ROYAL OAK MINES INC.
Arsenic Trioxide - Surface Storage and Handling
Project Scoping Document

Royal Oak
Mines Inc.

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Project Scoping Document

Prepared for:

Northwest Territories
Water Board
Yellowknife, N.T.

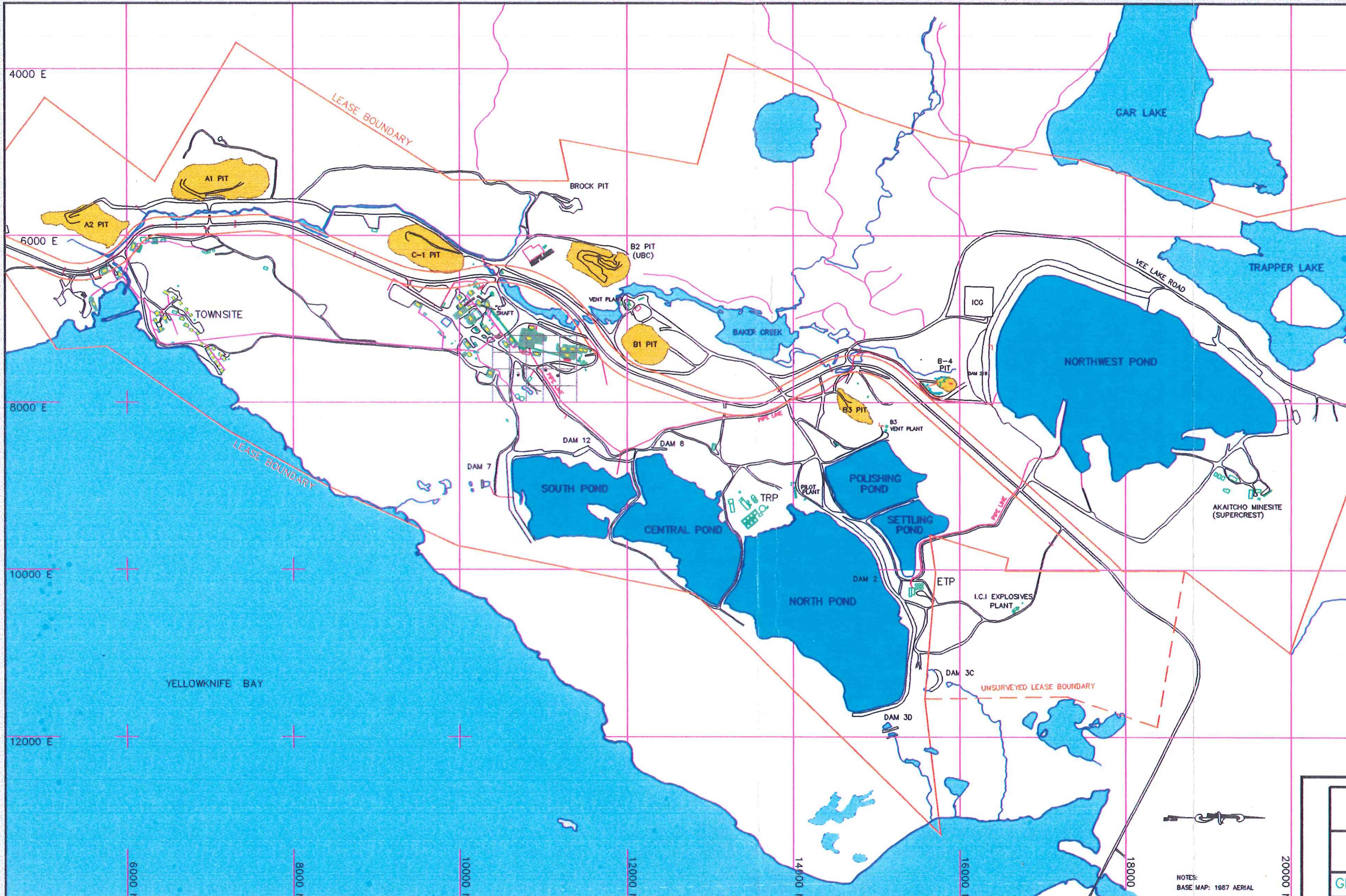
Prepared by:

Royal Oak Mines Inc.,
Yellowknife, N.T.

and

EBA Engineering Consultants Ltd.,
Yellowknife, N.T.

December 1997



NOTES:
BASE MAP: 1987 AERIAL

Royal Oak Mines Inc.

GIANT MINE
SURFACE PLAN

GENERAL MINESITE LAYOUT

DATE: DEC. 1992	SCALE 1" = 800'
UPDATED BY: MSL	DATE: JANUARY 29, 1997

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S-92-14

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December 19, 1997

N.W.T. Water Board
P.O. Box 1500
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Attention: Mr. Gordon Wray
Chairman, N.W.T. Water Board

Re: Arsenic Trioxide - Surface Storage and Handling, Project Scoping Document

Dear Mr. Wray,

We are pleased to submit 30 copies of a Project Scoping Document for your review and consideration.

The purpose of the following document is to provide a brief synopsis of Royal Oak's existing and proposed Arsenic Trioxide Management Plan.

The document is intended to stimulate discussions between the Company and various regulatory agencies and stakeholders regarding potential concerns and issues involved in the Arsenic Trioxide Management Plan. Specifically, comments are invited on the requirements for a risk assessment, the approval of a surface storage facility, and the related materials handling systems. The approval of a surface storage facility is the first step in the implementation of the Plan, which would include cessation of the current practice of underground storage.

We trust that the information provided in the following document is sufficient to begin the process of environmental assessment and regulatory approval according to the requirements of the Canadian Environmental Assessment Act, concurrent with the Company's ongoing technical investigation and design.

Please contact me at the Kirkland office at 425-822-8992 for any additional information.

Yours truly,
Royal Oak Mines Inc.

Richard D. Allan, P. Eng.
Manager, Mining Projects

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1.0 INTRODUCTION

1.1 Project Rationale

This document describes a management strategy for the long term handling of arsenic trioxide bearing dusts produced as a byproduct of the roasting process at the Giant Mine.

These baghouse dusts are currently transported to underground storage chambers for disposal. Concern has been raised regarding this storage practice, as a permanent solution to the disposal of these wastes. This disposal method has been safely utilized since 1950.

It is Royal Oak's intention to evaluate alternate solutions that are technically and economically viable and cooperate with government agencies to ensure that the long term objective of preventing the untreated release of this arsenic to the environment is achieved.

This document further describes Royal Oak's intention to implement above ground storage of arsenic trioxide. Future production of the waste products would be stored in surface containment so as to be readily available at such time as a plant can be commissioned to economically process the material into a marketable form.

Royal Oak has committed to the development of process alternatives that will allow for the treatment of the current production, as well as the recovery and processing of material placed in underground storage.

Royal Oak believes that if technical and economic viability can be established, the removal of the arsenic bearing dusts from underground storage and conversion to a marketable product offers the best long term solution to the concern expressed with the long term storage of arsenic trioxide at the Giant Mine.

1.2 Project Description

Current operational practice at the Giant Mine is to pneumatically convey the arsenic bearing dusts to an underground storage location.

It is desirable to replace the practice of underground storage, with above ground storage methods for current production, in anticipation of the development of an economic process and the commissioning of a new processing plant. This plant would treat the stored material, plus normal daily production, into a marketable form.

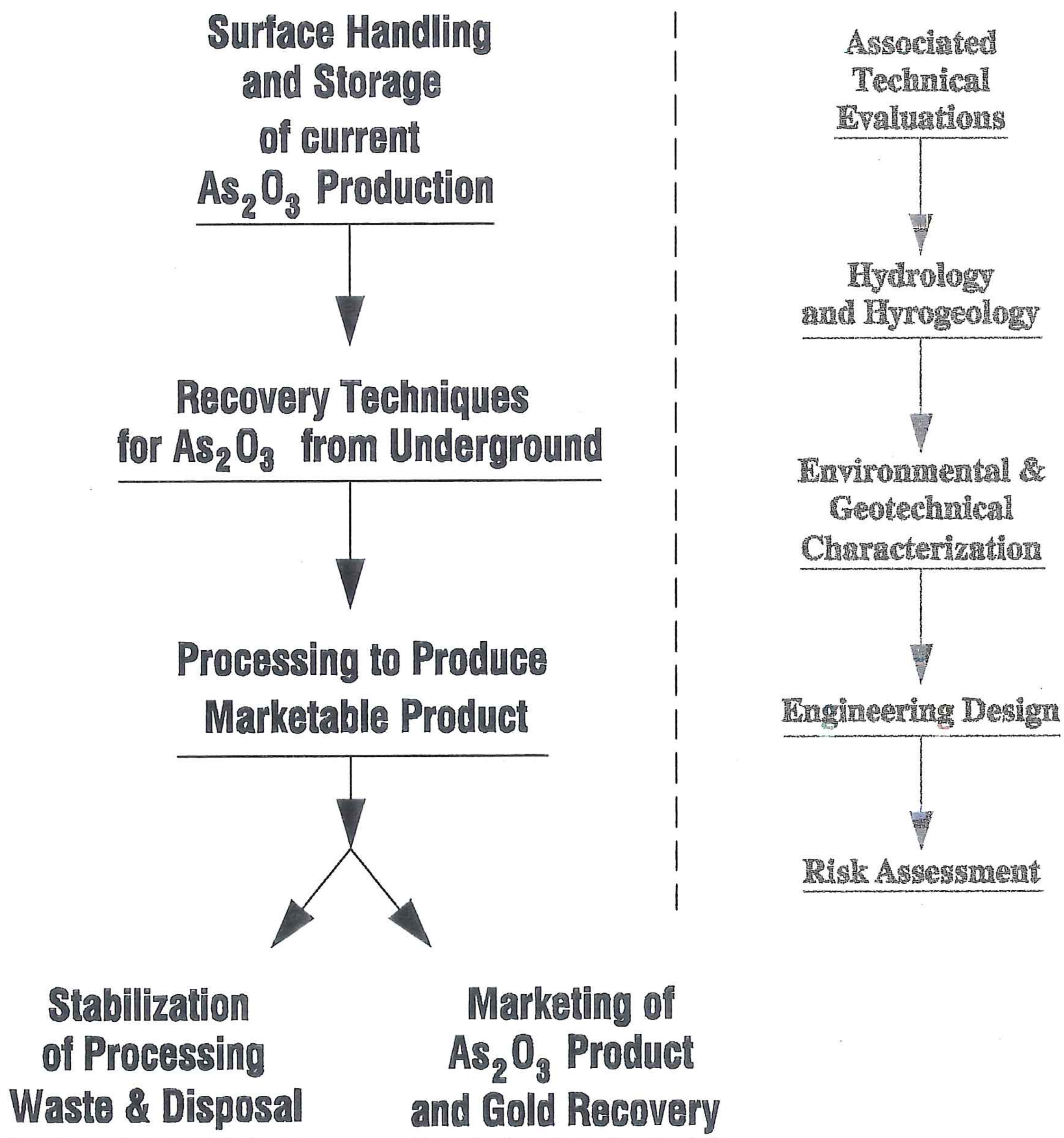
This project deals primarily with the technical and environmental issues related to the surface handling and storage of the arsenic bearing dusts. These issues will be treated separately from the mining, new process plant and off site transportation concerns. If technical issues can be resolved and environmental risk can be mitigated, then work could proceed on construction of these surface storage facilities. Consideration of this element of the project is an initial step in the implementation of a new management strategy for the ultimate recovery and disposal of this material. An outline of the Arsenic Trioxide Management Plan is presented as Figure 1.

Materials handling design is underway and will incorporate many of the successful operating techniques derived over many years of operation. These will be described in this document. Consideration is being given to minimum re-handling and reducing exposure by keeping the system confined to a minimal area.

Surface storage arrangements are being examined, with the following basic containment systems available:

1. Bulk storage tanks
2. Large (1 tonne) bulk bags or drums stored in buildings

ARSENIC TRIOXIDE MANAGEMENT PLAN



Royal Oak Mines Inc.		
ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT		
TITLE: ARSENIC TRIOXIDE MANAGEMENT PLAN		
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Figure 1		

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In the case of bulk storage tanks, the possibility of utilizing the existing tanks at the TRP plant is under investigation. The construction of new tanks, specially built for this application, and located close to a potential new plant site is also being considered.

The opportunity to use bulk bags or drums for storage purposes is currently being examined and may present disadvantages due to the complexity of handling the number of bags / drums and breakage / life expectancy issues.

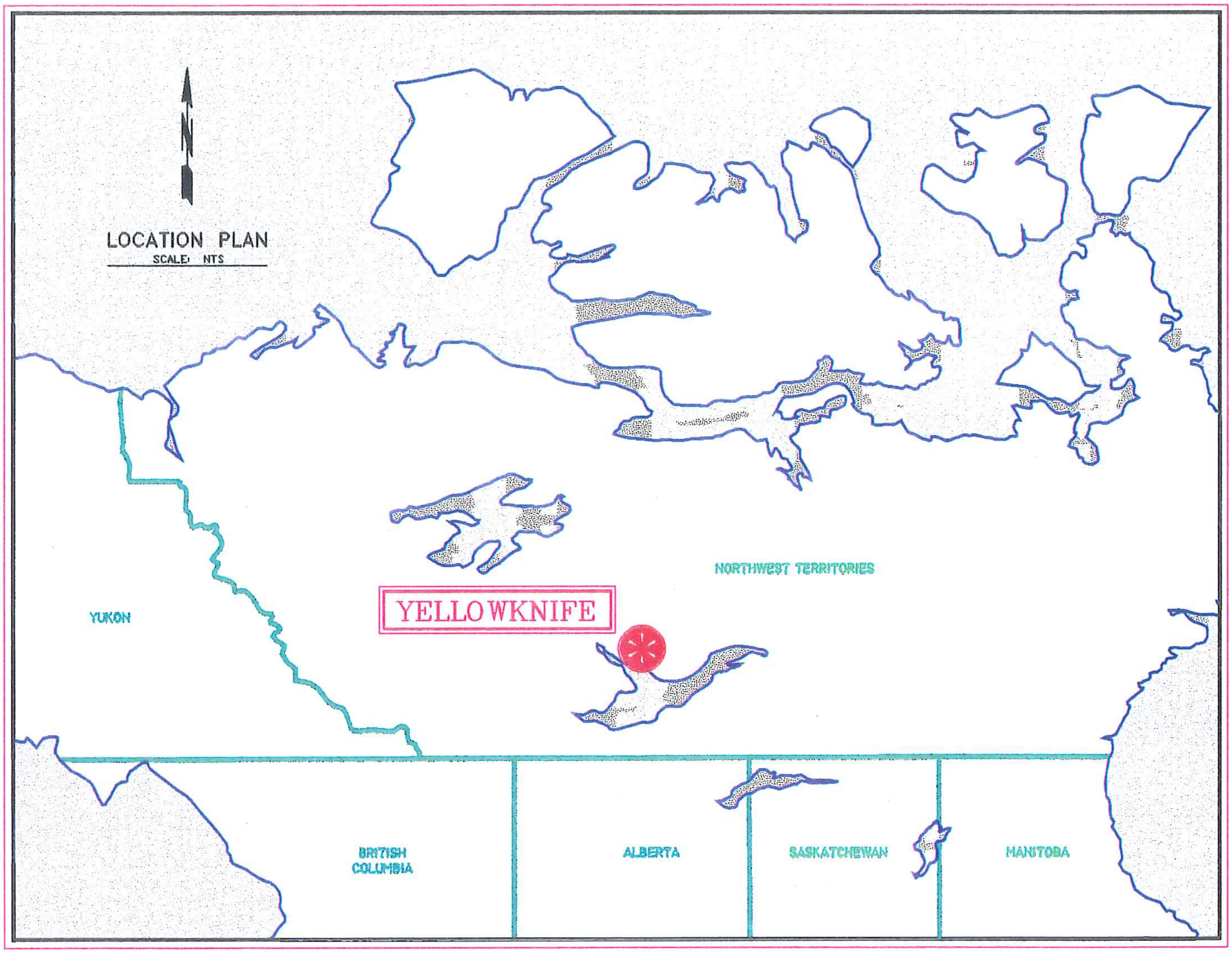
Mining methods have been investigated which will allow recovery of a large portion of the material in the storage chambers. These methods and associated handling arrangements will be briefly described in this document. These methods relate directly to the surface storage and handling issues as material will be brought to the surface for temporary storage, which will allow for surge capacity and blending of the feed to the plant.

