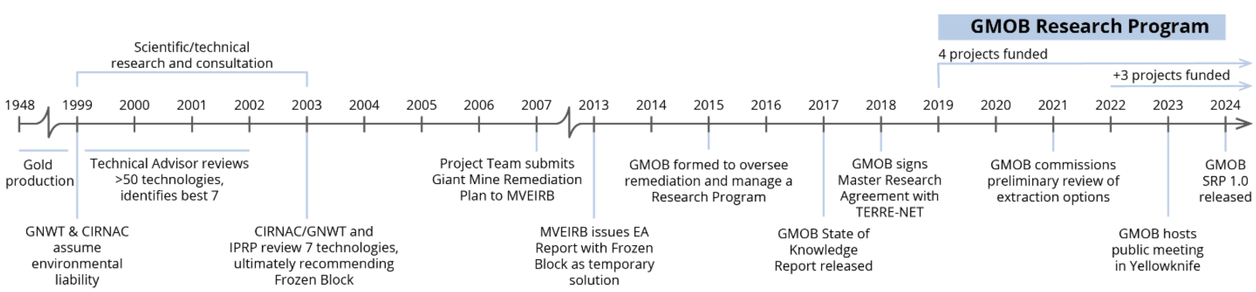


*Figure A1. Timeline summarizing key events regarding the underground arsenic dust and the GMOB Research Program.*

## The Frozen Block Selection Process and Considerations

Scientific/technical research and community consultation took place from 1999–2003 as the two governments, hereafter referred to as the Project Team, sought the best option for safely securing the underground dust in the long term.

In 1999, the Project Team appointed an independent Technical Advisor to analyze options for the arsenic dust and make a recommendation. In 2002, the Technical Advisor published a report identifying over 50 technologies that may be considered for remediating the arsenic dust.[1] They evaluated the technologies against three categories of risks/costs:

- The risk of arsenic release in the short term during the implementation of alternatives.
- The risk of arsenic release in the long term after implementation.
- The worker health and safety risks that would be faced during preparation, implementation, and post-implementation activities.

Through this process, the Technical Advisor proposed the seven best *in situ* ("leave it underground") and *ex situ* ("take it out") alternatives for managing the underground arsenic dust, including their overall risk, dominant risk category and estimated net cost range. An Independent Peer Review Panel provided an independent technical review of the selection process and the options. They recommended that of the seven management alternatives, the frozen block method (*in situ*) and encapsulating in cement (*ex situ*) go to public consultation.[2]

Subsequently, the Project Team engaged the community to present the two alternatives and collect community feedback. Key findings from the workshops included:[3]

- General support for keeping the dust underground.
- A general preference for the freezing option.
- The most important factors in choosing an alternative were:
  - Worker health and safety
  - Technological feasibility
  - Environmental and human health
- Some participants did not consider cost to be a key factor.

Through this process, the frozen block method was identified as the preferred management alternative. It was considered the most robust, long-term option for the following reasons:[3]

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[1] Government of Canada. 2002. Final Report - Arsenic Trioxide Management Alternatives: Giant Mine. Department of Indian Affairs and Northern Development. Prepared by SRK Consulting, SENES Consultants Limited, HGE, and Lakefield Research. Project 1CI001.10. https://reviewboard.ca/upload/project_document/EA0809-001_Final_Report__Arsenic_Trioxide_Management_Alternatives.pdf

[2] Independent Peer Review Panel. 2003. Review of SRK's Final Report Dated December 2002 'Arsenic Trioxide Management Alternatives' Giant Mine, Yellowknife, N.W.T. Prepared for: Giant Mine Remediation Project Team, Indian Affairs and Northern Development, Yellowknife, NT. https://www.dropbox.com/scl/fi/f75mz425lz7p3b4h5zru4/2022-12-Review-by-IPRP-of-SRK-Final-Report-Arsenic-Trioxide-Management-Alternatives.pdf?rlkey=j9rihdcuih7zgseqhuuk1hr4u&e=1&dl=0

