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Indian and Northern Affairs Canada
Department of Indian Affairs and Northern Development

Giant Mine

Independent Experts Panel Risk Assessment of Roaster Complex, Baker Creek, and Bulkheads Related to Arsenic Trioxide Migration

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EXECUTIVE SUMMARY

At the Giant Mine in Yellowknife, Northwest Territories, Canada, approximately 237,000 tonnes of arsenic trioxide dust is stored in stopes (underground openings where mining took place) and chambers in the upper 250 feet of underground mine workings. Remnants of the dust remain in the Roaster Complex. Concrete bulkheads are used to contain the arsenic trioxide dust in the stopes and chambers. Water containing arsenic trioxide in solution, or in a paste of arsenic trioxide dust, seeps through, or past, some of these bulkheads. Seepage can occur through the bulkhead, at the bulkhead-rock contact, or in natural or mining-induced rock fractures adjacent to the bulkhead.

Increased migration of arsenic trioxide dust from the underground stopes and chambers could occur as a result of flooding of the underground mine workings. Flooding could result for a number of reasons including ice build-up and blockage, channel failure, or extreme flood events, in Baker Creek which flows across the mine site. Migration of arsenic trioxide dust from the Roaster Complex could occur as a result of a fire in the complex. Any additional arsenic trioxide dust migration would result in negative public and media comment, increased remediation costs, and in possible impacts to human health and the environment.

The proposed final remedy as described in a 2007 *Giant Mine Remediation Plan* includes: (a) rerouting of Baker Creek to increase its flow capacity and to prevent any overtopping and flow into the open pits and hence flow into the underground workings; (b) freezing of those parts of the underground mine where arsenic trioxide dust is contained behind bulkheads in stopes and chambers to prevent migration of arsenic trioxide; (d) long-term pumping and treatment of arsenic impacted mine waters; and (e) demolition of the Roaster Complex and disposal of contaminated materials in an underground chamber;

Implementation of the site remediation has been delayed pending completion of an *Environmental Assessment* in accordance with the Mackenzie Valley Resource Management Act. As a result of abandonment by Royal Oak Mines, Indian and Northern Affairs Canada (INAC), Northern Affairs Contaminated Sites Program, has taken responsibility for the Giant Mine. They are concerned that the risks and consequences of increased migration of arsenic trioxide dust during this delay may be high enough to warrant exercising the Crown's prerogative to proactively implement the remediation plan. Accordingly, they requested that an Independent Experts Panel (IEP) undertake a formal risk assessment of the arsenic issues and provide: (a) its evaluation of whether continuing with the Environmental Assessment results in risk that, in their experience, is inadvisable; and (b) recommendations for any appropriate risk mitigation measures.

The IEP, comprised of five technical specialists in risk assessment and mining technologies (rock mechanics, concrete technology, hydrology, groundwater and mine reclamation) relevant to the issues performed a review of available information and studies, including the *2007 Remediation Plan,* and undertook a mine-site inspection. They conducted a Failure Modes and Effects Analysis (FMEA) to identify and make quantitative and qualitative assessments of the likelihood and consequences of failures. This assessment, together with their experience related to risk assessments for mines and mine remediation forms the basis for their findings.

The IEP finds, that while there is risk of additional arsenic trioxide dust migration from the underground stopes and chambers and from the Roaster Complex, these risks can be mitigated, and the resulting level of the risks (i.e., the likelihood and resulting consequences) do not justify pre-empting the environmental process.

Accordingly the IEP recommends that INAC review the findings of the formal risk assessment workshop and in particular consider implementing the mitigation measures identified by the participants of the formal risk assessment workshop.

The risk assessment and findings are based on the assumption that the Environmental Assessment, followed by implementation of the remediation plan to a stage where the risks currently identified would be effectively eliminated, would take between five and ten years. The IEP cautions that the current findings may not be valid in the event of longer delays, as this would increase the risks identified. Delays much longer than ten years to the start of the remediation program may justify pre-emptive action by the Crown to limit excessive mitigation costs and risks to human health and the environment.

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1 INTRODUCTION

1.1 General

This report is prepared by Robertson GeoConsultants, Inc. (RGC) for Indian and Northern Affairs Canada (INAC) at the request of Mr. Michael Nahir, P. Eng. of INAC. This report describes conditions at the Roaster Complex, Baker Creek, and underground bulkheads at the Giant Mine, Yellowknife, NT as they pertain to potential migration of arsenic trioxide dust. The report then proceeds to document the following:

- A Risk Assessment of the potential for increased migration of arsenic trioxide dust.
- The recommendation of this Independent Experts Panel (IEP) whether to
  - proceed to immediate implementation of remedial works due to the severity of the risk,
  - or to implement select mitigation and/or remedial works to address specific risks,
  - or to delay implementation of remedial works pending completion of an environmental assessment of the proposed final remedy because the risks are being adequately managed for the short-term.

1.2 Project Background

In 2007 the *Giant Mine Remediation Plan* (*Remediation Plan)* (SRK, 2007) was issued. The plan calls for the following actions at the mine facilities included in the IEP Risk Assessment:

- ***Bulkheads:*** Freeze the underground mine stopes and specially-constructed chambers that contain arsenic trioxide dust which is stored behind a series of concrete and/or cemented-tailings bulkheads. This activity is the essence of the remediation plan for the Giant Mine.
- ***Baker Creek***: Relocate and improve Baker Creek to reduce the likelihood of overtopping the creek banks during extreme flood events and subsequent flooding of the underground mine workings—the proposed relocation and creek-upgrade is

planned to be undertaken after relocation of a section of the highway that passes through the mine site.

- ***Roaster Complex***: Decontaminate and demolish the complex and place contaminated debris in an existing empty underground chamber.

Approval of the *Remediation Plan* and its implementation (the establishment of permanently frozen conditions) could take a decade or more. In the meantime, the site is managed to limit arsenic trioxide migration from the roaster complex and the underground chambers and stopes where arsenic trioxide dust is stored behind bulkheads.

An annual risk assessment has been conducted by others using INAC's risk assessment protocol (INAC, 2008a.) That work has identified the following high-level risks associated with mine facilities:

- ***Roaster Complex***: Damage to the complex by fire, wind, or vandalism resulting in dispersal of arsenic trioxide dust and other contaminants.
- ***Baker Creek***: Flooding of the creek resulting in increased seepage directly into the mine workings or flowing into the open pits adjacent to the creek and hence flowing through the bottom of the pits into the underground mine workings.
- ***Bulkheads:*** Ongoing deterioration or failure of the bulkheads resulting in increased migration of arsenic trioxide dust or arsenic contaminated water to the underground mine workings and/or off site. Failure of a bulkhead is most likely if flooding of the mine workings causes increased pressures on the bulkhead. Failure of a bulkhead could, however, occur due to time-dependent deterioration of the concrete or cemented tailings that constitutes the mass of the bulkhead.
- ***Crown Pillars, Stope Walls, and Stope Filling***: Ongoing deterioration of open and/or tailings-backfilled stopes may add to the risk of mine flooding and/or loss of containment of the arsenic in the chambers.

INAC is concerned that during the extended period involved in approving the *Remediation Plan* and subsequent implementation of the selected remedy, a sequence of events may occur that could lead to a release and/or additional migration of arsenic trioxide dust or impacted waters, with the result that remediation costs are increased, implementation of the *Remediation Plan* is compromised or infeasible, or there is an adverse impact on human health and the environment.

1.3 Project Objectives

The objective of the risk assessment project described in this report is to revisit, revise, expand, and update prior risk assessments pertaining to the Roaster Complex, Baker Creek, the bulkheads and migration of arsenic trioxide dust to the environment and receptors, and/or the underground mine workings and groundwater.

The panel of independent experts (Table 1) was asked by INAC to prepare a report to INAC and other decision makers on risks pertaining to the following courses of action, and to provide an opinion based on their mining remediation experience of the acceptability of such risk in implementing one or more of the following courses of action:

- ***Continue As-Is***, i.e., proceed as-is with the currently anticipated schedule for review of the *Remediation Plan* and implementation of the selected remediation option. In other words, undertake no remediation until the approval process mandated by the Mackenzie Valley Resource Management Act is complete.
- ***Expedited Action***, i.e., exercise the right of the Crown to undertake immediate action to address a real and current situation that requires attention, including pre-emptive remedy implementation.
- ***Mitigation,*** i.e., institute additional interim (temporary) mitigation measures pending implementation of the final remediation plan that may reduce the likelihood and/or consequences of migration of arsenic trioxide from the Roaster Complex and/or underground chambers & stopes.

1.4 Report Layout

In addition to this introduction, this report includes these sections:

- ***Section 2 – Site Description*** including a brief description of the site and facilities specifically those relevant to the risk assessment of the Roaster Complex, Baker Creek, and the bulkheads.
- ***Section 3 – Previous Risk Assessments*** including a description of risk assessment undertaken by other parties preceding this risk assessment.
- ***Section 4 – Conduct of the Risk Assessment*** including a description of the parties involved in the formal risk assessment workshop, their deliberations, and the results of the risk assessment. Note that the formal risk assessment workshop (i.e., the formal process of identifying and evaluating risks and mitigation measures) included the members of the IEP, INAC staff, a specialist consultant to INAC, staff from PWGSC, and Giant Mine staff.
- ***Section 5 Independent Experts Panel Findings (IEP*)** in which the key findings of **IEP are listed.**
- ***Section 6 - Specific Risks that Merit* Action** in which the higher risk failure modes are discussed together with the potential mitigation measures that may be considered to reduce such risk.
- ***Section 7 – Recommendation of the IEP*** including the recommendations of the IEP and reasons for these recommendations. Note that only members of the IEP contributed to, and concur with, the contents of this section.
- ***Risk Assessment Matrices*****,** summarizing the failure modes considered, and results of the risk assessments for each of these are provided on a separate CD; this is done as the matrices are large and not amenable to convenient incorporation in this report.

