The Giant Mine

Water License Study
Abandonment & Restoration

An Assessment of Scientific Data Relating to the Permanent Storage of Arsenic Trioxide in the U/G Mine Workings at the Giant Mine

Progress Report
1996

Giant Mine Water License Annual Report for 1996
April 3, 1997

Background

One of the requirements of the current Water Use License for the Giant Mine is to carry out a study of closure and abandonment options for the permanent storage of arsenic trioxide bearing baghouse dust in the underground mine workings at the Giant Mine. Terms of Reference for this study were approved by the Northwest Territories Water Board in 1994. The agreed upon terms of reference called for completion of the study and the submission of a final report at the end of 1997 with updates to be provided with the 1994, 1995 and 1996 Water License annual reports.

The Giant mine has been producing approximately 15 tons per day of an arsenic trioxide bearing baghouse dust from its milling operations since the mid 1950's. The primary gold bearing mineral mined at the Giant mine is arsenopyrite. The gold contained in this arsenopyrite is not recoverable until the aresenopyrite crystal lattice has been physically broken apart and the contained sulphur and arsenic removed. At the Giant Mine this conversion is achieved by roasting the arsenopyrite at high temperature. The arsenic is volatilized and oxidized into arsenic trioxide which is then recovered from the roaster gas stream in a conventional baghouse dust collector. This baghouse dust is stored in underground sorage vaults specially created for that purpose. The abandonment and restoration plan for the Giant mine indicates that this material is to be left underground in the storage vaults which would be isolated by bulkheads and permanently frozen so that groundwater did not come into contact and mobilize the contained arsenic.

The purpose of this study was to collect and assess scientific data relating to the permanent storage of this arsenic trioxide to develop a permanent engineered closure plan. The final study report would present the information collected and the decision process used to evaluate closure options and would propose an engineered closure plan with an assessment of the consequent risk to the receiving environment.

The study was broken down into five areas of investigation:

1) Physical Stability of the Storage Chambers
2) Options for Permanent Abandonment
3) Analysis of Permafrost in the Existing Storage Chambers
4) Analysis of Hydrology in the Area of the Storage Chambers
5) Risk Assessment

This section of the annual Water License report is intended to provide the Northwest Territories Water Board with a brief update on the progress made to date on each of these areas of investigation.

Physical Stability of the Storage Chambers

Plan and sectional drawings of all of the baghouse dust chambers have been prepared by mine staff. A full inventory and operational history for each chamber has been completed. Three dimensional drawings have been prepared for the following eight storage chambers:

B-230, B-233, B-234, B-235, B-236, #11, #12 and #14

These drawings are suitable for carrying out wall rock stress analysis.

In 1996 the FSC Group (Ferguson, Simek Clark Engineers and Architects of Yellowknife) were retained by Royal Oak to carry out the following scope of work:

- review the engineering plans of the existing storage chamber bulkheads to determine their hydrostatic load capacity,
- model the structural loads on these bulkheads, and
- report on the adequacy of the bulkheads to meet their design objectives.

Structural modeling of the bulkheads for six of the storage chambers (#10, 11, 12, 13, 14 and 15) has been completed. Assumptions made for this analysis are summarized as follows:

f_c=20 Mpa for concrete strength
f_y=300 Mpa for reinforcing bars
f_y=210 Mpa for other structural steel where source is not defined

The results of the structural analysis of the existing bulkheads in storage chambers #10, 11, 12, 13 & 14 indicate that all of these bulkheads meet the engineering design criteria and would sustain the full hydrostatic force that would be placed on them if the mine were flooded.

Inspection indicated no safe means of gaining access to bulkheads # 47,48 and 49 (all located in the area of older inactive storage chambers). FSC's scope of work was expanded to include the provision of new structural designs for hydrostatic bulkheads to replace older bulkheads # 47,48,49, 50 and 51 where adequacy of the bulkhead cannot be confirmed either due to lack of safe access, suitable information on the original bulkhead construction or due to a bulkhead construction that does not pass current structural requirements for the design objective for these bulkheads.

A monitoring program of these storage chambers and bulkheads has been developed and is ongoing.

Options for Permanent Abandonment

The following options for the abandonment and closure of the u/g arsenic storage vaults were identified in 1993:

i) use of winter air by means of forced ventilation to enhance the re-establishment of the permafrost in the vicinity of the storage chambers,
ii) use of additional or secondary bulkheads to isolate the storage chambers from the groundwater regime,
iii) use of grout curtains to isolate the storage chambers from the groundwater regime, and
iv) creation of artificial ice plugs behind the bulkheads to enhance isolation of the storage chambers from the groundwater regime.

