Ventilation Planning at the P.T. Freeport Indonesia's GBC Mine

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ABSTRACT: This paper describes the ventilation planning that was performed for the P.T. Freeport Indonesia's Grasberg Block Cave (GBC) deposit located in the province of Irian Jaya, Indonesia. The mine is located at an elevation of around 3,000 m in the Puncak Jayawijaya Mountains and about 90 km from the coast. The GBC mine will be one of the largest underground block cave mines in the world with projected production at 160,000 tons per day. Primary personnel and supply access to the mine will be via a 6.0 km tunnel called the AB Adits. From the AB Adits, a shaft will convey personnel and supplies up to the main workings in the GBC. Primary ventilation is through 2.6 km tunnels with four as intake and three as exhaust. A fourth exhaust is in parallel with the conveyor system. A series of network simulations were conducted to evaluate ventilation raise locations, size and number of airways, and the duties of the primary exhaust fans. Analyses also investigated fixed facility ventilation systems and dust control strategies for three 60,000 tpd crusher stations. The paper describes the challenges with the design due to limitations in the intake and exhaust airway tunnels, distribution of airflow over a large area, and the requirement to have a ventilation management system to control regulators and other infrastructure.

1 INTRODUCTION

P.T. Freeport Indonesia, 90.64% owned by Freeport-McMoRan Copper & Gold and 9.36% owned by the Indonesian government, operates the largest gold mine and the third largest copper mine in the world at its mine operation in Papua, Indonesia. Presently, the mine complex consists of the Grasberg open pit mine and two underground mines, DOZ and Big Gossan. Total production from the mining complex is approximately 240,000 tpd. Figure 1 shows the location of the mine in Indonesia.

The future of the mine will be to develop one of the largest block caves in the world below the current Grasberg open pit. In addition to this expansion, the company is planning a deeper block cave mine below the current DOZ mine. The production goal from the Grasberg Block Cave (GBC) mine is 160,000 tpd with an additional 80,000 tpd from the new DMLZ block cave mine and 7,000 tpd from the high grade Big Gossan stope mine. This production would make this complex the largest tonnage underground mine in the world.

The basic design of the GBC block cave mine consists of an undercut level, production level, ventilation level, haulage level, and drainage level. Access to the mine will be through an access tunnel below the mine horizon called the AB tunnels. This tunnel system will be used to bring in all supplies and personnel to the mine. A hoisting shaft from the AB tunnel to the various levels in the mine will be the primary means to bring personnel and supplies to the mine. The mine also includes numerous fixed facilities including three primary crushers, conveyor systems, offices, fuel bays, maintenance bays, and rail shops.

Ventilation to the mine will primarily be through multiple ventilation drives. Four intake drives connect to surface at the side of a mountain and slope downwards to the ventilation sublevel. The tunnels, termed Grasberg Ventilation Drives (GVD) are approximately 6.8 m wide by 9 m high for a length of 2.6 km. The design also includes three primary exhaust drives of the same dimensions with fans located in the tunnels near the exhaust portals. Twin conveyor drives with a service drift (GVD 8) are also on exhaust to surface. The conveyor systems tie into an existing conveyor that feeds the current stock pile in front of the processing plant.

On large projects such as this one, there are challenges coordinating the mine planning work with the ventilation design. The ventilation design follows the planning design and once ventilation modeling is performed, it is often the case where the design iterates to change airway dimensions and/or add ventilation infrastructure such as doors, raises, etc. The design described in this paper represents a snapshot of the mine layout at the time of this paper was prepared. The final design may differ from what is presented here.

2 DESIGN CRITERIA

The primary design criteria for this project was to provide a minimum velocity of 1 m/s per drive with diesel equipment, provide at least 0.06 m^3/s/kW of diesel power, and a design philosophy of placing strategic return airways near dust generation points and to exhaust air from maintenance bays and fuel bays. For certain fixed facilities the airflow was based on air changes per hour. Velocity limits on primary intake and exhaust airflows of 10 m/s were included in the design.