2 SITE DESCRIPTION

2.1 General

This section is a brief description of the site and the facilities considered in the risk assessment[1]. Some of the potential failure modes evaluated in the FMEA, that contribute to on-going risk at this site are mentioned. Accordingly, this section includes the following subsections:

- ***The Mine and Its History***, including a brief overview of the mine location, history, and the layout of the above-ground facilities. This subsection is brief as considerable additional detail is readily available in the references
- ***The Roaster Complex***, including a description of its current condition and factors that affect an assessment of the risk of additional release of arsenic trioxide dust.
- ***Baker Creek,*** including a description of its layout, flow characteristics, and potential for flooding.
- ***Underground Bulkheads***, including a description of their locations, construction, and current conditions as is relevant to potential failure resulting in increased release of arsenic trioxide dust confined in stopes and chambers behind the bulkheads.
- ***Underground Mine Waters***, including a description of the pathways by which surface waters may enter the mine workings and flow to the stopes and chambers that contain arsenic trioxide dust.
- ***Crown Pillars***, including a description of the condition of the crown pillars and stopes that surround and underlie the stopes and chambers that contain arsenic trioxide dust.
- ***The Final Remedy,*** as described in the Remediation Plan is summarized in the final subsection of this section.

2.2 The Mine and its History

2.2.1 Location and Current Status

The Giant Mine is within the municipal boundary of and in close proximity to the city of Yellowknife, Northwest Territories, Canada. The mine produced gold from 1948 to 1999 when the mine went into receivership and was transferred to the Department of Indian Affairs and Northern Development (DIAND). DIAND entered into an agreement with Miramar Mines Ltd. who continued to operate the mine from 1999 until 2004. When mining ceased in 2004, DIAND again took control of the site. DIAND continues to control the site and on behalf of INAC, PWGSC has contracted with the Deton'Cho-Nuna Joint Venture to continue maintenance and environmental management.

[1] The valuable assistance of John Brodie, consultant to INAC, in locating and understanding site conditions is acknowledged.

2.2.2 Mine Development

Underground mine development began in 1945 with sinking of the A-Shaft. The B-Shaft was sunk in 1946 and C-Shaft in 1949. C-Shaft was connected to the A- and B-Shafts via the 750 level by 1952.

Open pit mining began in 1974. Five open pits were developed. Baker Creek was relocated to allow for mining of the open pits.

Underground mining involved both cut and fill and open stoping. Waste rock and natural gravel excavated on surface were used as stope fill until 1957, when mill tailings became the primary backfill material. Tailings backfill continued until 1978.

15 of the stopes and specially mined chambers contain arsenic trioxide dust and the security of these deposits and the storage areas are determined by the stability of mine workings, as well as potential inflows of surface water that may transport arsenic out of the storage areas.

Underground mine dewatering was performed during mining operations, which maintained water levels below the 2,000 level. Dewatering was discontinued in 2005 and mine flooding has occurred to 800 level at which level new pumps maintain the flooded level. Maintenance of dewatering is required to prevent flooding of the arsenic trioxide storage chambers.

2.2.3 Processing

Processing of the Giant Mine ore involved roasting which created arsenic trioxide dust as a waste by-product. The dust is about 60 percent arsenic. Approximately 237,000 tonnes of the dust were produced and stored in fifteen purpose-built chambers and mined-out stopes located above the 250 level.

2.3 Roaster Complex

2.3.1 General Description

The Roaster Complex consists of interconnected buildings ranging in height from one to three stories. The exteriors of the buildings are wood and/or asbestos paneling. One building is wood-framed; the rest are steel-framed. Floors are concrete. The buildings enclose a complex system of mezzanines, catwalks, steel platforms, interior steel frames, and equipment.

The *Remediation Plan* (SRK, 2007) notes that the Roaster Complex includes these components: roaster plant, kiln plant, carbon plant, baghouse, stack, arsenic trioxide silo, and truck loading shed.

2.3.2 Current Status

An inspection of the Roaster Building Complex in 2007 (Public Works, 2007) notes the following about the condition of the complex:

- The wood structure shows no signs of significant rot.
- No evidence of corrosion or “deflection” of the main structural elements, e.g., beams, columns, and trusses.
- Loose and/or damaged exterior asbestos panels are present.

- Gaps in the roofing, corrosion of fasteners and panels, and a concern that excess wind loading could lead to compromise of the roof's integrity.
- Corrosion of parts of the catwalk.

The inspection report recommends monitoring of asbestos panels and keeping the catwalks out of bounds. The report states that repair of the wood finish, asbestos panel finish, and catwalks is not warranted due to the cost and because the building is not used for its original function.

2.3.3 Hazardous Materials Concerns

The *Remediation Plan* summarizes hazardous material concerns at the Roaster Complex, noting these materials are present:

- ***Asbestos Containing Material****:* Non-friable construction materials, including large quantities of friable insulation material.
- ***Arsenic Containing Material***: Large quantities of process residues, with high soluble arsenic contents.
- ***PCB Materials***: Possible small quantities of solid PCB materials.

The *Remediation Plan* notes that in the Roaster Complex are approximately 700 tonnes of process residues containing greater than 10,000 mg/kg total arsenic. The *Remediation Plan* also notes that an additional 1,500 tonnes of process residues in the Mill and Roaster complexes may be expected to contain less than 10,000 mg/kg total arsenic.

2.3.4 Mitigation

Mitigation of risks associated with the Roaster Complex has been undertaken. This quote from the *Remediation Plan* notes:

> *The site buildings were inspected in 1998. The purpose of the inspections was to visually identify the types and approximate amounts of hazardous materials associated with each building. The inspections identified asbestos materials, lead-based paints, and potential for PCB contaminated materials as remediation concerns. Asbestos containing materials identified included non-friable construction materials, such as siding and roof shingles found on all of the older site buildings, and friable asbestos materials used for insulation. Large quantities of friable asbestos were found in the process buildings associated with the roaster and roaster-gas handling systems.*
>
> *Most of the buildings have been painted on the exterior and interior surfaces, and since lead was widely used in the manufacture of paints until 1977, lead-based paints were probably used. Non lead-based paints have been applied over the original paint on most interior and some of the interior surfaces. The original paint on many exterior surfaces is now peeling, cracked, or flaking, which could result in lead contamination of soils immediately adjacent to the older buildings.*

2.3.5 Final Remedy

The *Remediation Plan* (SRK, 2007) calls for all buildings and infrastructure to be removed. Arsenic-contaminated materials will be removed and placed in an empty underground chamber. The following are details from the *Remediation Plan* (SRK, 2007)

> *All of the site buildings without a continuing function will be demolished. Hazardous materials and potential contaminants will be removed from the buildings prior to demolition, when this is safe and practical. Some hazardous materials may need to be left in the buildings while they are partially or completely demolished. For example, some of the arsenic contaminated process residues and process equipment would have to be handled using large equipment, and it may not be possible to gain safe access to these materials with the building standing. Measures will be taken to control dust generated during the demolition, when it is likely to be contaminated with arsenic or asbestos.*
>
> *Hazardous materials removed from the buildings before demolition, or recovered from the demolition debris, will be handled and disposed of according to industry best practices and the GNWT regulations. The preferred disposal location for materials with high soluble arsenic is the empty chamber 15, which would then subsequently be frozen.*
>
> *Some of the friable asbestos materials in the Roaster complex may be expected to contain arsenic contaminated dust, and could also require secure disposal within the areas described above. Waste asbestos materials that are not contaminated with arsenic would be buried in tailings at the Northwest Pond.*
>
> *The demolition of all the buildings on the site is expected to generate a total of approximately 90,000 cubic meters of waste. The majority of the waste volume is expected to consist of non-hazardous construction materials and equipment, or materials that can be cleaned to remove contaminants. Stable non-hazardous demolition waste will be deposited in the B1 Pit, outside the frozen zone. The remaining non-hazardous demolition waste would be placed in a new facility constructed on the Northwest Pond*.

2.4 Baker Creek

2.4.1 Location and Description

Baker Creek flows across the mine site. A portion of the creek was diverted in 1983 to make way for excavation of the C-1 open pit. Its course has also been altered as a result of development of pit A2, and to reduce seepage to the underground mine. Normal flow in the creek is contained within the creek that is bounded by cuts into the natural soils of the area, rock slopes, and soil dikes and berms. Short reaches of the creek have been lined with an impermeable liner to control seepage from the creek bed. The creek passes through a culvert under the highway where it leaves the mine property.

2.4.2 Flooding

During the winter ice builds up in the creek. It is currently not always possible to remove the ice that builds up. Ice build-up restricts flow of the spring freshet in the creek, and it is possible that a combination of unremoved ice and a higher than average spring freshet flow could result in water flooding the ice-affected creek and overtopping of the banks of the creek. Depending on where this occurs and the quantity of flood waters escaping the creek, flooding of the underground mine workings could occur.

Extreme floods generally greater than those associated with a one in three-hundred year recurrence interval may flood the creek, causing an exceedance of flow capacity with attendant escape of water that may erode dikes and berms and cause flooding of the underground mine workings.

