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REPORT ON

Giant Mine Underground Disposal Options for Arsenic Waste

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REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by AECOM to complete an assessment of the underground disposal options of the arsenic-impacted waste currently stored in containers on surface in the tailings management facility at the Giant Mine Remediation Project. This assessment included the following:

- reviewing the applicable sections of the Developer's Assessment Report (DAR; INAC and GNWT 2010) and Report of Environmental Assessment (MVLWB 2013), and relevant meetings related to the long-term disposal of arsenic-contaminated waste and soil;
- obtaining the volume and description of arsenic-impacted waste from AECOM;
- determining the available volume of underground storage in Chamber 15 and any drifts that may freeze as a result of freezing Chamber 15;
- determining methods of accessing Chamber 15; and
- providing a trade-off of the access methods and recommending an access and disposal method.

2.0 DOCUMENT REVIEW AND COMMENTS

Section 6.12.3 of the DAR (INAC and GNWT 2010) indicates that process residuals from the roaster and mill complexes, as well as any other materials or machinery contaminated with soluble arsenic, will be disposed within one of the planned freeze zones. The disposal options identified in the DAR were based on preliminary estimates that identified 4,200 m^3 of soluble arsenic waste at the mine site. Based on the remedial and investigation work completed to date, the volume of soluble arsenic wastes requiring disposal is estimated at about 14,000 m^3. This volume will increase to approximately to 43,000 m^3 if the disposal also includes the disposal the containers that the arsenic wastes are stored in at the material storage area.

Various forms and quantities of soluble arsenic waste are currently stored in a number of areas on the Giant Mine site as outlined in Table 1.The DAR outlined several disposal location options for soluble arsenic trioxide wastes that have not already been added to the arsenic stopes and chambers including the following:

- Chamber 15;
- B1 pit backfill, within the zone to be frozen;
- a new underground chamber that will be built as close as possible to the roaster area; and
- a new pit or quarry located near to the roaster area and subsequently backfilled.

A purpose-built chamber, such as Chamber 15, could be excavated to store additional arsenic-impacted waste. The material from the excavation could be used elsewhere for underground stabilization, and additional freeze infrastructure will be required.

Based on the above, it is the goal of this work to determine whether current arsenic-impacted waste stored on surface from the roaster demolition work can be disposed of and contained in Chamber 15.

Freezing the soluble arsenic waste associated with the roaster demolition work in near-surface pits has not been investigated to determine whether migration of arsenic can be contained by freezing of the backfill material it will be co-mingled with. Studies have been conducted as part of the freeze optimization program to show that the frozen bedrock around the arsenic dust filled stopes and chambers can prevent migration in the absence of continuous and open discontinuities in the bedrock. The proposed performance criteria of -5°C over a 10 m thickness (as measured from the boundary of the void) for the arsenic dust filled arsenic stopes and chambers will also apply to the arsenic waste associated with the roaster demolition and debris.

3.0 VOLUME OF ARSENIC-IMPACTED WASTE

The inventory of arsenic-impacted wastes identified at the Giant Mine site is presented in Table 1. This inventory has been developed based on actual numbers of filled waste containers; however, in the case of the arsenic wastes remaining in the mill and tailings reprocessing plant (TRP), the volume is estimated since the decontamination of these two facilities has not been completed. The storage locations of these wastes are indicated in Figure 1.

Table 1: Summary of Arsenic-Impacted Waste Locations and Volumes

Storage Location	Source	Estimated Volume of Containerized Waste (m^3)	Additional Information
Material storage area	Roaster Deconstruction Project	8,407	Stored in containers and inside marine shipping containers
Material storage area	Roaster Deconstruction Project	1,100	Unpackaged waste within marine containers
Northwest Pond	Generated from previous maintenance and clean-up activities	594	Stored in barrels, repackaged in 2015
Northwest Pond	Generated from previous maintenance activities	10	150 mm diameter piping, approximately 16 ft long
Northwest Pond	Generated from previous maintenance activities as well as from re-packaging project	88	Bags stored in bags in two 20 ft and one 40 ft marine shipping container
Tailings reprocessing plant (TRP)	Generated from previous maintenance and clean-up activities	66	Stored in barrels and in bulk on pallet
Underground	Generated from previous maintenance and clean-up activities	68	Stored in barrels outside arsenic waste chambers
Underground	Arsenic distribution piping	140	150 mm and 100 mm diameter piping located underground
Mill/TRP	Ore process residuals and impacted wastes in mill and in TRP thickener	3,250	Estimated value – material remains in place
Total	**---**	**13,723**	**---**

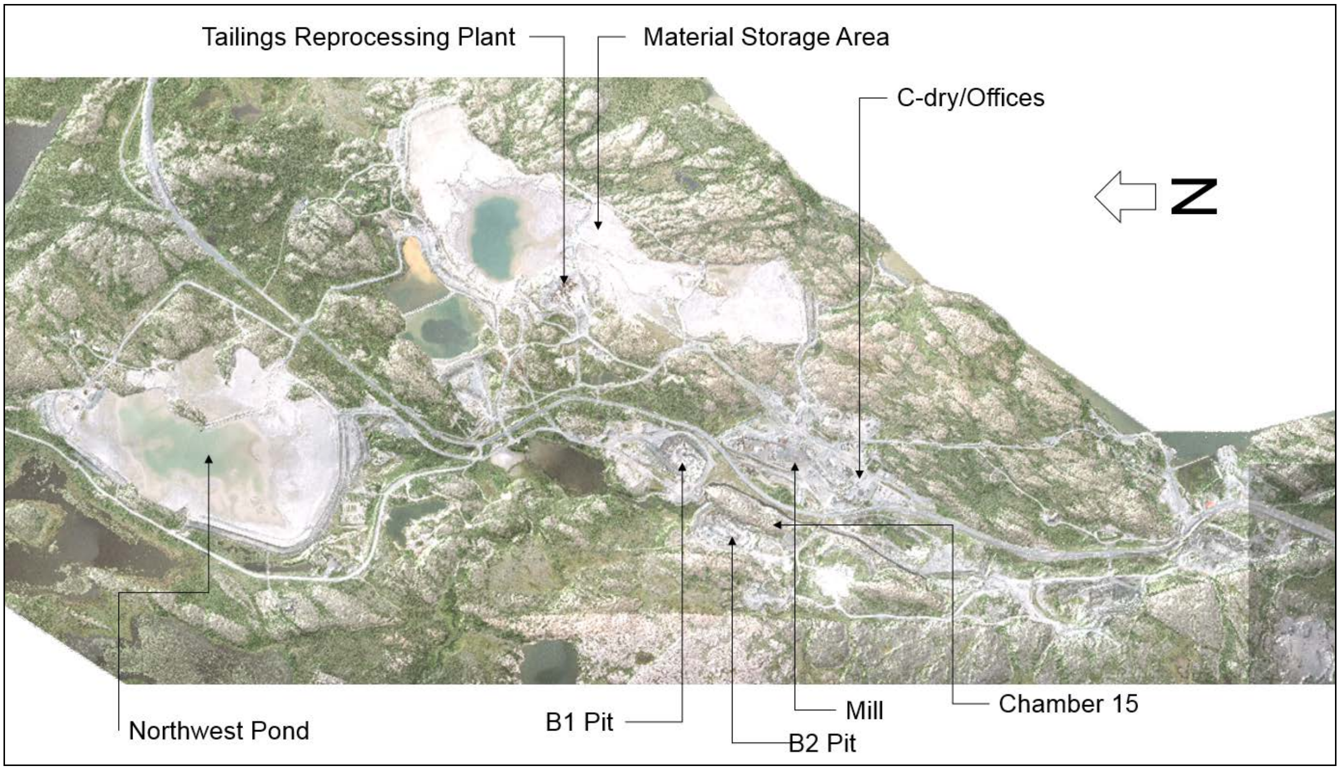


Figure 1: Schematic of the Location of the All Sources of Arsenic-Impacted Waste

The following tables summarize the volume of arsenic-impacted waste separated by storage type as provided by AECOM (e-mail communication of spreadsheet). The total volume of containers containing arsenic is estimated to be 43,000 m^3 (Table 2). There is approximately 14,000 m^3 of arsenic-impacted waste in these containers (Table 3). If the containers were collapsed, there will be approximately 3,400 m^3 of containers (Table 4).

Table 2: Volume of Containers Containing Arsenic-Impacted Waste

Storage Type	Individual Volume (m^3)	Count	Total Volume (m^3)
Drums (all sizes)	0.36	2,020	727
20 ft container with packaged waste	39	2	78
40 ft container with packaged waste	77	180	13,860
53 ft container with packaged waste	121.3	179	21,713
40 ft container with unpackaged waste	77	34	2,618
Waste on pallet	1	1	1
Arsenic distribution pipes (capped), 16 ft lengths	-	-	150
Contingency for process waste/wood in TRP and mill	3,250	1	3,250
Total Volume of Containers and Waste			**42,397**

Moving the containers underground and storing them there is likely not a preferred approach, as discussed in Section 5.0. An assessment of the volume of the material inside the containers is provided in Table 3.

Table 3: Volume of Arsenic-Impacted Waste Inside Containers

Storage Type	Individual Volume (m^3)	Count	Total Volume (m^3)
Drums (all sizes)	0.36	2,020	727
1 m bags within containers	1	6,553	6,553
2 m bags within containers	2	44	88
3 m bags within containers	3	618	1,854
Unpackaged waste material within containers	-	-	1,100
Waste on pallet	1	1	1
Arsenic distribution pipes (capped), 16 ft lengths	-	-	150
Contingency for process waste/wood in TRP and mill	3,250	1	3,250
Total Count and Volume of Waste	**-**	9,237	**13,723**

During roaster deconstruction, bags were loaded carefully onto pallets and then into the containers in the open air (e.g., not under containment), and it is assumed that little or no spill has occurred inside the bags although some remain open (e.g., the bags are not sealed). Photograph 1 shows a typical open container with demolition waste bags placed neatly on pallets.

Photograph 1: Typical Configuration of Waste Material in Bags Placed on Pallets and Added to Containers

It is assumed that unloading of the bags from the containers could be done in a careful manner in the open air without the need for major containment in the area as this is the reverse of what was carried out during roaster deconstruction. If spillage or damage to the bags occurs during transport, this may not be the case.

It is assumed that the containers were clean prior to the contaminated material being placed in them. This study looked at whether there is potential for efficiently moving the waste underground while keeping it in the shipping containers (e.g., they will be stored underground with the waste) or if the contents need to be removed. In consideration of the unlikely event that the containers themselves need to be stored underground, for example if they become contaminated during removal of the waste and it is deemed they cannot be cleaned, the option of placing the collapsed containers in the underground is included in the study and an estimate of their volume is provided in Table 4.

Table 4: Volume of Collapsed Containers

Storage Type	Unit Volume (m^3)	Quantity	Total Volume (m^3)
20 ft container	5.2	2	10
40 ft container	9.5	180	1,710
53 ft container	9.2	179	1,647
Total	**-**	**361**	**3,367**

If the containers need to be cleaned to be moved off site or disposed of in a hazardous or non-hazardous landfill, some effort will be required to do so.

4.0 VOLUME OF UNDERGROUND VOIDS

Chamber 15 is a relatively simple rectangular shape in plan and is a constant height. Other development openings excavated to enable excavation of arsenic Chambers 12, 14, and 15 are connected to and adjacent to Chamber 15 (Figure 2).

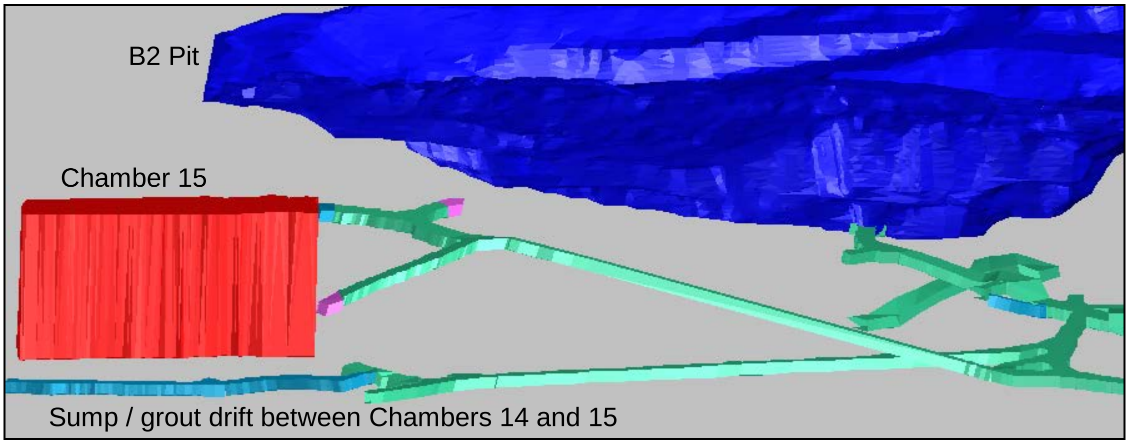


Figure 2: Schematic Showing the Relative Location of the B2 Pit, Chamber 15, and the Neighboring Development Openings – Screen Capture of 3D Surpac Model (looking east)

The volume of Chamber 15 was estimated from plans and sections and should be confirmed with a cavity scan prior to final design. In addition, there is a known fracture-controlled seasonal water flow in the southern end of Chamber 15, which is presumably one reason why the chamber was never filled with arsenic dust. A study to determine whether mitigating this water flow prior to freezing and filling the stope is required should be completed.