The methodology to be used for risk assessment will be described.

1.3 Site Description

The Giant Mine Site is situated approximately five kilometres north of the City of Yellowknife, adjacent to Great Slave Lake along the western shore of Yellowknife Bay (Figure 2). The mine is situated within a zone of discontinuous permafrost and the local topography is characterized by a series of exposed bedrock highs with minor overburden deposits. The site is located within a northerly trending valley, at an approximate surface elevation of 1830 metres (mine datum), with prominent topographical highs forming the valley walls. Baker Creek flows southerly toward Yellowknife Bay along the valley floor.

The mine has been in operation since 1948, following the discovery of gold within the country rocks. The mine has produced over seven million ounces of gold since the initial discovery. The Giant Mine is located within the structurally complex Yellowknife Greenstone Belt of Archean Age on the



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

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Figure 2

geological time scale. The belt extends from Great Slave Lake for a distance of over 50 kilometres. and is comprised of a homoclinal steep easterly to vertically dipping sequence of metabasalts and metagabbros intruded by sheeted dykes and overlain by sedimentary units. The package of rocks was subsequently intruded by granitic intrusions.

Gold mineralization is present within the metabasalt units, of the Kam Group, associated with arsenopyrite mineralization. The rocks have undergone middle greenschist to middle amphibolite facies metamorphism. Arsenopyrite is a naturally occurring arsenic bearing mineral. The gold mineralization is refractory meaning that the arsenopyrite mineralization must be broken down and oxidized to allow the recovery of the gold.

The Yellowknife Greenstone Belt is a structurally complex sequence of rocks. Three prominent fault trends exist within the Giant Mine; 000 to 025° , 060° , and 160°, with the main structural features known as the Town site Fault, the 3-12 Fault, and the West Bay Fault. The 160° faults are prominent faults with variable easterly dips and are characterized by clay fault gouge and breccia. The sense of movement on these faults is sinistral. The 060° faults are generally characterized by having little or no clay gouge and may appear as thin hairline fractures. The sense of motion on these faults is dextral and they dip to the west. Faults with the 060° trend may occur as major faults or appear as lesser faults. Water seepage into the mine generally occurs along the major fault zones.

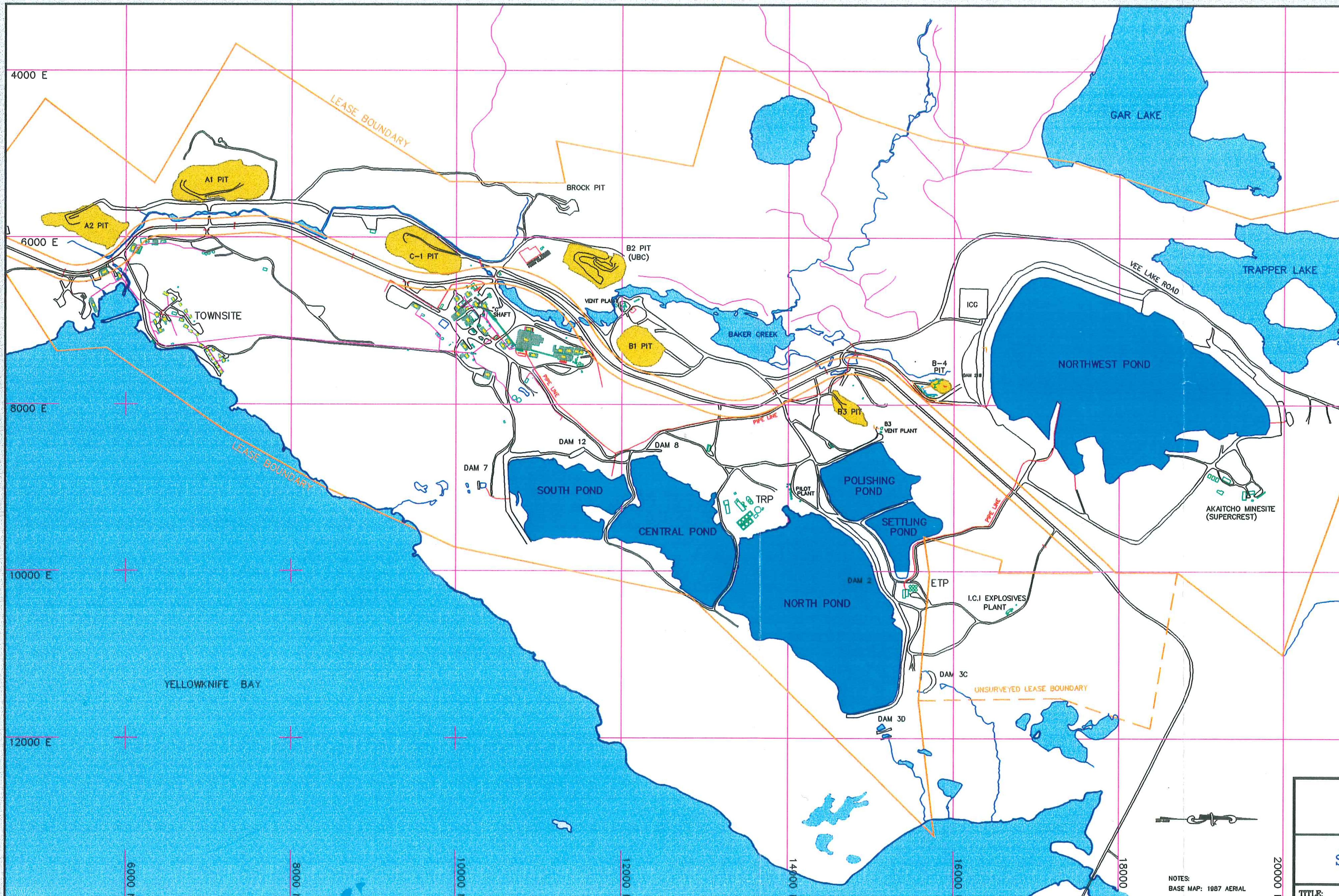
Hydrogeologically, the Giant Mine is situated within a complex zone with the overall groundwater regime predominantly controlled by the regional topography and structural trends present. Groundwater movement will occur predominantly as fracture flow, as is evidenced from observations noted within the mine workings. The mine currently produces approximately 1.5 litres per second (i.e. 400 igpm) of water which is collected and discharged to the tailings pond for seasonal treatment.

The Giant Mine is operated primarily as an underground mine, at an approximate production rate of 1100 tonnes/day. Several inactive open pits are also present on the site. The ore body has a strike length of over 4500 metres and is currently accessed through a main production shaft and two ramp systems. Mining is principally by mechanized cut and fill methods.

The mine site infrastructure consists of several buildings which are required for the production of gold. Included within the infrastructure are the mill, several office buildings, the mine headframe, and various buildings housing support service such as engineering, carpentry, and mechanic shops. Waste produced by the mining operation is deposited in two tailings impoundments, the Northwest Pond (primary) and the North Pond (secondary). There are also two additional ponds which are used for water treatment purposes, the Settling and Polishing ponds. All effluent discharge is treated in a plant then passed through the two ponds before final release to the environment (i.e. Baker Creek). A detailed site description is provided as Figure 3.

1.4 Historical Information on Arsenic Trioxide Management

Arsenic trioxide dust is currently produced at the Giant Mine at an approximate rate of 11 to 13 tonnes per day as a by product of the gold milling operation. The arsenic trioxide dust is produced when arsenopyrite is physically broken to recover the refractory gold mineralization and the contained arsenic and sulphur mineralization is removed. The conversion process employed at the Giant Mine consists of high temperature roasting of the arsenopyrite concentrate from the flotation circuit. The arsenic is volatized and oxidized into arsenic trioxide which is recovered from the roaster gas stream in a conventional baghouse dust collector. The baghouse dust is then pneumatically conveyed into underground storage areas/chambers. The underground storage for arsenic trioxide dust was first initiated in the early 1950's with the arsenic placed in abandoned mine stopes fitted with concrete bulkheads. With the continued storage of arsenic underground, specifically designed storage chambers were constructed. Currently there are a total of fifteen storage stopes and/or chambers.



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

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Figure 3

Transportation of the arsenic trioxide dust occurs by pneumatic conveying of the material through a standard 100 millimetre (four inch) diameter pipeline from the baghouse to the underground arsenic storage location. The air used to transport the dust is returned via a parallel 150 millimetres (6 inch diameter) pipeline and is vented into the baghouse inlet flue. This transportation system is therefore a closed system.

Since the first production of arsenic trioxide dust, Giant Mine has constantly re-evaluated and updated its arsenic disposal practices to ensure adherence to existing regulations and to maintain the practice of environmentally acceptable disposal methods using the best available technology of the day. With the implementation of underground arsenic storage at the site in the 1950's, the Giant Mine was recognized as providing " an environmentally sound disposal concept" which was readily accepted by the regulators of the day as being progressive. With a better understanding of arsenic chemistry over the past ten to fifteen years, it has become evident that the continued practice of underground arsenic storage was not a completely risk free disposal method.

Arsenic management plans subsequently developed for the Giant Mine in the early 1990's, as a component of the mine's abandonment and restoration plan, called for the arsenic trioxide material to be left underground in the storage areas as a final disposal procedure. The arsenic storage areas would then be isolated by bulkheads and permanently frozen to minimize the potential for the material to leach into the groundwater.

Four potential options for the permanent abandonment and closure of the underground arsenic storage chambers were initially reviewed in 1993. These various options included:

1) use of winter air by means of forced circulation to enhance the re-establishment of the permafrost in the vicinity of the storage areas.
2) use of additional or secondary bulkheads to isolate the storage chambers from the groundwater regime.
3) use of grout curtains to isolate the storage areas from the groundwater regime.
4) creation of artificial ice plugs behind the bulkheads to enhance the isolation of the storage chambers from the groundwater regime.

The technical feasibility of these preceding disposal options were evaluated and the potential arsenic abandonment options considered to be viable were upgraded in 1994 to include the options of;

1) leave the baghouse dust in place in the underground storage chambers and use winter air by means of forced ventilation to enhance the re-establishment of the permafrost in the vicinity of the storage chambers.
2) leave the baghouse dust in place in the storage chambers and continue to depress the groundwater table by pumping so that no groundwater comes into contact with the stored material.
3) leave the baghouse dust in place in the underground storage chambers and create a preferential pathway for groundwater to move around the arsenic storage chambers
4) the removal of the arsenic trioxide from the underground storage chambers.

It was recognized that each disposal option offered disadvantages as well as advantages. The following document focuses on the implementation of option #4. The other three options are also currently being evaluated by Royal Oak Mines Inc., and will be discussed separately.

The existing " Arsenic Trioxide Management Plan" currently implemented at the Giant Mine is comprised of the following components;

1) ensure the long term objective of preventing the untreated release of arsenic trioxide to the environment is achieved.
2) investigate the technical and economic viability of recovering the arsenic trioxide dust from the underground storage areas, and bringing it to the surface where it would be upgraded or processed into a marketable product. This work is focused on three primary areas;

   -development of mining techniques to safely and effectively recover the arsenic trioxide dust from the underground storage areas and transport the dust to surface storage facilities.
   - development of economic process technology to upgrade the arsenic trioxide dust into a refined arsenic trioxide product suitable for sale.
   -analysis of the current market status and the outlook for world supply for an upgraded arsenic trioxide product.

3) provide a detailed proposal suitable for environmental assessment, for the permanent removal or securing of the arsenic trioxide currently stored underground at the site.
4) complete the development of the appropriate technology, obtain the necessary environmental and regulatory approvals and construct and commission the appropriate facilities.

2.0 PROJECT COMPONENTS

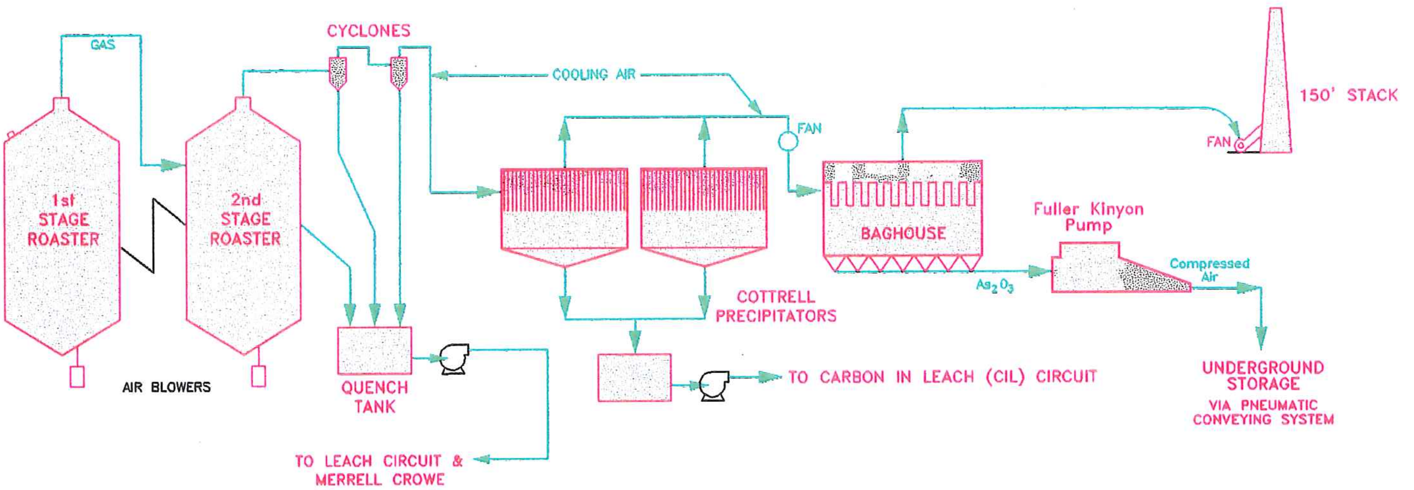
2.1 General

Royal Oak Mines Inc., proposes to implement a surface handling and storage system for future production of arsenic trioxide dust, as an alternative to the existing underground storage system. The proposed system is designed as a short term solution to replace the existing underground storage system until the commissioning of a re-processing facility, and to provide surge utilization for the facility . The arsenic trioxide stored above ground would then be re-processed through a selective processing system designed to recover gold mineralization associated with the material and to convert the dust into a marketable product. The re-processing of the surface stored material would be supplemented by the recovery of underground stored arsenic trioxide, thereby achieving the desired removal of the material from its existing underground storage locations.

As a component of the proposed study, a detailed discussion of the existing operation of handling arsenic at the mine site will be presented. This information will be used to provide background information for the proposed implementation of surface storage of arsenic trioxide. Various options for the potential storage location and method of storage will be presented including a discussion of potential reprocessing options. The evaluation will also include an economic analysis of the various storage and processing options as well as an evaluation of the potential risks associated with the proposed storage location (i.e. risk assessment). The risk assessment will incorporate all the data and information collected in a comprehensive evaluation of the potential human and ecological risks associated with the above ground storage of arsenic trioxide.

2.2 Current Arsenic Handling Practices and Storage System

As discussed previously, arsenic trioxide dust is currently produced at an approximate rate of 11 to 13 tonnes per day at the Giant Mine, as a by-product of the gold milling operation. The arsenic trioxide produced is stored underground in storage areas or chambers. A flow sheet summary of the existing arsenic handling and storage system is presented as Figure 4.



ROASTER GAS FLOWSHEET

Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: EXISTING ARSENIC PRODUCTION AND STORAGE SYSTEM

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Figure 4

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As a component of its existing arsenic trioxide recovery and storage system, safety measures to minimize the potential exposure to arsenic have been implemented. These measures include the wearing of protective clothing, dusk masks and respirators and the implementation of regular testing to accurately measure a worker's exposure to arsenic.

2.2.1 Roaster/Baghouse Operation

The existing roaster installed at the Giant mine consists of a two stage Dorrco Fluo-solids roaster. This roaster currently operates with two Cottrell hot precipitators units in parallel, which handle the gases and dust from the roaster. After passing through the hot Cottrells, the roaster gases are air cooled to 230 degrees Celsius for arsenic fume condensation before entering the baghouse. Filtered gases from the baghouse continue on through a booster fan to a 45.7 metre (150 foot) brick discharge stack. The dust in the hot Cottrells is processed for gold recovery and the arsenic collected in the baghouse is pneumatically conveyed to underground storage.