2.4.3 Remediation Plan

The *Remediation Plan* notes with regard to Baker Creek that the public highway through the site may have to be relocated to facilitate demolition of the Roaster Complex and in particular facilitate relocation of Baker Creek. This is what the plan says in this regard:

> Highway No. 4 (the Ingraham Trail), and the Vee Lake Road run through the Giant Mine site along a 60-meter wide right-of-way. The road is used by residents of homes on the Ingraham Trail, and by other members of the public for recreational purposes. The road is owned and maintained by the Government of the Northwest Territories. The road passes close to several key site components, such as Baker Creek, the A2 and C1 Pits, and the Roaster Complex. The road also passes close to or directly above several of the underground mine trioxide storage chambers and stopes.

The route of the relocated highway is not yet established; there are a number of very different alternatives under discussion. Accordingly the route of the proposed relocated Baker Creek is not currently established. It will not be possible to relocate Baker Creek to a final route until the highway is relocated.

2.5 Bulkheads

2.5.1 General Description

Arsenic trioxide was placed in ten specially mined chambers and in five selected stopes that were initially mined to extract ore. Both chambers and stopes developed for storage have been sealed by the construction of bulkheads. Since stopes are located in areas affected by mining, while chambers are located outside the influence of other mining activities, a distinction is drawn between bulkheads for chamber and bulkheads for stopes. There is a greater risk that mining-induced rock deformation could affect the performance of stope bulkheads as compared to chamber bulkheads.

Of the 71 bulkheads in the mine, 20 are not associated with containment of arsenic trioxide dust. Of the remaining 51, 38 are accessible and 13 are inaccessible. Of the accessible bulkheads, 26 are categorized as upper bulkheads and 12 are lower bulkheads. All of the 13 inaccessible bulkheads are lower bulkheads, as summarized in the table below.

Lower bulkheads are those that could be subjected to internal or external water pressure; they are accordingly at risk for release of arsenic trioxide dust or affected waters. Bulkheads are further differentiated by their geometry and construction. Bulkheads constructed into near-horizontal drifts are referred to as “vertical bulkheads”. Bulkheads constructed to seal inclined or sub-vertical raises are referred to as “horizontal bulkheads.” There is at least one mild-steel pipe through most of the vertical bulkheads. Historically, the pipes were used to bleed water accumulation behind the bulkheads. Only lately have some been used to get pressure readings or monitoring of some description. In the case of upper bulkheads; various pipes were for injection of arsenic dust and exhaust of air, Other potential openings in the lower vertical bulkheads include holes installed to inject grout into the contact zone between the bulkhead and surrounding rock or into the subtended chamber or stope.

Inaccessible lower bulkheads are summarized as follows:

Area	Inaccessible Lower Bulkhead #	Type	Comment
AR1	None	-	-
AR2	47	Vertical	Could be accessed by mining
	48	Vertical	Could be accessed by mining
	49	Horizontal	Could be accessed by mining
	56	Vertical	Within zone contained by BH 58
AR3	1	Vertical	Within zone contained by BH's 10 – 15
	3	Vertical	Within zone contained by BH's 10 – 15
	5	Vertical	Within zone contained by BH's 10 – 15
	10	Horizontal	Limited access recently achieved
	11	Horizontal	Limited access could be achieved
	12	Horizontal	Limited access could be achieved
AR4	33	Horizontal	-
	34	Horizontal	Limited access through 3-10/202 stopes
	35	Horizontal	
			-

Vertical and horizontal bulkheads are most likely to have different performance characteristics due to the nature of their construction. In general, horizontal bulkheads are expected to provide better containment because:

- Any cold joints which may be present due to the sequence of construction are perpendicular to potential seepage pathways, rather than parallel.
- The natural slumping of the concrete tends to form a tight seal on all 4 sides, unlike vertical bulkheads where the concrete can slump away from the roof,
- Debris (loose muck or formwork cuttings) will not be present on the sides of a horizontal bulkhead in the way that it could be present on the floor of a horizontal bulkhead.

Bulkheads for containment of arsenic were constructed over a period of nearly 40 years under the direction of several engineers. This resulted in different approaches being taken in the design and construction. Some key differences include:

- Plug and semi-plug bulkheads, where the bulkhead length approaches the width of the drift or raise being sealed,
- Use of cemented tailings for several bulkheads,
- Thin slab design with heavy reliance on steel rebar for structural capacity.

Despite these variations, all of the lower bulkheads were designed to resist the hydraulic thrust of the hypothetical situation where a chamber was filled with water to the ground surface. Furthermore, the plug type design (which applies to all lower bulkheads except #68 which is accessible) provides a very high factor of safety (>10) against complete failure even with deteriorated concrete. All of the bulkheads have the potential to leak arsenic-bearing water, and in many cases a paste of wet arsenic dust could ooze past the bulkhead, However, complete catastrophic failure of a bulkhead is improbable.

Many of the upper bulkheads are access/inspection ports generally kept closed by a thin metal plate. These inspection “ports” originally were meant to confine the dust, with rubber gaskets and tightened to make the chamber/stope “airtight” so the exhaust system worked. They provide some water management capacity, if they were rehabilitated to original condition. In the current arrangement, they could easily allow inflow of water to a chamber if there were a mine flooding situation.

2.5.2 Current Condition

The following lower bulkheads are of particular concern:

- ***Bulkheads 10, 11, and 12***. Bulkheads 11 & 12 are inaccessible for inspection. Failure of these bulkheads would lead to uncontrolled release of dust into the underlying stopes.
- ***Bulkhead 36.*** Year-round seepage (less than one litre per minute) has been observed from the north end of stopes B212, 213, and 214. Failure of bulkhead 36 would lead to uncontrolled release of dust into the underlying workings. Water pressures at bulkhead 32 are being monitored and resulting hydrostatic pressures are used to predict conditions at bulkhead 36.
- ***Bulkheads 47, 48, and 49***. The condition of these bulkheads is not known. They are located under stope C212 and Baker Creek. Water draining from the creek could cause fluctuating pressures on these bulkheads.
- ***Bulkhead 68.*** This lower, vertical bulkhead seals chamber 14 which is located in proximity to the current alignment of Baker Creek. This bulkhead has experienced chronic seepage and leakage of arsenic sludge.

2.5.3 Dust Migration

Observations by mine personnel are that arsenic trioxide paste has squeezed or flowed past two of the lower bulkheads[2] and has been deposited outside the chambers. Seepage or evidence of it has been observed at the majority of accessible bulkheads. The most significant seepage was observed along the bulkhead concrete to rock contact. The rate of seepage increases in the weeks and months following the spring freshet. Testing of the seepage water indicates a high arsenic content, i.e., about 2,000 to 4,000 mg/L As.

2.5.4 Bulkhead Functionality

Accessible bulkheads are inspected on a regular basis. Generally they are considered to be currently functional. Some bulkheads, however, are characterized by seepage and/or physical deterioration; accordingly, mitigation measures have been implemented as potential ways to promote the continued functionality of accessible bulkheads pending implementation of a final remedy. These mitigation measures include:

- Reduce water flow into the arsenic dust chambers, (such as draining the mill pond and pumping out B1 pit)
- Drain or release any water from the chamber to prevent a build-up of water pressure in the chamber. (such as the gravity and pumped discharge system for B208)
- Reinforce the bulkheads to increase their resistance. (such as the construction of BH 14a in front of BH14)
- Additional bulkheads could also be installed if the need arises.

2.6 Underground Mine Water

2.6.1 Openings from Surface to Underground

There are numerous openings from the surface to the underground mine workings. The openings include intercepted raises, tunnels, man-ways, and adits. Some have been capped or blocked. Many stopes connect to the open pits. These stopes were backfilled prior to open pit mining. There are subsidence areas in the C1 pit where the bottom intersects backfilled stopes. In the event of surface flooding, one or more of these openings could act as conduits for the flow of surface water to the underground mine workings.

2.6.2 Mine Inflow

Sources of water entering the underground mine workings include limited seepage from groundwater in the saturated bedrock that surrounds the mine workings, infiltration through soils and bedrock in the mine area, runoff flowing into the open pits, seepage from Baker Creek, and seepage from the tailings containment areas.

In the past, water that entered the mine, ultimately drained into the mine dewatering system located at the C-Shaft. Routine pumping of water was to the NW Pond for storage prior to treatment. During

[2] Bulkheads 68 and 14 which was rebuilt in 2004.

periods of high mine inflow in the spring and summer, minewater was periodically pumped to the surface through the C-Shaft and discharged to the South Pond.

In 2008, a new mine dewatering system was installed to control the mine water after flooding to the 750 Level. This system was installed near the Aikatcho Shaft and discharges mine water to the northwest tailings pond. This system was operational in October and started pumping in late October 2008 when the mine water reached the approximately the 800 Level.

Flooding of the lower levels of the mine was started in July 2005 when pumps on the 2000 Level at the bottom of the mine were shut down and removed. Before flooding of the lower mine levels, the dewatering rate averaged about 2,400 cubic meters per day with peak dewatering rates as high as 4,000 cubic meters per day during the freshet period (SRK, 2005.)

2.7 Crown Pillars

The stability of the crown pillars over the stopes and chambers containing arsenic trioxide dust was investigated in 2004 and 2005 (SRK, 2005). Evaluations using three different methods of stability assessment indicated that the B208 stope, the B235/B236 stopes and the combined B212 to B214 stopes are in a "state of marginal stability, if the lower range of rock properties" control stability. SRK 2005 recommended remediation measures to the B212 stope because of the possibility that failure of this area would develop a connection between the stope and Baker Creek.

The *Remediation Plan* (SRK, 2007) states that the crown pillars above the chambers that contain the arsenic trioxide dust are relatively thick and failure is considered to be unlikely. The *Remediation Plan* notes that the crown pillars above the stopes are not as thick and their stability may be a concern.

Evidence of collapse of tailings and waste-rock-filled mine workings in stope C5-09 was observed at an accessible location by the IEP members during a site visit in late November 2008.