Newmans Geotechnique Inc. (NGI 2015) determined that Chamber 15 could be cooled to meet the freeze criteria (a minimum 10 m thick freeze wall of minimum -5°C) using the same freeze hole configuration outlined in the DAR, with the exception that horizontal freeze pipes are not required (communication to project team from SRK Consulting).

NGI also provided an assessment on which portions of the underground development openings connected to Chamber 15 that could be anticipated to eventually fit the freeze criteria (10 m thick freeze wall of -5°C). The study showed that only the small drift between Chambers 15 and 14 will be cooled to a level that met the criteria. Additional freeze drilling and thermosyphons will be required to freeze other existing underground development openings. The relative location of the development openings adjacent to Chamber 15 and the B2 open pit are shown in Figure 2. The estimated volume available for storage in each is summarized in Table 5.

Table 5: Summary of Void Volumes for Storing Arsenic-Impacted Waste

Area	Volume (m^3)
Chamber 15	23,000
Neighboring freeze drift	560
Total	**23,560**

The volume of material that can be stored in these voids depends on several factors including whether the containers themselves are stored or whether they are emptied out and the contents stored. The bulking factor for either approach and the angle of repose of the dumped material are also unknown.

5.0 WASTE DISPOSAL OPTIONS

The following general options were considered:

1) Place the containers in the chamber.
2) Remove the waste from the containers underground and place or dump it in the chamber.
3) Dump the containers directly into the chamber from underground.
4) Combination of 2 and 3 as required.
5) Excavate raises to surface and dump the waste into the chamber.

All options assume that Chamber 15 is a non-personnel-entry void, meaning it is not safe for personnel to access the opening. The ground support present in the back of the opening is only present for overall crown pillar stability. The Chamber 15 crown pillar has been previously deemed stable.

5.1 Option 1 – Place Full Containers in the Chamber

Option 1 requires approximately 44,000 m^3 of underground storage capacity (Table 3), and it is estimated that Chamber 15 has approximately 23,000 m^3 of storage capacity (a schematic of what "placed" containers will look like is shown in Figure 3). Therefore, to store all of the arsenic-impacted waste underground an additional chamber, similar in dimension to Chamber 15, will have to be excavated. The main advantage of this option will be that the containers do not have to be opened and the arsenic waste does not have to be exposed. The main disadvantages of this option include the excavation of at least a second chamber and the difficulty in placing the containers in a non-entry area (the back of Chamber 15 is not supported), which requires remote equipment.

For Option 1 to be feasible, the containers could be placed either with an automatic system similar to that of a port for container trucks and ships or using traditional mining strategies. The port-type system will require a unique crane system (similar to a gantry crane), which will likely have to be installed in the back of each chamber. This will likely involve the installation of a complex system of Alimak rails, cable bolt support to ensure the chamber back could support the weight of the crane and the heaviest container, and a port-type container movement system.

Alternatively, the containers could be placed in the chamber remotely using traditional mining strategies. The containers could be placed in lifts with the void between containers filled with waste rock or paste. This will require excavating multiple ramps in a style similar to the "attack ramps" used in the cut and fill mining method. These ramps will be excavated every three vertical meters and will be to be tied into the existing underground development. The new and existing development will have to be sized to accommodate the containers. The containers will also have to be placed remotely because the back of Chamber 15 is not supported and personnel cannot enter the main void. This will hinder productivity and greatly increase the disposal time and costs.

Using paste backfill to co-mingle with the waste, in this options or others noted below, will reduce the permeability of the material placed in the stope void and will reduce the flow of water though the waste prior to freezing.

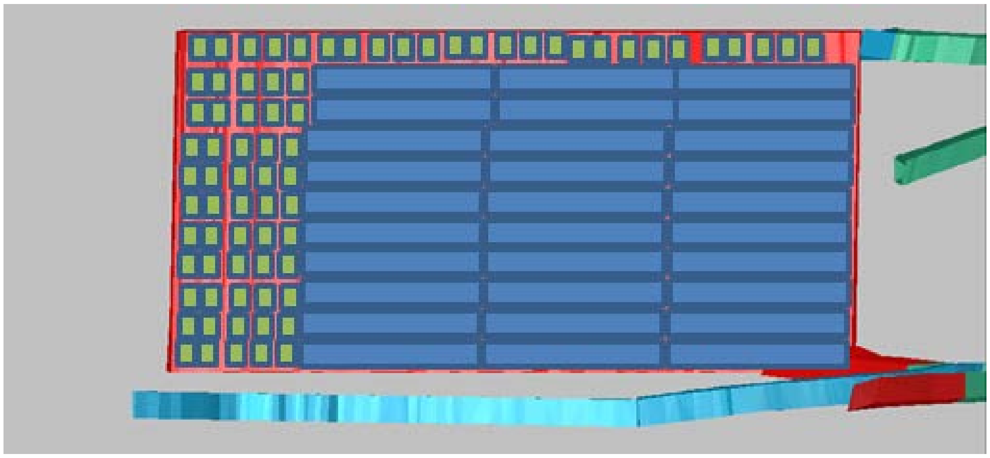


Figure 3: Schematic Longitudinal Section Showing the Perfect Placement of Containers in Chamber 15

Because of the access limitations, increased cycled time (effort), and additional excavations required, Option 1 is not preferred.

5.2 Option 2 – Remove the Waste Bags from the Containers and Place or Dump Them in the Chamber

The second option involves removing the waste from the current containers and subsequently placing it or dumping it in the chambers. This option likely allows for storage of all or most of the impacted waste, but additional checks are described in Section 6.0.

To place the bags in the chamber, some form of cable/pulley system will be required to gently lower them from the top the chamber to the floor, or they will be need to be placed in the chamber itself from the bottom using remote equipment in a manner similar to that described above for placing full containers into the chamber. This approach will require either remote equipment and cut and fill attack ramps, or the removal of the monitoring bulkhead from the overcut of Chamber 15.

Removing the material from the containers, either outside in the open air or underground, transporting it to the chamber, and dumping it could be done in several ways. Forklifts/pickers could tram the material from containers parked either outside or underground and dump it into the chamber. A conveyor system could be constructed and the bags added to them either inside or outside and then dumped into the chamber. Some material may not be in bags and may require special handling.

The process of dumping the bags into the chamber will most likely result in impacted dust entering the underground atmosphere in Chamber 15. The resulting health hazard could be mitigated with appropriate ventilation planning, filtering, and use of water mists.

Both approaches (dumping or placing) will require proper ventilation and dust suppression design as the risk of contaminated dust production from placing bags in the chamber cannot be ruled out.

Because of the increased cycle time to individually extract each palleted bag from the containers and place it in the chamber, the general approach outlined in this option is not preferred.

5.3 Option 3 – Dump the Waste from the Containers Directly into Chamber 15 from Underground

The third option will require construction of a dump point from which the containers can be tilted and the contents emptied into the chamber. The construction of the dump point should not be a problem. However, it is reported that some containers contain long steel members or pieces of wood which will require special handling (i.e., not dumping) to prevent hang-up during dumping. This approach will likely be the quickest for containers that contain bags only, but longer for those that contain longer pieces of waste. Similar to Option 2, this option will require proper ventilation and dust suppression planning to mitigate the dust created by dumping the waste.

Option 3 is thought to be the most efficient approach. However, the exact ratio of containers that can be freely dumped vs. those that will require manual intervention is unknown. Assuming that the majority of the containers can be dumped, another option is required to deal with the small number of containers that cannot be readily dumped directly into the chamber.

5.4 Option 4 – Combination of Options 2 and 3

Assuming that the majority of the containers can be dumped per Option 3, Option 4 is required due to the small number of containers that cannot be readily dumped directly into the chamber and require some re-handling of the waste. The waste in some containers will need to be removed piece by piece and placed in the chamber, possibly under some form of containment. The main impact as outlined later in the report will be increased costs due to higher cycle times and the addition of other equipment.

Like Options 2 and 3, Option 4 will require proper ventilation, dust collection, and worker protection to be designed when emptying containers. The viability of this option will depend on the ease of access to the chamber (discussed in the next section).

5.5 Option 5 – Dump the Waste into Surface Raises That Are Connected to the Chamber

The fifth option will be to create multiple raises from the top of Chamber 15 to the surface. The top of Chamber 15 is approximately 30 m below a hill on surface. To accommodate the containers, a 5 m by 5 m raise will be required from the top of the hill. Two raises will be required to increase the dumping capacity of the chamber and in case one raise blocks. Considering the bulking factor of blasted rock, this represents approximately 2,220 m^3 of material from the construction of the raises that will end in Chamber 15 and reduce the amount of void available for arsenic waste. In addition, a suitable road will have to be built to the top of the hill and a container dumping system will have to be installed next to the holes. Because dumping the containers may create fugitive arsenic dust, a surface building will also have to be installed. This option introduces a risk that the raises “hang up” during dumping of long steel or wood material and additional effort and hazard must be expected to remove it. This long waste material that could potentially plug the raises will have to be handled in a special manner. However, this option may be the cheapest because there will be minimal underground construction and no excavation.

For Options 2, 3, 4, and 5, the ventilation and dust collection system can be designed to prevent the fugitive arsenic dust liberated from dumping the containers from leaving the underground. Chamber 15 has one access drift, and for these options it will contain a ventilation bulkhead containing a fan and dust collection units through which all of the air from Chamber 15 will flow. The collected dust could either be put back into Chamber 15 or treated at the effluent treatment plant. In all cases, a detailed implementation plan will be required at the next phase of study.

5.6 Summary

In general, any option that involves removing the waste bags stored on pallets carefully pallet by pallet will be plagued by long cycle times (e.g., high labor). The containers were loaded bag by bag during roaster deconstruction as the waste was generated, so cycle time was not critical. Dumping the bags will drastically reduce the effort required to get the material in the chamber.

Regardless of how the bags are placed in the chamber, we likely cannot avoid from the potential risk that some could break and airborne dust could be a problem that needs to be dealt with using misting and/or ventilation and air filters.

Options 4 and 5 were considered for further analysis.

Chamber 15 was not used for placement of arsenic dust during production mining due the presence of a water-bearing fault system that was intersected during the excavation of the Chamber. This fault was observed to allow water flow into Chamber 15 during the spring freshet (Golder 1998). A plan to mitigate the water flow was provided to Royal Oak Mines, but the plan was not implemented. The use of Chamber 15 for storage of the arsenic-impacted waste will require one of the following approaches to deal with the water flow into the Chamber:

- Grout off the leakage prior to placement of arsenic waste.
- Cool the rock prior to placement of the arsenic waste in Chamber 15 so any water entering the area freezes before it can enter the chamber.
- Use the existing sump in the drift between Chamber s14 and 15 to collect any contaminated water that exits Chamber 15.

We assume that one of the latter two options will be pursued and no additional costs to deal with the leak are incurred. Also, as water misting may be a way to mitigate any fugitive dust generated during dumping or placing of the bags in the chamber, additional arsenic-contaminated water may report to the contaminated arsenic water management system, called the high-test system.

6.0 ESTIMATE OF CHAMBER 15 VOLUME AVAILABLE FOR WASTE

The overall volume of the chamber and the neighboring drift is approximately 24,000 m^3. However, accurate estimation of the volume of waste that can be placed in Chamber 15 after its removal from the containers is difficult because the angle of repose of the material is not known and the amount of material that can be dumped depends on the dump point.

To understand the impact of these two variables, the available dump volume was geometrically calculated from two dump points: the north end of the chamber where there is access and constructing a new access to the west side of the chamber, assuming angles of repose between 20 and 45 degrees. Figures 4 and 5 show the assumed dump points, and Tables 6 and 7 summarize the volume calculations. The void volume estimates assume that it is possible to dump from the entire width of the overcut on the north end of the chamber, although this has not been confirmed. Dumping from the center of Chamber 15 (Figure 4) requires excavation of a new access to that point and assumes one dump point.

