Ventilation System Design for the Wassa Underground Mine

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Location

The mine is located in Ghana which presents the difficulty of an elevated surface wet bulb temperature

The Wassa Project

The Wassa Underground Mine was designed to be developed out of the bottom of an existing open pit.

The ventilation design was to be developed in two phases;

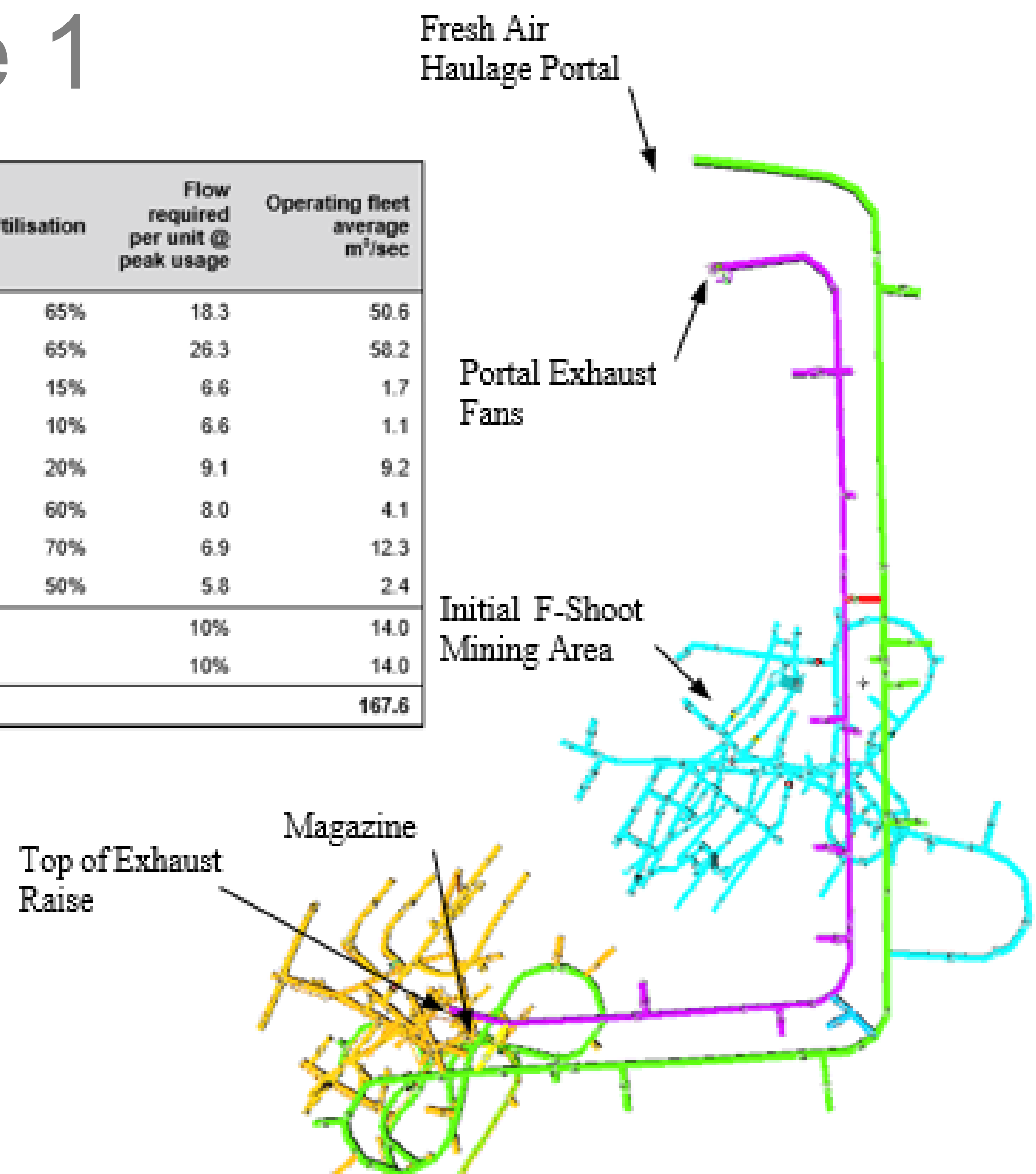
- Phase 1 - development and initial production
- Phase 2 – full production

The production rate was increased which required a redevelopment of the ventilation plan