2.8 Remediation Plan

The *Remediation Plan* (SRK, 2007) calls for all buildings and infrastructure to be removed. Arsenic-contaminated materials will be removed and placed in an empty underground chamber.

The *Remediation Plan* (SRK, 2007) calls for the arsenic trioxide dust and the rock around each chamber and stope to be frozen and to be maintained completely frozen in perpetuity.

For an undetermined period following ground freezing, contaminated minewater will continue to be extracted through a series of wells, piped to a new water treatment plant, treated to remove contaminants, and then discharged to Yellowknife Bay.

After remediation, the site will consist of a small surface area that will need to remain under active management which will include maintenance of the ground freezing system and long-term treatment of contaminated minewater.

In the absence of remediation, arsenic releases from the site could increase to many thousands of kilograms per year. Remediation is expected to decrease but not eliminate arsenic release from the site. Arsenic releases from the site will decrease from the current level of approximately 500 kilograms per year to less than 200 kilograms per year.

Implementation of the remediation was anticipated in 2007 to commence in 2009. Most surface work was anticipated to be complete within five years. Ground freezing which develops over time was anticipated to be substantially complete within ten years. It is currently not known when remediation is likely to begin. The IEP selected to evaluate the risk of failure over either a 5 or 10 year period when performing the FMEA.

3 PREVIOUS RISK ASSESSMENTS

3.1 General

A risk management program is in place at the Giant Mine. The findings of previous risk assessments are used to make site management decisions and to undertake control and mitigation activities. However it has not proven to be feasible to mitigate all the risks that are identified. For example, many bulkheads are inaccessible. Work is in progress to evaluate stope stability as it may be affected by loss of backfill in the area of stope C5-09.

In addition to risks associated with the mine, INAC has identified that the physical deterioration of the roaster and the potential for fire in the roaster is a risk with associated potential for distribution of arsenic dust.

3.2 Remediation Plan

The *Remediation Plan* (SRK, 2007) does not explicitly characterize or quantify the risk of specific events. However, it notes these key concerns as the basis for selection of the preferred remedy:

- The potential for uncontrolled release of arsenic following reflooding of the mine.
- The possibility of water ingress and spreading of arsenic dust following physical instability of the crown pillars in the area of the dust storage areas.
- The possibility of significant release of arsenic dust and water quality impact following failure of one or more of the bulkheads that hold back the dust in chambers and stopes.

3.3 Risk Management Report

The *Risk Management Report* (INAC, 2008a) notes the following risks that are relevant to this report:

- ***A2 Baker Creek rock cut***: Failure could lead to creek overtopping the mine road and discharging into open pit A2, hence flowing to the mine workings. The likelihood is rated as “possible. The reputation and cost consequences are rated as “moderate” and “major” respectively.
- ***C1 Baker Creek Diversion***. Failure would result in uncontrolled flow of water into open pit C1 and to the mine workings. The likelihood is rated “possible.” The environmental impact is rated “major.”
- ***Arsenic trioxide behind bulkheads***. Collapse of a bulkhead would release arsenic trioxide to the underground and this would lead to an overload of the water management system. The likelihood is rated “possible.” The reputation consequences are rated as “major.”

4 RISK ASSESSMENT

4.1 General

The risk assessment workshop participants (Table 2) included the IEP, INAC and PWGSC staff, mine personnel, and John Brodie, an independent consultant to INAC. While INAC, PWGSC, and mine personnel participated in the formal risk assessment workshop, they did not participate in subsequent private deliberations by the members of the IEP (Table 1), nor did they formulate opinions, findings, or recommendation as described in Sections 5 to 7 of this report. The FMEA forms that record the risk assessments that were completed are provided in Tables 3 and 5 for the Mine and Roster Complex respectively.

4.2 Site Visit

Through November 26 to 28, 2008, members of the IEP visited the site accompanied by INAC and mine staff. The following was the scope of their site observations:

- ***Roaster Complex***: Only the outside of the complex was observed as it was considered unsafe to enter the complex.
- ***Baker Creek***: The site and the creek were covered by snow at the time of the site visit. Water was observed to be flowing in the lower part of the creek. The general site and creek topography, adjacent rock slopes, and soil dikes and embankments were able to be observed in general outlines. An understanding of creek access and ice-formation potential was gained.
- ***Bulkheads:*** Selected accessible vertical bulkheads were observed. In particular, the following conditions as described in detail in the references were observed: deteriorated concrete, seepage of water at the juncture between the bedrock and the bulkhead, and the small to moderate (tens of kilograms) quantity of arsenic trioxide dust/paste that had migrated passed the bulkheads (primarily BH 68).
- ***Underground Mine Workings***: General rock conditions were observed. The upper part of stope C5-09 was observed.

4.3 Risk Assessment

4.3.1 General

Subsequent to the site visit, a formal risk assessment was undertaken. This section summarizes the process and the results of that risk assessment.

4.3.2 Technical Approach

The risk assessments described in this report were conducted using a modified INAC risk management approach (INAC, 2008b). The following are two definitions of risk management from INAC, 2008b:

- The culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.
- The systematic application of management policies, procedures and practices to the task of communicating, establishing the context, identifying, analyzing, evaluating, treating, monitoring and reviewing risk.

The INAC risk management approach includes these steps:

- ***Establish the Context***: Establish the internal and external context process, identify risk tolerances of the organization and develop definitions accordingly.
- ***Identify Risks***: What could go wrong, where, and when? Develop a broad range of risk scenarios (events) for all aspects of the project.
- ***Analyze the Risk***: What are the consequences of these events and how likely are they to occur? How does existing control affect the risk levels?
- ***Evaluate Risk:*** Is the risk acceptable? Risks are evaluated relative to the risk tolerance of the organization. The ALARP (As Low as Reasonably Practical) principle is applied.
- ***Treat the Risk***: Each level of risk triggers a predetermined level of action. Identify and assess options. Develop and implement risk treatment/mitigation plans. Evaluate residual risk.
- ***Monitor and Review***: Review factors that may affect consequences and likelihood that may have changed. Monitor progress against risk treatment plans (performance measurement.) Monitor implementation of the process.

The INAC risk management approach considers these consequences of the potential realization of a risk:

- Human health and safety
- Legal obligations
- Environmental impacts
- Special considerations (including impacts on traditional land use)
- Community, media, and reputation
- Cost.

The following are specific risks related to underground mine workings and contaminant release listed by INAC, 2008b:

- Presence of hazardous materials in uncontrolled underground setting leads to community concern.
- Seepage from underground hazardous material storage area leads to contaminant discharge into receiving waters.
- Mine water seepage leads to contaminant discharge into receiving waters.

- Catastrophic release of toxic material (e.g., arsenic trioxide) from controlled underground storage facility.
- Bulkhead failure leads to release of mine water into unflooded underground areas.

4.4 Risk Assessment Method

Some changes were made to the INAC risk assessment process to accommodate the specific issues associated with the Roaster Complex, Baker Creek, and the bulkheads. In particular the scales for the likelihood and for the cost consequences were adjusted (RGC, 2008) to better reflect the times for remediation and the cost consequences of risk actualization. The following are some examples of the changes:

- ***Periods Considered***: Risks were assessed for two specific periods, namely 5 and 10 years. Five years represents the anticipated time to review and start implementation of the proposed remediation plan. Ten years represents the time likely to elapse before remediation has progressed to the extent that in essence the risks can no longer be actualized. The likelihood of an event occurring increases the longer the period. Thus if the start and/or substantial completion of remediation is delayed and is longer than five and ten years respectively, the likelihood of the event increases more or less in proportion to the increased period of delay.
- ***Likelihood Scale***: The following likelihood scale was used. One difference is that the scale used in the current risk assessment provides for a range of probabilities of occurrence (likelihood), whereas the INAC scale focuses on single point values of occurrence. In our experience, participants in a risk assessment review tend to have difficulty applying the point value approach. The revised scale also has a shift in the scale to allow for differentiation between events of very low likelihood.
- ***Expected,*** i.e., the likelihood of occurrence during the period of assessment (five to ten years) exceeds 10 per cent. Compare this to the INAC scale of likelihood in which the highest likelihood category is “almost certain” implying a frequency of occurrence of more than once every five years.
- ***High***, i.e., the likelihood of occurrence is between 1 and 10 percent. This implies that the likelihood of the event occurring in the period of interest is between one in ten and one in a hundred. The corresponding INAC likelihood descriptor (likely) implies an occurrence once in every 15 years.
- ***Moderate***, i.e., the likelihood of occurrence is between 0.1 and 1 percent. This implies the event could occur in the period of interest with a likelihood of between one in 100 to one in 1,000. The corresponding INAC descriptor (possible) implies an occurrence once every 30 years.
- ***Low***, i.e., the likelihood of occurrence is between 0.01 and 0.1 percent or the event has a probability of occurrence of between 1 in 10,000 to 1 in 1,000. The corresponding INAC likelihood descriptor (unlikely) implies an occurrence one in every 100 years, or about 1 in 10 during a 10-year period (10%).

- ***Not Likely***, i.e., the likelihood of occurrence is between 0.001 and 0.01 percent or the event has a probability of occurrence in the period of interest of less than I in 10,000. Compare this to the INAC descriptor of likelihood in which the lowest scale of likelihood is "Very Unlikely" implying a frequency of occurrence of once every 1,000 years or approximately 1 in 100 during a 10-year period (1%).

- ***Cost Consequence Scale***: The following cost consequence scale was used—note that it differs in some categories from the INAC cost consequence scale. The change was made to reflect the much higher potential cost consequences of the occurrence of a risk at the Giant Mine associated with migration of arsenic trioxide dust than is generally associated with other mines under INAC care and management.