The results of the investigations undertaken in 1994 thru 1996 have altered the list of technical options still considered to be viable to the following:

a) use of winter air by means of forced ventilation to enhance the re-establishment of the permafrost in the vicinity of the storage chambers.

Yellowknife is located in an area of dis-continuous permafrost. As a general rule permafrost exists where there is a blanket of till or other organic soil of sufficient thickness to insulate the permafrost from summer warming. The permafrost does not generally exist in areas below bedrock outcrops or below larger bodies of water. The permafrost will commence at a depth of approximately 50 to 75 feet and continue to a depth of 300 to 400 feet below surface in areas where this naturally insulating blanket exists.

The Giant ore body lies below the Baker Creek valley. This valley is characterized by exposed volcanic bedrock outcrops along the east and west sides of the valley. The floor of the valley had a significant blanket of till in place before surface mining commenced. Baker Creek itself is a relatively shallow stream with minimal natural flow other than during the spring freshet. The surface mining activity at the Giant mine has resulted in the removal of most of this till blanket from the Baker Creek valley in the vicinity of the mine. In addition discharges from the mine's tailings impoundment have increased the annual flowrates observed in Baker Creek during the summer months when the mine's effluent treatment plant is operational. Open pit mining has both exposed bedrock in the bottom of the Baker Creek valley and has increased the surface area through which heat can be passed into the underlying ground. Underground mining activity with its resultant ventilation air has further increased the transfer of heat into the underlying bedrock. All of these factors combined have acted to melt the permafrost that once existed under the Baker Creek valley in the vicinity of the Giant mine.

However based on our understanding of how permafrost was originally formed in the Baker Creek valley we have an opportunity to re-establish this permafrost and to maintain it after the Giant mine is closed. The Giant mine has created a network of approximately 34 km of tunnels and openings in the bedrock under the Baker Creek valley. Upon closure of the mine the mine ventilation system can be employed to pump cold winter air back into the upper mine workings (between 50 and 300 feet below surface) to re-establish the permafrost in the ground. When focused on the areas in which the arsenic storage chambers are located it is predicted that the ground can be totally re-frozen within two normal winters. An insulating blanket of till or other suitable soil would have to be placed on surface across the entire width of the valley in the areas under which the storage chambers exist to maintain the permafrost re-established underground. By utilizing the mine ventilation system to pump cold air back into the bedrock in the upper areas of the mine the arsenic storage chambers can be frozen so that no groundwater movement takes place in this area. The installation of a soil insulating blanket on surface will enable the ground to be maintained in a frozen condition with no future maintenance required and serves to keep all surface waters and precipitation runoff from entering cracks and fissures in the bedrock and coming into contact with the permafrost. This option is considered technically viable and is still open for further investigation. It is recognized that this option would have risk attached which would require ongoing maintenance and monitoring to ensure success. It is not a risk free solution but does offer significant opportunity.

b) leave the baghouse dust in place in the u/g storage chambers and continue to depress the groundwater table by pumping so that no groundwater comes into contact with this stored arsenic trioxide

The current practice used to prevent any release to the surrounding environment of arsenic trioxide from the underground storage chambers is to keep the groundwater table depressed to an level below the bottom of the lowest storage chamber (approximately 350 feet below surface). This is achieved by collecting and pumping all of the groundwater from the underground mine workings below these storage chambers. This action depresses the groundwater table in the immediate vicinity of the chambers. The water is pumped to the Giant mine tailings impoundment area where it is subsequently treated in the mine's effluent treatment plant. In this effluent treatment process arsenic is precipitated from the water as ferric arsenate. The resulting ferric arsenate precipitate is removed from the treated water in a polishing pond. The treated water which typically contains concentrations of total arsenic below 0.5 mg/l is then released to the receiving environment (Baker Creek into Great Slave Lake). This concentration of 0.5 mg/l is the minimum acceptable Federal and NWT Water Board standard for industrial discharge of arsenic in water for release to the environment.
One closure option is to leave the arsenic trioxide containing baghouse dust in place in the u/g storage chambers and to permanently lower the groundwater table in the area of

these storage chambers by pumping. Mine dewatering pumps would have to be operated in perpetuity under this option with the water pumped out of the mine being treated through the effluent treatment plant so that arsenic and other contained metal levels are removed prior to the water being released into the Great Slave Lake watershed. This option has been proven to be technically viable as demonstrated by the success attained over the past 40+ years of operation. It is recognized that this option has some risk attached and requires a permanent commitment of financial resources for ongoing operation, maintenance and monitoring to ensure success. It is not a risk free solution but does offer a viable alternative to other options.

c) the creation of a preferential pathway for groundwater to move around the arsenic storage chambers.