The two Cottrell precipitators are type K, rod curtain units, each having two parts which operate in parallel. Each part has two sections in series, which have seventeen ducts formed by eight foot by 12 foot collecting curtains. The power supply (550 volts) is rectified by two mechanical units which transforms the voltage to 70,000 volts. Rapping hammers used to dislodge the dust from the electrodes, are time controlled on both wire and pipe curtain frames. The dust is collected in V-shaped hoppers below the Cottrells and is removed by screw conveyors to a quench tank from which it is pumped to a special treatment tank.

The baghouse for the collection of arsenic is an eight compartment, No. 30 Dracco type. Each compartment contains 300, five inch diameter by 10 feet Orlon bags. A shaking device (triggered by pressure drops across the filter) , is provided for dislodging the dust from the bags. Each of the two compartments is provided with a V shaped hopper and screw conveyor for the collection and removal of the arsenic. A cross collection conveyor and a Fuller-Kinyon pump is provided to transfer the arsenic to underground storage.

The gas volume leaving the roaster is approximately 20,500 c.f.m. at 840 degrees F. These gases are air tempered to a volume of 25,500 c.f.m. at 685 degrees F before entering the hot Cottrell. The temperature drop across the Cottrell is 130 degrees F. The average of ten tons of dust collected daily in the Cottrells contains 85 per cent of the gold in the roaster exit gases. Further air tempering at the mixing fan gives a volume entering the baghouse of approximately 56,000 c.f.m. at 230 degrees F. The dust product contains greater than 99% per cent of the arsenic content in the gases leaving the hot precipitator.

2.2.2 Pneumatic Conveying

Transportation of the arsenic dust produced by the roaster operations, is by pneumatic stowage-conveyance of the material passing through a standard 100 millimetre (four inch) diameter steel pipe from the baghouse building to the particular arsenic chamber being filled. The pipes are run underground in specially driven drifts used for this purpose only. These distribution drifts are isolated from the general mine workings. The pipes enter the chamber through the top of the engineered concrete bulkhead. In most cases there is more than one line of varying lengths entering the chamber. The longest line into a chamber is utilized first, filling from the back of the chamber towards the front. As the chamber fills, the lines are switched to each shorter line.

The air used to transport the dust into the chamber is returned by a parallel six inch diameter pipe and is vented back into the baghouse inlet flue. The system is therefore a closed system. Dust loss does not occur during transportation, as the only place for the dust to settle out of the transportation air bed is inside the chamber being filled.

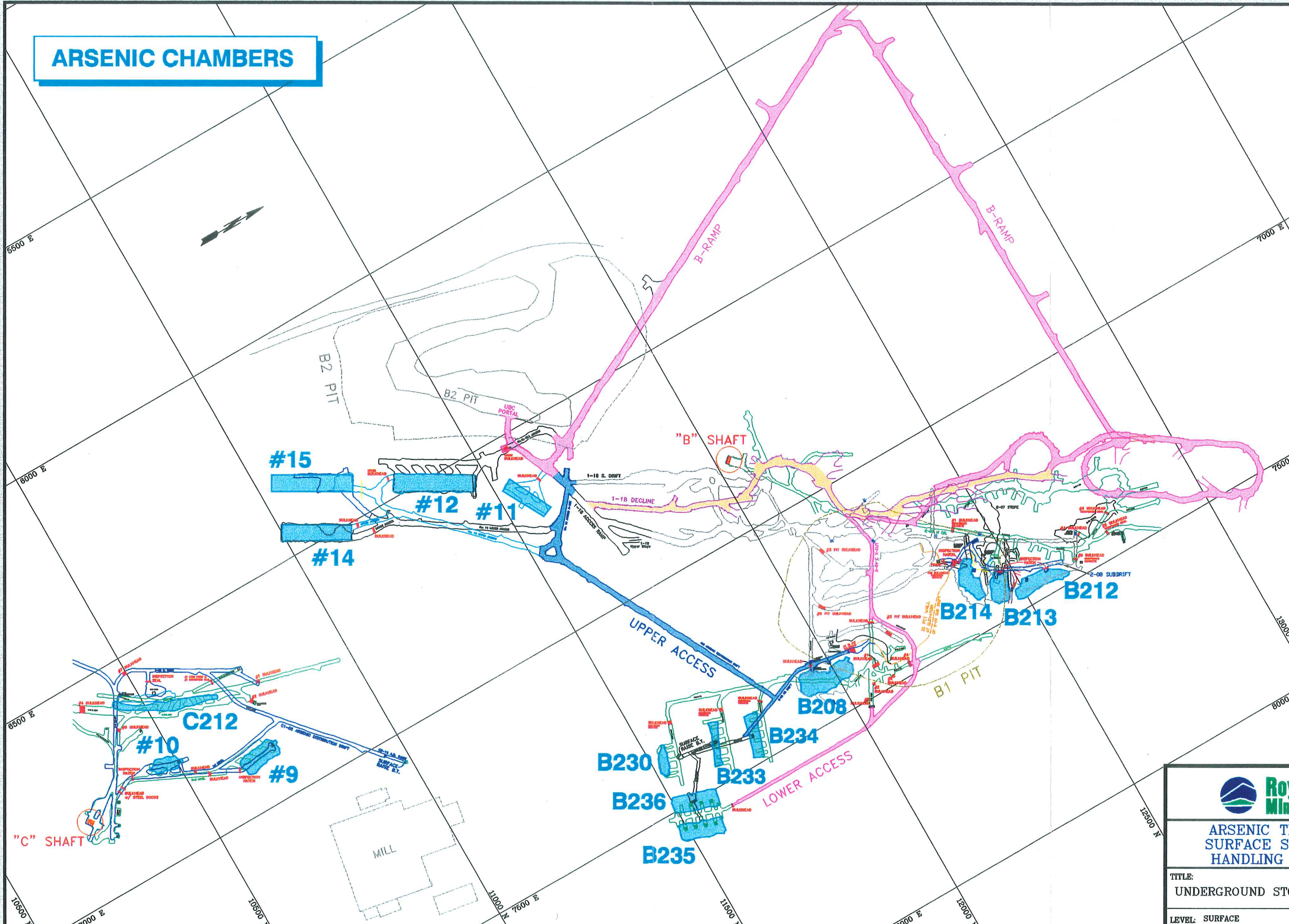
An approved back-up system of transporting the arsenic trioxide dust, is also in place at the mine site in the event of mechanical problems with the pneumatic transportation system. The dust can be pumped directly into the storage chamber from the surface via reamed long-hole drill holes or diamond drill holes. A vacuum or bulk delivery truck is used in the contingency program to transport the dust from the baghouse to the surface access points using the existing road network on the property.

A silo structure 425 cubic metres capacity (15,000 cubic foot), 8 metres (26 feet) in diameter by 17 metres (56 feet high), situated adjacent to the baghouse is also used for arsenic storage purposes in the event of a shut down of the underground pneumatic disposal system. The silo can store 10 to 15 days of baghouse arsenic trioxide dust at current production rates. The silo is maintained under negative pressure as air is displaced while it is filled. The air is drawn through a fabric baghouse type filter and returned to the roaster gas handling system. Precautions are taken to prevent any material leaving the silo and entering the loading equipment when a truck is not in position.

A screw conveyor transports the dust from the silo to the top of the trucks being loaded. An adjustable tight fitting loading spout mounted on the discharge end of the screw conveyor directs the product into the truck. Dust generated at this drop point is minimized by placing the truck tank and loading spout under negative pressure. Air and dust displaced during the loading cycle are drawn through the fabric baghouse type filter located on top of the silo and returned to the roaster gas handling system.

2.2.3 Underground Arsenic Trioxide Storage Chambers

Currently there are 15 underground storage chambers, including the active B-14 storage chamber (Figure 5). The storage areas contain approximately 260, 000 tons of dust containing approximately 200,000 tons of arsenic trioxide. The underground storage of arsenic was initiated in October 1951 and continues to the present day. The current arsenic storage chambers are specifically designed storage chambers, rectangular in shape, with the first chambers comprised of mined out ore chambers of irregular shape. The minimum thickness of the rock between the top of the storage chambers and the surface varies from 9.1 metres (30 feet) to 57 metres (188 feet) with an average thickness of approximately 24 metres (80 feet). Each of the storage areas is isolated from the mine workings by a concrete bulkhead. It is noted that the earlier storage areas contained wooden bulkheads. These areas have all been upgraded with the addition of concrete bulkheads. All bulkheads have been



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: UNDERGROUND STORAGE LOCATIONS

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Figure 5

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designed to withstand hydrostatic pressures.

The design of the storage chambers considered the following criteria:

-the chambers were to be located and enclosed in an envelope of permafrost.

- the openings were to be sealed to prevent the escape of arsenic trioxide dust.

- the storage areas were to be excavated in competent ground and the storage area was to be dry before arsenic storage commenced.

The fifteen arsenic storage chambers are grouped into four specific groupings, representing the various years in which disposal occurred. The first set of groupings include the earliest chambers used and hence the location of these chambers are in the direct vicinity below the baghouse and roaster stack. This grouping is composed of the oldest chambers and include chambers numbers B2-08, B2-30, B2-33, B2-34, B2-35, and B2-36. The second grouping is located just north/east of the mill, under or adjacent to the B-1 pit and is comprised of chambers B2-12, B2-13, and B2-14. The third grouping consists of chambers B-9 and B-10, and C2-12 and is located southwest of the mill. The final and fourth grouping includes the most recently developed storage chambers, B-11 to B-15. The location of these chambers is west of the mill on the west side of Baker Creek under a local topographical high.

The majority of the arsenic storage areas are currently accessible through existing workings. However, storage areas B2-12, B2-13, and B2-14 are isolated from the mine workings and are not accessible following the mining of the B1 Surface Pit. In addition, access to chambers B2-30 and B2-34 are through surface raises which are currently unaccessible.

It is noted that storage chamber B-15 is currently under development, with the storage capacity of B-14 expected to be reached by July 1998.

Various studies have been implemented by the staff at the Giant Mine with the objective of evaluating the long term stability of the stored arsenic trioxide underground. Storage chambers B-14 and B-15 were evaluated in 1996 for structural features that may contribute to the potential groundwater migration of the arsenic trioxide. Five diamond drill holes were collared within the lower sill of the storage chamber B-15 to assess the rock competency and to locate any major structural features near the chamber. Evaluation using RMR (rock mass rating), Q (flow), and RQD (rock quality designation), indicate rock of good quality.

Storage chambers B-11, B-12, B-14 and B-15 are located within the greenstone belt of meta-volcanic rocks. the composition of which varies from a dacite to a basalt. Additionally, historical data indicates that storage areas B2-30, B2-33, B2-35, B2-36, B-9, and B-10 are located within massive basaltic volcanic flows containing minor chlorite schist zones.

Chambers B2-08, B2-12, B2-13, B2-14, and C2-12 were formerly high grade ore chambers. The mineralization and ore zones in these areas were characterized as broad zones of silicification and/or quartz carbonate veining with disseminated sulphide mineralization. The mineralization is hosted within a shear zone with the lithology varying from a chlorite schist to a sericite schist.

Royal Oak Mines is currently evaluating the potential of developing a joint cooperative hydrogeological study with the Department of Indian Affairs and Northern Development. The objective of this proposed study would be to obtain a better understanding of the complexities of the existing bedrock aquifer associated with the mine site. It is anticipated that the study would also provide data which would enable a further comparison and evaluation of the potential risks associated with the underground storage of waste materials and the proposed above ground storage method.

2.3 Proposed Surface Handling Practice and Storage System

Royal Oak Mines Inc. proposes to implement a surface handling and storage system for the future production of arsenic trioxide dust, as a potential alternative to the existing underground storage system. The proposed surface storage system would be implemented as a first step, until an arsenic trioxide re-processing option is selected and the appropriate infrastructure constructed. A flow diagram depicting the proposed arsenic storage system is presented as Figure 6.

Safety measures to be implemented with the proposed arsenic surface storage system will be thoroughly evaluated with respect to new technology, the results of the risk assessment, and experience with existing handling procedures. The safety measures will be designed to minimize exposure of the workers to arsenic trioxide dust and to prevent unexpected release of arsenic to the environment.

2.3.1 Roaster /Baghouse Operation

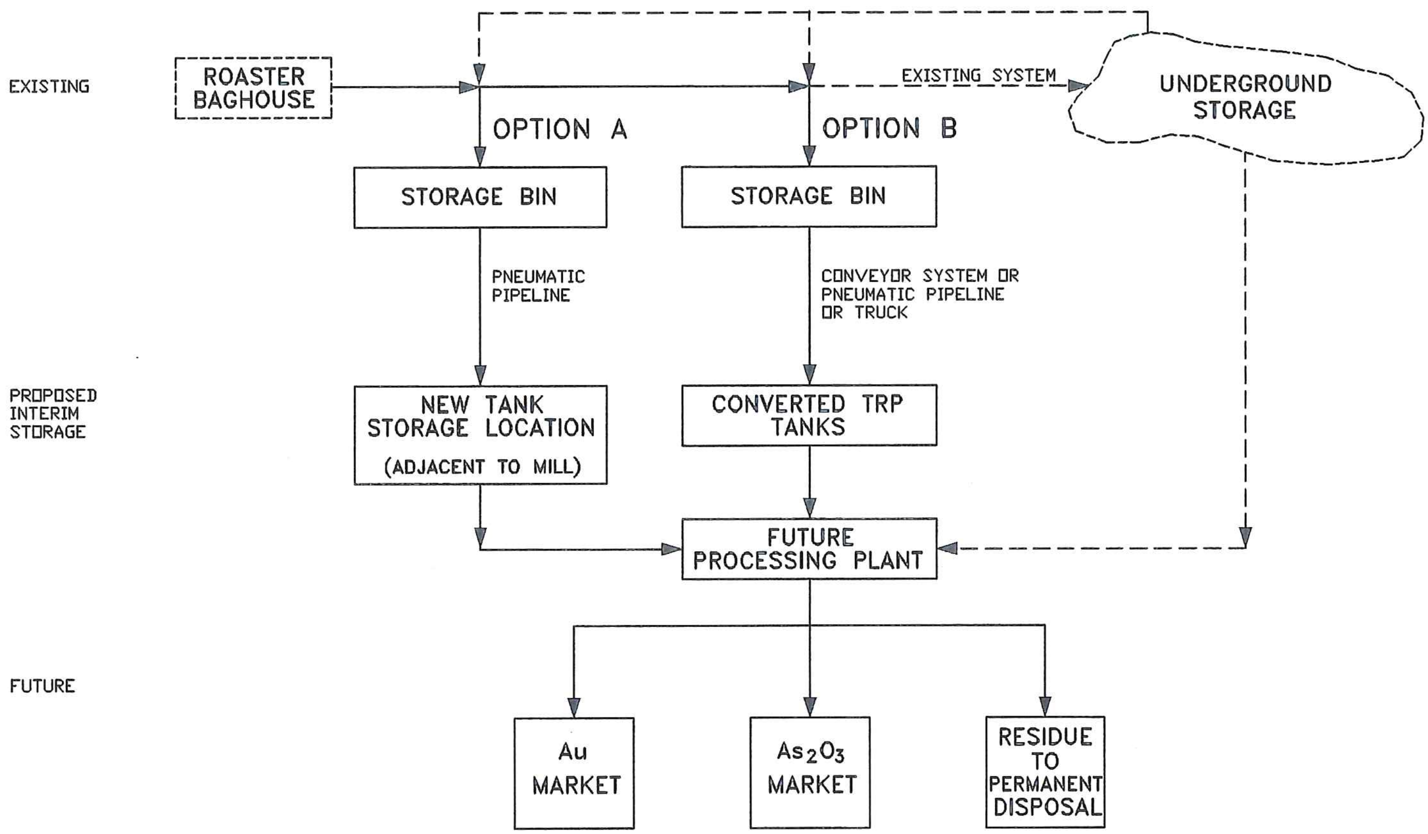
The current roaster/baghouse operation will remain unaffected with the implementation of a surface method of arsenic trioxide storage. The processing of the ore and the resulting off gases would continue to operate in the same manner as described previously. The only difference with the two systems would be the ultimate disposal location of the arsenic trioxide waste material.