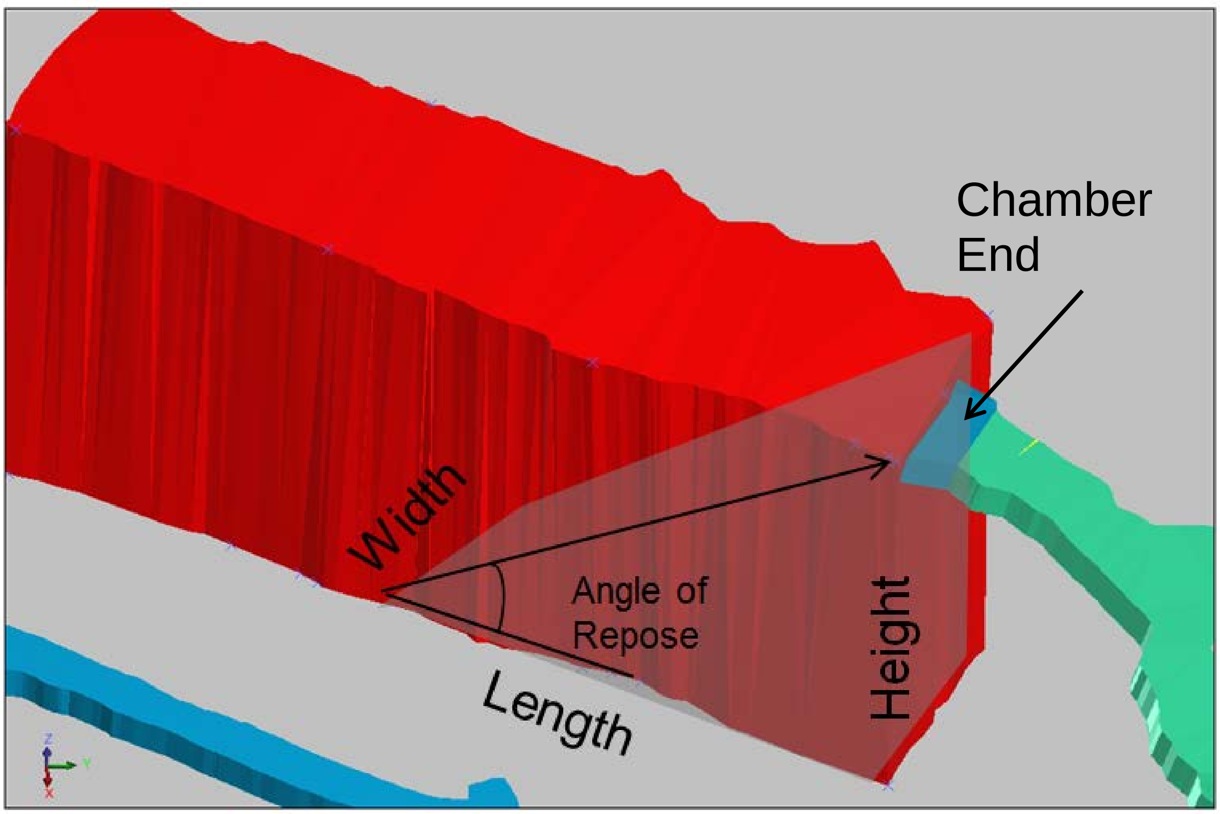


Figure 4: Schematic of the Available Void Volume Dumping from the North End of Chamber 15

Table 6: Estimated Storage Capacity of Chamber 15 for Various Angles of Repose Loaded from the North End

Angle of Repose (deg)	Length (m)	Width (m)	Height (m)	Volume (m^3)
20	84.6	13.5	30.8	17,582
25	66.0	13.5	30.8	13,721
30	53.3	13.5	30.8	11,084
35	44.0	13.5	30.8	9,139
40	36.7	13.5	30.8	7,626
45	30.8	13.5	30.8	6,399

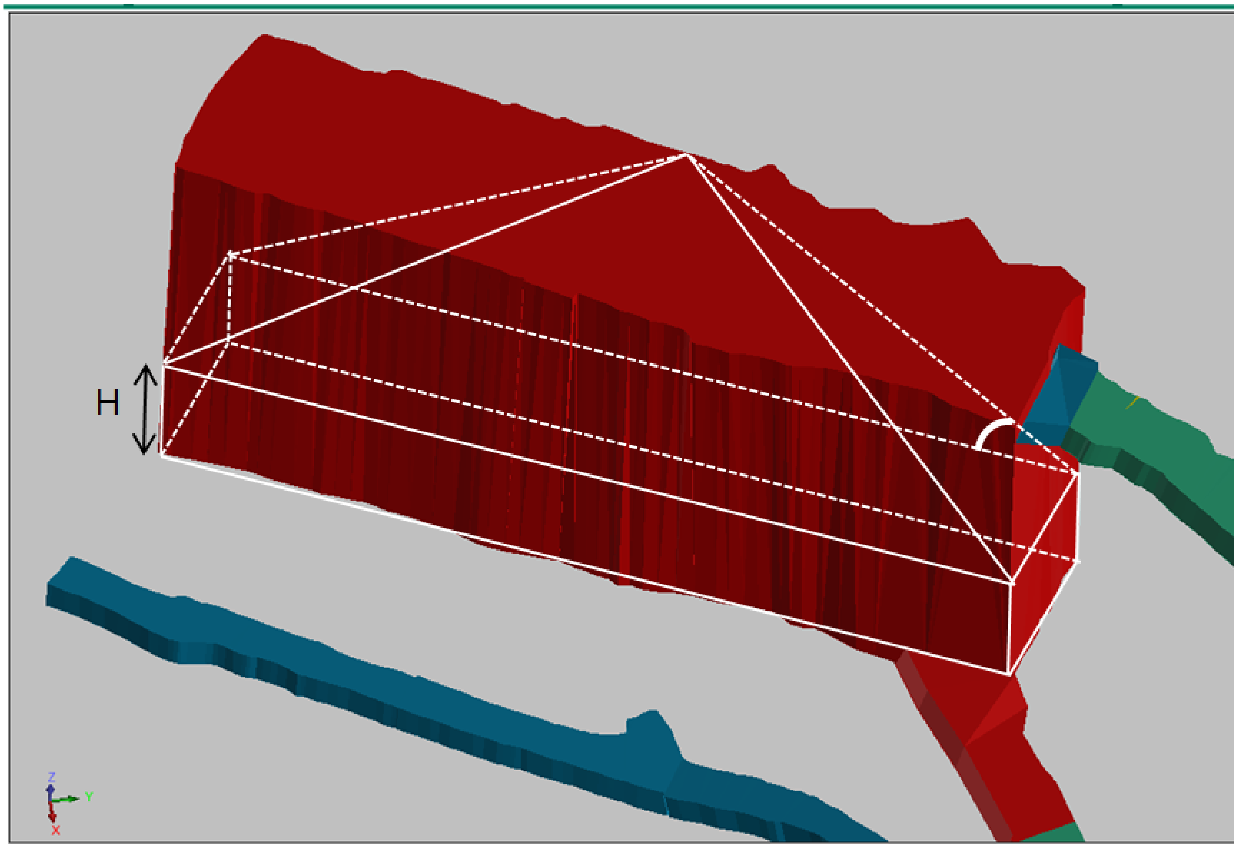


Figure 5: Schematic of the Available Void Volume Dumping from the Side (center of Chamber 15)

Table 7: Estimated Storage Capacity of Chamber 15 for Various Angles of Repose Loaded from the Side

Angle of Repose (deg)	Height of Rectangular Prism (m)	Total Volume (m^3)
20	19.6	19,369
25	16.5	17,627
30	13.0	15,737
35	9.3	13,646
40	5.0	11,282
45	0.0	8,543

A minimum of 13,723 m^3 of space is required to store the existing waste after it is removed from the containers. Therefore, if the existing access at the north end were to be used as a dump, then the minimum angle of repose of the material will have to be 25 degrees to fit all the waste. This is not considered achievable. If the side of Chamber 15 were used as a dump, then the minimum angle of repose of the material will have to be 35 degrees, which is considered a more reasonable value for arsenic bags.

These volume estimates are preliminary, but the side dump estimates are considered accurate enough for the raise option. If the arsenic waste were dumped from above, it is believed that a slightly shallower angle of repose relative to the side-dump option will result. Therefore, if there is enough room from the side, then there is enough room from the raises.

This work indicates that all of the waste in the containers and the collapsed containers can be placed underground in Chamber 15 by dumping from the center of the chamber, which requires a new access to be excavated either as a tunnel to the side of the chamber or as raises to surface. However, at this time it is anticipated that crushed containers do not need to be stored in the chamber.

If the dump point is accessed through a tunnel to the side of the chamber, then using a cemented paste material, possibly produced using impacted soil co-mingled with the arsenic bags, could possibly allow for development of a stable dumping platform inside Chamber 15. This could allow the dumping vehicle, on remote, to "push" impacted waste into the chamber and increase the void usage. This is a benefit to Option 4; however, the risks of placing remote equipment on such a dumping platform will be high.

7.0 CHAMBER 15 ACCESS FOR OPTION 4

Three access options were considered to move the waste underground for Option 4. The first is using the existing drifts to access the overcut of Chamber 15, the second is to excavate a new drift from the transformer pad area, and the third is to excavate a new drift from inside the B2 pit. Figure 6 shows the location of the portals for all three options.

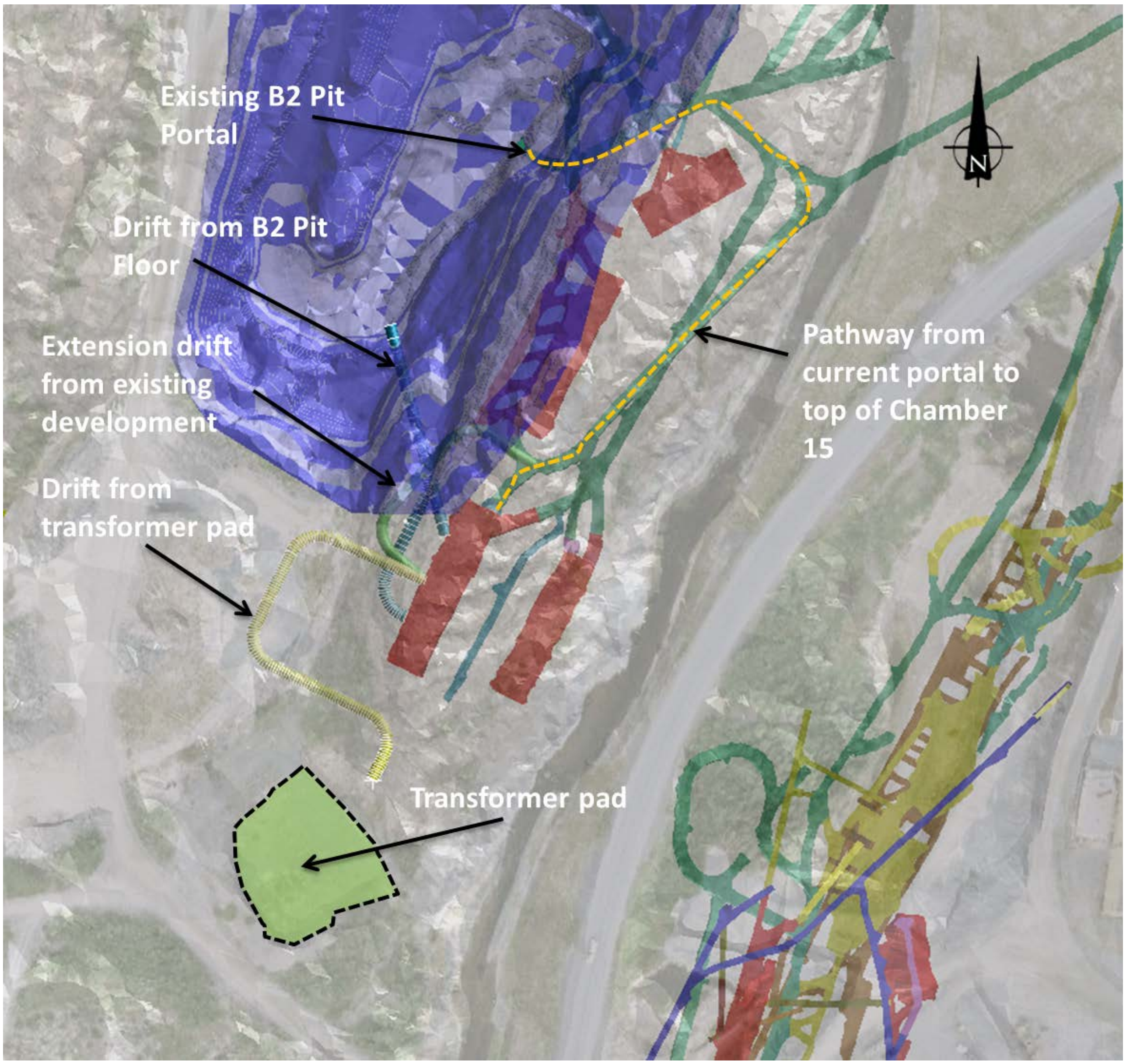


Figure 6: Schematic of the Existing B2 Pit Portal and Possible New Portals Required for Arsenic Waste Storage

Figure 7 shows the location of Chamber 15 on a larger scale plan map for reference.