[3] Terriplan Consultants. 2003. Giant Mine Underground Arsenic Trioxide Management Alternatives. Moving Forward: Selecting a Management Alternative. Workshop Summary Report. Prepared for: Giant Mine Remediation Project, Indian Affairs and Northern Development, NWT Region, Government of Canada.39 pp. https://reviewboard.ca/upload/project_document/EA0809-001_Giant_Mine_Arsenic_Management_Workshop_Summary_Report_July_2003.pdf

- Freezing from underneath and the sides eliminates the possibility of "windows" in the frozen block.
- Freezing takes advantage of the wet dust to create even more ice.
- Supplementing the active freezing method with cold air pipes from the surface gives added protection from thawing.
- The option is flexible and can be monitored, and if there is a concern about thawing, the freezing mechanism can be reactivated to refreeze the blocks.
- Very little energy is required to maintain the frozen blocks once they are frozen solid, which reduces the long-term cost of the option and the extent of the long-term maintenance required.
- The method is reversible by mining the frozen material when a permanent solution is found.

In the 2007 Giant Mine Remediation Plan, the Project Team proposed the frozen block method for the underground arsenic dust. As part of this plan, it was understood that the freezing system would need to be maintained in perpetuity. It was also identified that mine water treatment would need to continue indefinitely, requiring the construction and perpetual operation of a new water treatment plant. The Plan included monitoring of surface water, treated water, mine water, groundwater, air, environmental effects, and frozen ground, as well as physical monitoring and inspections by permanent staff.

In 2013, the Mackenzie Valley Environmental Impact Review Board released the *Report of Environmental Assessment and Reasons for Decision - Giant Mine Remediation Project*. In this report, they approved the frozen block approach, but only as a **temporary** measure to last no more than 100 years, with periodic review required every 20 years. As part of its decision, the Review Board mandated the formation of an independent oversight body to oversee the Remediation Project (Measures 7 and 8).[4]

### Why did the Review Board Consider Frozen Block a Temporary Solution?

In its environmental assessment, the Review Board concluded that the frozen block was the best available technology for securing the arsenic dust, but concluded that it was a temporary measure only (Measure 1, p.70). Their reasons for this decision were because:

- the dust will remain in its original location,
- the dust will remain in its original form, which could release arsenic if contacted by liquid water, and
- active monitoring and maintenance of the frozen block will be needed in perpetuity.

[4] Mackenzie Valley Environmental Impact Review Board. 2013. Report of Environmental Assessment and Reasons for Decision: Giant Mine Remediation Project. 245 pp. https://reviewboard.ca/upload/project_document/EA0809-001_Giant_Report_of_Environmental_Assessment_June_20_2013.PDF

Taken together, the Review Board concluded that in the very long term (i.e., >100 years), there was a foreseeable risk of failure of the frozen block option.

### Different Views Regarding the Temporary Nature of the Frozen Block

Within the Environmental Assessment, the Review Board noted that it would be a challenge to get the Project Team to implement a permanent solution. The Project Team had stated that they felt it unlikely there would be a "markedly superior" option found for the following reasons:

- they felt that the 2000–2003 investigation of alternatives was sufficiently thorough,
- they considered the challenges in excavating the arsenic prohibitively high even if a better treatment were available, and
- they noted the considerable amount of money already spent on the Project and implementation of the frozen block.

Despite viewing the frozen block method as the long-term solution, rather than a temporary one, the Project Team agreed to support a research program to develop a permanent solution at the request of the Review Board.

## Additional Key Decisions from the Environmental Assessment

In its Environmental Assessment report, the Mackenzie Valley Environmental Impact Review Board made several key decisions regarding the underground arsenic dust and its oversight:

1. The Project is an interim solution to last no more than 100 years (Measure 1, p.70).
2. An independent review of the project is required every 20 years, to be commissioned by the Project Team (Measure 2, p.70).
    a. If a better option for the arsenic dust has become available, the Project Team will study it and publish their findings publicly.
3. A multi-stakeholder research agency will be formed to research options for the arsenic dust and share the results of its research to the 20-year reviews (Measures 3 and 4, p.71).
    a. GMOB was established to fulfill this role, among other responsibilities (see The GMOB Research Program).
4. An independent oversight body will be created (Measure 7, p.93). Its responsibilities include (Measure 8, p.93):
    a. overseeing the Project Team's monitoring activities and results,
    b. reviewing whether funding for the Project and ongoing research are adequate,
    c. advising the Project Team, and
    d. sharing its conclusions with the public in a culturally appropriate manner.