- ***Negligible,*** i.e., a cost consequence of less than $100,000. This is the same as the INAC scale.

- ***Low,*** i.e., a cost consequence of between $0.1 and $1 million. The corresponding INAC category ranges from $0.1 to $0.5 million.

- ***Moderate,*** i.e., a cost consequence of between $1 and $10 million. The corresponding INAC category is $0.5 to $2.5 million.

- ***High,*** i.e., a cost consequence of between $10 and $100 million. The corresponding INAC category is between $2.5 and $10 million.

- ***Extreme,*** i.e., a cost consequence of greater than $100 million. The corresponding INAC category is greater than $10 million.

The above modified scales are both order of magnitude geometric progressions so that the product of likelihood and consequence is also a geometric progression and preserves the order of magnitude step difference between the resulting risk ratings.

A similar comparison between the other consequence severity categories is not described here, but may easily be done by the reader. In all cases the scales adopted for this risk assessment are considered to better reflect the ranges of likelihood and consequences applicable to migration of arsenic trioxide dust at the Giant Mine.

4.5 Events Evaluated in Formal Risk Assessment Workshop

4.5.1 General

The following events were defined and evaluated in the formal risk assessment workshop---see RGC 2008 for details:

4.5.2 Roaster Complex.

Two specific events evaluated are:

- ***Catastrophic failure resulting from a fire***. This would result in damage and release of arsenic to the environment.

- ***Human Exposure***. A trespasser or vandal may access the complex and suffer acute exposure to high levels of arsenic through ingestion, direct contact and inhalation. Alternatively or in addition the trespasser or vandal might suffer physical harm from falling or falling objects.

4.5.3 Baker Creek.

The following events were evaluated:

- ***Extreme flood events***. This would occur if an extreme flood overtops the channel bank, and flows into a pit and underground mine workings. This event excludes flows directly into chambers and/or stopes that contain arsenic trioxide dust as such flows are considered separately. The result of creek flooding by the creek could be one or more of the following: (a) water rising to below the lowest bulkhead--the requiring that the dewatering system undertake additional water pumping and treatment; (b) water rising above lower bulkheads but below the lowest upper bulkhead; (c) water rising above lowest upper bulkhead but remains below surface; and (d) water rising to surface and discharges at the surface. These different results or outcomes are considered separately as they have different likelihoods and consequences.
- ***Channel Blockage***. This includes overtopping of channel banks as a result of blockage by ice jams, or channel bank failure, or debris, with subsequent flooding into adjacent pits or other areas causing flow into the underground mine workings. Again this event excludes flows directly into dust chambers. Results are as for extreme flood events.
- ***Structural Failure*** of a slope or dike or embankment that defines the creek channel cross section. An example is Pit C1 slope failing during an extreme flow event and causing inflow to pit and underground mine workings.

4.5.4 Bulkheads

Separate risk assessments were undertaken for the chambers and for the stopes as there are some differences in the scenario, risk, likelihood, and consequence for chambers as compared to stopes. The chambers were designed and constructed in solid rock in areas not generally underlain by mine workings, whereas the stopes are simply the result of normal mine development and are underlain by other mine workings. The following failure modes were evaluated for both:

- ***Internal flooding of a chamber or stope*** subtended by an intact, functional bulkhead. Examples of chambers in this category include chambers in Areas AR1 (The driver is chamber 14, with Bulkhead 68) and AR3. Examples of stopes in this category include stopes in Areas AR2, AR3, and AR4; the risk rating is highest for stope C212. Effects examined include: (a) order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s; (b) increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase); and (c) discharge to deeper mine workings of increased volumes of arsenic paste (by either bypassing and/or failure of bulkhead/s). In the eventuality of consequence (c); while the freezing remedy can still be applied to the bulk of the arsenic retained in the failed chamber, the remedy becomes only partially effective, requiring long-term treatment of water with a greatly increased arsenic concentration. It is noted that an escape to the environment is not contemplated – the consequence is additional cost for long-term monitoring and treatment, not a large environmental or health and safety impact.

- ***Drawdown of water after external flooding of the mine workings***. This event includes the possibility that the mine flood waters in the mine workings exterior to the stopes and chamber will be drawn-down at a faster rate than the flood waters in the chamber or stope. The impact would be that the fluid pressures in the stope or chamber would exceed the fluid pressure exterior to the stope or chamber. The result could be an increase in the rate and quantity of arsenic trioxide paste or contaminated waters seeping from the stope or chamber. The possible levels of loss would be similar to the previous case.
- ***Drawdown After Internal Flooding of a Chamber or Stope with a Deteriorated Bulkhead***. In this case the failure of the deteriorated bulkhead would result in migration of a greater quantity of arsenic trioxide from the chamber or stope than would occur had the bulkhead been intact. The possible levels of loss would be similar to the previous case.
- ***Migration Past a Deteriorated Bulkhead- No Flooding***. This event assumes that current seepage conditions result in migration of contaminated water and/or arsenic trioxide dust (as a paste) past a bulkhead as a result of the deterioration of the bulkhead. Examples include the stopes in Areas AR2 (C212 and include chambers 9 and 10), AR3, and AR4.
- ***Unrecognized Failure of an Inaccessible Lower Bulkhead***. This event assumes that an inaccessible bulkhead may fail due to any one or more of the above-described events considered for accessible bulkheads and/or other events. Examples include stopes and chambers in Areas AR1, AR2, and AR3. Assessment is of necessity based on knowledge relating to the accessible bulkheads tempered by the recognition that there is an added level of uncertainty associated with the inaccessibility and lack of ability to inspect these bulkheads.

4.5.5 Underground Rock Failures.

These include two possible events:

- ***Surface Crown Pillar*** failures that breach the integrity of the dust storage chambers. Consequences are as for (c) in the first failure mechanism in 4.5.4 above.
- ***Internal Crown Pillar*** failures that breach integrity of the dust storage chambers. Consequences are as for (c) in the first failure mechanism in 4.5.4 above.

4.6 Results of Formal Risk Assessment

The FMEA work sheets that record the results of the risk analyses are included as Tables 3 and 5. Both the INAC risk assessment process and that adopted for this risk assessment employ a color coding system to identify events that warrant attention as compared to events that do not. Both systems code events blue, green, yellow, orange, or red. Generally blue coded events have both low likelihoods of occurrence and low to moderate consequences. Conversely red events are both likely and have major to critical consequences. The reader is referred to INAC, 2008 and/or RGC, 2008 for the complete system.

Most events were assessed to have a combination of relatively high likelihoods but with low to moderate consequences and coded blue, green, or yellow, and therefore generally do not represent a risk requiring immediate and urgent management attention. A factor limiting consequences is that almost all failure mechanisms result in arsenic releases within the mine where it is contained and not released to the environment and do not represent a significant risk to human health and safety for either the public or workers. The quantity of water that would have to removed from the mine for treatment would not be materially increased but the arsenic concentration and hence the cost of treatment and sludge disposals would. In most cases a failure would result in only a partial release of arsenic trioxide from one chamber/stope and the proposed remediation of freezing could still be applied to immobilize the remainder arsenic trioxide. If release is to the mine then consequences of most concern are the increases in future costs to cover

The current risk assessment identified no RED events: events that are both expected and of extreme consequences.

The events that coded ORANGE and, to a lesser extent, those coloured yellow, are the risks of greatest consequence. The findings of the IEP regarding these risks as well as a discussion of potential mitigation measures to reduce these risks and recommendations for risk mitigation are described in Sections 5 to 7.

4.7 Mitigation Measures

Included in Tables 3 and 5 are a listing of potential mitigation measures for those failure modes with higher risk. The potential risk reduction that is expected occur after such mitigation measures are applied were evaluated for the bulkheads in the mine and the reassessment results are provided as second set of risk assessment columns on Table 3.

While the recommended mitigation measures are formulated primarily to address orange-coded events, the same mitigation measure will also address blue-, green-, and yellow-coded events.

5 INDEPENDENT EXPERTS PANEL FINDINGS

5.1 General

This section describes the findings of the members of the IEP relating to technical matters. Aspects relating to social, stakeholder expectations and legal aspects are not addressed. All members concur in these findings. Neither INAC nor mine staff participated in the formulation of these findings.

5.2 IEP Findings

In order to reach the conclusions that follow, we have:

- Examined selected documents pertaining to the Giant Mine and its proposed remediation.
- Observed representative parts of the site and the underground workings.
- Participated in discussions with our peers and those familiar with the current conditions at the Giant Mine relative to this report and its findings.
- Facilitated and participated in a formal risk assessment workshop.

On the basis of these activities we note as follows:

- Considerable work has been done by other parties to characterize the site, to identify risks & mitigation measures, and to identify and compare alternative remediation approaches.
- Considerable risk mitigation work has been done, is in progress, is planned, or could still be done and such mitigation work has and can substantially limit or eliminate the risks previously and currently identified and documented.

The current conditions at the site are such that one or more of the following individual events or a sequence of such events could occur in the next five to ten years. 5 and 10 years assessment periods were selected for this review as representing the shortest and longest terms likely to be required to the normal process of remediation option review and permitting and for implementation of the remediation option to the extent that the on-going risks are materially reduced:

- Ice build-up or rockfalls in Baker Creek with subsequent overtopping due to the spring freshet causing partial or complete flooding of the underground workings (including arsenic-trioxide-containing chambers and stopes.)
- Overtopping of Baker Creek due to extreme flow events causing partial or complete flooding of the underground workings (including arsenic-trioxide-containing chambers and stopes.)
- The passage of surface waters to the underground mine workings where the arsenic trioxide dust is stored thereby causing pressure build-up in those arsenic-trioxide-containing chambers and stopes.
- Deterioration of a bulkhead impounding arsenic trioxide dust causing increased leakage of contaminated seepage and/or arsenic trioxide dust.