Phase 1

Fleet Type	Equipment Model	Engine Rating (kW)	No.	Availability	Utilisation	Flow required per unit @ peak usage	Operating fleet average m³/sec
LHD	Caterpillar 2900	305	5	85%	65%	18.3	50.6
Truck	Caterpillar AD55B	439	4	85%	65%	26.3	58.2
Twin Boom jumbo	Sandvik Axera 7	110	2	85%	15%	6.6	1.7
Longhole drill	Sandvik DL411	110	2	85%	10%	6.6	1.1
Light vehicles	Toyota Landcruiser V8	151	6	85%	20%	9.1	9.2
Mine Grader	CAT12H	133	1	85%	60%	8.0	4.1
Service IT's	CAT930K	115	3	85%	70%	6.9	12.3
Explosives truck	Normet Charmec	96	1	85%	50%	5.8	2.4
Leakage						10%	14.0
Contingency						10%	14.0
Total							167.6

All ventilation is developed off of the declines

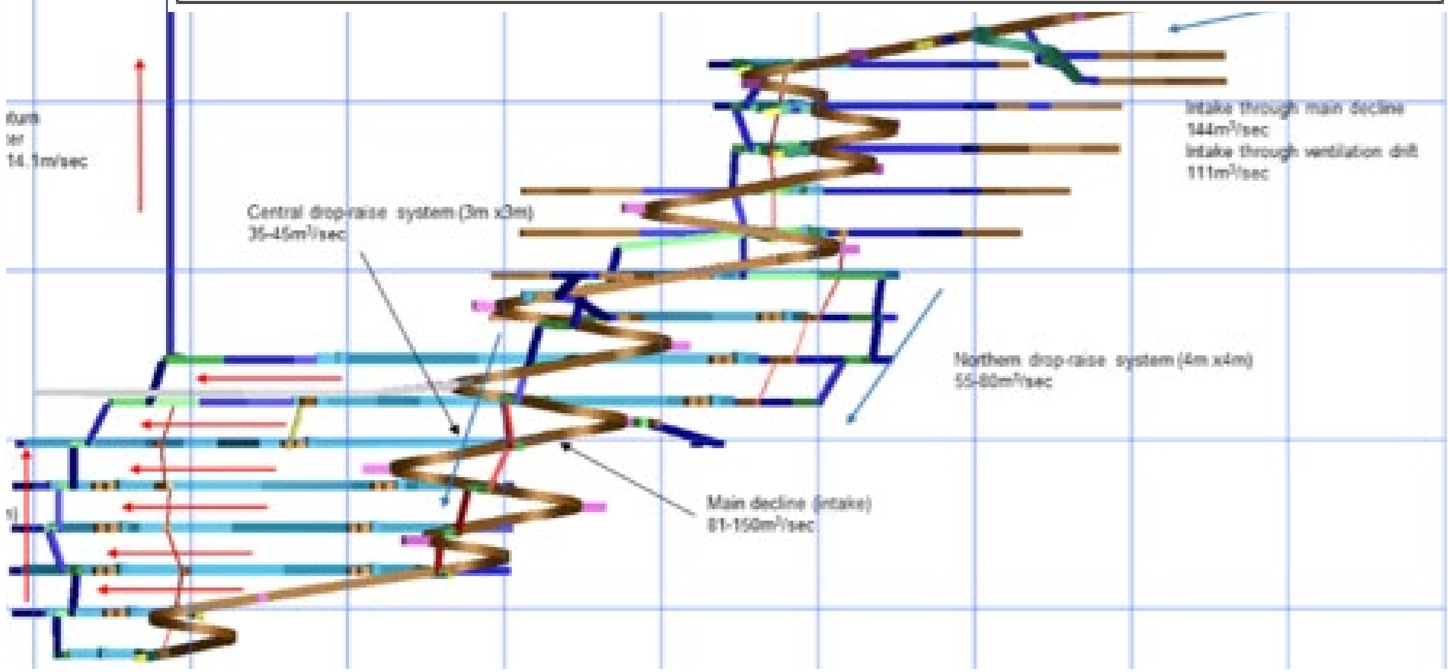


Phase 2

Flow through ventilation system is established

2,500 tpd production rate

Fleet Type	Equipment Model	Engine Rating (kW)	No.	Availability	Utilisation	Flow required per unit @ peak usage	Operating fleet average m3/sec
LHD development	Caterpillar 2900	305	4	85%	63%	18.3	39.2
LHD production mucking	Caterpillar 2900	305	1	70%	58%	18.3	7.4
Truck	Caterpillar AD55B	439	6	85%	67%	26.3	90.0
Twin Boom jumbo	Sandvik Axera 7	110	2	80%	15%	6.6	1.6
Longhole drill	Sandvik DL411	110	2	85%	15%	6.6	1.7
Light vehicles	Toyota Landcruiser V8	151	10	85%	20%	9.1	15.4
Mine Grader	CAT12H	133	1	85%	60%	8.0	4.1
Service IT's	CAT930K	115	3	85%	70%	6.9	12.3
Explosives truck	Normet Charmec	96	1	0.85	0.5	576%	2.4
Leakage						20%	34.8
Contingency						0.15	26.1
Total							235.1