## The GMOB Research Program

In 2015, the Giant Mine Oversight Board (GMOB) was established by the *Giant Mine Remediation Project Environmental Agreement* as an independent entity to fulfill the following two purposes:

1. Independently monitor, promote, advise, and support the responsible management of the remediation of the Giant Mine site; and
2. Manage a research program to seek a permanent solution to the arsenic trioxide dust stored underground at the Giant Mine.

As one of its first steps, GMOB commissioned a state of knowledge report that reviewed alternative options for dust recovery and stabilization. *Giant Mine State of Knowledge Review: Arsenic Dust Management Strategies*[5] was released in 2017. The State of Knowledge review summarized the previous assessments of alternatives; defined performance criteria; and conducted a technical assessment of methods for onsite management, dust extraction mining, dust stabilization and processing, and disposal against these criteria. The Review made the following conclusions:

- There have been significant advances in hydraulic borehole mining, and this method could be expected to perform effectively and safely for extracting the arsenic dust.
- The frozen block method performed very well against the performance criteria.
- Vitrification was the top-ranked dust stabilization and processing method based on its potential for long-term stability, moderate costs, and potential for gold recovery. This approach was recommended for further research.
- Cement stabilization/cemented paste backfill and mineral precipitation were considered the next-best options and were also recommended for further research.

In 2018, GMOB hosted a workshop in Yellowknife with TERRE-NET[6] to provide further context for the research mandate and introduce TERRE-NET's expertise. The focus of the joint research program was developed at a follow-up workshop in Edmonton in late 2018.

In 2019, GMOB signed a four-year Master Research Agreement with the University of Waterloo. This agreement guides the administration of the GMOB Research Program and approved four research initiatives:

- Examination of arsenic trioxide dust composition and solubility
- Sulfidation of $As_2O_3$ to low-solubility arsenic sulfide ($As_2S_3$)
- Incorporation of $As_2O_3$ into cemented-paste backfill

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[5] Arcadis Canada Inc. 2017. Giant Mine State of Knowledge Review: Arsenic Dust Management Strategies. Report prepared for Giant Mine Oversight Board. 157 pp. https://gmob.ca/wp-content/uploads/2017/09/2017-08-Giant-Mine-State-of-Knowledge-Review_FINAL.pdf

[6] TERRE-NET (Toward Environmentally Responsible Resource Extraction) is a research network funded by NSERC Strategic Partnership Grants for Networks. It is headquartered at the University of Waterloo.

- Leaching behaviour and geochemical stability of vitrified arsenical glass

In 2021, GMOB commissioned a preliminary review of options for extracting the arsenic dust by the Wolfson Centre for Bulk Solids Handling Technology at the University of Greenwich. The final report recommended combining dry extraction using agitators to remove the majority of the dust, followed by liquid extraction to capture the remaining dust. It assumes the dust is dry and non-frozen when extracted.[7]

In 2022, GMOB co-funded three additional projects with the Natural Sciences and Engineering Research Council of Canada (NSERC), bringing the total number of funded projects to seven. The additional projects are:

- Stability of iron arsenate phases
- Biogenic sulfide precipitation
- Implementation and application of antimony (Sb) isotope systems

In 2023, GMOB hosted a two-day workshop in Yellowknife, during which the lead researchers presented on each of the seven projects to GMOB, the Project Team, the Parties to the Environmental Agreement, and finally, the public. An overview of the projects is provided in the Workshop Report.