- Passage of increased quantities of arsenic trioxide dust, paste, and/or contaminated waters through the bedrock discontinuities associated with the bulkheads and surrounding bedrock.
- Collapse of a crown pillar above or below arsenic-trioxide-containing chambers or stopes thereby compromising the integrity of the bulkheads or the foundation of a chamber or stope.

Probability of occurrence was assessed and in most cases is moderate to high. In the event that one or more of these events or a sequence of such events were to occur, we believe the consequences could include:

- Partial or complete flooding of the Giant Mine (and connected open pits) and discharge of mine water with elevated arsenic concentrations into Baker Creek and Great Slave Lake for a limited period. It is noted that the likelihood of complete flooding of the mine to the extent that mine water is discharged is much less that the likelihood of some mine flooding. Thus the likelihood of a discharge to the lake is low.
- The presence of arsenic trioxide in an uncontrolled release to underground portion of the mine results in deterioration of mine water quality and increased community concern and increased water treatment costs. However it does not result in significant increased public or worker health and safety.
- Release of arsenic-contaminated seepage from arsenic chambers and/or stopes into flooded and/or unflooded areas of the underground mine workings has a high probability. Small amounts of seepage is currently occurring, which is collected and treated. This failure event considers substantially larger rates of leakage that could bypass the collection facilities.
- Increased remediation costs resulting from the increased need to deal with released and migrating arsenic trioxide, including cleanup and/or extended periods of treatment of contaminated mine waters.

While the identified risks are real and significant, we do not believe that they are significantly different from those that have existed for a long time at the site. Furthermore; based on our experience with risk assessment and criteria with which we are generally familiar, we do not believe that the risks are at a level that demands immediate remediation. In particular, we do not believe that the risks are so high that they requires expedited action to implement the proposed final remedy or that it is necessary for the Crown to undertake immediate action to implement substantial parts of the final remedy.

Specifically, with regard to the INAC, 2008b consequence categories and severity ratings we find as follows:

- ***Environmental Impact***: Arsenic is currently being released from the site and will continue to be released from the site albeit at a significantly lower rate even after implementation of the proposed remediation.
- ***Human health and safety***. We believe that identified risks involve low-level short-term risks and thus are manageable in the normal course of events.

Special Considerations, Legal and other Obligations and Community, Media, and Reputation impacts were not in the review mandate of IEP.

We emphasize that our findings are based on our readings and observations about current site conditions, current engineering studies, and the assumption that the start of implementation of remedial action could be delayed for up to five years resulting in a period of ten years before remedial action has progressed to a sufficient extent that the risks and consequences we identified are no longer likely. If ongoing studies and the implementation of the mitigation works we recommend result in a delay of longer than five and ten years, we note that the risks could increase, but the magnitude of those increases cannot be determined/predicted at this time.

6 SPECIFIC RISKS THAT MERIT ACTION

6.1 General

In this section we bring discuss specific issues that were identified by the formal risk assessment workshop to require attention.

6.2 Baker Creek Channel Blockage

Ice builds up in parts of the creek during the winter. Because of the difficult access conditions, the ice is not cleared over the full length of the channel. There is a risk that normal to high spring freshet runoff cannot pass down the channel because of the ice blockage, and hence the creek flow overtops the creek banks (possibly into an open pit) and hence floods the underground mine workings.

Although there are several locations where this risk exists (B1 pit, C1 pit, and A2 pit), the risk is greatest at C1, where the channel freeboard is the least and the dike between the pit and channel is a narrow roadway. This roadway consists of mine waste and/or insitu till that is believed to be up to 1 metre thick. This section of the channel has less than 2 metres freeboard from the nominal water level to the crest of the channel. A breach of this section of the channel would result in a portion of the flood overtopping into the C1 pit. Access to close the breach would be very limited during the period of flooding.

If this were to occur, in a manner in which most or all of the flow were directed into the open pit and if it occurred for a sufficiently long time before the blockage were noted, cleared, and the channel repaired, then it is possible that there would be a discharge of arsenic-contaminated water to Baker Creek and the Great Slave Lake.

The consequences of flooding of the mine workings would include a negative public reaction, media scrutiny, and possibly detrimental impacts on human health and the environment resulting in an increase in the cost of implementing the final remedy. The probability of this event may be reduced by one or more of:

- Modifying the dike along the C1 pit to reduce the risk of overtopping and/or a breach
- Immediately improving access to those parts of the creek where ice build-up has traditionally occurred, and implementing a program of ice build up monitoring and proactively doing ice clearance when ice build up is deemed to pose a threat to mine flooding,
- Developing a resource list of people and equipment that can be mobilized together with an emergency response plan to implement should all preventative measures fail.

Based on the field inspection of site conditions and the IEP's experience with the anticipated remedial actions, any period of mine inflow during flooding that may occur would be of limited duration.

6.3 Baker Creek Extreme Event Flooding

Extreme flood events in Baker Creek could cause flood flow over the creek banks, possibly flooding into an open pit, and hence flooding of the underground mine workings. As for ice-blockage, the potential to fill the mine workings depends on the percentage of the flow that leaves the creek and the period before the inflow is noticed and response measures implemented.

The consequences of flooding of the mine workings would include a negative public reaction, media scrutiny, and possibly detrimental impacts on human health and the environment resulting in an increase in the cost of implementing the final remedy.

The probability of this event could be mitigated by increasing the flow capacity of the creek by one or more of:

- installing additional berms, and/or strengthening berms, and/or increasing existing berm heights, and
- preparing and implementing a *Flood Response Plan* that would provide for monitoring of winter snow build-up and provision of flood control equipment.

6.4 Flooding of Chambers &/or Stopes Containing Arsenic Trioxide Dust

Water ingress and/or accumulation has been occurred in recent years in all 4 storage areas (AR1-4). Excessive inflows could result in increased migration of arsenic trioxide dust, paste, or contaminated waters to the mine workings adjacent to and below the stopes.

The result could range from a minor increase in water treatment costs to conditions that cannot readily or cost-effectively be cleaned up or included in the proposed remediation plan.

Mitigation of this event would include, in order of priority:

- Implementation of means to reduce water inflows, (It is understood that this has been done to the extent practicable at this time).
- installation in vulnerable stopes and chambers of both of pressure monitoring instruments and dewatering facilities to control and limit pressure build-up that could increase arsenic trioxide migration rates.
- Minimize or preferably eliminate all blasting in the vicinity of chambers/stopes which are known to have internal water accumulation. (The IEP understands that blasting in the vicinity of B208 resulted in liquefaction of arsenic dust and release of arsenic paste past BH 14 before it was repaired.) If blasting is necessary, water pressure in the chamber/stope should be relieved before blasting commences.

6.5 Accessible Bulkhead Concrete (Chambers & Stopes)

The observed chemical and bacterial-induced concrete degradation of both cement and cemented tailings bulkheads may also affect the concrete at the juncture of the bulkhead and the surrounding rock. Under increased pressure conditions in a chamber or stope resulting from the presence of excess seepage from surface and/or underground flooding, additional quantities of arsenic trioxide paste could rapidly displace deteriorated concrete, escape the chamber/stope, and pass to the lower mine workings.

This would result in the development of a pool of mine water with highly elevated arsenic concentrations (about 2,000 to 4,000 mg/L) in the mine workings that underlie the failed bulkhead. The consequence would include public concern, media attention and criticism, and probably a significant increase in the duration and cost of remedy implementation.

The probability of this event and its potential consequences can be reduced and mitigated by:

- Implement recommendations 1, 2 and 3 as per Section 6.4, above,
- implementing a bulkhead evaluation and testing program to determine the extent to which deterioration has occurred,
- reinforcing afflicted bulkheads (if needed) and/or
- providing additional facilities to pump and treat excess contaminated mine waters from the mine workings and from within any flooded chambers or stopes.

6.6 Inaccessible Bulkheads (Chambers & Stopes)

The condition of these bulkheads is not known. It is likely that they are in a state that is similar to accessible bulkheads that were constructed at more or less the same time and in a similar way. Unforeseen conditions are, however, possible. It is neither practical nor cost-effective to access them to observe their condition.

Thus there is a risk that they may not be able, under normal and particularly extreme events (specifically mine flooding), to contain the arsenic trioxide dust. Failure of one or more of the inaccessible bulkheads would first be noticed by an increase in arsenic concentrations in the pool of mine water which is monitored in the C-Shaft and/or in the mine water pumped to surface at the Aikatcho Shaft.

Mitigation of the likelihood and consequences of this event would include:

- Implement recommendations 1, 2 and 3 as per Section 6.4, above, and
- the provision of additional pump and treat capacity as for the accessible bulkhead failure mode discussed above.

6.7 Stopes Beneath Arsenic Storage Areas

Loss of fill at C5-09 during flooding of the underground mine workings and consequential roof collapse could undermine a stope and its associated horizontal bulkhead. This could result in the development of a pool of mine water with highly elevated arsenic concentrations (~2,000 to 4,000 mg/L As) in the mine workings underlying the collapsed bulkhead.

Consequences would include adverse public and media comment, loss of containment of the arsenic trioxide dust, and increased remediation costs.

To reduce this risk, it may be possible to backfill vulnerable stopes where the loss has already occurred. However, it is not possible to mitigate against stopes failing where fill loss may yet occur[3].

[3] We note that SRK is currently further evaluating conditions and potentially necessary actions in this regard. Accordingly, we do no more than note it here for the sake of completeness.