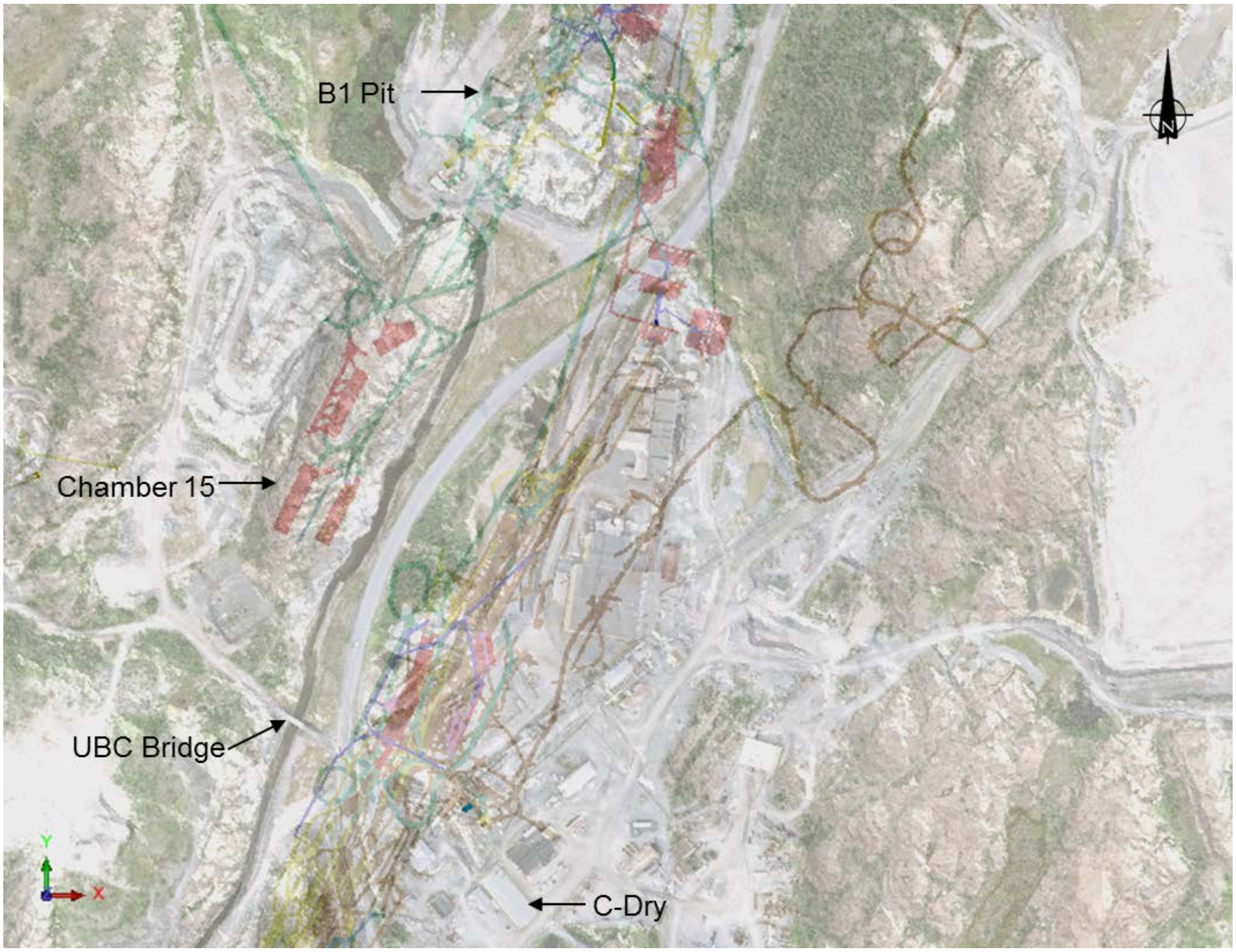
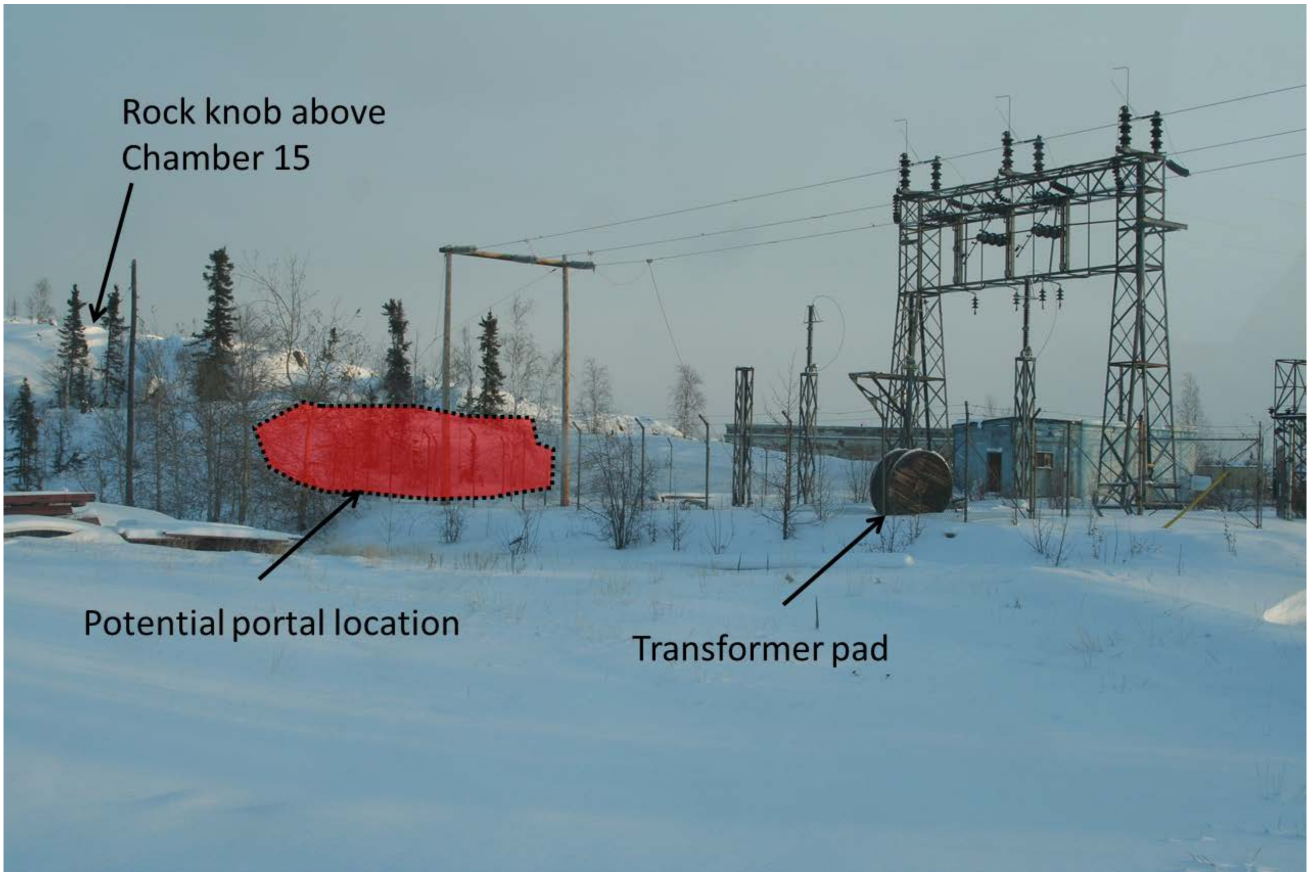


Figure 7: Location of Chamber 15 – Giant Mine Site

The existing underground model was reviewed for the first option to make the sure the containers could fit. Sections taken at regular intervals between the portal in the B2 pit and overcut of Chamber 15 indicate that the containers will not fit and a drift enlargement program will be required. The smallest drift cross-section is 2.4 m high by 3.2 m wide. The containers are all 2.59 m high. In addition, there are six corners in the existing pathway from the UBC portal to the existing opening at the upper/northern side of Chamber 15 that will also have to be widened and a containment bulkhead removed to allow the containers to freely move to the top of Chamber 15. The amount of enlargement will have to include ventilation requirements to accommodate equipment capable of transporting the containers. The enlargement and rehabilitation will likely be easier than excavating a new drift.

During the underground model review, it was noted that one section of the existing access has a high average gradient. This could be an error in the model, or may be real. Anecdotal evidence from site indicates that there is a steep gradient in this area, but the true gradient is not known. The final as-built details of this drift will have to be confirmed prior to a drift enlargement program.

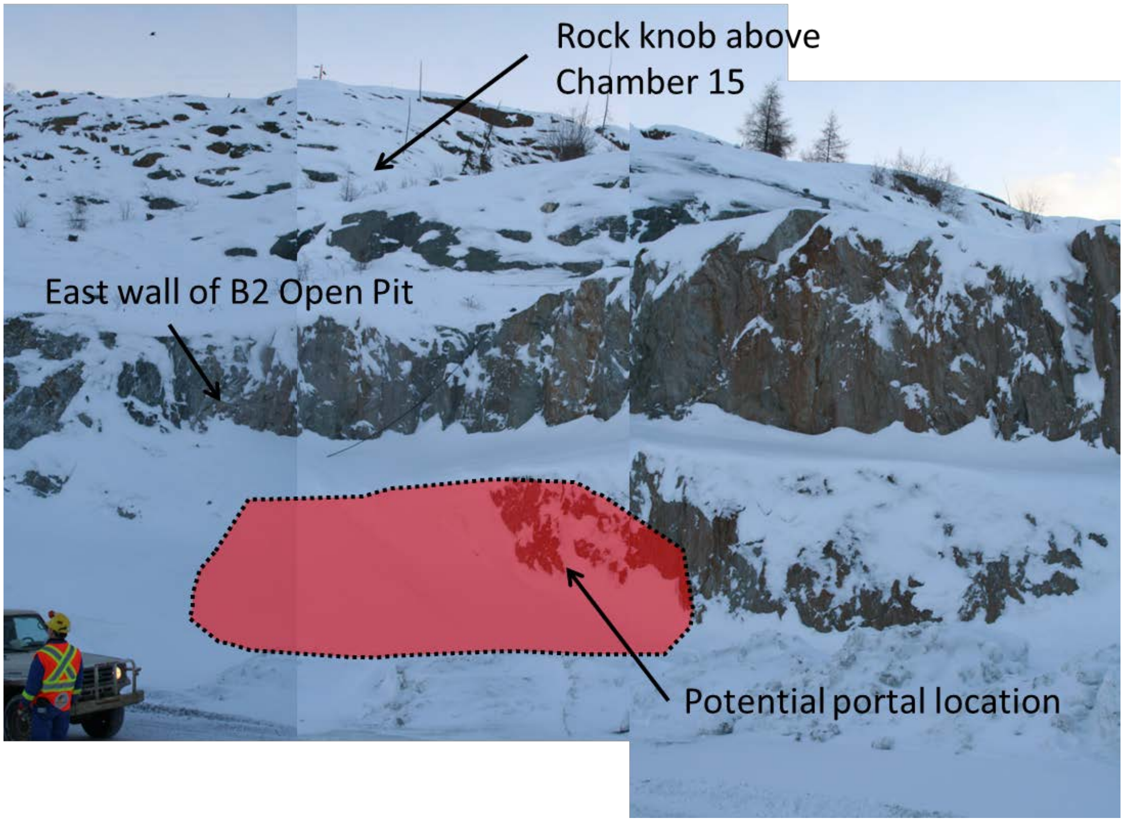
A conceptual drift was laid out from the existing disused transformer pad situated south of the large rock knob that lies above Chambers 11, 12, 14, and 15. Photograph 2 shows the rock knob above Chamber 15, the transformer pad, and a potential portal site for this approach.



Photograph 2: Transformer Pad and Rock Knob above Chamber 15 (looking northeast)

The portal area was chosen because it is ideal for a lay down area for tunnel excavation and dump construction. The majority of the infrastructure for dust collection for Option 4 will be inside the mine, on the other side of the chamber. However, descending to the top of the chamber will require a drift with an average grade of approximately 12%, requiring multiple turns (making it difficult to move entire containers). To access the top of the chamber directly in a straight line will require a drift with a gradient greater than 30%.

A conceptual drift was also laid out for the third option (from the B2 pit). This drift will have a grade of 12.5% up, and a straight line to the side of Chamber 15. Photograph 3 shows the rock knob above Chamber 15, the transformer pad, and a potential portal site for this approach.



Photograph 3: Southeast Corner of B2 Open Pit Ramp – Potential Portal Location (looking east)

This drift access from the B2 open pit could more easily be designed to accommodate the containers (there are no corners). However, the portal is in the pit wall, there is a limited suitable lay down area nearby, and an additional portal in the pit will introduce more traffic to the pit ramp. In addition, another portal in the B2 pit will require additional pit wall stabilization.

The B2 pit drift option is recommended to access the side of Chamber 15 for Option 4. This drift is the shorter of the two proposed new drifts and provides a straight line access to the top of the chamber. It can be designed to accommodate the containers and does not require corners. The lay down area inside the pit can be managed because it is anticipated that loading Chamber 15 will be the main activity in the pit and the muck created during excavation can be end-dumped into the pit outside the portal. This option will also provide the most flexibility for emptying containers and provide an area to help prevent the impacted dust from escaping to the environment.

8.0 WASTE TRANSFER AND DUST CONTROL

Dumping of arsenic-impacted waste out of the containers into the chamber will likely create impacted dust which requires mitigation. Placement of bags is anticipated to create less dust in the chamber, but the possibility cannot be ignored. The impacted dust generated in the chamber from dumping could be managed by water mists and/or creating negative ventilation from the working areas to a dust collection system.

Extraction of arsenic wastes from containers carefully on surface is assumed to be possible in the open air without containment, as the reverse was carried out during roaster demolition. Dumping of containers from a surface raise (Option 5) could require some containment or mitigation on surface at the raise collar where the dumping takes place.