[7] The Wolfson Centre for Bulk Solids Handling Technology. 2021. Review of Extraction Technologies for Subterranean Deposits of Consolidated Arsenic Trioxide Dust. Prepared for Giant Mine Oversight Board. University of Greenwich. 14 pp. https://gmob.ca/wp-content/uploads/2024/05/2021-02-04-Review-of-Extraction-Technologies-for-Subterranean-Deposits-of-Consolidated-Arsenic-Trioxide-Dust-Wolfson-Centre.pdf

# Appendix 2. Full Performance Criteria and Weighting Table

**The following criteria are repeated directly from *Section 2.5, Setting of Performance/Assessment/Ranking Criteria* of the following report commissioned by GMOB:**

**Arcadis, 2017. Giant Mine State of Knowledge Review - Arsenic Dust Management Strategies. Report prepared for Giant Mine Oversight Board, Arcadis Canada Inc., 100296/ 43001000.0000, August 2017, 107 p. and appendix.**

**The full State of Knowledge report is available online.**

## 2.5 Setting of Performance/Assessment/Ranking Criteria

As stated above, a semi-quantitative system of ranking criteria was used to evaluate the methods. The selection of the ranking criteria defines the important characteristics of the desired handling/treatment/processing/isolation methods. The criteria used are inclusive of those used in the original assessment, with some modification, (SRK, 2002) and incorporated other ranking criteria developed by Arcadis and requested by the GMOB. During the original SRK assessment, the following criteria were used to evaluate technologies:

- Technical viability;
- Field experience;
- Available and adequate evaluation data;
- Robustness— (long-term solution);
- Implementation- including environmental acceptability; and
- Performance monitoring of method.

Working with these initial criteria, Arcadis developed modified criteria to evaluate promising methods. Promising methods were those which had passed through the initial screening showing high level of technical maturity, relatively low level of health and safety risks, and identifiable development since 2002. These criteria and descriptions were sent out to each expert as part of the method rating sheet. During the course of the evaluations, a clearer concept of some of these criteria developed. Both the initial definition, and the modified/final (if applicable) definitions are given below. The low versus high ranking indicates how a given method scored for that ranking with high being desirable and low being less desirable so that a low score equates to a high risk or high cost, for example.

- **Technical Maturity**

- Initial: Probability of becoming a practical, useful technology, likely time required to develop a technology to the point of being implementable, availability of data for evaluation, fundamental soundness of technology.
  - Low = implementation > 10 years out, Moderate = implementable within < 10 years, High = immediately implementable.
- Final: No changes

- **Effectiveness (Long-term Stability/Permanence)**
  - Initial: How material an impact will the method have compared to the currently implemented remedial strategy (performance evaluation defined as arsenic flux). Does the method have a high probability of a being a permanent solution?
    - Low = long-term stability unknown or unproven, Moderate = moderate long-term stability (100 years), High = long-term stability likely.
  - Final: No changes
- **Technical Independence**
  - Initial: Does the method provide benefit if it is the only change made, or, does it require additional technical changes or invention during implementation?
    - Low = requires additional unproven, expensive, or high risk methods to be effective, Moderate = requires some modification of existing condition using established methods, High = can be implemented effectively, essentially independent of other methods used at the site.
  - Final: How many additional levels and steps are required within the integrated treatment process for the complete remedy? Are these additional methods unproven, expensive or high risk?
    - Low = requires many additional unproven, expensive, or high risk methods to be effective, Moderate = requires moderate interim processing steps using established methods, High = standalone process.
- **Confidence in Predictive Models**
  - Initial: Low = lack of or poor predictive models and/or the absence of long-term performance data for technology, Moderate = accepted predictive models available or field data for 5-10 years of performance available, High = Field data for >10 years, and/or well validated predictive models exist for analogous systems.
  - Final: No changes
- **Pilot Testing/Design/Pre-Installation Requirements**
  - Initial: Low = requires extensive pilot/field/design work before implementation, Moderate = requires a modest level of pilot/field/design effort prior to implementation, High = requires minimal or no pilot testing, low-moderate level of design effort required.
  - Final: No changes
- **Operation, Maintenance and Monitoring (OMM) Requirements**
  - Initial: How much active management will be required