7 RECOMMENDATIONS

7.1 General

On the basis of our reading of referenced documents, site observations, participation in the risk assessment workshop, and peer deliberations, we make recommendations as described below for ongoing activities at the Giant Mine.

7.2 Remediation Plan

We recommend that INAC implement risk mitigation measures identified during the FMEA and allow the review of the *Remediation Plan* to proceed in accordance with regulation and practice, and specifically to support the preparation of an *Environmental Assessment Report* in compliance with the Mackenzie Valley Resource Management Act.

7.3 Roaster Complex

We acknowledge that demolition of the Roaster Complex and disposal of contaminated debris in an existing chamber that is part of the area to be frozen is part of the *Remediation Plan* and thus is rightly included in our recommended approach to ongoing *Remediation Plan* review and preparation of an *Environmental Assessment Report*.

Nevertheless, we recommend that demolition should proceed subject to approval being obtained regarding a disposal location, funding being available and rigorous H&S procedures.

Reasons for this recommendation include:

- We consider that the likelihood of events (notably a fire) that could cause substantial impacts on health and environment is not high. However, the consequences could be substantial.
- Ongoing maintenance and mitigation of risk at the complex is costly and potentially unsafe for workers.
- Storage of the demolition material in an existing underground chamber can be done provided a chamber can be prepared by isolation or freezing so that migration of arsenic dust can be prevented. To avoid risk to users of the highway, it would be preferable to delay demolition until such time as the highway has been re-located.

Accordingly we believe that the Crown is justified in pre-empting the normal process of community deliberation and exercising Crown prerogative to proceed with demolition in the interests of human health and safety and cost reduction.

7.4 Baker Creek

We acknowledge that implementation of the *Remediation Plan* involves relocation of Baker Creek in conjunction with the relocation of the highway. We acknowledge that relocation of the highway and hence Baker Creek is the subject of considerable discussion amongst stakeholders and that this discussion may take considerable time to bring to conclusion.

Nevertheless because of the risks associated with flooding and overtopping in the creek and subsequent impact on mine workings and arsenic trioxide-containing chambers and stopes, we recommend immediate implementation of risk mitigation measures including those that are neither conducive to nor consistent with the final remediation plan.

Mitigation measures that we recommend include preparation and execution of three focused plans, namely:

- ***Baker Creek Plan Capacity Improvement Plan*** to fully assess the capacity of the creek for various storm and snow-melt events and identify appropriate and necessary engineering and hydraulic works that would improve the capacity of the creek to pass flows without a significant risk of overtopping likely to result in flooding mine workings leading to impact.
- ***Surface Water Management Plan*** to fully identify surface water features and events that may be conducive of increasing the likelihood of increased flow to the underground mine workings and hence to formulate engineering works that may reduce or eliminate such features and events.
- ***Ice Removal Plan***, to evaluate and specify detailed activities to be undertaken to facilitate access to those parts of the creek where ice build up causes a restricted flow and where it would be prudent and necessary to remove such ice buildup prior to the occurrence of the freshet.

We recognize that the issues that we recommend be addressed in these plans overlap and that some of the engineering works may be common to one or more plan. Thus we recommend that consideration be given to preparing these plans as an integrated whole. Regardless of the specific scope of one or more plans on the general issues of surface water management, we recommend specific attention be paid to the need for, engineering details of, and the cost of the following works that we recommend be considered and constructed, in order of priority:

- Road B1 Raising (recently completed)
- Road A2 Raising and Creek Clearing (recently completed)
- C1 Pit diversion channel can be stabilized by installing an in-pit buttress and liner to the channel
- General channel rock removal in areas of flow restriction
- Ice removal access road.
- Other surface water control facilities
- Mill pond sealing and drainage improvements if feasible and economic. (partially completed)

7.5 Bulkheads

We acknowledge past and ongoing work on inspection and maintenance of the bulkheads. Nevertheless, we recommend additional evaluation and testing of the condition of the bulkheads and implementation of additional maintenance, repair, and upgrade work as established to be necessary and cost-effective pursuant to the recommended evaluations and testing.

In particular, we recommend preparation and implementation of a bulkhead evaluation and upgrade plan. As a minimum this would include, in order of priority:

- Install water pressure monitoring equipment &/or means to relieve excess water accumulation in chambers/stopes
- Bulkhead testing and concrete quality evaluation
- Selected bulkhead upgrades
- Selected stope and chamber backfilling, e.g., B3-06 and/or C5-09

We recommend further detailed consideration of the independent report (AMEC, 2008) on the bulkheads by Dudley Morgan (Table 2), one of the Technical Experts contributing to this report. In summary, he recommends that cores be extracted from areas of softened concrete on the bulkheads so that petrographic analyses can be conducted to determine the depth of softening and whether concrete deterioration extend deeper into the concrete. On the basis of the findings of this work, a program should be implemented to remove deteriorated concrete and contaminants, installing dowels to stabilize and reinforce affected bulkheads, and, as appropriate and necessary, installing a wet-mix, macro-synthetic fiber-reinforced, silica-fume-modified shotcrete to further enhance the performance of affected bulkheads.

7.6 Arsenic Chambers/Stopes

We acknowledge past and ongoing work to monitor and control water levels/pressures in the chambers and stopes containing arsenic trioxide dust. However, this program currently does not cover all stopes and chambers for which it is advisable.

We accordingly recommend expansion of this program to encompass all chambers and stopes where the potential for water pressure increases exists, including those with inaccessible bulkheads. Where excessive pressure in chambers or stopes are observed these should be alleviated to protect the bulkheads.

7.7 Mine Dewatering

We acknowledge that mine dewatering, including ongoing pump and treat of affected waters from the mine, is part of the long-term remediation approach. We note that current mine dewatering and treatment facilities will, as described in the *Remediation Plan*, be upgraded.

We recommend, as a proactive risk mitigation measure, that the mine dewatering facilities be upgraded in a manner that is, as far as practical, cost-effective, and conducive to and consistent with the final remedy. Site management should undertake a detailed review of the existing system capacity in light of risks identified here, and modify the mine dewatering & treatment plan accordingly. This may include pumping systems, augmentation of mine water treatment capacity, temporary storage of arsenic-trioxide-affected wasters in lined or unlined ponds, facilities to collect arsenic trioxide paste, etc.

In particular, we recommend preparation of a *Mine Dewatering Plan* and of an *Arsenic Trioxide Control and Collection Plan*. We recommend that in preparing these plans, the following facilities and/or equipment be considered, designed, and as appropriate, constructed and/or installed:
Temporary lined area in tailings pond

- Some additional pumps and piping to improve capacity and reliability
- Arsenic paste collection facilities
- Monitoring facilities
- Pumps (e.g., additional submersible pumps in C-Shaft and associated piping.)
- Expanded water treatment facilities.

7.8 Stopes Beneath Arsenic-Trioxide-Containing Stopes or Chambers

We are concerned about the implications of the potential that conditions such as those observed at C5-09, i.e., loss of fill during flooding, could lead to roof collapse and undermining of overlying stopes that contain arsenic trioxide dust.

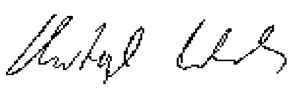
Accordingly, we recommend expedited evaluation of the condition at C5-09 and other similar areas, a study we understand is currently underway. As established by such recommended evaluations, remedial plans should be formulated and implemented.

8 SIGNATURES

We the undersigned, as members of the IEP, concur with the findings of the formal risk assessment and the findings of the IEP as documented in this report.

Andrew McG Robertson P. Eng.

Ian Hutchison, P.E.



Christoph Wels, P. Geo.

Dudley R. Morgan, P. Eng.

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9 REFERENCES

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SRK (2008a) "Baker Creek Flood Studies."

SRK (2008b) "Arsenic Migration Studies."

Table 1. INDEPENDENT EXPERTS PANEL (IEP) MEMBERS

Andrew MacG. Robertson, P.Eng., Ph.D.,

Andrew Robertson is a civil engineer with a Ph.D. in rock mechanics. He has worked as a consultant to the mining industry for ~30 years specializing in rock mechanics and slope stability, tailings dam design and mine waste management, acid rock drainage, control and closure planning, risk assessments and risk management. His project role is to lead the team.

Ian Hutchinson, P.E., Ph.D.

Ian Hutchinson is a civil engineer with over 35 years experience in mining, environmental engineering, and surface water management. His project focus is surface water and in particular the potential for flooding of Baker Creek.

Christoph Wels, P. Geo., Ph.D., M.Sc.

Christoph Wels is a senior hydrogeologist and a principal of RGC. He has a M.Sc. in Watershed Hydrology and a Ph.D. in Hydrogeology with over 15 years experience in applied academic research and professional consulting.. His project focus is groundwater and the migration of surface water to and through the underground mine workings.

Dudley R. Morgan, P.Eng., Ph.D.

Dudley Morgan is a civil engineer with more than 40 years of experience in mining and structural engineering. His project focus is the concrete of the bulkheads and the overall integrity and stability of the bulkheads.

Jack Caldwell, P.E., MSc(Eng), LLB

Jack Caldwell has over 35 years experience in mine-related civil and geotechnical consulting. As an engineer with Robertson GeoConsultants. He consults to mines in Canada and the United States on tailings and mine waste. He also writes for InfoMine on the science, technology, and engineering of mining. He is the primary author of this report.

Table 2. FORMAL RISK ASSESSMENT WORKSHOP PARTICIPANTS

Mike Nahir, Manager, Engineering Services, INAC

Bill Mitchell, Manager Giant Mine Remediation Project, INAC

Martin Gavin, Manager Giant Mine Remediation Project (Designate), INAC

Ben Nordahn, Mine Services Officer, INAC

Des O'Connor, PWGSC Project Officer, PWGSC

Mark Cronk, PWGSC Senior Project Manager, PWGSC, YK

John Brodie, Geotechnical Engineer, Brodie Consulting Ltd.