3 GENERAL VENTILATION DESIGN LAYOUT

The primary personnel and supply access to the mine will be through the AB tunnels. These tunnels are located below the mining horizon and connect not only to GBC but also to the Big Gossan and DMLZ mines. In consideration of controlling any adverse fire event in any of these mines on this level, the AB tunnels are designed to exhaust air from each mine to the portal. Access from the AB level to the primary GBC levels will be through a hoisting shaft and ramp system. The hoisting shaft is expected to be the primary access for most personnel and supplies.

In 2021 (when the infrastructure is expected to be developed to achieve the first full 160,000 tpd production goal) the ventilation system is expected to consist of 4 primary intake adits, GVD 1 through 4, and three exhaust adits from the service level of the mine, GVD 5, 6, and 7. Twin conveyors exhaust air in parallel with a fourth exhaust drive GVD 8 (also considered a service drive). In addition to the GVD intakes and returns, the GBC mine intakes a limited quantity of air through an existing mine connection at CI3. Figure 2 represents the entire mine in 2023.

Although excavated at a large dimension, the long GVD intake and exhaust drives limit the total airflow capacity in the mine because of velocity constraints and significant increases in fan pressure for marginal increases in total mine airflow. The total flow for the GBC mine is predicted to be 3,070 m^3/s. This quantity of air appears low when compared to other block cave mines. Calculating flow based on mining tons per day, shows the GBC mine to be approximately 0.019 m^3/s/tpd. Other block cave mines have ratios from 0.017 to 0.04 m^3/s/tpd (Wallace, 2001). The low ratio infers that the GBC mine does not have excess air and that a ventilation management system will be required to maintain adequate airflows in all areas where personnel and equipment operate. The flow also reflects that GBC will use electric rail haulage systems which significantly reduce the flow requirements over a truck haulage system.

The primary fans for this project were specified by preliminary analyses conducted by Freeport engineers. These analyses were based on initial ventilation modeling. The fan duties were verified in later modeling that took into consideration the airflow computed to achieve a full flow balance while maintaining 10 m/s in the GVD drives. The fans specified for this project are Howden MF 107/0.91/38.5/19 mixed flow fans each with 4,100 kW motors. Each fan is predicted to operate at approximately 720 m^3/s at a total fan pressure of 4.5 kPa.

3.1 *Production Areas*

The primary production areas of the mine are the Undercut, Production, Haulage, and Drainage Levels. These areas account for the majority of the airflow allocated in the mine. Each of these levels connects to the Ventilation Level with raises. The Ventilation Level intake and exhaust drives are on the same horizon.

3.1.1 *Undercut Level*

The undercut will be initiated in two cave zones. This will require two separate areas to be ventilated. There are only two or three entrances into the Undercut Level which will allow for the intake airflow to be closely controlled. The air will be exhausted through a series of raises located on the perimeter of the level close to the development areas. Approximately 180 m^3/s will be required for the Undercut Level based on the equipment load projected for the level. This value is likely to increase in the final design in addition to the way air will be delivered and exhausted from this level.

3.1.2 *Production Level*

The Production Level in 2023 is shown on Figure 3. Also shown on this figure is the Ventilation Level that is below the Production Level. The airflow for a single extraction drift segment is based on achieving a minimum airflow velocity of 1 m/s required for dust dilution. For a nominal airway cross-sectional of 17.6 m^2 this results in a value of 17.6 m^3/s. This value was rounded up to 18 m^3/s for modeling purposes. If the airflow requirement was based on diesel dilution then the one operating R1700G LHD (231 kW) would require a minimum of 13.6 m^3/s.