2.3.2 Handling Options

With the implementation of a surface arsenic storage facility various handling options to transport the arsenic trioxide to the selected disposal site will be evaluated. The various transportation modes currently being evaluated include the following;

a) pneumatic transport
b) conveyor belt system (closed)
c) trucking or vehicle transport
d) slurry pumping

The transportation options will be assessed with the selection process based on the waste material storage location (i.e. distance from the baghouse, etc.), the degree of risk associated with each transportation option and ultimately the cost and economics of implementing the various transportation modes.



BASED ON WESTMAR CONSULTANTS INC. DWG. #77007-SK-004

Royal Oak Mines Inc.

ARSENIC TRIOXIDE –
SURFACE STORAGE &
HANDLING PROJECT

TITLE: PROPOSED ARSENIC DUST HANDLING		
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Figure 6		

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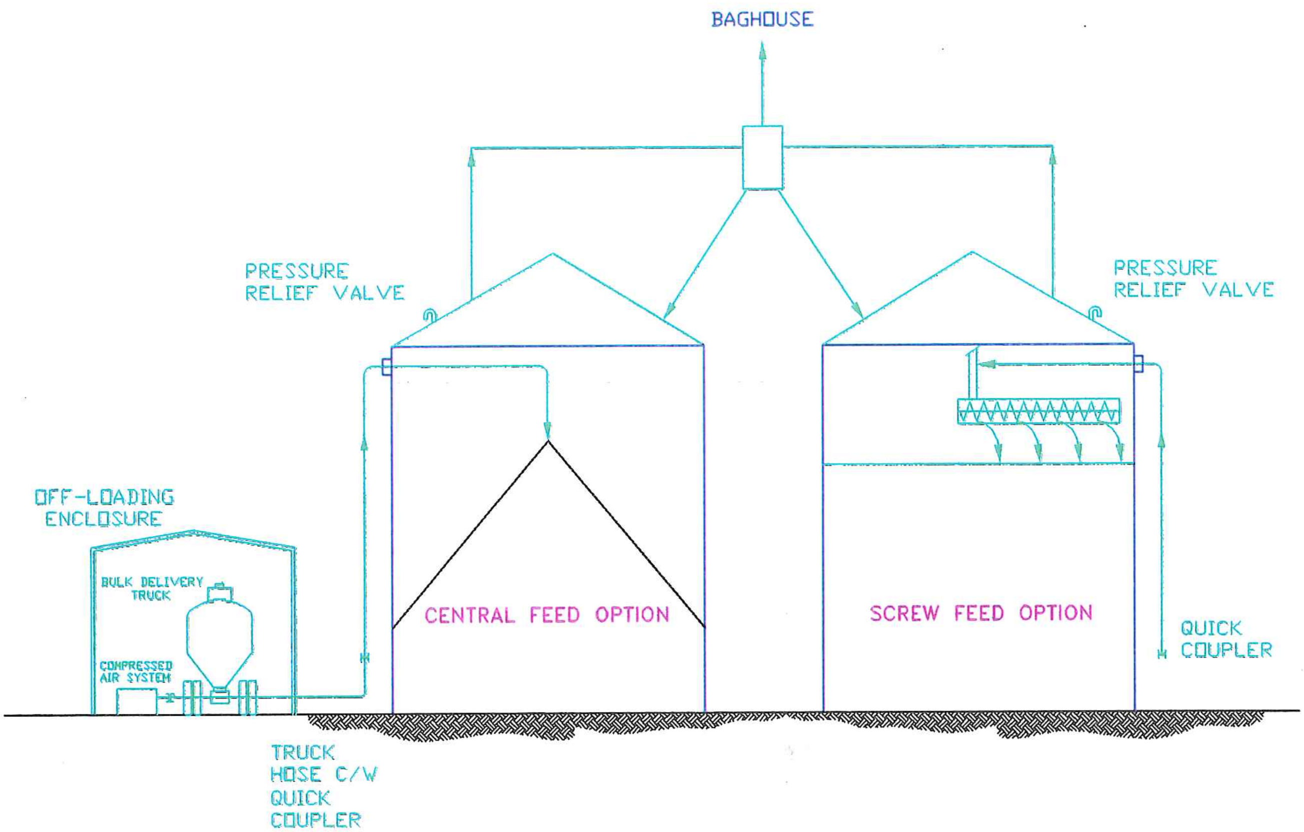
2.3.3 Storage Options

As with the discussion of various potential transportation modes of the waste material to a selected disposal site, various options for the surface storage of arsenic are under evaluation. The material could be stored in drums or bags, in the decommissioned TRP tanks, or in a facility constructed specifically for that purpose.

Storage in bags or drums is potentially cheaper in the short term but may result in a hazardous material disposal problem once they are emptied. There may also be concerns about integrity of the system.

Construction of a new facility is potentially expensive but may offer the best solution in regards to addressing potential containment concerns. Modifying the TRP tanks (adding sealed roof, containment measures, developing add-on materials technology) may be the most attractive solution on the basis of economics. The tanks were not designed for this purpose, therefore structural analysis and material testing is underway to determine the mechanical and chemical suitability for storage of arsenic trioxide dusts.

Transferring the arsenic trioxide into storage tanks is not anticipated to be technically difficult. Any process to remove the material from the tanks would encounter similar difficulties to those encountered during removal of the material to surface and is considered more technically challenging. Several options are currently under evaluation, including rotating screw conveyors and articulated or telescoping vacuum arms. Diagrams outlining potential transfer and removal technologies that could be implemented with the TRP tanks should this location be selected as the storage location are presented as Figures 7 and 8.



EXISTING STORAGE TANKS – RETROFITTED

BASED ON WESTMAR CONSULTANTS INC. DWG. #77007-SK-004

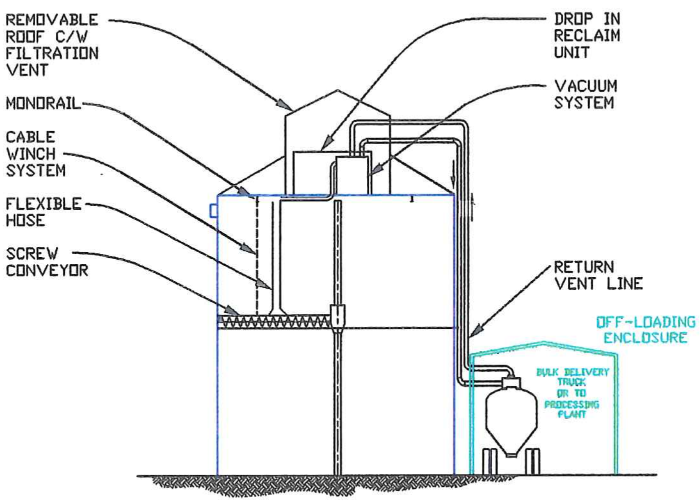
Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: TRP ARSENIC STORAGE TANKS– LOADING TO TRP ARSENIC STORAGE TANKS		
LEVEL:		SCALE: 1"= NTS
DRAWN: MSL	CHECK:	DATE: DEC. 9, 1997

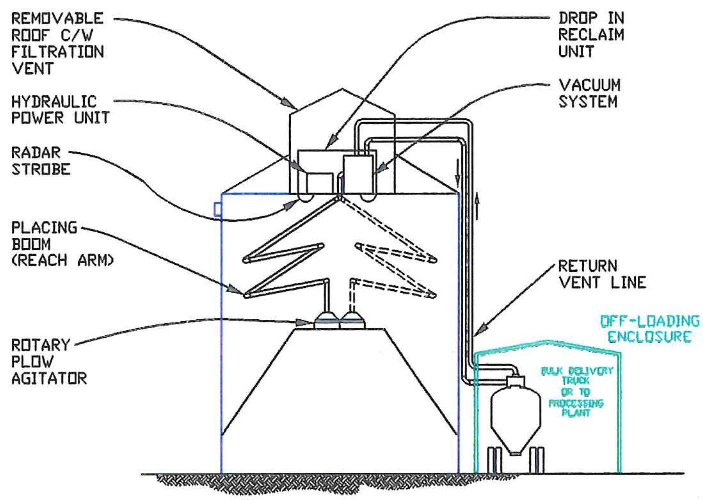
File Name: MASTER\ARSENIC\TRPTANK2.DWG

Figure 7



EXISTING STORAGE TANKS – RETROFITTED

OPTION 1



EXISTING STORAGE TANKS – RETROFITTED

OPTION 2

BASED ON WESTMAR CONSULTANTS INC. DWG. #77007-SK-004

Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: TRP ARSENIC STORAGE TANKS– RECLAIM FROM TRP TANKS			
LEVEL:		SCALE:	1"= NTS
DRAWN: MSL	CHECK:	DATE:	DEC. 9, 1997

File Name: MASTER\ARSENIC\TPRTANKS.DWG

Figure 8

2.4 Metallurgical Process

Several options are being investigated for processing and upgrading of the arsenic trioxide at the Giant Mine. The objectives of the new process are:

- to upgrade the arsenic trioxide to a marketable quality, which includes lowering impurity levels to acceptable values.
- to recover gold values from the residue from the upgrading process.
- to provide a stabilization technique for the final tailings that must be disposed of at the site, either in a tailings pond or underground.

Royal Oak has an inventory of arsenic trioxide containing flue dust stored in underground chambers (> 260,000 tons). This material grades from 40 % to 90 % arsenic trioxide, and from 0.12 opt (ounces per ton) to over 2.00 opt gold. The product must be upgraded to >95% to meet market specifications. Antimony and iron, contained in the dust, are considered impurities, and the concentrations must be reduced significantly.

The primary use for the arsenic trioxide is in the wood preservative industry. The major markets are in the United States where the wood preservative industry would use the high grade arsenic trioxide as a feed source for copper chromated arsenite (CCA). CCA is recognized world wide as the most acceptable wood preservative product.

There are four processes that have been considered for producing this marketable product. They are hot water leaching, ammonia leaching, methanol leaching, and fuming.

Test work is ongoing at the Giant Mine laboratory, currently investigating the hot water leach and ammonia leach processes. Extensive modifications to the lab have taken place in order that this work can be conducted to the highest standards. It was decided to do the testing at Giant where the personnel are more adept/experienced at handling the material. This type of work had been conducted previously in the late 70's and then through the 80's at Giant.

2.4.1 Hot Water Leaching

This process is based on the solubility difference of As_2O_3 in hot water and cold water. Arsenic is dissolved in hot water to produce a saturated solution. The saturated solution is separated from the residue and cooled. As the solution cools, As_2O_3 crystallizes and is recovered.

The problems encountered with this process are dissolution of iron and antimony with the arsenic, and difficult solid-liquid separation of the saturated solution from the residue. Potential methods of separating arsenic and antimony involve differential chemistries of the two elements with respect to pH, oxychlorides, and complexes with sulfate, oxalate and tartrate ions.

Extensive testing was done at Giant in the 80's, which will shorten the current testing process. The technology is fairly well understood, especially with the experience at the Con Mine's arsenic plant which used this process, with relative success.

Current testing includes the following characterization:

- effect of residence time, water addition, and temperature
- baseline determination of crystallization using optimum conditions
- purification procedures

The probability of success using this processing approach is very high, assuming that the application of best available technology leads to a high quality product. Work on this process has been given high priority.

2.4.2 Ammonia Leaching

This process is based on the effect of the NH_4 ion on the solubility of As_2O_3. Ammonia solubility at 30° C hits a maximum at a molar ratio of 1 and falls to ½ when the molar ratio NH_4 / As is increased to 2. $NH_4\ AsO_2$ is precipitated by the added ammonia. The solution returns to the leach operation and the solids are either sold 'as is' or calcined to drive off NH_3, which is recycled.

Problems with this process are similar to the hot water process, including dissolution of antimony and iron with the arsenic and difficult solid-liquid separation of the saturated solution from the residue. Test work proposed includes methods to separate the antimony and arsenic utilizing the differential chemistries of the two elements. Test programs are underway and include a similar set of conditions and variables to the hot water process.

Additional problems with the use of this process are the handling and plant design problems related to using large quantities of this chemical. Final effluents may contain quantities of ammonia that cannot be effectively treated or destroyed to the extent to which a release to the environment would be allowable.

Previous test work at Giant, as well as current testing, indicates a low probability of success in implementing this process.

2.4.3 Methanol Leaching

This process is based on the solubility difference of As_2O_3 and Sb_2O_3 in methanol. Arsenic is dissolved in methanol, while antimony reportedly is not. This is due to a chemical conversion of the arsenic into a methanol compound. The saturated solution is separated from the residue and evaporated to recover the arsenic oxide. Off-gases are treated to condense and recover the methanol.

Questions exist with the solubility of arsenic, antimony, and other impurities in methanol, the ease of separating saturated solution from a residue, recovery of methanol, the arsenic circulating load in the methanol, and the effect of moisture in the feed.

Limited testing was performed at Lakefield earlier this year, the results were inconclusive. No further work is planned using this process, at this time.

It is suggested that the handling and safety issues related to this process will be difficult to overcome, and test work has not indicated that the process has significant advantages with respect to purification.

The probability of success using this system is considered to be low.

2.4.4 Fuming (WAROX)

This process is based on the boiling point difference between As_2O_3 (221°C), and Sb_2O_3 (1380°C). The flue dust would be heated to a point where the arsenic evaporates, leaving the impurities in the residue. Arsenic would be recovered by cooling the air, condensing the arsenic, and recovering the powder.

Test work in the 80's, including pilot plant work, resulted in questions on product purity and operational problems with the equipment. The process developed by Giant using this process was code named 'WAROX' for White ARsenic OXide. The material produced is extremely fine which creates a handling, and hygiene problem.

No further test work is planned although the previous experience and design are being investigated to see if there is potential to use this method, incorporating updated technology.

The probability of success using this method is high although technical issues remain to be solved.

2.5 Storage and Plant Site Locations

Two locations have been proposed as storage locations, as a component of the proposed arsenic surface management plan; Location A, adjacent to the existing mill and Location B, the existing TRP (Tailings Recovery Process) site. Each location is currently being evaluated by Royal Oak as a possible surface storage location at which a potential arsenic processing plant could also be located.

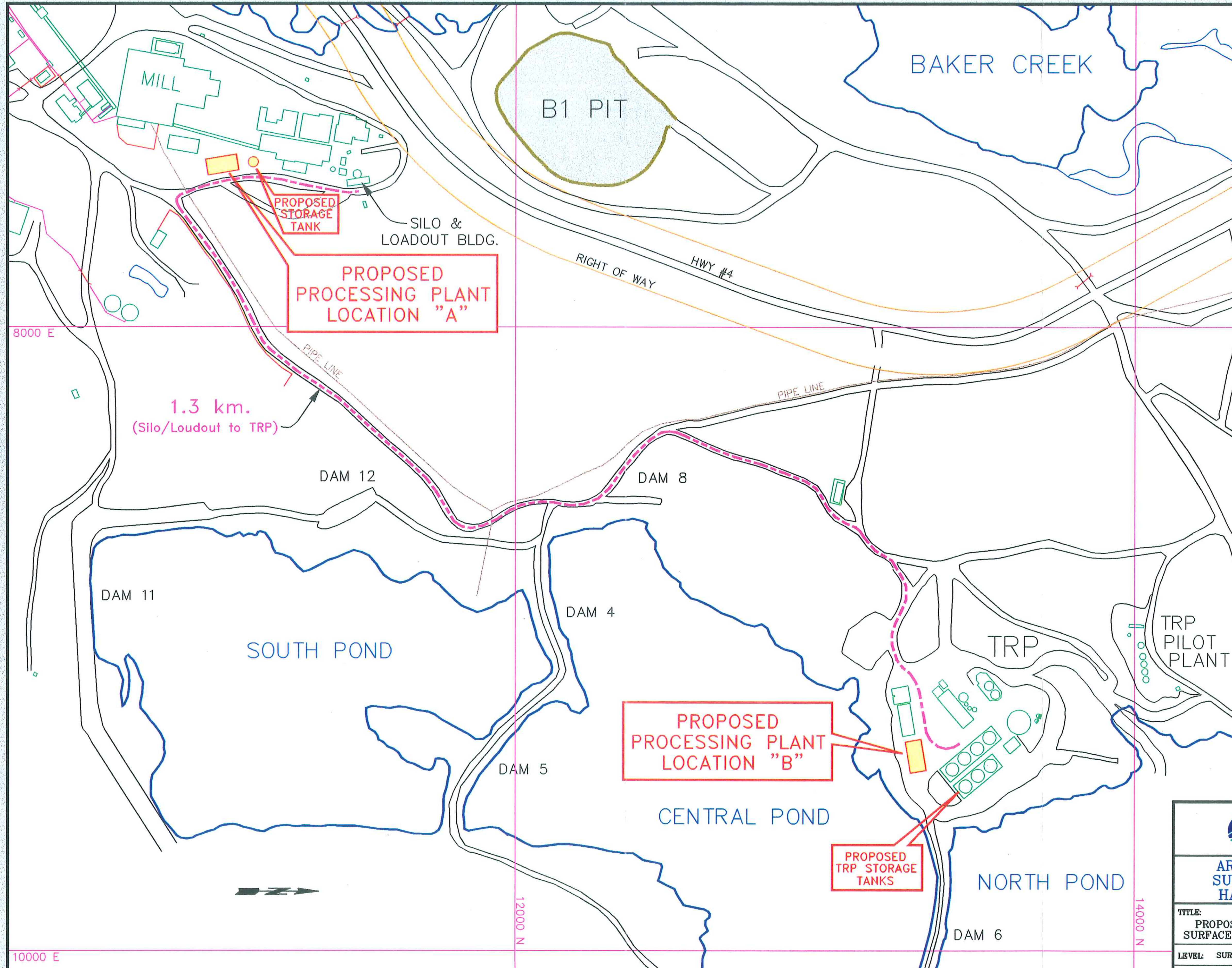
A site plan depicting the potential storage locations is presented as Figure 9. Included with the diagram is the footprint of a possible processing plant.