Dust mitigation systems could easily be developed for use in an underground by installing suitably sized ventilation fans to create airflow from the surface access (portal or raise collar) to the chamber and out existing overcut (where the fan will be installed). The dust can be collected on the other side of the fan using water mists and dust collectors. Water mists applied directly to the chamber could also be used to suppress dust. Contact water resulting from mists could be directed into the existing “high test” arsenic-contaminated sump system already present in this area of the underground (see sump location in Figure 2), and therefore no additional construction effort or costs are required. The existing access at top of the northern end of the Chamber 15 could be used as a point where all ventilation from the new access and the chamber itself is directed.

Such a dust mitigation system is applicable to both Options 4 and 5. In Option 4, the waste dumping and transfer will be occurring underground and no additional excavation or building construction is required. The transfer occurs outside in Option 5, and a sprung tent, or an equivalent shelter capable of a negative pressure environment, will be required on top of the raises; additional costs are included in the estimate.

9.0 OPTIONS ASSESSMENT

The general disposal options presented in Section 5.0 need to be combined with potential access options to refine the approach. This section assesses the various disposal and access options and provides the advantages and disadvantages of each combination. The result is a recommended option to pursue. There are three options for disposal (in containers, out of the containers (bags), and a hybrid approach), and each disposal option has four access options: existing drifts, a new drift from the transformer pad, a new drift from the B2 pit, and raises to surface.

9.1 Pros and Cons

The main advantages and disadvantages of the container and bag disposal options are summarized below. Additional advantages and disadvantages of each combination were discussed relative to four criteria listed below:

- safety;
- amount of excavation;
- ease of access for waste disposal; and
- estimated cost.

The advantages and disadvantages of container disposal are listed in Table 8. The main advantage is that there is no need for a transfer station (the containers do not have to be opened). The main disadvantages are as follows:

- Not all the containers will fit in Chamber 15.
- The containers will not fit in the existing drifts.
- A unique container-crane will have to be designed and installed, which may be cost prohibitive.
- A purpose-built trailer will be required to bring the containers underground.

The advantages and disadvantages of bag disposal are listed in Table 9. The main advantage is that all of the arsenic-impacted waste, including the collapsed containers, will fit in Chamber 15. The main disadvantage is that an arsenic waste transfer station and appropriate environmental and personnel exposure protection infrastructure is required underground or on surface.

Table 8: Advantages and Disadvantages of Container Disposal Option

Access Option	Category	Advantage	Disadvantages
Existing Drifts	Safety	The state of the existing underground infrastructure is known.	Existing drifts were not built for the planned activity and additional hazards may exist, such as a high gradient slope in the drift to the chamber. The drifts will have to be enlarged, requiring more underground work, which has inherent risk. Containers will be difficult to move underground. They will require a purpose-built trailer and/or skid.
	Excavation	Easier excavation compared to new drifts.	A detailed survey of the drifts is required to determine the extent of the drift enlargement program. The drifts will have to be significantly expanded, and there may not be enough space between the existing drifts and chambers for the bigger drift.
	Access	It exists.	Ventilation may be an issue if large equipment is required to move the containers. The chamber edge will have to be modified (floor or back) to allow the tipping of the large containers, or a large loading platform will have to be excavated to pick up the containers for placement in the chamber. Modifications to the overcut will likely fall into the chamber, reducing the available volume. Bulkhead deconstruction required. Chamber is not big enough to hold all the containers.
	Cost	Rehabilitation is likely cheaper than a new drift.	
Transformer Pad Drift	Safety	Drift can be designed to move the largest piece of equipment necessary to current safety standards and codes. Large lay down area next to portal.	A long drift with a steep gradient could pose a haulage problem and may require improvement. New excavations underground will increase the chance of a worker injury. Containers will be difficult to move underground. They will require a purpose-built trailer.
	Excavation	Drifts could be designed to accommodate the largest piece of equipment. Additional drifts could be used to create multiple dump sites on the side of the chamber, which will increase the amount of material that could be dumped into the chamber. The excavation design could be such that limited muck rock enters the chamber.	Corners will be have to be large to accommodate the large containers. New excavations will create more muck that requires disposal.
	Access	The chamber edge can be designed to accommodate containers. Multiple dump sites will increase the quantity of material that will fit. Ventilation will be easier to control with two accesses to the chamber.	Multiple dump sites will create additional muck.
	Cost	Fit for purpose drift design, meaning larger equipment could be used with fewer back and forth trips to surface. New development to accommodate the largest piece of equipment could be expensive.	Long new drift will be a relatively expensive option. Multiple dump sites will cost more.
Pit Drift (Continued)	Safety	Drift can be designed to move the largest piece of equipment necessary and to current safety standards and codes.	Small lay down area next to portal. Increased pit traffic. Containers will be difficult to move underground. They will require a purpose-built trailer. New excavations underground will increase the chance of a worker injury.
	Excavation	Drifts could be designed to accommodate the largest piece of equipment. Additional drifts could be used to create multiple dump sites from the side. Drift is up-gradient for easier excavation.	Will create more muck that requires disposal.
	Access	The chamber edge can be designed to accommodate containers. Multiple dump sites will increase the quantity of material that will fit. Ventilation will be easier to control with two accesses to the chamber.	Multiple dump sites will create additional muck.
	Cost	Shorter distance to excavated means relatively cheaper option. Fit for purpose drift design, meaning larger equipment could be used with fewer back and forth trips to surface.	Multiple dump sites will cost more.

Table 9: Advantages and Disadvantages of Bag Disposal Option

Access Option	Category	Advantage	Disadvantages
Existing Drift	Safety	Less drift modification required because smaller equipment can be used.	A transfer area has to be built to move the arsenic-impacted waste out of the containers and into smaller bags if necessary.
	Excavation	Easier excavation compared to new drifts. Extensive rehabilitation or drift enlargement is likely not required.	Dealing with legacy excavations has more unknowns and could lead to more problems.
	Access	May fit all of the arsenic waste.	Ventilation may be an issue if large equipment is required to move the containers. Ventilation design to keep workers out of the arsenic may be difficult to implement. New drifts will have to be excavated to create multiple dump sites (only one site available). Bulkhead deconstruction required.
	Cost	Likely cheapest of all bag options.	Many trips in and out of the underground will be required.
Transformer Pad Drift	Safety	Purpose-built drift to current standards and regulations. Two access points to the chamber will allow the creation of a positive pressure area underground to reduce arsenic exposure during container movement.	Underground excavation is risky.
	Excavation	Large lay down area.	Long underground drift with many corners.
	Access	Two accesses to the side of the chamber are possible. Two or more accesses will make ventilation design easier. Likely fit all of the arsenic waste.	Multiple dump sites will create additional muck.
	Cost	Likely the most expensive option.	Long new drift will be a relatively expensive option.
Pit Drift	Safety	Purpose-built drift to current standards and regulations. Two access points to the chamber will allow the creation of a positive pressure area underground, to reduce arsenic exposure during container movement.	Small lay down area increases the risk for accidents.
	Excavation	Short underground drift with few corners.	Muck disposal outside the portal may be difficult.
	Access	Straight line to the top of the chamber. Easiest design to create multiple accesses to the side of the chamber. Likely fit all of the arsenic waste.	Multiple dump sites will create additional muck.
	Cost	Shortest lateral excavation.	Multiple dump sites will cost more.
Raises to Surface	Safety	Work will be carried out inside a building Road building expertise readily available	Trucks will have to back up a steep incline (14%).
	Excavation	No lateral excavation. No ground support required	Difficult to drill and blast a 5 m by 5 m raise accurately.
	Access	Possibly the quickest cycle time	The waste may be hung up in the raises.
	Cost	Likely the cheapest option	Likely the highest risk.

9.2 Options Ranking

The following assessment is a relative comparison of the ease of construction and ease of use of the various options described in Sections 5 and 6. It is based on safety, excavation, ease of access, and cost, and was completed to assist with choice of the preferred option. Each category is ranked on scale of 1 to 5, and the meaning of the rankings is shown in Table 10. The costs are qualitatively ranked relative to the other options.

Table 10: Access and Disposal Selection Ratings

Description	Rating
Low Difficulty/Cost	1
Moderate Difficulty/Cost	2
High Difficulty/Cost	3
Very High Difficulty/Cost	4
Severe (Fatal Flaw)	5

The rankings for the four base options and for various surface-underground accesses are presented in Table 11. The approach indicates that moving bags or containers down a new drift from the B2 pit or dumping the containers down the raises are the preferable options. The only fatal flaw will be trying to design a raise to accommodate dumping a container, and the only activity that is considered to have low difficulty is modifying the existing excavations to accept a vehicle carrying bagged arsenic-impacted waste. The high and very high difficulties reflect either the complicatedness of placing all of the waste inside the chamber(s) or the activity of repackaging the waste from containers to bags.

Table 11: Access and Disposal Options Matrix

	Category	Safety	Excavation	Ease of Access	Cost	Total
Containers	Existing Drift	2	3	4	4*	13
	Transformer Pad	2	2	4	4*	12
	B2 Pit	2	2	4	4*	13
	Raises to Surface	2	3	4	5**	14
Bags	Existing Drift	4***	1	4	2	11
	Transformer Pad	4***	2	2	3	11
	B2 Pit	3***	2	2	3	**10**
	Raises to Surface	3***	2	2	3	**10**
Hybrid (bags and containers)	Existing Drift	4***	3	4	3	14
	Transformer Pad	4***	2	2	3	15
	B2 Pit	3***	2	2	3	**10**
	Raises to Surface	3***	3	2	3	11

*Requires additional chambers to be excavated.

**Not considered realistic to dump the containers down the raises.

***Requires ventilation system for containment of dust.

10.0 CONCLUSION

The discussion presented in the previous sections recommends the arsenic-impacted waste be dumped in Chamber 15 either through a new tunnel with a portal in the B2 open pit (Option 4), or via raises from surface (Option 5). The main benefits of these options are as follows:

- require minimal new excavation;
- provide access to the side or top of the chamber, increasing the likelihood that all the existing arsenic waste, and possibly more if it is generated, will fit in the chamber; and
- are flexible enough create a repackaging station with negative pressure, if required or desired for regulatory reasons, to control fugitive dust during dumping.

A new drift from the B2 pit will have additional benefit of being able to accommodate the containers if it is required that some small number of highly impacted containers must be placed underground.

All options presented are reversible as the material could be removed via mining methods if and when alternative treatment and storage options are identified in the future.

11.0 COST ESTIMATE

A conceptual design and cost estimate was completed for Options 4 and 5. The cost estimate is based on the main unit cost inputs summarized in Table 12 and on the assumptions described below that table. The ±40% accuracy cost estimate was focused on capturing construction activities including contractor profit (e.g., all Division 1 costs may not be accounted for).

Table 12: Unit Cost Inputs for the Cost Estimates

Item	Unit	Cost ($)
Labour	Per hour	54
Operator	Per hour	62
Foreman	Per hour	122
Engineer	Per hour	98
Senior engineer	Per hour	156
Drift	Per meter	7,000
Paste	Per cubic meter	144
Mobile crane	Per hour	200
Low-boy trailer	Per hour	137.5
Crew truck	Per hour	20
Hoisting equipment	unit	67,100
Contingency (new drift)	Each (20% of cost)	937,000
Contingency (raises)	Each (20% of cost)	919,000

The design for Option 4 is summarized in Table 13 and presented in Appendix A, and the cost is presented in Table 15. The design for Option 5 is summarized in Table 14 and presented in Appendix B, and the cost is presented in Table 15. The designs presented in the appendices vary slightly from those discussed in the preceding sections. However, the conclusions previously drawn are still applicable. In both cases, the cost estimates are based on the following assumptions:

- The cost estimate was developed to an accuracy of ±40%.
- The cost to freeze Chamber 15 was supplied by NGI (2015).
- The cost to stabilize the pit wall above the proposed B2 pit portal (Option 4) has been included.
- The containers are all based in the tailings management facility and it is a 6 km round trip to the dump point.
- Ninety percent of the containers will be end dumped into the chamber.
- Ten percent of the containers will require manual involvement to move the waste into the chamber.
- A vehicle capable of backing the containers up a 14% gradient is available on the market.
- The project duration is based on a two 10-hour shifts per day, 5 days per week schedule, and there are 50 productive minutes per hour.

- The labor cost is based on Golder's database of costs.
- All services, including power, water, and compressed air, are available and close to the proposed portal or surface raise collar.
- The void remaining in Chamber 15 after completion of the waste disposal will be filled with paste.
- A 20% contingency on costs was added to account for northern works and a design allowance on installation costs and excavation overbreak.