Airflow is drawn from the perimeter fresh air raises to the central exhaust raise located near or adjacent to the ore pass. Only one LHD will be operated in a single extraction drive segment. The GBC Extraction Level will actively ventilate up to 44 segments to support the 44 LHDs in the production area. An additional 290 m^3/s is supplied to achieve this airflow. Air doors will be required at each end of a fully developed extraction drive to limit airflow when not in use. If the doors are not used then airflow cannot be limited to a single side of an extraction drive. Regulators will be required for each exhaust and intake raise leading to the Extraction Level. The regulators will be located on the Service Level to avoid equipment, blasting, and local non-permitted adjustment. Ventilation controls are required in the extraction drives to maintain an even airflow distribution (louvers, partially opened doors, or doors with removable panels). Trying to achieve an even airflow distribution across the extraction level in a block cave is always an onerous and difficult task. One of the best ways to achieve an even airflow distribution is to provide a dedicated fresh air raise for each extraction drive segment, however, with larger mining footprints this results in a significant quantity of vertical development. Isolation or low resistance doors can be placed along the perimeter drives to further separate the extraction drifts if fresh air raises are developed for multiple extraction drives but this often results in operational concerns dealing with traffic flow. Small booster fans are another option on the fresh air and exhaust raises to apply the required pressure to achieve an even distribution. This system can work, but can also have unintended consequences of creating recirculation loops if not closely monitored. In addition, the system will result in significant electrical power requirements. Without these controls, the even distribution of flow is not attainable.

For the GBC Production Level a single fresh air raise is developed for every three extraction drives. A small resistance is applied at the entrance to each extraction drive segment in the form of an open door to slightly restrict flow (by 5 to 15 Pa). This allows the airflow to be more evenly achieved across the panel. Panels not in production were modeled with closed doors. Panels no longer drawing ore are assumed to be sealed from the ventilation system (no access). Because of the large number of controls required, the system needs to be designed such that the controls can be remotely operated. These controls will need to be part of a ventilation management system that can be controlled from a central underground location and tied to daily production plans.

3.1.3 *Haulage Level*

The airflow on the Haulage Level enters the level through raises located on the north side of the rail fixed facilities and is drawn both towards the north (active ore chutes) and the south (through the rail fixed facilities and rail loop). The airflow exhausts the level at the outer perimeter of the level both on the north side (after the chutes) and through the ore dump bins (on the south side). The Haulage fleet consists of electrified rail haulage with only intermittent diesel equipment, or construction equipment at the perimeter. A flow of 520 m^3/s is allocated for this level which will provide an air velocity of between 0.3 m/s and 1 m/s in each of the parallel haulage loops.