Location A consists of an area situated immediately to the east/southeast of the existing baghouse and roaster structures. The scenario currently being evaluated by Royal Oak would consist of the construction of a new storage facility, possibly a steel tank with approximate dimensions of 23 metres (75 feet) in diameter by 18 metres (60 feet) in height. This proposed tank would provide approximately one to two years storage capacity of arsenic trioxide. Additional tanks as required by timing related to the process development and dust production may be added. Other potential storage facility structures such as a warehouse or a concrete bunker may also be evaluated as a component of the proposed study.

The mill location would offer many practical advantages including accessibility to the mill/roaster and existing underground storage chambers, potential ease of transport for the arsenic trioxide dust once it was present on the surface, and would be relatively non intrusive. As current facilities do not exist at this location, a new containment structure would have to be constructed. The construction would allow for the installation of technologically advanced containment measures such as the installation of an liner designed to prevent migration of contaminants into the underlying overburden and bedrock.

The chief disadvantage of this location may be the cost of constructing a new containment facility as compared to upgrading other existing facilities for the storage of arsenic trioxide. A potential further disadvantage is the relative proximity of Baker Creek as compared to the proposed TRP site.

The TRP site is the second option currently under review by Royal Oak as a potential location for the surface storage of arsenic trioxide. The plant is located approximately 1.5 kilometers north of the Giant Mine Mill, immediately adjacent to the North Pond tailings area. The TRP is situated on a local topographical high at an approximate elevation of 1860 metres (mine datum). The TRP was commissioned in 1989 and operated for two seasons, as a reprocessing location for tailings. The



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: PROPOSED PROCESSING PLANT AND SURFACE ARSENIC STORAGE LOCATIONS	
LEVEL: SURFACE	SCALE: 1"= NTS
DRAWN: MSL / CHECK:	DATE: DEC. 5, 1997

Figure 9

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plant operations ceased due to economic and technical reasons. Access to the site is provided by gravel covered roads which are maintained by mine site personnel and roughly parallel the Ingraham Trail (Highway No.4).

The TRP site covers an approximate aerial extent of 3.2 hectares and consists of an office complex, a cold storage building, a treatment plant with water storage tanks, and a thickener. A tankfield consisting of seven tanks, approximate capacity of 2900 cubic metres, that were used to leach gold from the tailings slurry, is present. The tanks are situated in two rows, one row of four tanks and a second row of three tanks. Each of the two rows of tanks are enclosed by a concrete berm approximately 0.5 metres in height. The tanks are constructed on an engineered fill base with no containment measures implemented to prevent migration of spilled fluids into the overburden and exposed bedrock.

The overburden at the site consists of approximately 1.5 to 2.0 metres of sand and gravel fill overlying the bedrock. Bedrock exposures (consisting of mafic volcanic rocks) are predominant in the area immediately surrounding the TRP.

Royal Oak is currently evaluating the potential of utilizing the existing steel storage tanks situated at the TRP for the surface storage of arsenic trioxide. The arsenic trioxide dust would be recovered from the existing baghouse structure located at the mill and transported to the TRP site via one of the transportation options currently under evaluation. The dust would then be pneumatically off loaded into the steel tanks for storage. The storage capacity of the steel tanks is estimated at approximately three years at the current rate of production for arsenic trioxide (i.e. 11 to 13 tons daily). The suitability of the steel tanks for the storage of arsenic trioxide is currently being evaluated by Westmar Consultants located in Edmonton Alberta.

The selection process for determining the location for the surface storage of arsenic trioxide will be based on a process which will evaluate the potential impacts and perceived risks associated with human health and the environment and on overall economical considerations.

The selected storage site will be thoroughly evaluated as a component of determining potential environmental impacts and the completion of a risk assessment study, the results of which will be presented in the Environmental Screening Document. The physiographical and ecological conditions at the selected site will be described in detail. These descriptions will include a review of the regional and local meteorological , hydrological, hydrogeological, geotechnical, and geological conditions associated with the site. The identification of "baseline" environmental conditions associated with the selected site will also be determined prior to the construction of new facilities or the rehabilitation of pre-existing structures. Where data gaps exist, field studies will be evaluated and implemented to acquire the data.

2.6 Recovery of As_2O_3 from Underground Chambers

Arsenic trioxide dust is a byproduct of ore processing at Giant and has been stored underground since the 1950's. Abandoned production chambers as well as specially excavated storage chambers have been used for the storage of more than 260,000 tons of the dust to date. Figure 5 shows the locations of the chambers relative to other surface and underground installations and facilities. There are a total of 15 storage chambers.

The goals of the arsenic trioxide dust mining recovery program are:

- to recover the material to process for arsenic and gold revenue
- to empty the chambers that were production chambers so as to recover remnant ore adjacent to or closely located to the chamber
- to neutralize remnant materials, not recoverable by mining, for permanent disposal

As part of the development of this mining program a test chamber has been considered to evaluate methods of recovery from underground to a surface storage location or a process plant. Design restrictions include materials handling, worker safety and hygiene, and environmental contamination.

2.6.1 Material Quality and Characteristics

The stored material has variable physical properties but can generally be categorized into one of the following:

- dry and dusty (similar to processed flour)
- dry and compacted
- damp and compacted

In 1981, Geocon Inc. conducted a program of recovery and materials testing of the material in the underground chambers. The program involved drilling into seven of the chambers and recovering material from various horizons within each chamber. The material was found to have densities ranging from 41.6 to 91.9 lb/cu.ft., and moisture contents ranging from <1% to 6.4%.

2.6.2 Mining Methods

In addition to the variable physical properties, the condition of the storage chambers varies. Some of the chambers were specifically excavated for dust storage and consequently have vertical, regular shaped walls. Other chambers (5) are completed production chambers, converted for dust storage. These chambers are quite irregular in shape.

Due to the variability of material characteristics and geometry, a variety of excavation methods will have to be used. The potential methods include:

- vacuuming from boreholes, overhead and drawpoint locations
- clam bucket from an overhead access
- drawpoint mucking with remote controlled LHD's (Load Handling) or continuous miner
- slurry pumping systems

It is anticipated that a combination of methods will be required in order to achieve high extraction from a given chamber. Consideration will be given to each at such time as a test mining area can be prepared. Various mining methods are outlined in Figures 10, 11, 12.

2.6.3 Materials Handling Systems

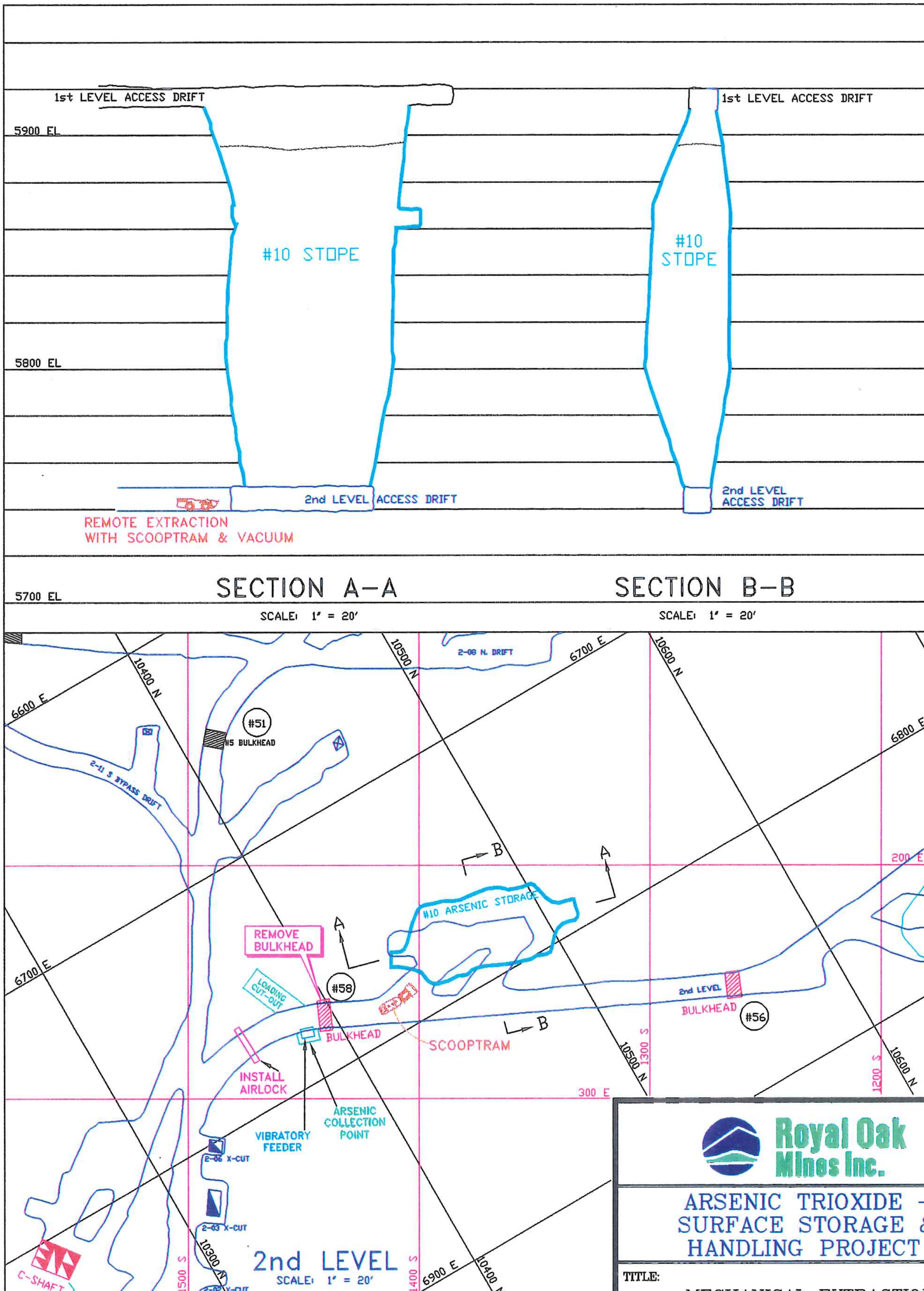
The main concern in handling the arsenic trioxide bearing dust is the potential for the dust to become airborne or contact and solubilize into surface waters or groundwater.

Any system under consideration must ensure containment during transport. The transport distance should be kept to a minimum to reduce risk. Rehandle or transfer must also be reduced or eliminated.

A vacuum system would allow the material to be piped directly to a surface storage facility. Dust collection systems would ensure that releases to atmosphere are minimized.

Slurry systems, which are most likely to be used for removing (washing) remnant material, will deliver the material by pipe directly to the process facility. The use of slurry systems will be kept to a minimum to reduce the potential impact to the groundwater.

All mechanical recovery systems would primarily use tubular drag conveyors for transporting the material to surface, and into storage or the process plant. These systems are enclosed, and have a low maintenance component. However they are also restricted in length and geometry, so transfer points and rehandle, possibly by truck, may be required.



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: MECHANICAL EXTRACTION	
LEVEL: 1st and 2nd	SCALE: 1"= NTS
DRAWN: P.C./MSL CHECK:	DATE: DEC. 5, 1997

Figure 10

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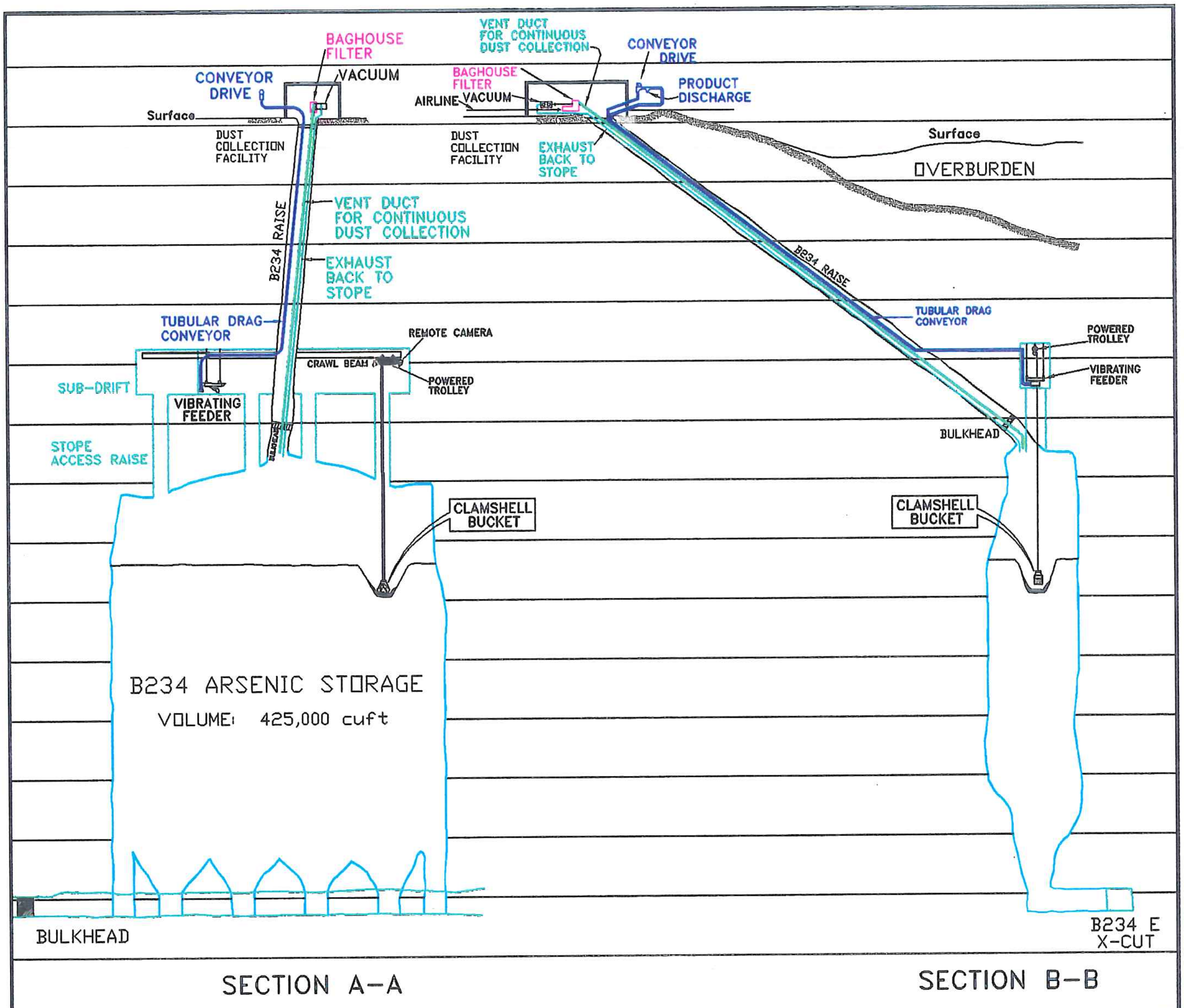

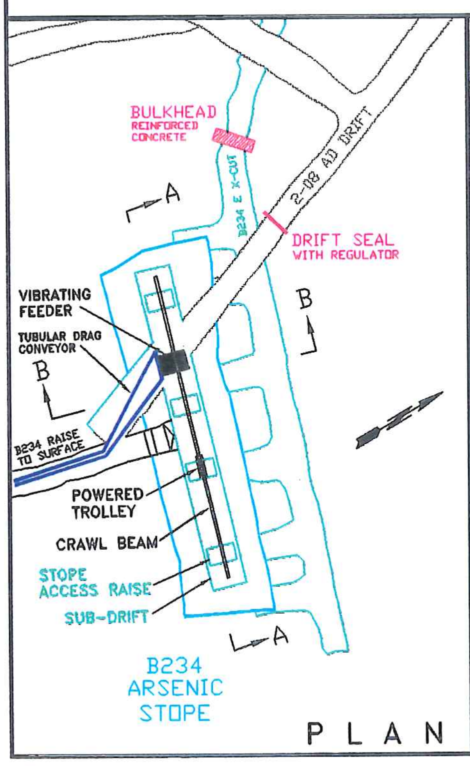

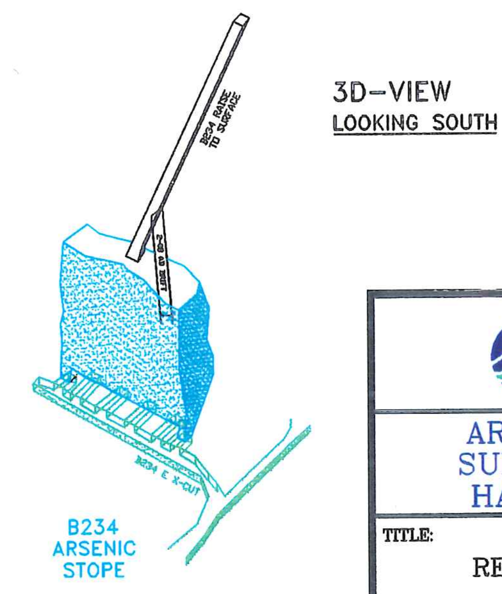

Royal Oak Mines Inc.