        - Low = requires active (OMM) quarterly or more frequently, Moderate = requires annual OMM, High = passive remedy, requires only monitoring for compliance purposes.
    - Final: How much active maintenance and system operation would be required after the implementation of the remedial alternative?
        - Low = requires active OMM quarterly or more frequently, Moderate = requires annual OMM, High = passive remedy, requires only monitoring for compliance purposes after remedial alternative is implemented.
- **Risk – Short-term Risk, Worker Health and Safety (H&S)**
    - Initial: In order to make an effective comparison against previously evaluated methods, short-term and worker health and safety risk categories, as defined in supporting document (SD) 18 of the 2002 SRK Report were used. Long-term stability, i.e., permanence, a priority in this review, is evaluated within the effectiveness category. These risk categories are described in more detail within SD 18 (SRK, 2002d); however, a brief description is given below. Risk type will be divided into two categories:
        - **Short-term risk** – The risk that a quantity of arsenic sufficient to affect ecological or human health could be released to the receiving environment during the preparation or implementation phase of each alternative and;
        - **Worker health and safety risks** – The conventional safety risks and the arsenic related health risks that would be faced by workers active in the preparation, implementation, and post-implementation activities.
            - Worker health and safety risk will be evaluated based on individual activities. Low, medium, and high-risk qualifiers will be used.
                - Drilling and installation of wells and/or freezing systems
                - Dust extraction and transport
                - Dust processing
                - Water treatment
                - Residue disposal.
    - Final: Short-term risk and worker H&S were evaluated during the method reviews by the Arcadis team and the expert reviewers. As stated above, the low versus high ranking indicates how a given method scored for that ranking with high being desirable and low being less desirable. In the case of risk, a low score equates to a high risk. Scores assigned were low, medium and high. The H&S scores were reviewed by an Environmental Health and Safety specialist on the project team before finalizing.
- **Practicality of Contingency Measures in Case of Failure**
    - Initial: Low = Difficult to apply an alternative method if the selected method is used, Moderate = the choice of a secondary back-up method is somewhat constrained in choice due to the primary method, High= secondary methods easy to implement.

- Final: No Changes
- **Time Required for Implementation**
  - Lead/development and implementation time required, in the context of conversion from the FB method. As with other criteria, the low versus high ranking indicates how a given method scored for that ranking with high being desirable and low being less desirable. A low score in this case would take longer for implementation.
    - Initial: Low = Would require more than 20 years to implement, Moderate = would require 10-20 years to implement, High = would require less than 10 years to implement.
    - Final: No changes
- **Ease of Implementation**
  - Initial: Compatibility with the currently implemented remedial alternative.
    - The process of switching from the Frozen Block Alternative to a new long-term approach will be a concern during implementation of any new remedy. Issues such as accommodation of thaw times, site conditions post-frozen block remedy, saturation of the dust, and site accessibility and stability will be discussed and evaluated.
      - Low = complicated and difficult transition from frozen block alternative, Moderate = moderately complex transition from frozen block alternative, High = easy transition from frozen block alternative.
  - Final: No changes
- **Compatibility with Future Land Uses in Giant Mine Area**
  - Initial: Low = final remedial alternative does not add any benefit to future land use, Moderate = final remedial alternative adds some benefit to future land use, High = final remedial alternative adds significant benefit to future land use.
  - Final: Focus on treatment 'footprint'. Very Low/Low = final remedial alternative significantly disrupts or could impact present or future development of land, Moderate = implementation of final remedial alternative will impact current or future development of land, and some long-term impacts may be anticipated, High = final remedial alternative may impact short term use, but minimally disrupts future development of land, Very High = final remedial alternative causes minimal disruption both in the short-term during implementation and in long term.
- **Cost – Initial and Total Lifecycle Cost**
  - As with other criteria, the low versus high ranking indicates how a given method scored for that ranking with high being desirable and low being less desirable.
  - Initial: Low = cost more than 25% greater than current remedy, Moderate = cost within 25% of current remedy, High = cost less than or equal to 75% of the cost of the current remedy
  - Final: Estimated cost range to be determined at time of evaluation.
- **Compatibility with Cold Climates**