Theoretically it is possible to create a preferential pathway underground for groundwater to move away from and around the arsenic storage chambers. This would create an area of stagnant groundwater in the immediate vicinity of the storage chambers from which contaminants would not flow. Hydraulically groundwater will follow the path of least hydraulic resistance. The use of grout curtains and ice plugs can be combined with the construction of drains around the storage chambers so that groundwater will naturally flow away from and around the chambers. This concept has been applied in the abandonment and closure of mill tailings generated from the processing of uranium ore in northern Saskatchewan. It is technically more complex than the first option but still viable. It also has significant risk and consequently would require a long term commitment to maintenance and monitoring. It is not a risk free option but does offer some potential.

d) removal of the arsenic trioxide from the underground storage chambers

Removal of the arsenic trioxide bearing baghouse dust from the underground storage chambers would appear at first glance to be the best option to reduce the risk of groundwater contamination at some point in the future. However, the problem becomes what to do with the baghouse dust once it is on surface. Transferring the baghouse dust from underground storage to surface storage only transfers the problem and associated risk factors. In fact the risk factors of contamination associated with long term surface storage of this arsenic trioxide would appear to be greater than for the current underground storage when the relative contamination transport methods (wind erosion, water erosion, corrosion, etc) are considered. The second problem to be faced in removing the baghouse dust from the underground storage chambers is overcoming the technically difficult challenge of removing all of the baghouse dust with a mining method that is safe to both the environment and to the workers carrying out the work. It will be technically possible but difficult to remove most of the baghouse dust using robotic mining techniques but recovering the last 5% to 10% from the irregular rock walls with their cracks and fissures will be technically challenging.

Assuming that the baghouse dust can be effectively and safely removed from the underground storage chambers, there are basically only three options for dealing with the arsenic trioxide once it is on surface:

a) Store the baghouse dust in a suitable storage facility constructed on surface for this purpose. There is currently in the order of 270,000 tons of baghouse dust containing approximately 165,000 tons of arsenic trioxide stored underground at the Giant mine. The required volume of a suitable storage facility for this material would be in the order of 8,000,000 cubic feet although it may be possible to reduce this to 2.7 million cubic feet utilizing compaction equipment to increase the bulk density of this baghouse dust.

b) Convert the contained arsenic trioxide into ferric arsenate. The arsenic trioxide contained in the baghouse dust would have to be first leached into solution, the valency of the arsenic changed from the +3 to +5 state using a strong oxidant such as hydrogen peroxide and then the arsenic precipitated as ferric arsenate using a soluble ferric ion source such as ferric sulphate. The required stoichiometric addition rate of ferric ion would be in the order of 5 to 7 units per unit of arsenic. This process would produce enormous quantities of ferric arsenate which would then have to be stored in an environmentally safe manner somewhere on surface. Ferric arsenate is significantly less soluble than arsenic trioxide when contacted with water, however under certain conditions (such as if the pH drops below 5.0) the solubility of the arsenic in the precipitated ferric arsenate increases significantly. Concern has been expressed in the scientific literature about the long term stability of arsenic precipitated as ferric arsenate. The prevailing belief is that the solubility of arsenic in ferric arsenate is variable dependent upon the crystalline structure of the precipitated ferric arsenate. Given the quantities of arsenic trioxide stored at the Giant mine this conversion of all of the arsenic trioxide into ferric arsenate is not a viable option and will not be investigated further by Royal Oak. This process would be cost prohibitive and would result in massive quantities of a ferric arsenate precipitate that is difficult to store in an environmentally safe manner. The risk of contamination from arsenic re-solubilizing from this ferric arsenate would be of major concern.

c) Convert or upgrade the arsenic trioxide containing baghouse dust into a useable form where it can be transported out of Yellowknife for use in the world market place. The primary end use of arsenic is as CCA (copper chromated arsenate) which is the primary wood preservative being used around the world to pressure treat lumber used in any outdoor application. CCA has undergone rigorous testing and has received approvals from EP and the US Coast Guard for use in residential and commercial use.