ARSENIC TRIOXIDE - SURFACE STORAGE & HANDLING PROJECT

TITLE: REMOTE CLAM MUCKING	
LEVEL: 1st and 2nd	SCALE: 1"= NTS
DRAWN: P.C./MSL CHECK:	DATE: APR. 29, 1997

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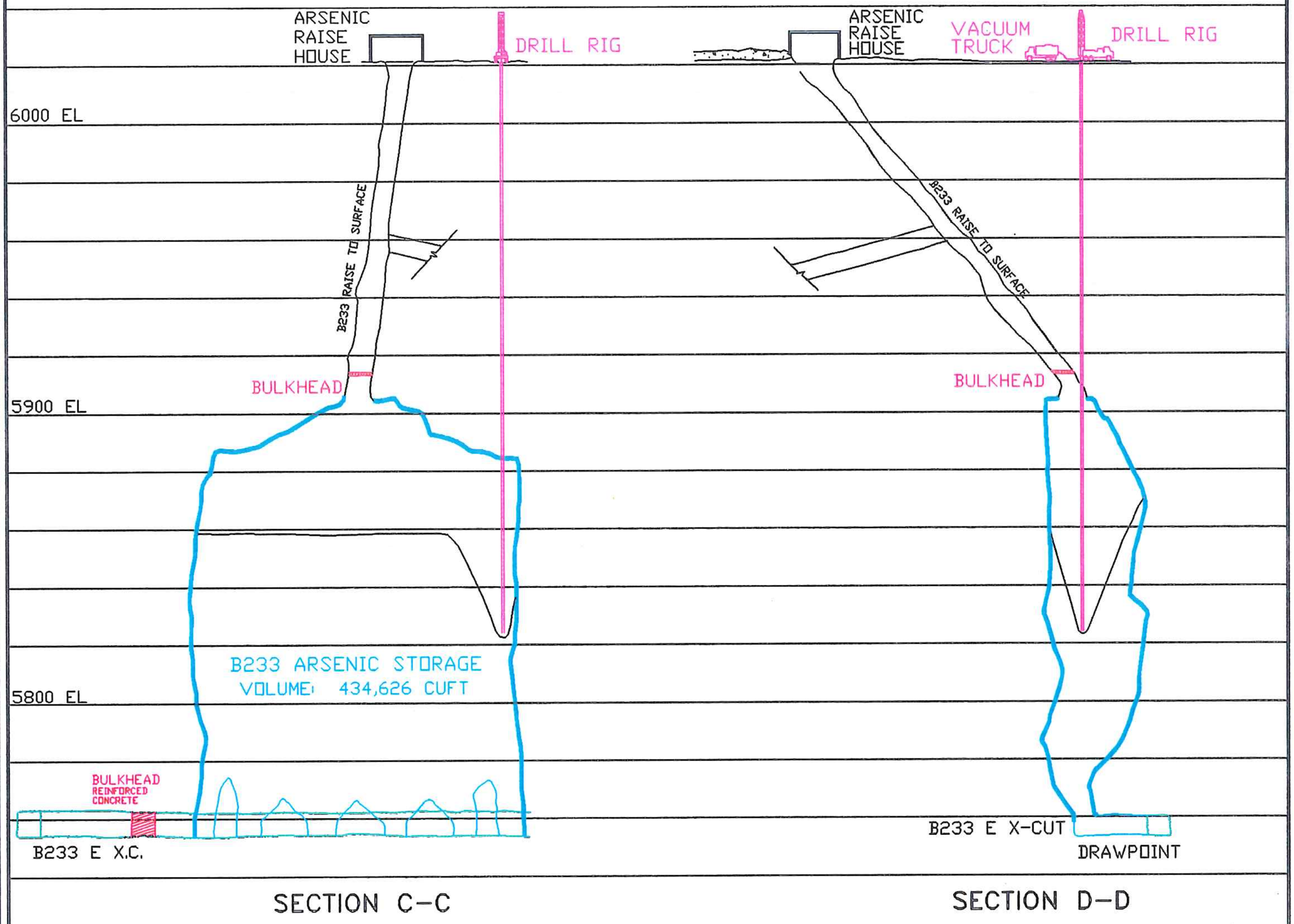
Figure 11



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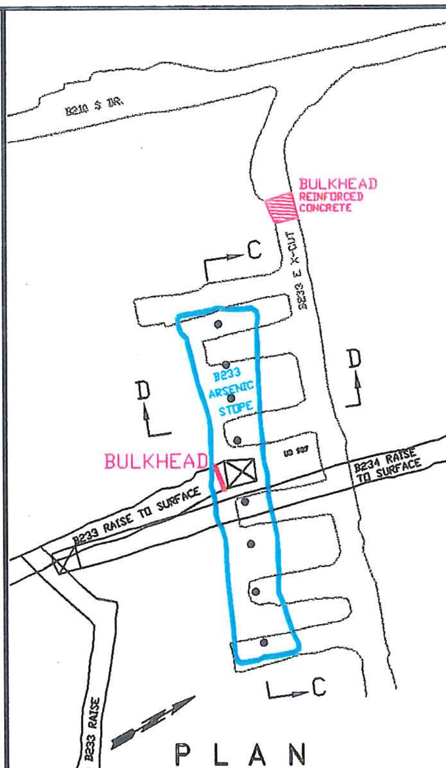


Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: VACUUM TRUCK EXTRACTION

LEVEL: 1st and 2nd	SCALE: 1"= NTS
DRAWN: P.C./MSL CHECK:	DATE: DEC. 5, 1997

Figure 12

File Name: MASTER\ARSENIC\AR97-1.DWG

3.0 PROJECT ECONOMICS

The project economics are comprised of the following components:

- laboratory tests, conceptual engineering, environmental and geotechnical studies
- pilot plant tests, flowsheet development, detailed engineering design
- capital cost for construction of plant and facilities
- operating costs for materials handling, processing and transportation
- revenue from sale of arsenic and gold
- closure costs for the plant, handling systems, and underground mine

These costs are described in this document in general terms as accurate figures will not be available until certain process decisions have been made, and developed to a design level.

3.1 Capital Costs

Capital costs for the project include:

- temporary surface storage facilities for surge and blending purposes
- mine development for extraction purposes
- mining and materials handling equipment, and facilities, for recovery of material stored underground
- handling and transport equipment to move recovered material to the process plant site
- the process plant, and any associated costs to modify or supplement support facilities
- warehousing and loadout facilities for transport to market
- containment facility for waste residue from processing facility

3.2 Operating Costs

Operating costs are related to:

- fixed costs for infrastructure such as power, water, heat, building maintenance
- administrative, supervisory and technical support
- environmental monitoring
- underground mining manpower and consumables
- materials handling costs including labor, consumables and maintenance
- process plant labor and materials
- transportation and marketing costs
- treatment costs for effluent and tailings from the process

Operating costs will be a function of the process selected, and concepts yet to be finalized.

3.3 Revenue Opportunities

It is anticipated that recovery and processing of the material from underground and also future production from the roasting operation will provide a marketable arsenic trioxide product. Recovery of this material should be in the order of 90% of the contained arsenic trioxide. Current market price is about $0.30 US per pound, however the market is sensitive to supply conditions. Demand in North America has been relatively steady at about 30,000 tonnes per year, for several years.

Gold will be recovered from the process residues. This recovery will be accomplished through cyanide leaching of the residue which may require an additional oxidation (re-roasting) step. Test work is underway to determine in what form the remaining gold occurs in the residue. Final recoveries are expected to be from 70 to 85%. The cyanide leach process and final gold recovery may be separate from the existing system at Giant if the solution kinetics are found to be incompatible.

Another potential revenue stream is the recovery and marketing of an antimony product. This will depend on the ability of the new process to separate the antimony and arsenic. There is only a low probability of this being successful to the point where it is economically viable.

3.4 Closure Costs

Closure costs assume the arsenic trioxide bearing dusts have been recovered from underground to the extent possible and reprocessed. Final tailings have been treated and stabilized then placed in a final disposal location which may be underground or in a surface tailings pond

The process plant will be dismantled and removed to a suitable disposal site.

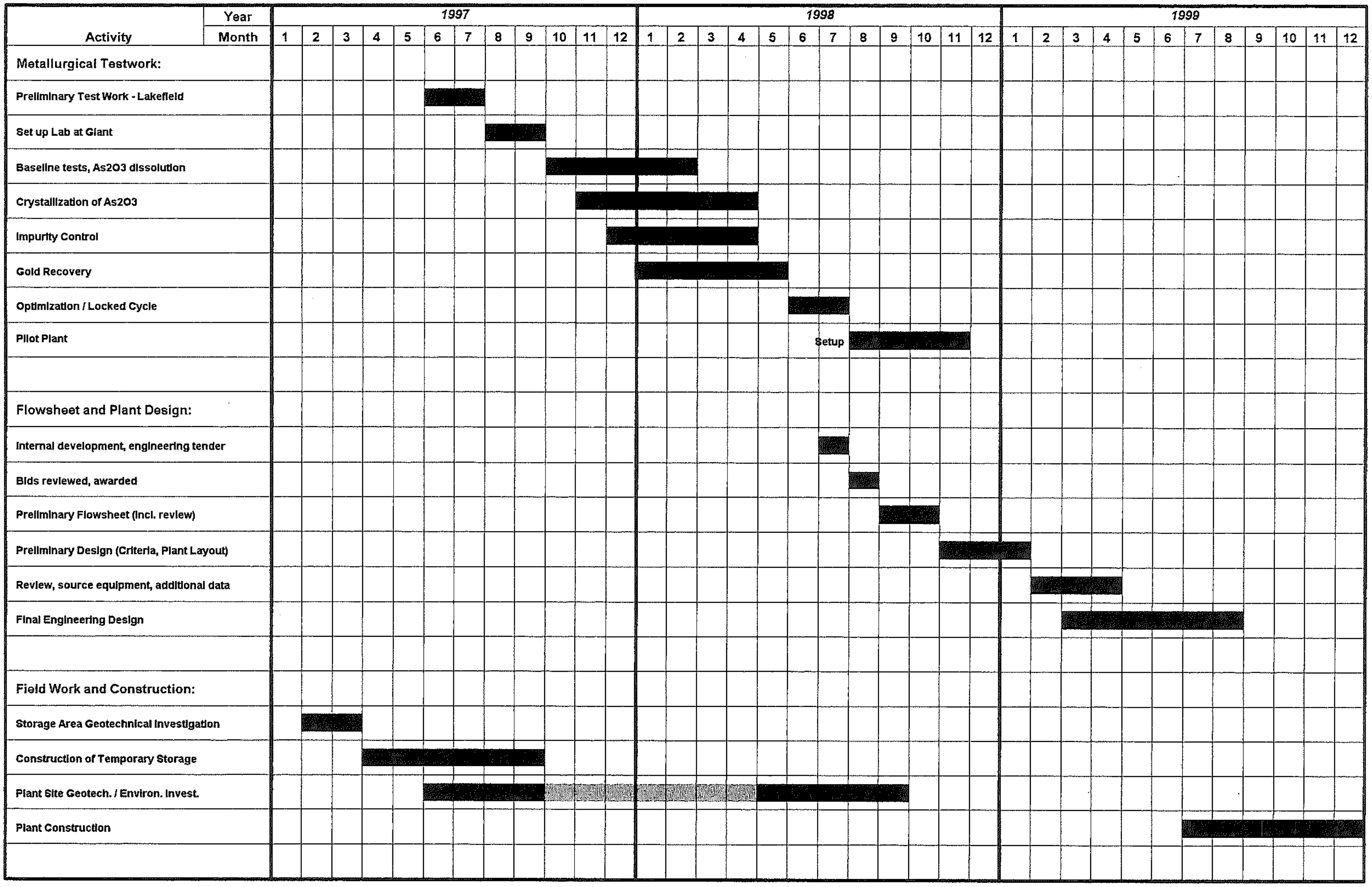
The underground storage chambers will be cleaned to the maximum extent possible and left in such a fashion that the remnant material does not impact the groundwater system. Underground openings will be sealed from inadvertent entry according to Mining Regulations.

The mine will be allowed to flood to its natural levels, and monitoring of site conditions will continue as deemed appropriate for the conditions at that time.

3.5 Implementation Schedule

The proposed schedule for the implementation of the project through to commissioning of the process is shown in Figure 13. This includes the immediate implementation of the concept of surface storage, which is illustrated in more detail in Figure 14.