Table 13: Summary of the Design for the New Drift from B2 Pit

Item	Description
Drift size	4.5 m wide by 4.5 m high
Drift length	100 m and 75 m
Drift gradient	8% and 12%
Volume of paste required	7,000 m^3
Total storage volume	20,336 m^3

Table 14: Summary of the Design for the Raises

Item	Description
Raise size	5 m wide by 5 m long by 30 m high
Haul road gradient	14%
Haul road size	12 m wide; 2 m wide berms on either side
Volume of paste required	7,000 m^3
Total storage volume	17,700 m^3

Table 15: Summary of the Cost to Dispose of the Arsenic-Contaminated Waste in Chamber 15

Item	New Drift (000$)	Surface Raise (000$)
Project management	188	187
Portal and underground development	1,571	---
Surface haul road and raise construction	---	500
Dump facilities construction and preparation	843	838
Disposal of arsenic waste	879	873
Paste fill of Chamber 15	1,203	1,194
Contingency	937	718
Additional freeze infrastructure	27,664	27,664
Surface dust containment facility (tent)	--	500
Carrying costs for cleaning containers if necessary	200	200
Total	**33,485**	**32,874**

It is estimated that 20 weeks (5 months) are required to move all of the identified waste from the tailings management facility to Chamber 15. The project schedule was chosen so that the project could be completed in the warmer months of the year. The extreme low temperatures that occur in Yellowknife, typically during the first quarter of the year, will therefore not be a concern. The current estimate assumes that the project will start in mid-April and end mid-September and is based on dumping 90% of the containers and manually unloading 10% of the containers. A sensitivity analysis on the manual/dumped ratio indicates that a 10% increase in the amount of containers requiring manual dumping extends the project by two weeks, which could extend the project into the colder months of the year and require additional cost and delays to account for the weather.

The total cost for Option 4 is 33.5 million dollars and for Option 5 is 32.9 million dollars, with the majority of the cost coming from the additional freeze infrastructure. Although Option 5 is less expensive, it presents increased risk in the form of “hung-up” raises which could prevent the complete disposal of the waste. Therefore, Option 4 is recommended. It is more expensive but provides increased storage volume which could handle as yet unidentified arsenic-impacted waste or soil.

12.0 DETAILED DESIGN

If Option 4 is determined to be suitable for the next level of project design, the following studies are required:

- a detailed implementation plan;
- a study on the benefits of co-mingling the waste with cemented paste backfill;
- completion of ventilation design to estimate the fan pressure required to create the drift velocity necessary for a negative pressure environment and the dust collection system to prevent the fugitive arsenic dust of impacting workers and leaving the underground mine;
- a study to determine whether mitigating the water flow that could result from the fracture controlled seasonal water flow in the southern end of Chamber 15 prior to freezing and filling the stope is required;
- field verification site visit;
- slope hazard assessment and slope support or protection design;
- a cavity scan of Chamber 15 to ensure that the volume estimates used in this report are accurate;
- review of the labor productivity and dust collection system design and cost estimate from the Roaster Demolition Project to ensure the rates used in future cost estimates are reasonable;
- determination of the final destination for broken material created during excavation of new drifts; it is currently assumed that the material will be used somewhere on site;
- design of the lifting and dumping system inside the tunnel;
- sourcing of a truck capable of backing up steep gradients with large loads;
- confirmation that the drift design is suitable to the ground conditions, particularly focusing on the intersection between the two drifts near the portal, and design of ground support system as required;
- excavation shape design and blast layout;
- a detailed review of the container contents to estimate the quantity of containers that will require manual handling to facilitate dumping of the contents; and
- a literature review to estimate the possible angle of repose of the material.

13.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or additional requirements, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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Senior Project Manager

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HC/DTK/ls/rs/cf/it/ah

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NGI (Newmans Geotechnique Inc.). 2015. Ground Freezing Options in Relation to Surplus Arsenic Waste Disposal. Draft technical memo to AECOM. July 6, 2015.

STUDY LIMITATIONS

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APPENDIX A

New Drift Conceptual Design for Costing

New Drift Conceptual Design for Costing

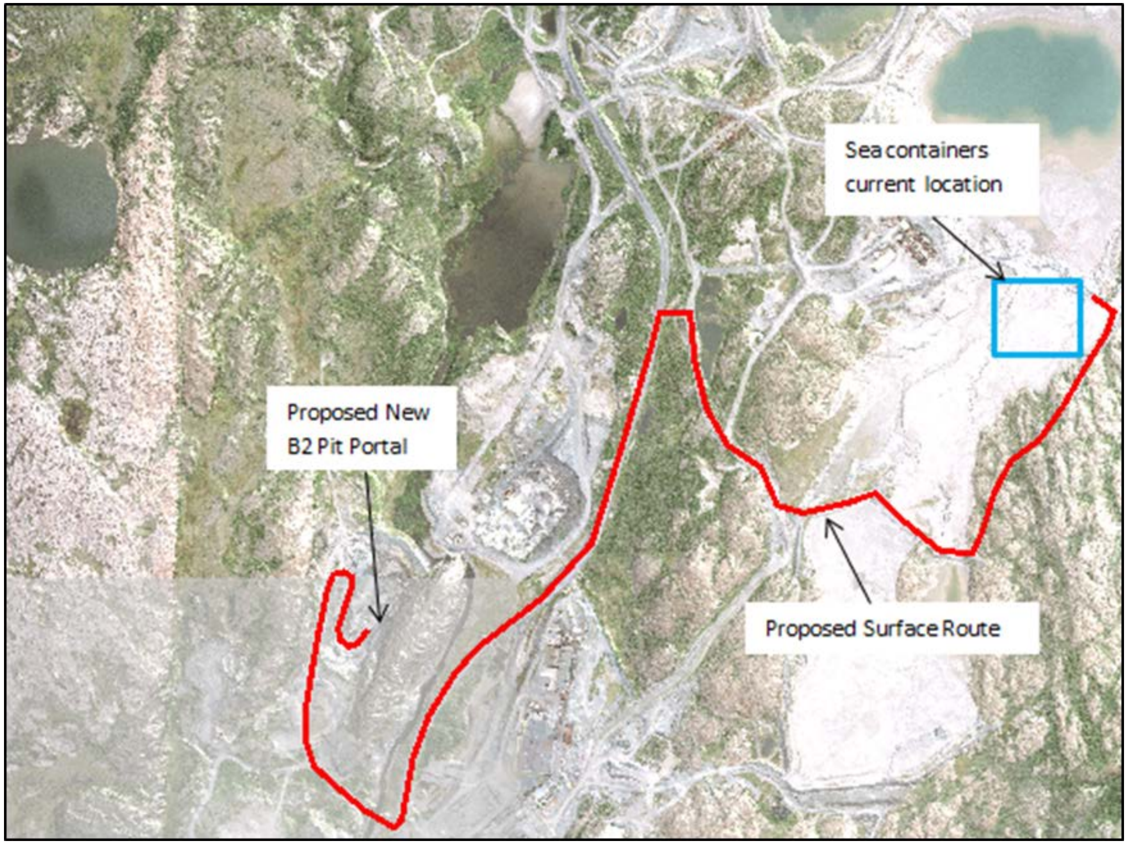
Giant Mine TA 29, Arsenic Waste Disposal

Outline

- Surface route and cycle times
- Describe disposal concept
- Volume of void available
- Fugitive dust control
- Cost estimate (PDF)

Surface Transport

- 395 Sea containers + misc waste at tailings management facility (TMF)
- 3km from TMF➔B2 Pit on low-boy trailer

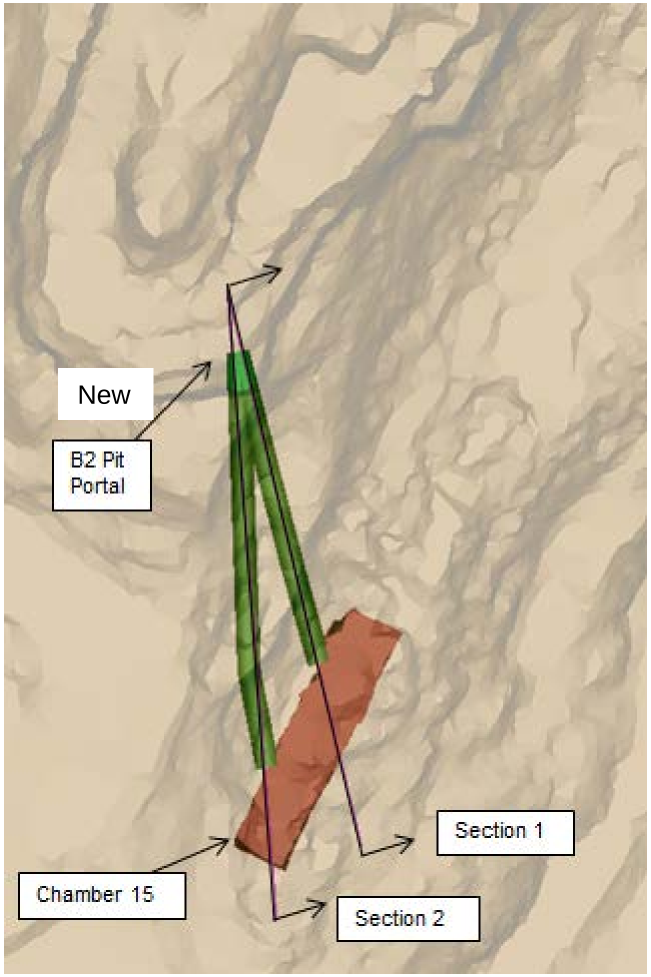


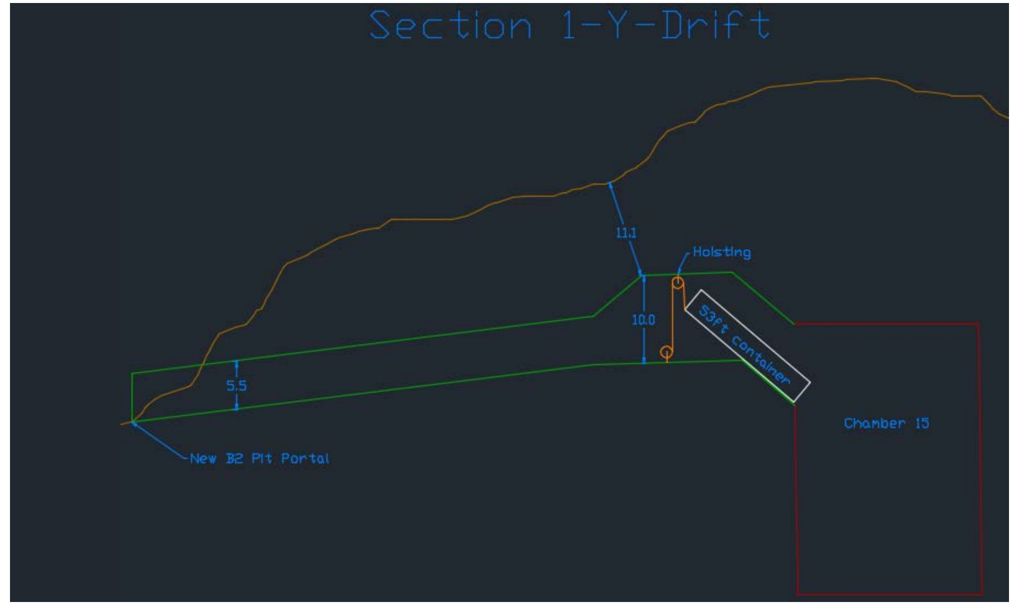
Cycle Times

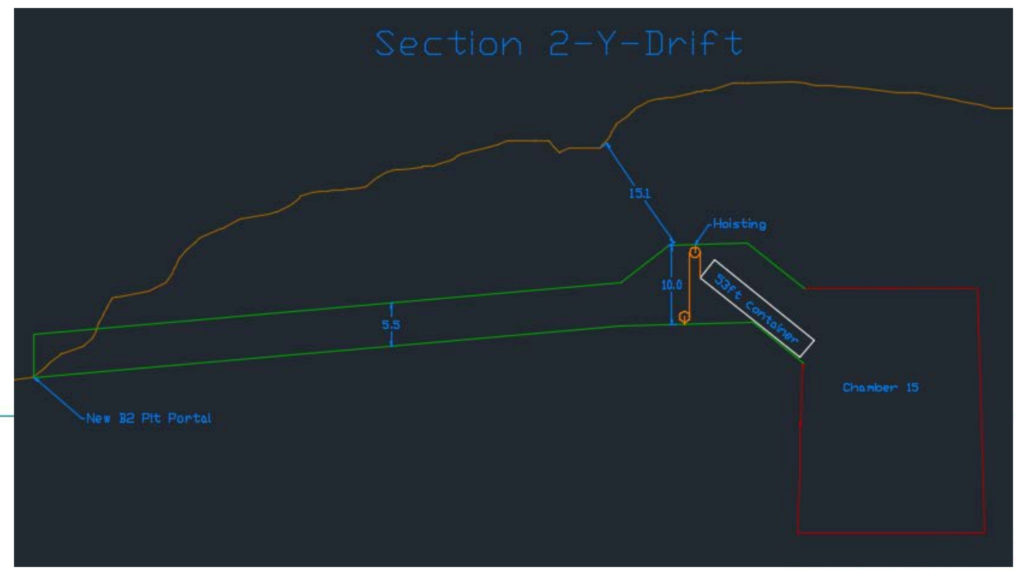
Container Type	Quantity*	Total time (hrs)	Total working days (20 hr days)	Total working weeks (5 days/week)
53' Cont w Pkg'd Waste	179	616	62	12.3
40' Cont w Pkg'd Waste	180	608	61	12.2
20' Cont w Pkg'd Waste	2	7	1	0.1
40' Cont w Un-pkg'd Waste	34	135	14	2.7
53' Container Load w Drums	22	117	12	2.3
53' Container Load w Pipes	3	14	1	0.3
Wood TRP/Mill (load in 53')	81	375	37	7.5
Totals	501	1,871.4	187.1	37.4