- Arsenic- and site-specific challenges are superimposed on general remediation challenges associated with northern environments. There are numerous examples where technologies developed for southern projects have been unsuccessful when applied to the northern context. Typical challenges include: equipment/geotechnical failures, low efficiency of chemical/biological processes and low human productivity in cold-weather environments. The risks of neglecting to consider the effectiveness of technologies in northern environments are significant and can include: major cost overruns, schedule delays, health and safety risks and complete project failure.
  - Initial: Low = major issues arise from implementing technology in cold climates, Moderate = moderate or unknown issues in implementing technology, High = technology is already successfully used in cold climates.
  - Final: No changes

## 2.6 Weighting Criteria Selection

The individual weights for each evaluation criterion were selected prior to the review and are presented in Table 4, and graphically in Figure 1. Because of the desire to find a permanent remedial option for the arsenic, priority weighting (a multiplier of 10) was given to the effectiveness criterion, which evaluates a method's long-term permanence in the absence of maintenance. A high weight (multiplier of 5) was given to the OMM requirements, short-term/worker health and safety risk criteria as these were identified by the GMOB to be of particular importance in considering a final solution. Collectively, effectiveness, OMM and short-term/health and safety criteria make up 52% of the entire score for each method.

The criteria given a medium weight (technical maturity, practicality of contingency measures, cost, and compatibility with future uses), are also important factors to be considered in selecting a method. However, these categories are not as significant to the specific technical goal of this review.

Lower weighting (versus the above) was assigned to compatibility with cold climates, technical independence, confidence in predictive models, pilot testing, time required for completion and ease of implementation criteria. Because of their relatively low weight, these criteria do not contribute as significantly to the score. However, including them in the evaluation yielded a more complete evaluation and may be useful in assisting with any future evaluations.

**Table 8. Scoring Criteria Weight Contribution by Percent**

| Evaluation Criteria | Weight | Percent Contribution to Total Score | Numeric Weighting (maximum value) |
|---|---|---|---|
| Effectiveness (Long Term Risk/Permanence) | Priority | 26.3% | 50 |
| OMM Requirements | High | 13.2% | 25 |
| Short-term/ H&S Risk | High | 13.2% | 25 |
| Technical Maturity | Medium | 7.9% | 15 |
| Practicality of Contingency Measures in Case of Failure | Medium | 7.9% | 15 |
| Cost | Medium | 7.9% | 15 |
| Compatibility with Future Uses | Medium | 7.9% | 15 |
| Compatibility with Cold Climates | Low | 2.6% | 5 |
| Technical Independence | Low | 2.6% | 5 |
| Confidence in Predictive Models | Low | 2.6% | 5 |
| Pilot Testing/Design/Pre-Installation Requirements | Low | 2.6% | 5 |
| Time Required for Completion | Low | 2.6% | 5 |
| Ease of Implementation | Low | 2.6% | 5 |
| | | **TOTAL** | **190** |

# Appendix 3. Implementation Plan

| ID | Component | What (Target) | Who (Responsible Party/Parties) | Timing | Status | Notes | Review status |
|---|---|---|---|---|---|---|---|
| A-1 | Extraction | State of Knowledge assessment commissioned.[8]<br><br>Recommendation: extract the dust using hydraulic bore mining. | GMOB | | Complete (2017) | Confirmed | Approved |
| A-2 | Extraction | Review of extraction technologies commissioned.<br><br>Recommendation: combine dry extraction using agitators to remove the majority of the dust, followed by liquid extraction to capture the remaining dust.[9] | GMOB | | Complete (2021) | Interpretation of recommendation flagged for review | Approved |
| A-3 | Extraction | Commission study into required extraction efficiency - i.e. how much ATRW can be left behind and still achieve target arsenic flux. | GMOB and Researchers | 2025 | Not started | Use updated information on ATRW solubility. This information will help to guide the extraction question - i.e. how much needs to come out. | Not started |

[8] Arcadis, 2017. Giant Mine State of Knowledge Review - Arsenic Dust Management Strategies. Report prepared for Giant Mine Oversight Board, Arcadis Canada Inc., 100296/ 43001000.0000, August 2017, 107 p. and appendix.