During the 1980's a serious effort was made by the Giant mine to market a portion of the crude arsenic trioxide baghouse dust to one of the US based CCA producers. The product was sporadically shipped to an upgrading facility in Georgia for a period of 12 to 18 months. This marketing attempt failed as the low grade of the baghouse dust produced at the Giant mine made the product more difficult to upgrade and less desirable than arsenic trioxide materials coming into North America from other countries (principally China).

A hot water leach process designed to upgrade the Giant arsenic trioxide bearing baghouse dust and Con arsenic trioxide bearing sludges was jointly tested by the Giant and Con Mines in the 1980's. A full scale hot water leach plant was constructed at the Con Mine for a period of two to three years before being shut down because of poor market conditions for the 95% pure AS_2O_3 product. If a higher grade product had been made economics would have been significantly different.

Analysis of Permafrost in the Existing Storage Chambers and Surrounding Rock

In 1994 and 1995 a review of historical data was undertaken by mine engineering personnel regarding observations and records relating to permafrost in the underground mine workings at the Giant mine. Documentation indicates that discontinuous zones of permafrost were encountered throughout various areas of the mine and led to the initial plan to store the arsenic trioxide containing baghouse dust in secure vaults in a complete permafrost envelope.

In June of 1994 six diamond drill holes were drilled into the bedrock from surface to investigate the status of permafrost in the bedrock surrounding the storage chambers. Five of the six holes are located in the vicinity of the active and inactive arsenic storage areas. The sixth hole was drilled in an area of bedrock not influenced by active mining conditions.

In each of the holes a string of thermistors was installed to monitor rock temperatures at various depths. The strings read temperatures at surface, at a 20 foot depth below surface and then at 55 foot intervals down until the bottom of each hole. A depth of 350 foot was used as the bottom of each hole as no arsenic storage chamber is located at Giant below this elevation.

These thermistors have been read on a regular basis since installation in 1994 and have been reported in previous years annual updates. The readings for 1996 and the first few months of 1997 are presented graphically for each of the six holes in this report. A map showing the locations of each of the six drill holes in relation to the mine surface infrastructure is included as part of this annual update.

Drill holes # AS1 and AS2 are located in the bedrock surrounding the currently active arsenic storage chamber # 14. Drill hole #AS3, AS4 and AS5 are in bedrock near the older inactive storage chambers. Drill hole AS6 is in the bedrock away from any active mining area (intended as a point for comparison).

In summary the monitoring results for the six holes suggest the following common conclusions:

i) Underground and surface mining activities at the Giant mine have disturbed the existence and dis-continuous pattern of permafrost in the rock.

ii) The influence of surface temperatures extends down to a depth of 15 feet below surface in the bedrock although there is a noticeable lag time between the surface temperature and the rock temperature.

iii) At a depth of 70 feet and below there is no measurable impact from surface temperatures on the bedrock temperature. At this depth and below bedrock temperatures do not significantly vary year round.

iv) At depths of 70 feet to 400 feet below surface the bedrock temperature is consistent with some minor variation between holes:

Hole #AS1	approximately +0.3 to +0.8 degrees C year round
Hole #AS2	approximately +0.8 to +2.0 degrees C year round
Hole #AS3	approximately +0.8 to +1.2 degrees C year round
Hole #AS4	approximately +1.5 to +3.7 degrees C year round
Hole #AS5	approximately +0.3 to +1.4 degrees C year round
Hole #AS6	approximately +0.9 to +1.5 degrees C year round

The variation observed is believed to be a function of the active mine ventilation system. In areas of higher activity and thus more air movement temperatures would be expected to be higher.

The data collected indicates that permafrost is no longer present in the ground in these areas. Underground mining activity and the removal of the overlying surface till insulating blanket have caused the permafrost to retreat from the bedrock in these areas. No aditional drilling was undertaken in 1996 as it was believed additional holes would only confirm the observations already gathered and would not add any new useable information to this study.

Analysis of Hydrology in the Area of the Storage Chambers and Surrounding Rock

From early December 1995 thru January of 1996 a series of five diamond drill holes were drilled around storage chamber #14. These D.D.H. have been equipped with MAREO plugs and fitted with valves and have been subsequently monitored by mine personnel to evaluate groundwater flow paths, groundwater quality and quantity in the vicinity of this chamber. Similarly five additional holes were drilled around storage chamber #15 which is under construction.

The core from these holes has been logged and the RQD, RMR and Q values determined. The geological structures were mapped from the core and from the lower sill in chamber #15 to again identify the probable groundwater flow paths.

The monitoring in this area is currently ongoing.

Risk Assessment

No specific work in the area of risk assessment was carried out in 1996.