* Quantity of containers either explicitly provided by AECOM or estimated by Golder

Undergound Disposal Concept





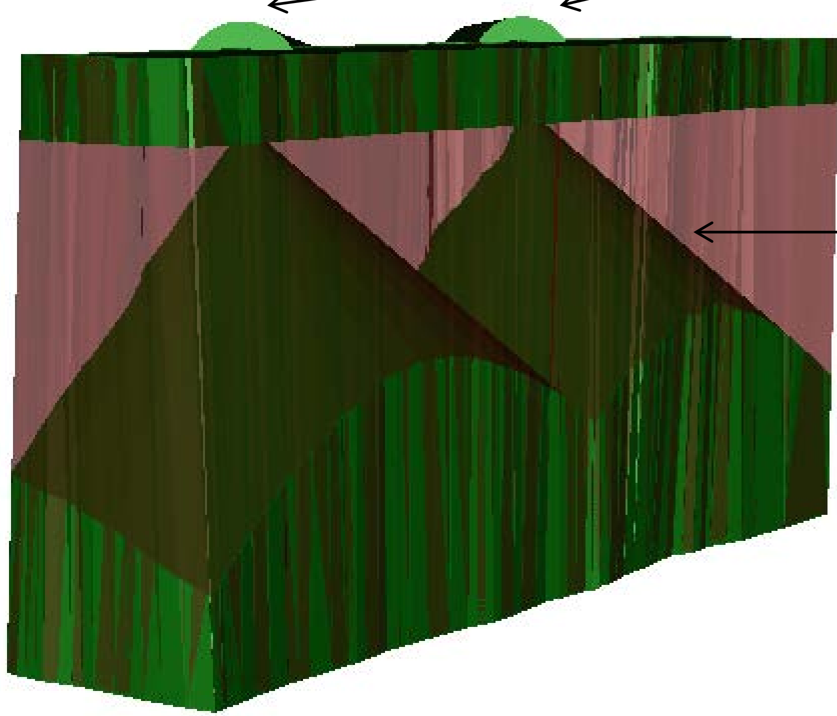


Undergound Disposal Concept

Total Volume Available = 20,336 m^3

Total Volume of Waste = 13,723 m^3

Collapsed containers = 3,367 m^3



Volume

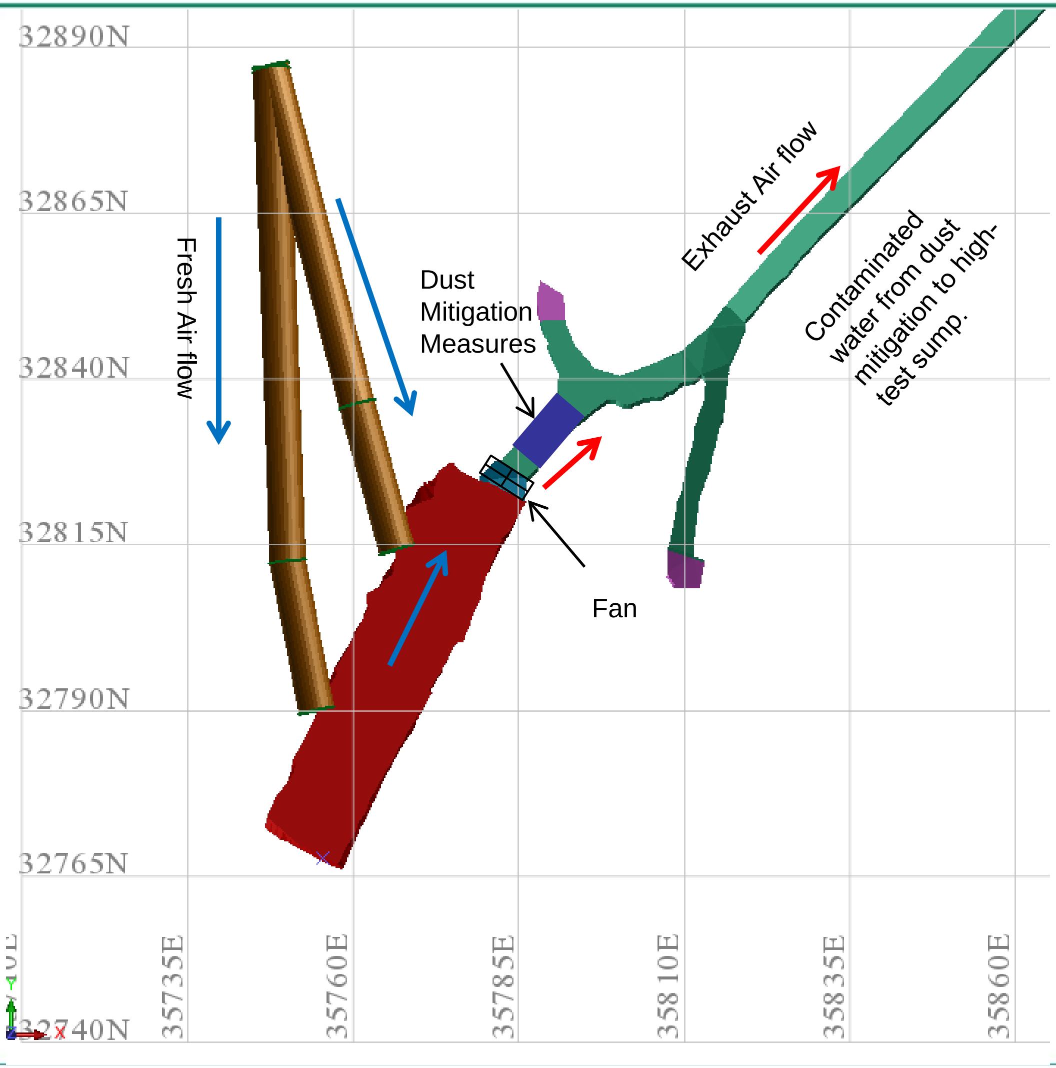
Void Volume Available for Filling

Item	Volume (m^3)
Fill cones	14,436
Top Cap	3,500
Drifts	2,402
Total space available	20,336

Paste Fill Volume Required

Item	Volume (m^3)
Chamber 15	23,000
Top cap	-2,250
Arsenic waste	-13,723
Paste required	7,027

Ventilation / Dust Control



APPENDIX B

Surface Raises Conceptual Design for Costing

Surface Raises Conceptual Design for Costing

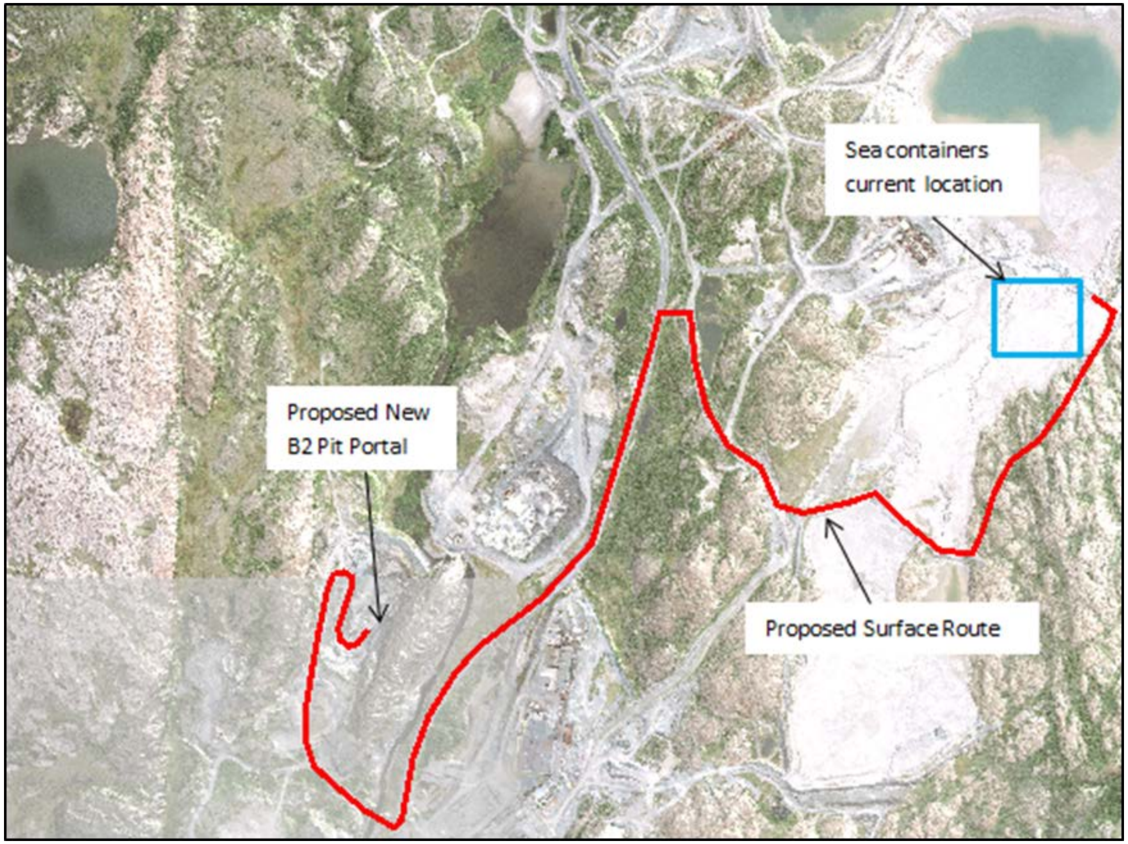
Giant Mine TA 29, Arsenic Waste Disposal

Outline

- Surface route and cycle times
- Describe disposal concept
- Volume of void available
- Fugitive dust control
- Cost estimate (PDF)

Surface Transport

- 395 Sea containers + misc waste at tailings management facility (TMF)
- 3km from TMF➔B2 Pit on low-boy trailer