[9] Wolfson Centre for Bulk Solids Handling Technology. 2021. Review of Extraction Technologies for Subterranean Deposits of Consolidated Arsenic Trioxide Dust. Report No: R/3780/1. 14 pp.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A-4 | Extraction | Identify or establish a research network (similar to Terre-Net) that can conduct research into potential extraction methods. Call for Proposals is released and one or more research projects is funded. | GMOB | 2025 | Not started | | Not started |
| A-5 | Extraction | Historical engineering study / review by Royal Oak in 1980s | GMOB/Research Network | 2025 | Not started | Integrate with research network A5 | Not started |
| A-6 | Extraction | Class 5 preliminary engineering study is conducted. | TBD | | Not started | Needs review | Not started |
| A-7 | Extraction | Class 2 engineering study is conducted. | TBD | | Not started | Needs review | Not started |
| B-1 | Stabilization | Stabilization research projects are selected and funded.<br>• Seven projects have been funded and initiated.<br>• For plain-language project summaries and progress updates for these projects, see GMOB's Research Program Report (November 2023).<br>• GMOB continues to evaluate proposals by interested researchers. | GMOB | Ongoing | Underway (2018–) | | Approved |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B-2 | Stabilization | Research projects are presented to the Project Team, Parties to the Environmental Agreement and the public.<br><br>Note: GMOB aims to hold public engagement on research results on two-year cycles. | GMOB and the Researchers | | Complete (2023) | GMOB engages and presents results of research publicly toward fulfillment of Enviro Agreement sect 7.2 and 8.2b | Approved |
| B-3 | Stabilization | Conduct additional work on a) improved vitrification and b) characterizing composition of 2023 Arsenic dust samples | GMOB and Researchers | 2025 | Ongoing | | Underway. |
| B -4 | Stabilization | Research projects are presented to the Project Team, Parties to the Environmental Agreement and the public.<br><br>**Note**: Presentations and public outreach will occur on two-year cycles. | GMOB and Researchers | 2025 | Planned | This is an on-going task. | Not started |
| B-5 | Stabilization | The highest-performing stabilization method(s) are identified and a recommendation from GMOB to the Parties is made. | GMOB | | Underway (pending completion of research projects) | | Not started |
| B-6 | Stabilization | Class 5 engineering study for preferred stabilization approach. | TBD | | Not started | For Review | Not started |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B-7 | Stabilization | A class 2 preliminary Engineering study is completed. The purpose of the study is to determine what is needed to scale up the process of transforming the dust into glass. The scope of this study would include determining:<br>● the type and size of factory needed,<br>● materials needed how much sand to bring in for the process,<br>● where to source electricity, and<br>● what to do with byproducts the steam and/or ice fog that will result from the process. | TBD | | Not started<br>- | For Review | Not started |
| B-8 | Stabilization | Stabilization project project description, consultation, environmental assessment, permitting, and construction. | TBD | | Not started | For Review | Not started |
| C-1 | Storage | Storage requirements are identified for the selected stabilized product. These questions are under evaluation as part of the research program. | GMOB and Researchers | | Pending selection of stabilizatio n method. | | Not started |
| C-2 | Storage | Onsite or offsite storage is selected. | TBD | | Pending selection | | Not started |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | of stabilization method | | |
| C-3 | Storage | Storage facilities are designed and constructed. | TBD | | Pending selection of stabilization method | | Not started |
| C-4 | Storage | Required long-term monitoring and maintenance are funded, conducted and reported. | TBD | | Pending selection of stabilization method | | Not started |
| D-1 | Residual | TBD | TBD | | Pending selection of an extraction and stabilization method. | | Not started |