Andrew MacG. Robertson, Civil & Geotechnical Engineer, Robertson GeoConsultant

Ian Hutchinson, Civil & Hydraulics Engineer, Strategic Engineering and Science

Christoph Wels, Professional Geologist & Groundwater Specialist, Robertson GeoConsultants

Dudley Morgan, Chief Materials Engineer, AMEC Earth & Environmental

Jack Caldwell, Civil & Geotechnical Engineer, Robertson GeoConsultants

TABLE 4. MITIGATION MEASURES [4]

BAKER CREEK

Prepare Plans

Baker Creek Capacity Improvement Plan
Surface Water Management Plan
Ice Removal Plan

Construction

Road B1 Raising
Road A2 Raising and Creek Clearing
C1 Pit diversion channel, buttress and liner
General channel rock removal
Ice removal access road.
Other surface water control facilities
Mill pond sealing and drainage improvements

BULKHEADS

Prepare Plans

Bulkhead evaluation and upgrade plan

Construction

Bulkhead testing and concrete quality evaluation
Selected bulkhead upgrades
Install pressure monitoring equipment
Selected stope and chamber backfilling, e.g., B3-06 and/or C5-09

MINE DEWATERING

Prepare Plans

Mine dewatering plan
Arsenic control and collection plan

Construction

Temporary lined area in tailings pond
Additional pumps and piping
Arsenic paste collection facilities

Equipment

Monitoring facilities
Pumps (e.g., additional submersible pumps in C-Shaft and associated piping.)
Treatment facilities.

[4] John Brodie, independent consultant to INAC, has costed these works. His costs are not included but are available from INAC on request.

TABLE 3 - FMEA - GIANT MINE (Nov 25, 2008) BULKHEADS AT STOPES

STRUCTURE	PLAN / AREA	ID	FAILURE MODE	EXAMPLES	EFFECTS	PROJECT STAGE	LIKELIHOOD	CONSEQUENCES: HUMAN HEALTH AND SAFETY	CONSEQUENCES: COMMUNITY / MEDIA / REPUTATION	CONSEQUENCES: CONSEQUENCE COSTS	CONSEQUENCES: LEGAL OBLIGATION	CONSEQUENCES: ENVIRONMENTAL IMPACT	CONSEQUENCES: IMPACT ON PERMANENT	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	MITIGATION/ COMMENTS	PROJECT STAGE	LIKELIHOOD	CONSEQUENCES AFTER MITIGATION: HUMAN HEALTH AND SAFETY	CONSEQUENCES AFTER MITIGATION: COMMUNITY / MEDIA / REPUTATION	CONSEQUENCES AFTER MITIGATION: CONSEQUENCE COSTS	CONSEQUENCES AFTER MITIGATION: LEGAL OBLIGATION	CONSEQUENCES AFTER MITIGATION: ENVIRONMENTAL IMPACT	CONSEQUENCES AFTER MITIGATION: IMPACT ON PERMANENT	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	COMMENTS
	BULKHEADS AT ARSENIC STOPES	BH5	INTERNAL FLOODING (Mine not flooded.)	Stopes in Areas AR2, AR3, and AR4 (Likelihood dominated by C212)	Order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s	5	H	N	N	N	N	N	N	H													
						10	H	N	N	N	N	N	N	H													
					Increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase)	5	H	N	N	L	N	N	N	H		Can be mitigated by monitoring and installing local paste collection/containment facilities as needed											
						10	H	N	N	L	N	N	N	H													
					Discharge of increased volume of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can only be partially cleaned up (Remedy becomes only partially effective)	5	H	L	M	H	N	N	L	M		Assumes monitoring pyrometers, and dewatering facilities will be installed and used to minimize the buildup of water pressure. For mitigation install depressurization system for C212. Consider further mitigation by impermeabilization of the Mill Pond and adjacent information. (Note, stopes B208 B214 "bin out" yellow)	5	M	L	M	H	N	N	L	M		
						10	H	L	M	H	N	N	L	M			10	M	L	M	H	N	N	L	M		
		BH6	DRAINDOWN AFTER EXTERNAL FLOODING for all stopes (during mine dewatering)	See Baker Creek examples above	Order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s	5	M	N	H	M	N	N	N	H		Ensure that operations and final remedy provide positive surface drainage and minimizes infiltration over chambers and slopes to limit infiltration.											
						10	M	N	H	M	N	N	N	H													
					Increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase)	5	M	N	H	H	N	N	N	M													
						10	M	N	H	H	N	N	N	M													
					Discharge of increased volume of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can only be partially cleaned up (Remedy becomes only partially effective)	5	L	N	H	H	N	N	N	M													
						10	L	N	H	H	N	N	N	M													
		BH7	DETERIORATION OF CONCRETE BULKHEADS (For INTERNAL FLOODING of stopes [Mine not flooded.]	Stopes in Areas AR2, AR3, and AR4	Order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s	5	H	N	N	N	N	N	N	M													
						10	H	N	N	N	N	N	N	M													
					Increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase)	5	H	N	N	L	N	N	N	M													
						10	H	N	N	L	N	N	N	M													
					Discharge of increased volume of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can only be partially cleaned up (Remedy becomes only partially effective)	5	H	L	M	H	N	N	L	L	H	Deterioration is observed and can lead to an increased likelihood of a water and paste release. Conduct further testing (specifically coring of concrete, check out pipes) and evaluations of concrete deterioration. Where indicated by this testing perform bulkhead repairs as necessary. Other mitigations as indicate in "Internal Flooding" FM above.	5	M	L	M	H	N	N	L	M		
						10	H	L	M	H	N	N	L	L	H		10	M	L	M	H	N	N	L	M		
		BH3	DETERIORATION OF CEMENTED TAILINGS BULKHEADS	Stopes in Areas AR2 (C212 and include chambers 9 and 10), AR3, and AR4	Order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s	5	H	N	N	N	N	N	N	M													
						10	H	N	N	N	N	N	N	M													
					Increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase)	5	H	N	N	L	N	N	N	M													
						10	H	N	N	L	N	N	N	M													
					Discharge of increased volume of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can only be partially cleaned up (Remedy becomes only partially effective)	5	H	L	M	H	N	N	L	L	H	Deterioration is observed and can lead to an increased likelihood of a water and paste release. Conduct further testing (specifically coring of cemented tailings) and evaluations of concrete deterioration. Where indicated by this testing perform bulkhead repairs as necessary. Other mitigations as indicate in "Internal Flooding" FM above.	5	M	L	M	H	N	N	L	M		
						10	H	L	M	H	N	N	L	L	H		10	M	L	M	H	N	N	L	M		
		BH4	UNRECOGNIZED FAILURE OF INACCESSIBLE LOWER BULKHEADS (Based in internal flooding)	Chambers in Areas AR1, AR2, and AR3	Order-of-magnitude increase in seepage of arsenic impacted water to underground workings by either bypassing and/or failure of bulkhead/s	5	H	N	N	N	N	N	N	L													
						10	H	N	N	N	N	N	N	L													
					Increased discharge of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can still be cleaned up (approximately order of magnitude increase)	5	H	N	N	L	N	N	N	L													
						10	H	N	N	L	N	N	N	L													
					Discharge of increased volume of arsenic paste (by either bypassing and/or failure of bulkhead/s) that can only be partially cleaned up (Remedy becomes only partially effective)	5	H	L	M	H	N	N	L	L		For mitigation install monitoring piezometers in the ones that need monitoring and dewatering facilities as needed, to minimize the buildup of water pressure. Note, need to evaluate methods and effectiveness of pressure relief systems. Consider further mitigation by sealing of the Mill Pond and adjacent information. (Note, stopes B208 B214 "bin out" yellow)	5	M	L	M	H	N	N	L	M		
						10	H	L	M	H	N	N	L	L			10	M	L	M	H	N	N	L	M		

STRUCTURE	PLAN / AREA	ID	FAILURE MODE	EXAMPLES	EFFECTS	PROJECT STAGE	LIKELIHOOD	CONSEQUENCES						LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	MITIGATION/ COMMENTS		PROJECT STAGE	LIKELIHOOD	CONSEQUENCES AFTER MITIGATION								LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	COMMENTS
								HUMAN HEALTH AND SAFETY	COMMUNITY / MEDIA / REPUTATION	CONSEQUENCE COSTS	LEGAL OBLIGATION	ENVIRONMENTAL IMPACT	IMPACT ON PERMANENT REMEDY							HUMAN HEALTH AND SAFETY	COMMUNITY / MEDIA / REPUTATION	CONSEQUENCE COSTS	LEGAL OBLIGATION	SPECIAL CONSIDERATION	ENVIRONMENTAL IMPACT	IMPACT ON PERMANENT REMEDY				
	ROASTER COMPLEX	R1	CATASTROPHIC FAILURE	Fire in old wood building	Damage and release of arsenic to the environment (during fire suppression and subsequently to air, soil and surface water)	5	L	M	H	L	L	L	N	M		Assumes continued training of city firefighter for dealing with fire suppression of contaminated industrial buildings. Develop fire suppression procedures manual that limits arsenic exposure during fire suppression.														
						10	L	M	H	L	L	L	N	M																
		R2	HUMAN EXPOSURE	Trespasser or vandal	Acute exposure to high levels of arsenic through ingestion, direct contact and inhalation	5	L	L	M	N	N	N	N	M																
						10	L	L	M	N	N	N	N	M																
					Physical harm by falling or falling objects	5	L	H	H	L	L	N	N	M																
						10	L	H	H	L	L	N	N	M																