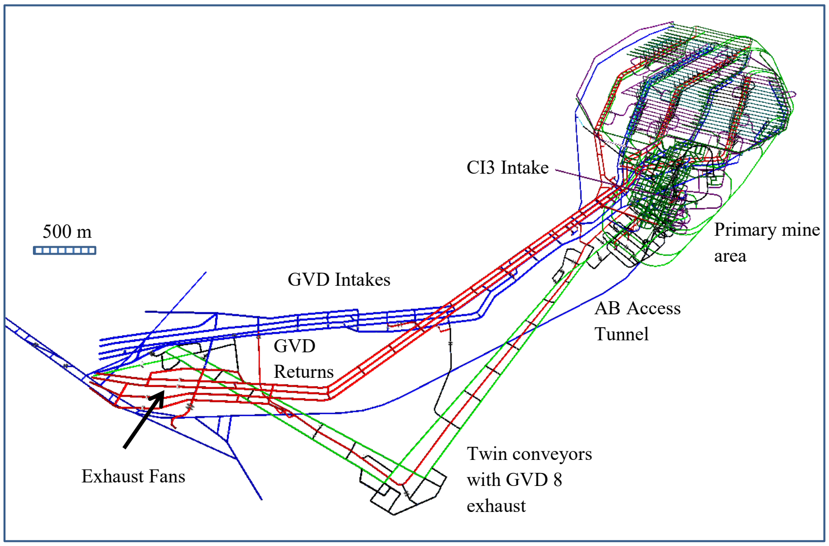
3.1.4 *Drainage Level*

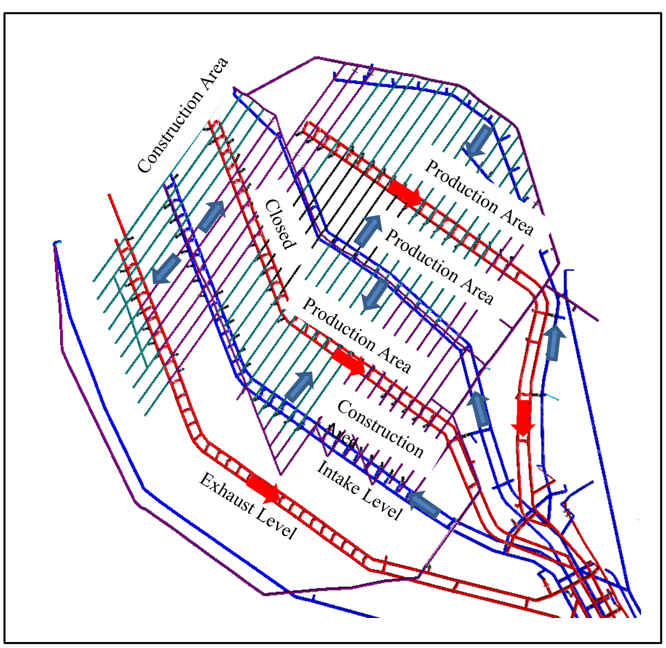
The Drainage Level will be ventilated by air exhausting from the north end of the Haulage Level. Because of the limited use of diesel equipment on the Haulage Level this airflow will remain reasonably fresh and can provide adequate ventilation for the equipment used intermittently on the Drainage Level. It is anticipated that the equipment will primarily consist of development equipment. An air velocity of about 1.3 m/s was used to estimate a total flow per heading of 38.6 m^3/s. This will be sufficient to support the limited diesel equipment on this level.

3.1 *Non-Production Mine Areas*

Because of the significant cost of providing additional airways into and out of the mine every airflow allocation not directly supporting production activities requires specific justification to ensure that the air is used in the most efficient manner. These areas include crushers, fixed facilities (e.g. shops, fuel bays, offices, etc.), conveyors, and pump stations.

Figure 1. Location of P.T. Freeport's mines in Indonesia.





The general design of each of these areas is presented along with the basic design rationale. These areas account for approximately 385 m^3/s which is not used to directly support production activities.

3.1.1 *Crusher Ventilation*

The crusher areas in block cave mining operations traditionally are generally poorly ventilated with air circulating from the Haulage Level bin dumps often flowing back into the Haulage Level areas. This has the effect of causing elevated dust levels on the Haulage Level.

A system like this relies totally on the ancillary dust suppression (sprays) and sometimes localized extraction (filtration) systems. These systems are often found to be clogged, ineffective, or inoperable. The ventilation system surrounding the GBC crushers and Haulage Level can best be described as a central exhaust system as shown in Figure 4. All of the air that flows through an area of significant dust generation will be directed to an exhaust raise. This allows any residual dust not controlled by the ancillary systems to be directly exhausted. Highlights of the system are shown on Figure 4 and are described below:

- 60 m^3/s will be directed to the exhaust at each Haulage Level bin dump, this relates to all of the airflow on the Haulage Level leading to the bin dump.
- 25 m^3/s will be directed to the exhaust at each crusher mid-level (apron feeder).
- The lower conveyor drift will have an airflow of 20 m^3/s of which 3 m^3/s will be directed to exhaust through the dust extraction system.

The ventilation system does not remove the need for the ancillary dust control systems, rather, the combination of both the ancillary control systems and the exhausting ventilation system should provide for good control of dust in the surrounding areas. This system does have the drawback of requiring additional airflow that could be used in other areas as it is not laden with Diesel exhaust gasses, but in order to minimize the dust contamination 88 m^3/s per crusher was considered to be an acceptable cost

3.1.2 *Fixed Facility Ventilation*

Fixed facilities for large block cave mining operations are very extensive. These facilities include fuel bays, maintenance shops, warehouses, locker rooms, lunch rooms, mosques, and churches. For GBC the facility is over 600 m in length and approximately 300 m in width (not including fuel bays or facilities on other levels). The facility is on the Production Level with one end connecting to access drives to production panels. Ventilation of these facilities is through intake raises near the production panel and exhaust raises at the other end of the facility. Figure 5 shows the fixed facilities at the time this study was performed. Since this time, numerous changes have occurred that re-oriented the fuel bay and other facilities. There is a strong desire by operation personnel to not have doors between the facility and the Production Level drives. From a ventilation perspective this is not ideal as the best design is to isolate the facility from the mine and provide a separate split of air through the fixed facilities to the exhaust raises.