Royal Oak Mines Inc. - Giant Mine
Overall Project Schedule
Figure 13

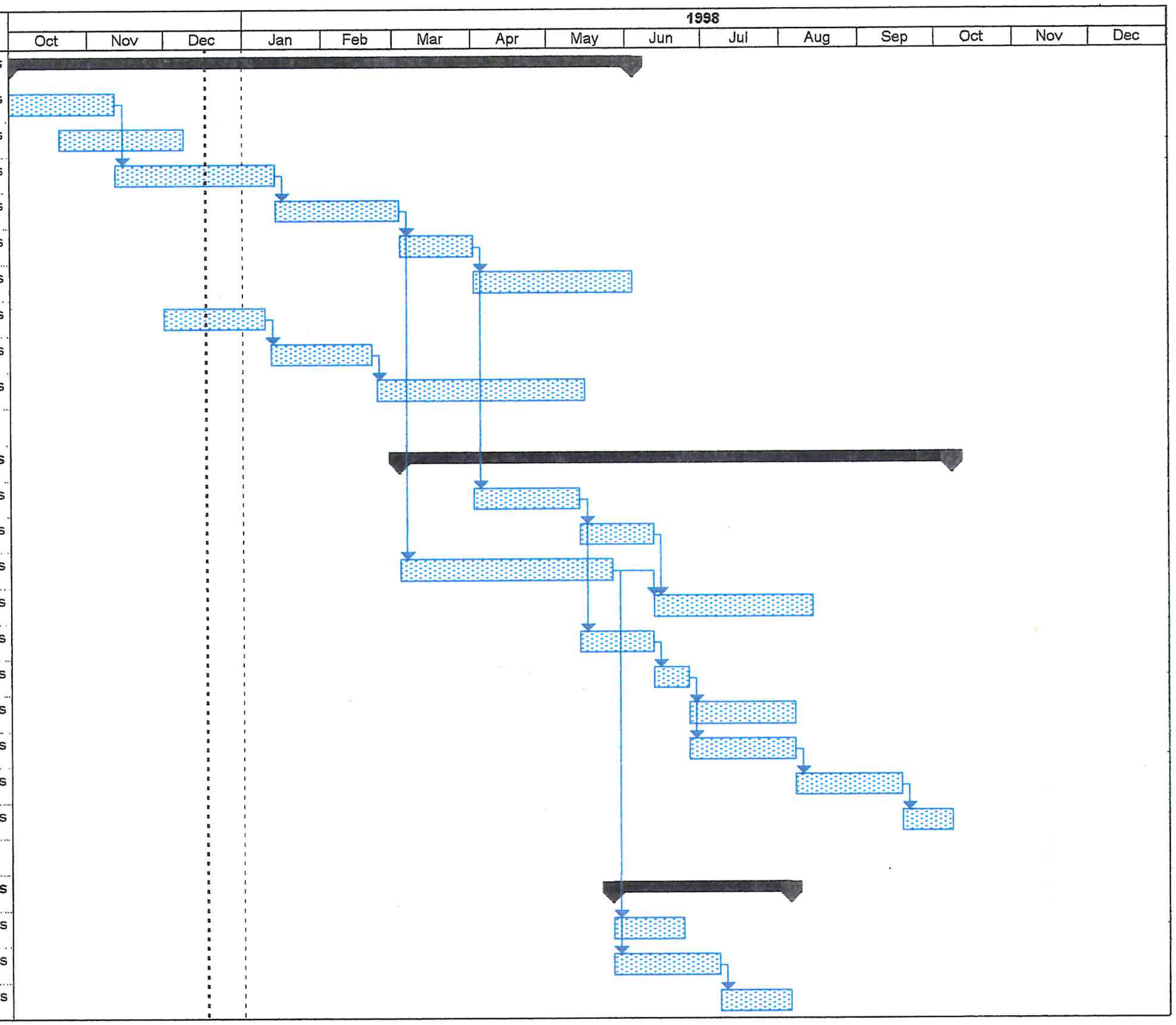


Note:
- assumes process design proceeds with hot water leach.
- assume relevant permitting issues and data collection are undertaken beginning in Jan. 1998.
- plant commissioning projected at April 2000

Royal Oak Mines Inc. - Giant Mine
Surface Storage (TRP Site)- Implementation Schedule

Figure 14

ID	Task Name	Duration
1	**Engineering and Approvals**	**176 days**
2	Preliminary Concepts	30 days
3	Materials Testing	35 days
4	Concept Scoping	45 days
5	Preliminary Design	35 days
6	Internal Review	21 days
7	Detailed Engineering	45 days
8	Environmental Scoping	30 days
9	Environmental Impacts / Risk Assessment	30 days
10	Permitting Review / Approval	60 days
11		
12	**Construction and Mechanical - TRP**	**156 days**
13	Electrical / Mechanical Refit - TRP Site	30 days
14	Remove / Modify Tank Structures / Access	21 days
15	Specifications / Quotes / Procurement	60 days
16	Install Piping, Caps, Duct Collection	45 days
17	Strip / Salvage TRP Area	21 days
18	Grade and Fill	10 days
19	Construct / Modify Containment	30 days
20	Construct Off-loading Building	30 days
21	Install Off-loading Elect/Mech Systems	30 days
22	Commissioning	14 days
23		
24	**Construction and Mechanical - Loadout**	**60 days**
25	Modifications to Silo	20 days
26	Upgrade to Conveyors, Buildings	30 days
27	Environmental, Spill Contingency	20 days



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4.0 RISK MANAGEMENT

4.1 Identification of Potential Receptors and Pathways

4.1.1 Human

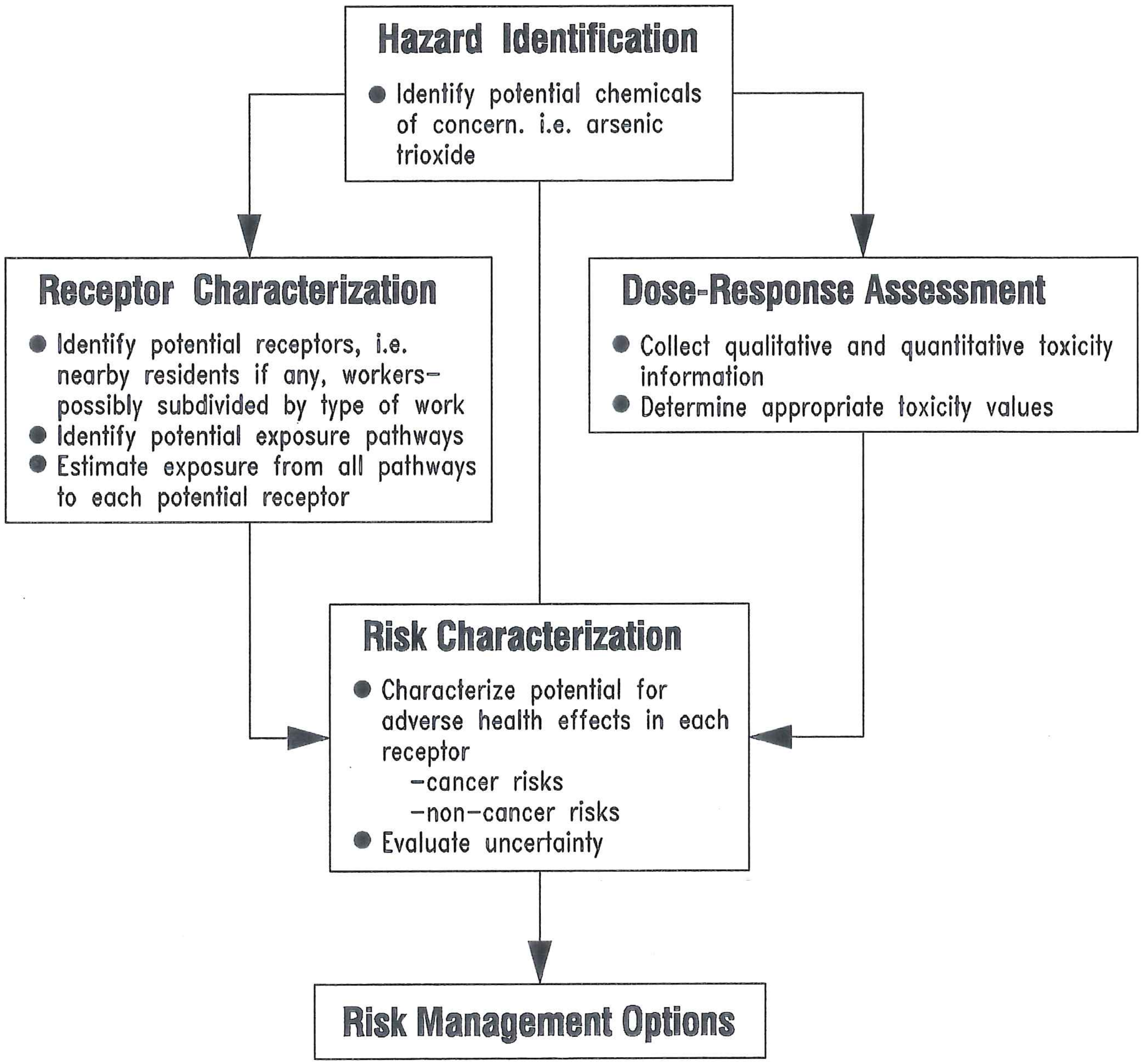
a) Onsite Occupational Workforce

The potential health risks to human receptors from exposure to arsenic trioxide must take into consideration **all known and projected pathways** of exposure to arsenic trioxide. For onsite workers, the key routes of exposure would include inhalation (of soil/dust), ingestion (of soil/dust), and dermal contact. However, given that not all workers would necessarily be exposed to the same degree of risk depending on the type of work they might be involved in (e.g. loading, truck driving, unloading, storage etc.), it will be necessary to review current or proposed occupational health and safety procedures/plans associated with the various work practices. Included in this review will be an assessment of the numbers of workers who would potentially be exposed, their specific job assignments, their location (s), their magnitude/duration of potential exposure, measures in place to mitigate exposure (e.g. personal protective equipment). An onsite inspection will be required as part of this task. The components of a human health risk assessment are outlined on Figure 15.

b) Public At Large

In order to estimate the magnitude of health risks that could be experienced by the public at large as a result of the surface transportation and storage proposal of the material, it will be necessary to identify all human receptors who might be exposed in the area from airborne or surface water contamination by arsenic trioxide. This would include a critical evaluation of atmospheric dispersion modeling done to date for this site as well as identification of typical non-occupational receptors. This would include identification of both normal and sensitive sub-populations (e.g. children, elderly etc.), potential high risk sites (e.g. homes, buildings). Also included in this assessment will be an

Human Health Risk Assessment



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: HUMAN HEALTH RISK ASSESSMENT	
LEVEL:	SCALE: 1"= NTS
DRAWN: MSL CHECK:	DATE: DEC. 11, 1997

Figure 15

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evaluation of existing reports/data pertaining to the level of toxicologically significant arsenic in drinking water, fish, local food plants etc. Local topography and site drainage conditions would also be part of this assessment.

4.1.2 Ecological Receptors and Pathways of Exposure

The goal of ecological risk assessment is to predict potential adverse effects and when appropriate, to measure existing adverse effects of chemical contaminants on the biota on or near the mine site, and to determine levels of those chemicals in the environment that would **not** be expected to adversely affect the biota.

A scoping level ecological assessment will be undertaken for the proposed arsenic trioxide storage option as outlined on Figure 16. This assessment would determine potential ecological receptors, the potential levels of the arsenic trioxide and potential exposure pathways. The area to be considered would be the area that could be affected by loading, transporting, and unloading the waste As_2O_3 byproduct. This would include soil, air, surface and ground water, and biota.

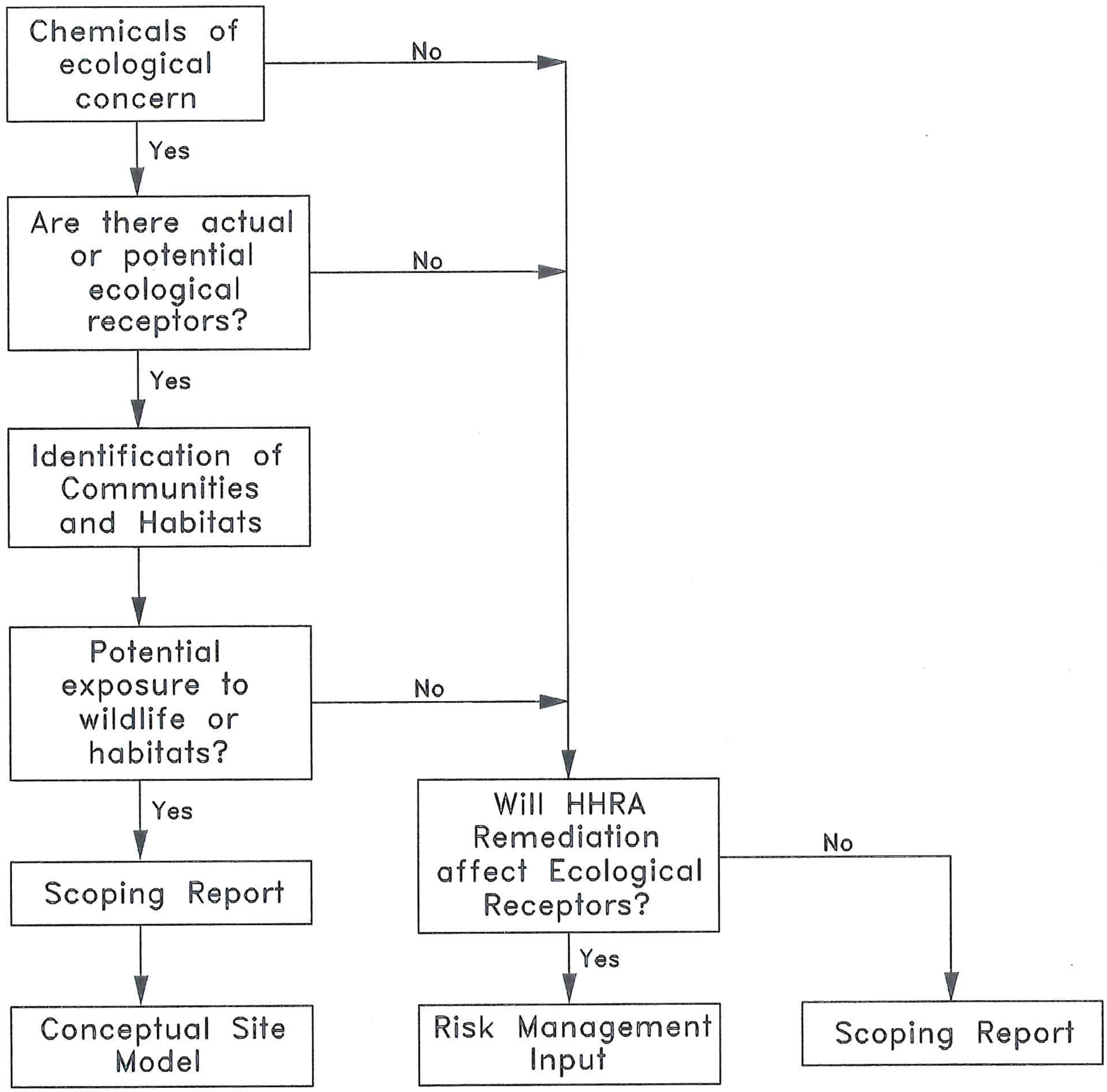
It is important to note that it cannot be assumed that the human health risk assessment will provide an estimate of threat to biota. Ecological receptors are frequently more sensitive to adverse contaminant-induced effects than humans. In addition, many terrestrial organisms may be exposed to higher concentrations of contaminants than humans. For example, burrowing animals, such as rodents, would typically be exposed to higher concentrations of soil compounds than humans.

The following steps will be performed:

1. Identification of Off-site Habitats and Receptors

In lieu of an extensive site-specific biological survey conducted over an extended period of time to physically identify all major species occupying each distinct on or off-site habitat, the species

SCOPING LEVEL ECOLOGICAL RISK ASSESSMENT



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: SCOPING LEVEL RISK ASSESSMENT

LEVEL:		SCALE: 1"= NTS
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Figure 16

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expected to occupy each habitat can be identified using available electronic data bases, publications, interviews of local experts etc. Of special interest would be rare, threatened or endangered species.

2. Identification of Contaminants of Concern

With regard to this site, arsenic trioxide in the air, soil, water, and biota on and near the proposed storage area has been identified as the compound of primary concern.

3. Identification of Potentially Complete Exposure Pathways

Pathway assessment will be conducted once potential species and habitats are identified. Pathway assessment identifies the potential for contact between biota and chemicals of concern in any medium and by any route. Media to be considered will include soil, air, surface and ground water, and biota. Of particular importance will be consideration and evaluation of physical and chemical characteristics which influence environmental fate and transport of arsenic trioxide.

Pathways may be direct, such as inhalation of air, or indirect, such as movement through the food web. Direct exposure routes to be considered will include inhalation, ingestion, and dermal contact. Indirect exposure via consumption of food items also warrants evaluation, especially for those chemicals of concern with physical parameters which indicate a potential to bioaccumulate. Pathways will be assessed according to whether:

- There was or is a potential release to the environment, based on site-history or preliminary characterization data.

- Transport of the contaminant to a point of exposure is possible based on preliminary site characterization data or fate and transport modeling.

- A point of contact exists for the contaminant and potential receptors.

- An exposure route, such as inhalation or ingestion, exists at the point of contact.

Pathways shall be considered complete unless there is scientific justification to demonstrate arsenic trioxide will not enter the medium or the receptor will not contact the medium, either directly or indirectly, now or in the future. For completeness, a qualitative description of the magnitude, duration and frequency of exposure to the various biological receptors, representing multiple trophic levels or area of contamination will be summarized in tabular form as follows:

Example Table: Assessment of Potentially Complete Exposure Pathways

Habitat Type	Potential Contaminants	Contaminated Media	Direct Exposure	Exposure			Food Web Exposure	Complete Pathway
				Magnitude	Duration	Frequency		
Soil	As_2O_3	Soil, air, water	Soil ingestion etc.				Soil invertebrates to mice etc.	Yes or No

If sufficient information exists, a qualitative habitat map will be constructed, outlining the general boundaries and extent of all major habitat types such as canopies, shrubs, and dominant herbs. It may not be necessary to conduct an assessment beyond the Scoping Phase if either of the following conditions are met:

1. The scoping assessment demonstrates that both the site and areas actually or potentially impacted by the site are not significantly utilized by biota and do not contain significant wildlife habitats, or

2. There are no actually or potentially complete exposure pathways.

However, if arsenic trioxide has contaminated, or may be reasonably expected to contaminate media which may contact on-site or off-site wildlife or wildlife habitats, directly or indirectly, the potential for exposure is considered to exist, then a Phase I predictive ecological risk assessment (PERA) would be conducted. The steps involved are explained in Section 4.3.2 and summarized in Figure 17.