Cycle Times

Container Type	Quantity*	Total time (hrs)	Total working days (20 hr days)	Total working weeks (5 days/week)
53' Cont w Pkg'd Waste	179	616	62	12.3
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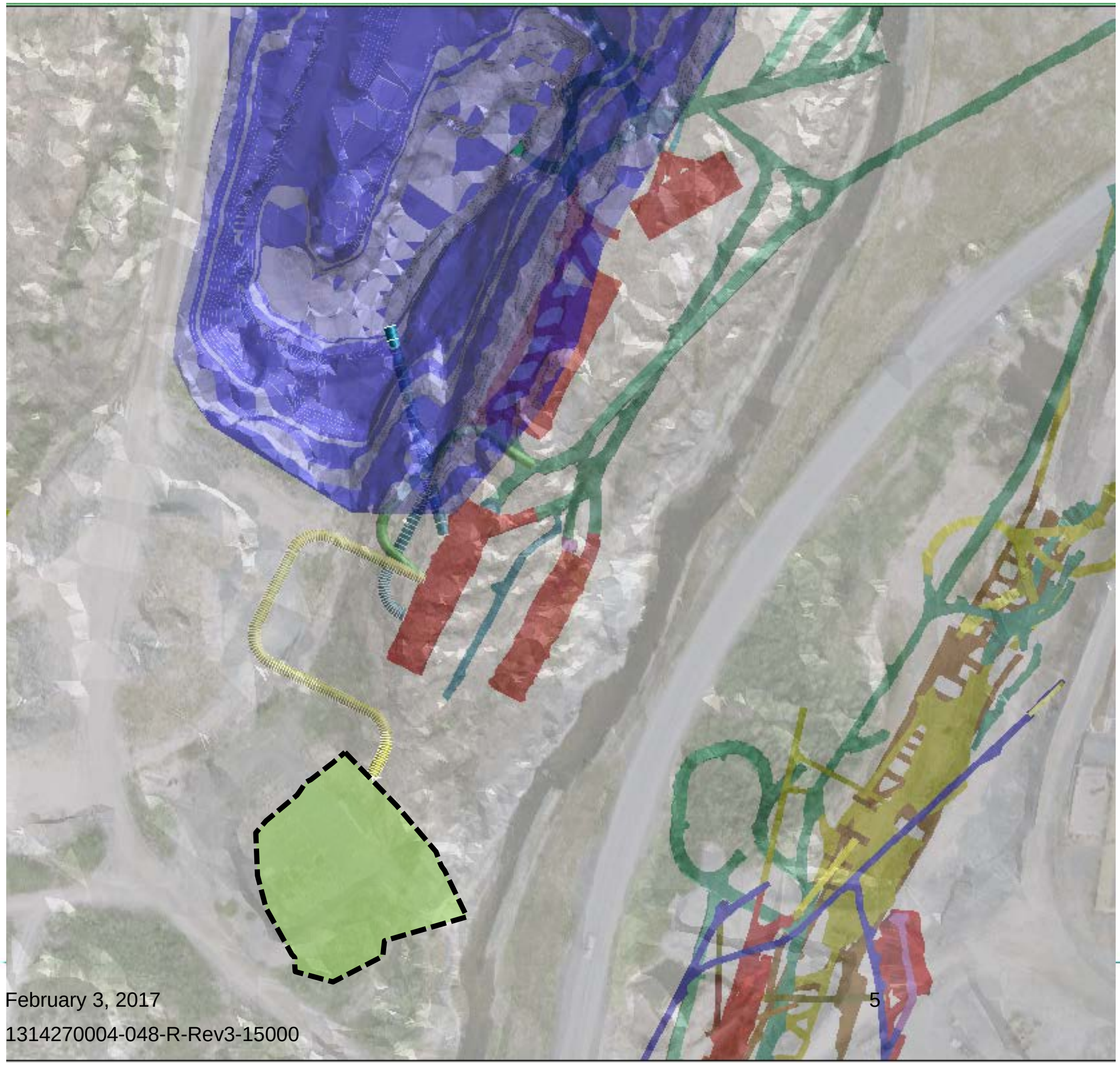
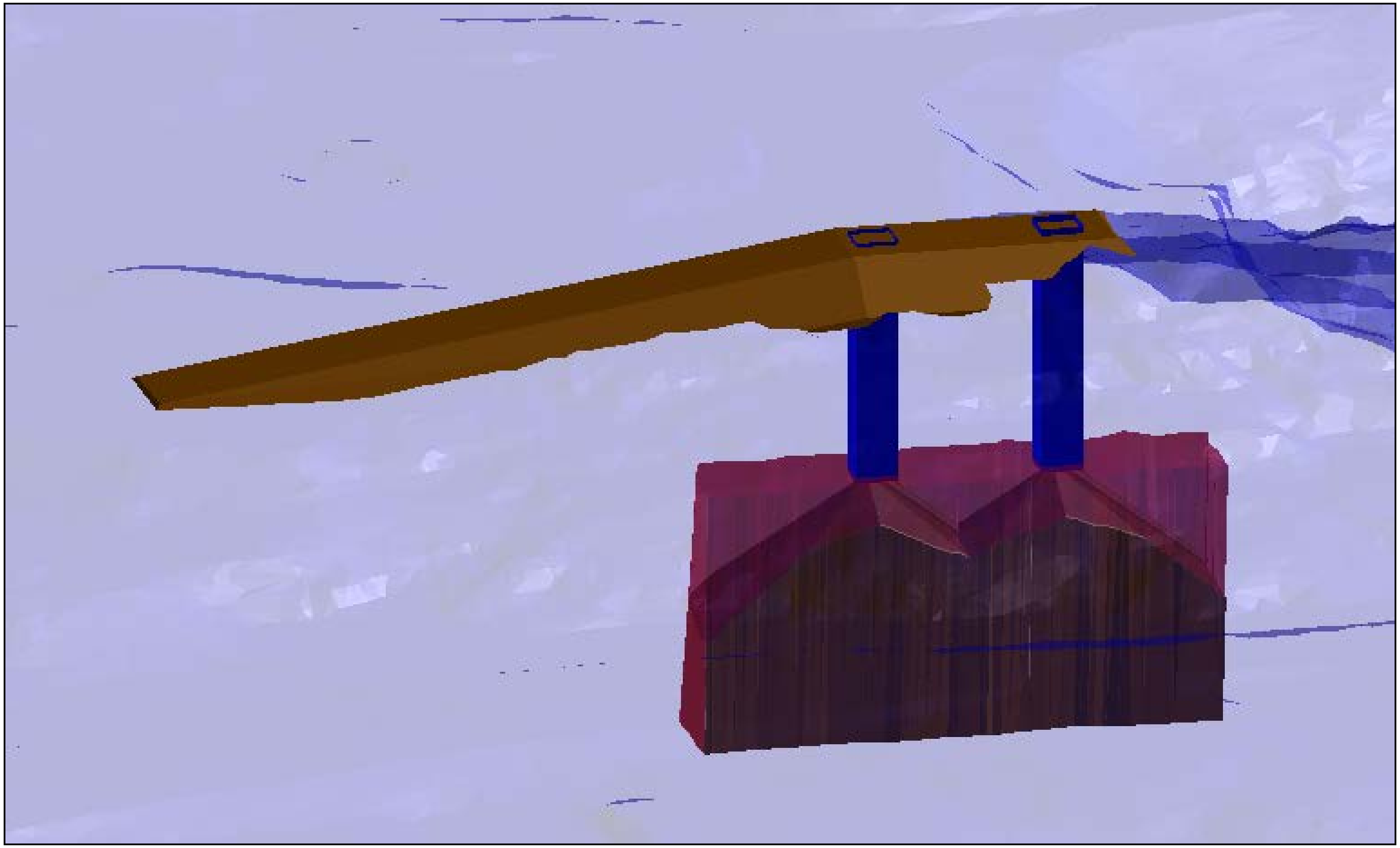
40' Cont w Un-pkg'd Waste	34	135	14	2.7
53' Container Load w Drums	22	117	12	2.3
53' Container Load w Pipes	3	14	1	0.3
Wood TRP/Mill (load in 53')	81	375	37	7.5
Totals	501	1,871.4	187.1	37.4

* Quantity of containers either explicitly provided by AECOM or estimated by Golder

Haul Road Option

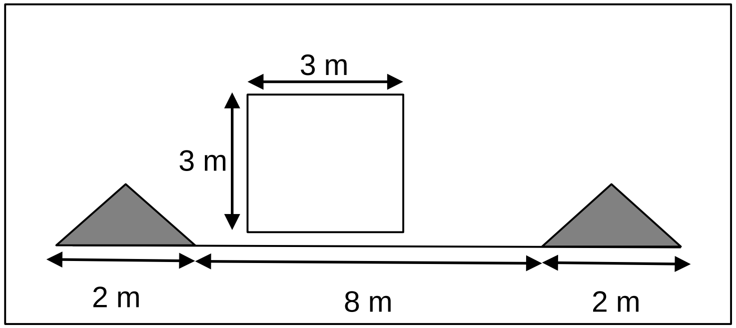


Haul Road Option

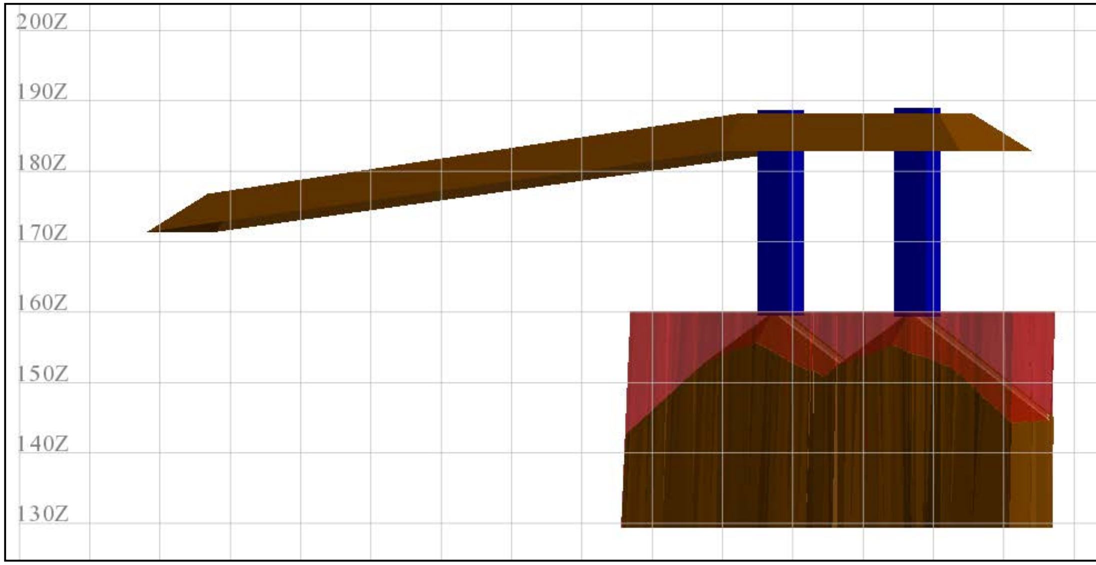


Haul Road Option

Schematic Road Design (NTS)



Longitudinal Section of Road and Raises



- Road Design:
  - Containers 3 m by 3 m
  - Maximum grade 14%
  - Maximum 8 m wide travel way
  - Road is ~120 m long
  - 2 m wide aggregate berms on either side of the road (0.75 m high)

Volumes

Volume Available for Filling

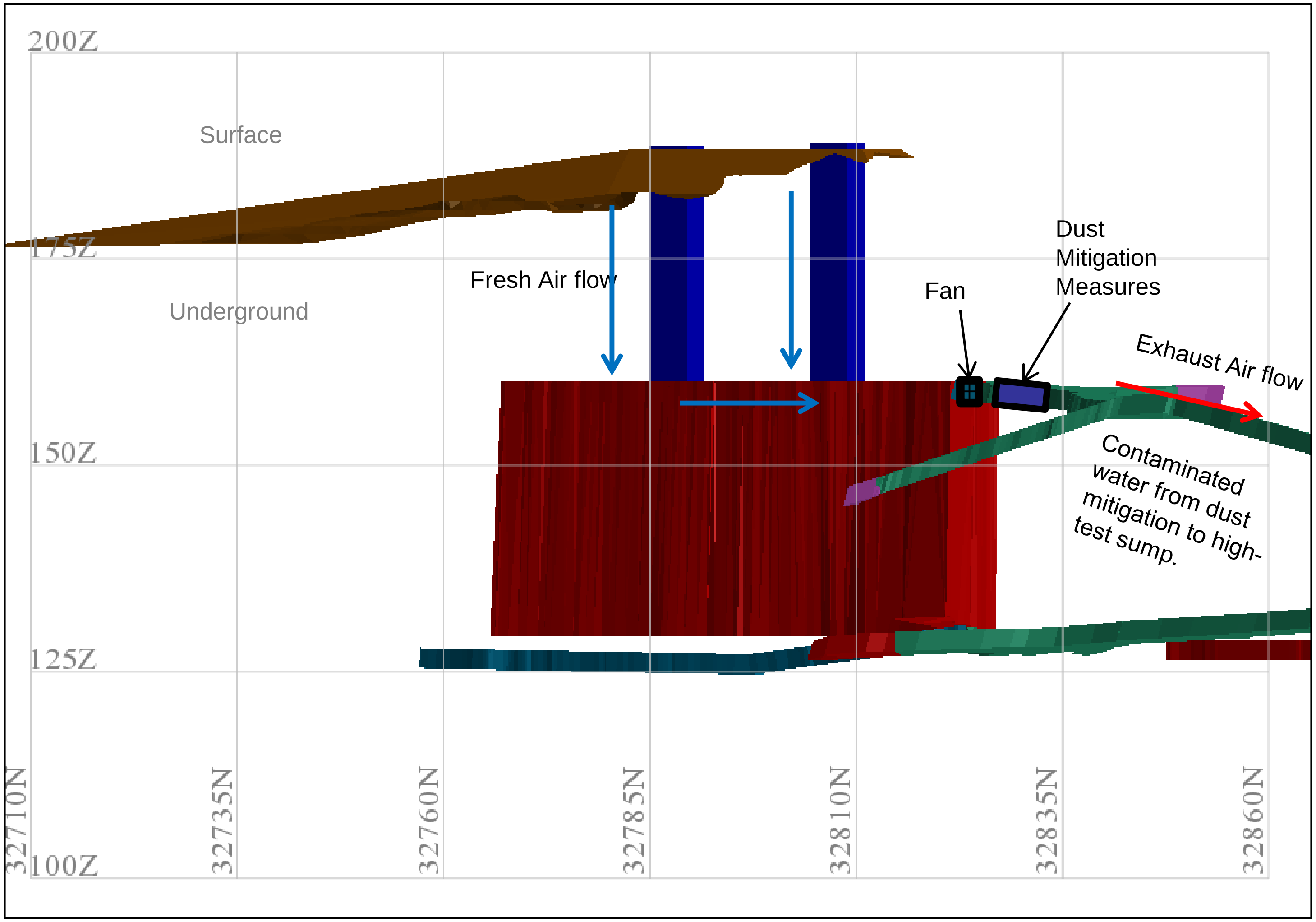
Item	Volume (m^3)
Fill cones	19,925
Raise muck (swelled)	-2,220
Total space available	17,705

Paste Required

Item	Volume (m^3)
Chamber 15	23,000
Arsenic waste	-13,723
Raise muck (swelled)	-2,220
Paste required	7,057

- Assuming:
  - 50% swell on raises (includes poor blasting)
  - 30% contingency on haul road volume
  - Raises are backfilled with aggregate from site

Ventilation / Dust Control



Raise Cost Estimate

Details

- 2 x 25 m^2 by 30 m long raises
- Drill Holes: 48
- Drill Meters: 1,440 m
- Hole Size: 114 mm
- Powder Factor: 1.22 kg/m^3

Cost

- Drilling Cost: 57,600 (@ $40/m; includes labour)
- Drilling Contractor Mob/demob: $20,000
- Blasting Products: $3,800
- Blasting Labour: 1 week @ 2 blasters (160 hours * $40/hr) = $6,400
- Blasting Contractor mob/demob: $10,000

Total Raise Excavation: $97,800

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