At the GBC mine, the current design uses a hybrid case where airflow enters the fixed facility about one-third of the way from the Production Level drives and splits – some air through the facility to the Production Level and the balance to the exhaust raises. In this design, all higher fire risk areas, such as maintenance bays, are in the split of air going to exhaust. The only higher risk facility that is on the mine side of the facility is the equipment parking area. Automatic fire or isolation doors are planned for each access to the Production Panel.

The airflow requirement for the fixed facilities was computed using ASHRAE standards for air changes required for machine/auto shops and offices. These calculations resulted in Table 1 that shows the flow requirements to be approximately 175 m^3/s. For design, the flow through the exhaust raises was modeled at 180 m^3/s. These raises are located on the bottom right of Figure 5.

Table 1. GBC fixed facility airflow calculation

Location	Airflow per area (m^3/s)	No.	Total Airflow (m^3/s)	Reuse Air?
Office on Fringe Drive	3	4	12	Y
Parking and Bus Loading Area*	15	3	45	Y
Office/Elect/bus area	10	1	10	Y
Primary Lunch Area	5	1	5	N
Toilet	2	1	2	N
Main Mosque	6	1	6	Y
Mine Warehouse and Office	30	1	30	Y
Shop Warehouse and Office	30	1	30	Y
Second lunch area and toilet	7	1	7	N
Second Mosque and Chapel	8	1	8	Y
Service Bays	7	12	84	N
Offices/training/elec on acc.	5	6	30	Y
Welding Bay	15	1	15	N
Crane Bay (vel of 0.5 m/w min)	60	1	60	Y
Total			344	
Reuse warehouse/office air -			168	
Minimum airflow required			176	

*Air from parking/bus loading area goes onto fringe drift.

3.1.3 *Rail Haulage Shop*

The rail haulage shop is ventilated with an intake raise located near the north end of the facility and an exhaust raise near the southern end. Normal operation is for 20 m^3/s to exhaust through the return raise. This air is exhaust air from welding and mechanical areas of the shop. Normal ventilation is for intake air to exhaust both ends of the shop. Airflow exhausting the south entries courses to the crusher dump bins and provide a portion of that airflow.

3.1.4 *Conveyors*

The GBC oreflow system consists of parallel conveyor drives separated by an exhaust/service drift. The service drive is maintained as an exhaust to minimize the differential pressure between the service drive and the conveyors in an effort to decrease leakage between the two systems.

Air is drawn from the crusher area through the two conveyor drives and courses toward portals. Because the main ventilation system is driven by exhaust fans (located in close proximity to the conveyors) air will also enter the conveyor system through the portal.

A connection midway down the second conveyor will draw the conveyor air into the exhaust system. At this point fresh air will be drawn from the portals and air will be drawn for the mine. Airflow from the portals will be controlled by a series of conveyor regulators/ belt checks. A minimum of 25 m^3/s of airflow is required in each conveyor drive based on a minimum air velocity of 0.75 m/s. The air velocity will increase due to leakage.

3.1.5 *Pump Station*

The GBC Mine will be located under the extensive Grasberg Open Pit Mine. There is a concern that excessive water inflow may occur. This has resulted in the design and incorporation of a significant pump room at the perimeter of the mining footprint just below the Drainage Level. The design incorporates up to 8 operating 420 kW pump motors. The size of the pump motors and the limited airflow available for ventilation means that the pump room could experience a significant heat load. A series of climatic simulations were undertaken to predict the temperature in the pump chamber for different airflow quantities. It was determined that an airflow of 30 m^3/s through the pump chamber would maintain the effective temperature at approximately 26 °C with a maximum wet bulb temperature of less than 22.5 °C. Figure 6 shows the predicted pump room temperatures.