4.2 Transportation Risk Assessment

A transportation risk assessment will be performed to characterize the environmental, financial and personnel safety risks associated with various alternatives being evaluated for the transportation of arsenic trioxide from the baghouse to the storage facility. In this assessment, emphasis will be placed both on obtaining absolute values of the predicted frequencies and consequences of a range of release scenarios and on the comparison of risks for the various options.

Four transportation scenarios will be evaluated:

1)Transport by vacuum truck from the baghouse to the TRP site.
2)Transport by conveyor belt from the baghouse to the TRP site.
3)Transport by pneumatic pipeline from the baghouse to the TRP site.
4)Transport by pneumatic pipeline from the baghouse to the proposed storage site adjacent to the mill.

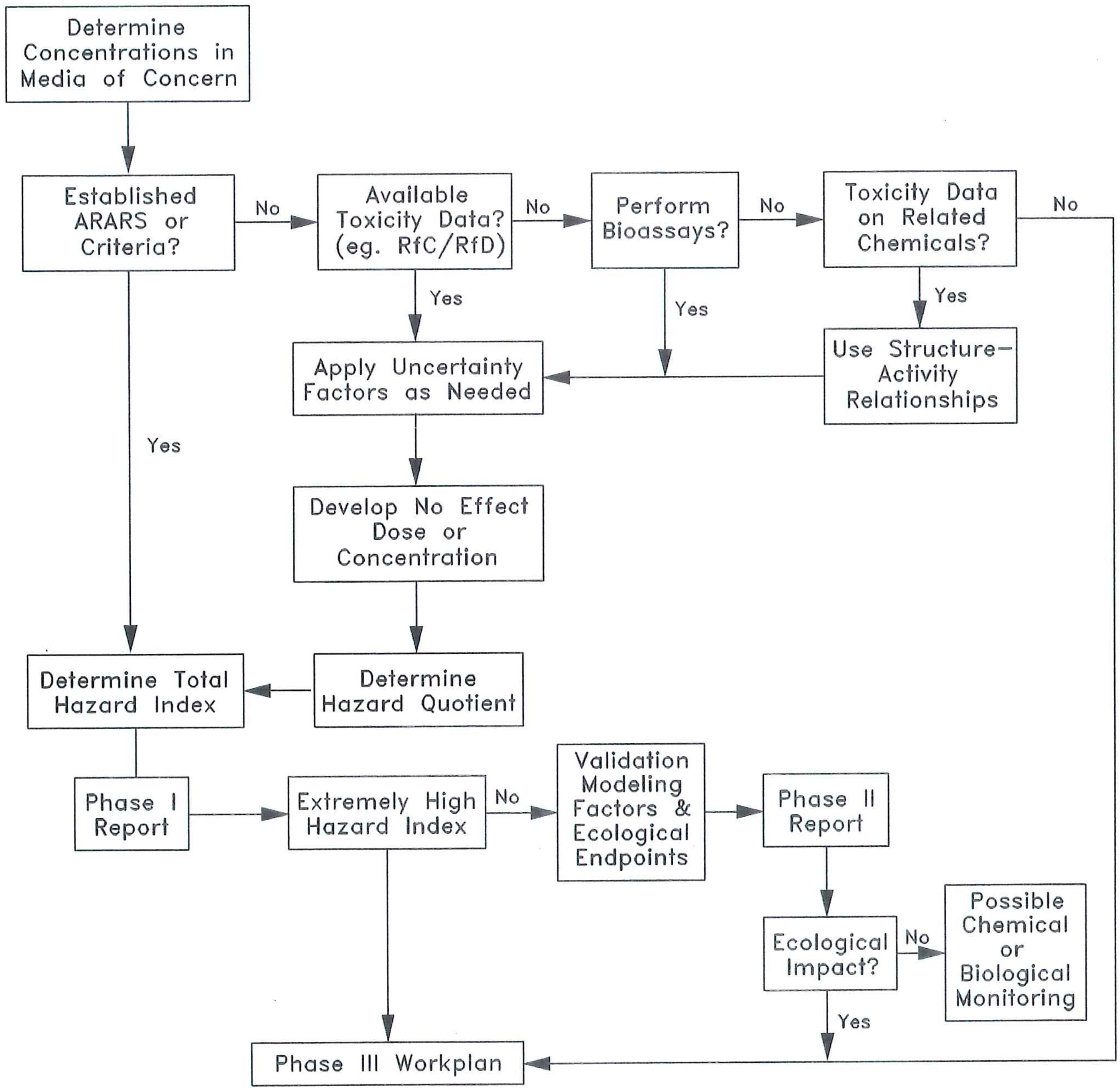
For each means of conveyance, the risk assessment will comprise seven steps:

The definition of the scope of the risk assessment. In general, this scope would include the loading of arsenic trioxide on to the means of conveyance, conveyance and unloading into storage.

A HAZOP analysis to ascertain how arsenic trioxide can be released from confinement. The analysis would be conducted using PHA-Pro software and would address normal operation, start-up, shut down and, for conveyance by pneumatic pipeline and conveyor belt and for loading and unloading, maintenance activities. It would also characterize the size of releases expected from the various release events and identify measures by which releases could be prevented or mitigated.

The division of the transportation route or means of conveyance into a number of distinct segments defined to characterize the likelihood and consequences of release at a point in the segment. For

PHASE 1 PREDICTIVE ECOLOGICAL RISK ASSESSMENT



Royal Oak Mines Inc.

ARSENIC TRIOXIDE – SURFACE STORAGE & HANDLING PROJECT

TITLE: PHASE 1 PREDICTIVE ECOLOGICAL RISK ASSESSMENT

LEVEL:		SCALE: 1"= NTS
DRAWN: MSL	CHECK:	DATE: DEC. 12, 1997

Figure 17

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truck transportation, a number of distinct segments would be defined to characterize road conditions, the presence of other traffic and the likelihood of an accident and spills as well as the consequences of a release along the route. Other segments would represent loading and unloading of the truck. For transportation by pneumatic pipeline, a finite number of distinct segments would be used to characterize the likelihood of pipeline leaks and rupture (perhaps as a result of vehicular impact, fatigue, flooding, support failure or corrosion). Other segments would represent loading and unloading of the pipeline. Finally, for transportation by conveyor belt, a number of distinct segments would be used to characterize the likelihood of leaks and rupture of the casing surrounding the belt (perhaps as a result of vehicular impact, support failure or the need to effect repairs at an intermediate point along the belt). Again, other segments would represent loading and unloading of the belt.

A probabilistic risk analysis is used to characterize the frequency and size distributions of possible releases. For loading and unloading, this analysis might include a fault tree analysis. The risk analysis would use generic accident and release data together with such accident data as are available. For example, reliability data for systems currently used on site (e.g., for pneumatic conveying) would be applied where appropriate, perhaps using a Bayesian update technique to merge these data with generic data.

A consequence analysis will be used to characterize the consequences of possible releases in the various route segments in terms of the dispersion of arsenic trioxide and the resulting ecological and safety impacts and the costs associated with them. These costs would include the costs of cleanup, remediation and penalties. Human safety impacts would be defined in terms of the likelihood of death or harm to health.

The determination of a probabilistic risk profile will be completed, along with the identification of major contributors to this risk. This step would be accomplished by combining the risk and consequence analyses and performing a Monte Carlo simulation.

The major contributors to risk will be reviewed with design engineers to ascertain whether steps could be taken to mitigate or eliminate them. If this is possible, the risk assessment would be revised to reflect these additional alternatives.

Having completed the risk assessment for each alternative, the alternatives will be compared, segment by segment and overall. The sources of differences in the risk predicted for the various alternatives will be identified. In this final review of risk, particular attention will be paid to identifying any risk that might be deemed unacceptable.

4.3 Storage and Handling Risk Assessment

4.3.1 Human Health

a) Toxicity of Arsenic Trioxide

Arsenic exists in several forms in the atmosphere. Some of these forms are more toxic than others. For example, trivalent arsenic is the most toxic form, while pentavalent arsenic is only slightly toxic. Most compounds of arsenic when heated in the presence of air (such as in the roasting of gold mining ores), are converted to arsenic trioxide. Because arsenic trioxide sublimes at 193°C, it is easily absorbed to suspended particulates in the air. These particulates may remain suspended for long periods of time and be transported long distances in the atmosphere under the influence of wet and dry deposition forces.

With respect to the Royal Oak Mines situation, humans may be exposed through either direct inhalation of these particulates or indirectly through ingestion of food or water that has been contaminated with arsenic trioxide, as well as potential dermal exposure.

b) Methodology

In Canada, no unilateral guidelines have been adopted for assessing health risks associated with contaminated sites. Each regulatory jurisdiction favours its own method (e.g. B.C. - probabilistic; Ontario - deterministic) thereby creating a pot pourri of approaches.

The quantitative human health risk assessment for Royal Oak's storage and handling proposal will utilize both deterministic and probabilistic methods in calculating the potential risk of adverse health effects. The deterministic approach will be used as a screening tool to obtain an initial upper bound level of risk. This approach uses a combination of average values and most reasonable upper bound maximum values to predict the risk level to the receptors from exposure to arsenic trioxide. On- and offsite exposure levels to arsenic trioxide would be established by review of existing industrial hygiene and atmospheric dispersion modeling data.

The output risk level from the deterministic approach is a point estimate and is less versatile than the output from the probabilistic method. For exposure pathways that have an unacceptable risk level using the deterministic approach, a probabilistic analysis will be performed to define the range of risks associated with the exposure to arsenic trioxide.

The probabilistic methods are based on Monte Carlo analysis for the estimation of the probability of adverse health effects. Probabilistic frequency distributions, rather than point estimates, will be developed for various receptor and exposure scenarios. Monte Carlo analysis will be conducted using the computer software package Crystal Ball (Version 4.0). The final output of this effort will be a probability distribution defining the range of risks for arsenic trioxide exposure via the pathways deemed most relevant. Probabilistic methods eliminate the overly conservative estimates of risk often associated with the use of point estimates.

Royal Oak Mines, proposes to establish the spatial boundary as being comprised of the mine site and adjacent potential receptors (i.e Back Bay and the City of Yellowknife). Temporally, the risk assessment will evaluate the potential risks associated only with the surface storage and handling of arsenic trioxide waste over an approximate period of three to four years (i.e. length of time required to develop processing option). In addition, we propose that a number of risk scenarios be developed in consultation with the various regulatory agencies. We propose to evaluate approximately six scenarios ranging from smaller or chronic releases to larger releases associated with a transportation issue or rupture in storage containment.

4.3.2 Ecological

As a general approach, an individual or population-level effect will generally be assumed to have ramifications at higher levels of organization (e.g. community or ecosystem level) unless there is evidence to the contrary. Although the goal of ecological risk assessment is to assess the magnitude and extent of threats to the structure and function of plant and animal communities and ecosystems (the assessment endpoint), many of the measurement endpoints addressed in the risk assessment will be at lower levels of organization, such as the population, individual, organ system, or biochemical. This is necessary because few chemicals have been tested for their impacts on plant and animal communities or ecosystems, and for many substances, the available toxicology data is from only single-species testing (USEPA, 1989b, USEPA, 1992, and MacDonald et al., 1992). Microcosm or mesocosm data may be available for arsenic trioxide. When available, these data may have some utility in the prediction of environmental toxicity under various exposure scenarios.

Predictive assessment of ecological risk is a process of comparison of measured or predicted concentrations or doses of toxic chemicals in biotic and/or abiotic environmental compartments with criteria for the protection of biota to arrive at a hazard index for each species evaluated. This involves selection of representative species and toxicity data, identification of measurement endpoints, evaluation of potential exposure pathways and contact rates, and calculation of hazard quotients and a **Hazard Index (HI)**.

Toxicity criteria for arsenic trioxide in soil, air, and water may be pre-existing, or will be derived by the assessor. They will be expressed as reference dosages (RfDs) for terrestrial receptors or reference concentrations (RfCs) for completely aquatic receptors.

For this project, the most reasonable exposure scenarios will be selected for ecological risk estimation (e.g. fish species - recreational, sport, commercial). To assess the level of exposure for fish in areas that could be impacted by arsenic trioxide, existing internal/external reports will be reviewed (e.g. Federal Yellowknife-Back Bay Study, November, 1996). The temporal and spatial boundaries for the ecological assessment will be similar to those established within the human health risk assessment process.

4.4 Contingency Planning

Contingency planning will be a major component of the risk evaluation of the proposed surface storage of arsenic trioxide material. Contingency plans will be developed which will outline the emergency response actions to be implemented in the event of an accidental release of the waste material. The plans will address the transport, handling and storage aspects of the proposed surface storage method. The scope and types of contingency plans prepared for review will ultimately be dependent upon the storage site selected, the mode of transportation implemented and the mode of waste material storage selected. Contingency plans will be submitted to the appropriate regulatory agencies for review and comment prior to implementation.

Several contingency plans for the handling and storage of arsenic trioxide currently exist within Royal Oak's database. These plans will be reviewed and revised as required and will provide the basis from which updated contingency plans are produced.

Alternative disposal arrangements in the event that a processing plant is not constructed in the near future, will also be evaluated. The evaluation will review the options of continued above ground surface storage of arsenic trioxide waste material, the return of the material to underground storage, the shipping of the material to an alternative disposal site, and any other potential disposal option that may available and deemed potentially practical.

5.0 ENVIRONMENTAL MANAGEMENT

5.1 Monitoring Systems

A systematic monitoring program will be implemented with the initiation of a surface storage and handling program at the Giant site. The objectives of the monitoring program will be to monitor potential impacts to the environment that may result from the surface storage of waste material. The scope of the monitoring program will be dependent upon the storage site and the mode of transportation selected for the disposal of the waste and final designs will be submitted for approval at that time.

It is anticipated that monitoring programs to monitor potential impacts to the groundwater, surface water, and the atmosphere will be designed and implemented. Groundwater monitoring wells (approximately three to six wells) will be constructed at the selected storage site to determine "baseline conditions" within the aquifer and the groundwater flow direction. These monitoring wells will then be sampled on a regular basis following implementation of the surface storage of waste material. Monitoring activities are proposed to occur on a quarterly basis with the water samples submitted for analyses of arsenic and other inorganic parameters.

Surface water contained within the storage containment area will be monitored on an as required basis prior to removal of the water for disposal. The surface water sample collected shall be analyzed for inorganic parameters, including arsenic. If the parameters measured are within appropriate guidelines, the water will be discharged to the environment. If the regulatory guidelines are exceeded, water shall be discharged to the tailings impoundment.

Air monitoring (i.e. dust controls) will be strictly enforced within enclosed structures that are associated with the handling of the waste material. Monitoring of dust levels, etc., will be addressed within the occupational health and safety portion of a safety manual required for the handling procedures of arsenic trioxide. An inspection schedule with the results recorded in a log book will also be implemented to monitor the storage facility and transportation route. Arsenic bearing air emissions from the storage facility are not anticipated.

5.2 Storage Containment and Plant Closure

The Abandonment and Restoration Plan for the Giant site was updated in 1994 and approved by the Water Board in July 1994. The basic concepts contained within this document will be applied to, and updated, as would be required by the proposed change of process. Those concepts include, but are not limited to, reclamation of mine site infrastructure, surface contamination, effluent treatment, the tailings containment areas, and the underground storage areas.

Royal Oak Mines, will update the existing A and R Plan as a component of this proposed project, to include the restoration of the surface storage and plant facilities. As the project components are designed and implemented, further refinement and updating of the A and R Plan will occur. The revisions to the A and R Plan will be completed in accordance with the Water Board's "Guidelines for Abandonment and Restoration Planning for Mines in the NWT", and Board Publication "Mine Reclamation in the Northwest Territories and Yukon".