3.1.1 *Batch Plant*

The batch plant, shown on Figure 7, requires a closed ventilation system to isolate and reduce dust emissions into the ventilation system, however, because of the significant quantity of shotcrete produced and degree of vehicle traffic isolation through the use of doors will be difficult to put into effect. The airflow around the plant is reduced through a by-pass raise in the main access ramp. This allows for the differential pressure across the plant to be significantly reduced (to 4 to 5 Pa).

By reducing this pressure difference the flow through the facility is much lower. An air mover (small jet fan) can be installed in the batch plant perimeter drive to reduce the quantity of airflow moving across the plant and exhausting through the southern ventilation raise. This allows for the removal of all doors in the haulage route through the batch plant and provides for a reasonable capture area for the 20 m^3/s exhaust from the Batch Plant.

4 SUMMARY

The GBC block cave mine will be one of the largest producing underground mines in the world. The ventilation system designed for the mine consists of 4 primary intake drives and 4 primary exhaust drives, each approximately 2.6 km in length. Access to the mine is through a 7.5 km tunnel, called the AB tunnel that is located well below the mining horizon. A hoisting shaft at the access tunnel will bring personnel and supplies to the various levels in the mine.

The airflow to the mine is approximately 3,070 m^3/s. The total flow is limited by the number of intake and exhaust drives, velocity limits of 10 m/s in these drives and maintaining primary fan pressures of below 4.5 kPa. Because of these limitations, the ventilation design needs to be carefully controlled. Each ventilation raise from the ventilation sublevel will be controlled with regulators. On the Production Level, controls within the production drives will be necessary. These controls will consist of doors to either close the un-used panel drive or a partially opened door to limit the flow entering the drive. These controls are possible because the LHD operation is completely within the panel (from the draw point to the orepass).

In order to ensure doors and regulators are configured correctly, a ventilation management system will be required. Currently the system envisioned will provide indication of the door and/or regulator position with the control room operator being able to remotely control the regulator settings. The system envisioned at this time is not reliant on sensors to determine the regulator settings.

The ventilation system described in this paper is based on the mine plan when the study was performed. The mine plan is very likely to be modified and the ventilation system presented may not represent the final design that will be constructed. Mine planners are currently considering changes to the number of GVD drives, increased flow to the AB tunnel ventilation system, and modifications to the block cave sequence plan (which impacts the undercut and production levels).

In addition, the fixed facilities, such as fuel bays, etc. will also likely be altered. None the less, the ventilation philosophy of airflow requirements, primary fan duties, and airflow distribution considerations, developed at this stage of the study is valid for any future possible mine planning modifications.

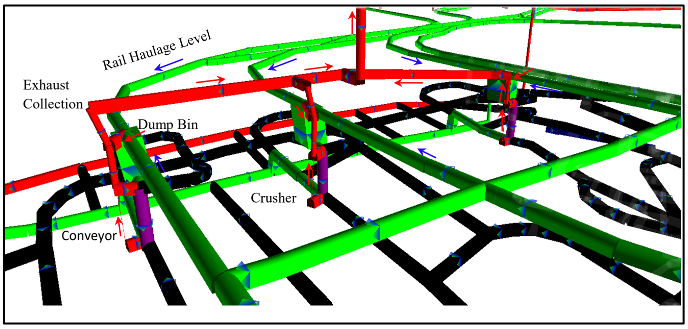


Figure 4: GBC crusher ventilation

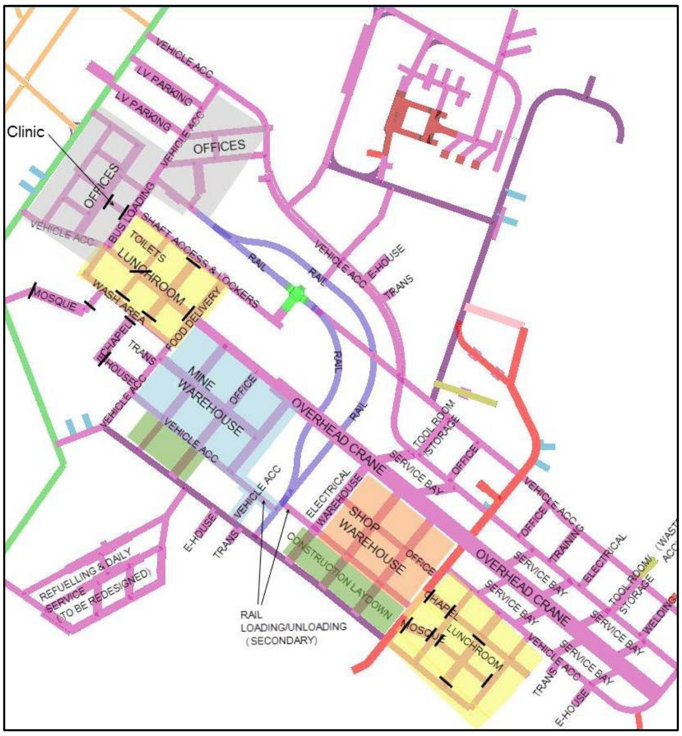


Figure 5: Layout of GBC fixed facilities

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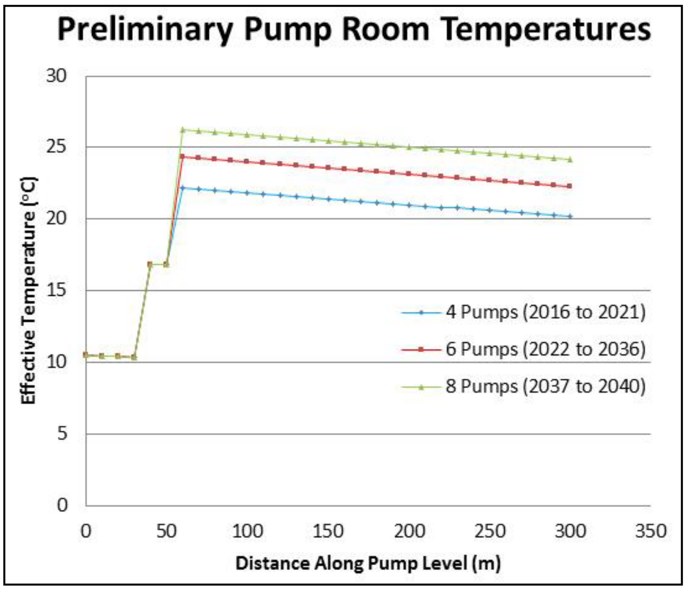

Figure 6: Predicted heat load in pump room

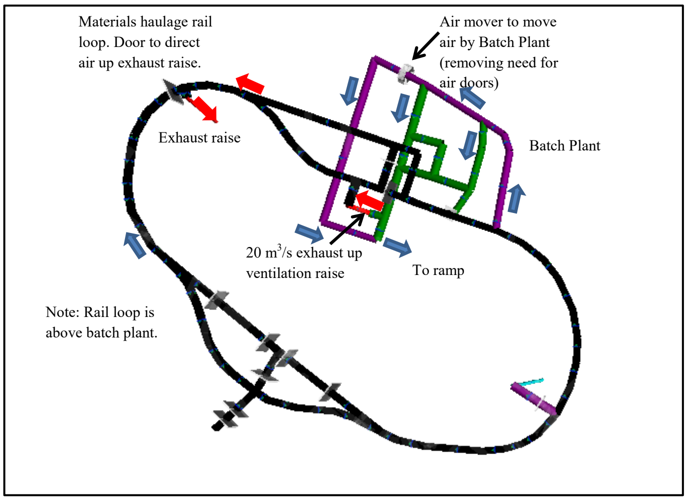

Figure 7: Layout of GBC batch plant facility