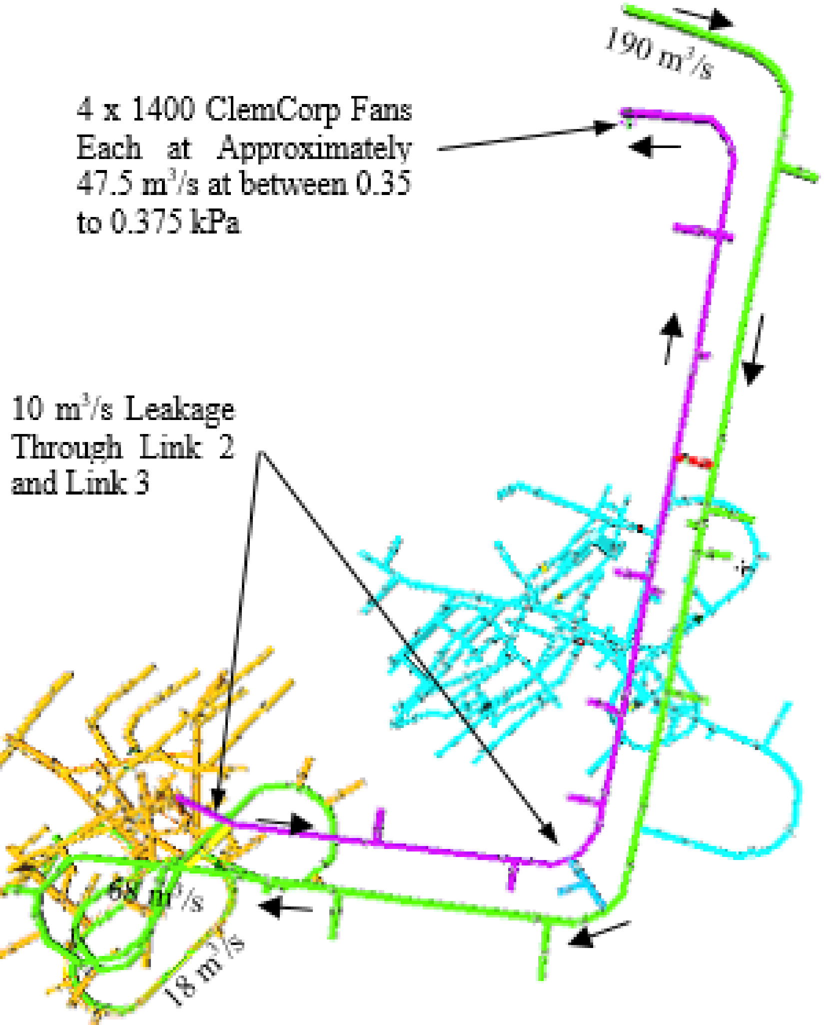


Phase 2 Elevated Production

Increasing the production rate to 4,000 tpd required a greater diesel load

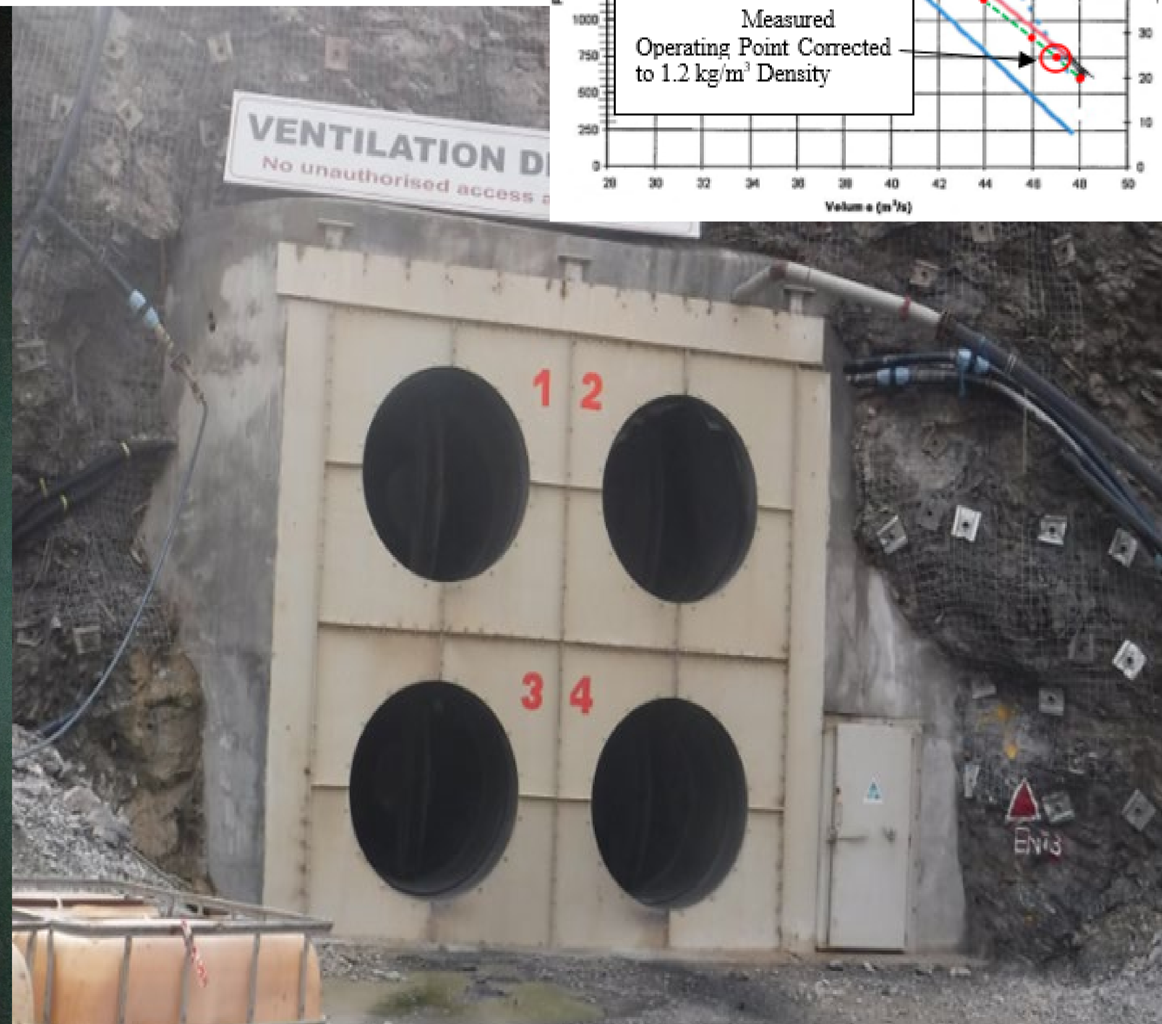
Equipment	Type	engine size (kW)	Total Fleet	Fleet in Mine Operating	Utilisation (%)	Airflow per Unit (m^3/s)	Operating fleet (m^3/sec)
LHD development	Caterpillar 2900	305	2	2	100%	18.3	36.6
LHD production mucking		305	4	3	100%	18.3	54.9
LHD production backfill		305	0	0	100%	18.3	0.0
Truck	Caterpillar AD60	567	9	8	100%	34.0	272.2
Twin Boom jumbo	Sandvik Axera 7	110	2	2	0%	6.6	0.0
Longhole drill	Sandvik DL411	110	3	3	0%	6.6	0.0
Light vehicles	Toyota Landcruiser	151	12	6	50%	9.1	27.2
Mine Grader	CAT12H	133	1	1	0%	8.0	0.0
Service IT's	CAT930K	115	3	2	100%	6.9	13.8
Charge-up machine	Normet Charmec	96	2	2	100%	5.8	11.5
Leakage						15%	62.4
Contingency						15%	62.4
Total							541.0

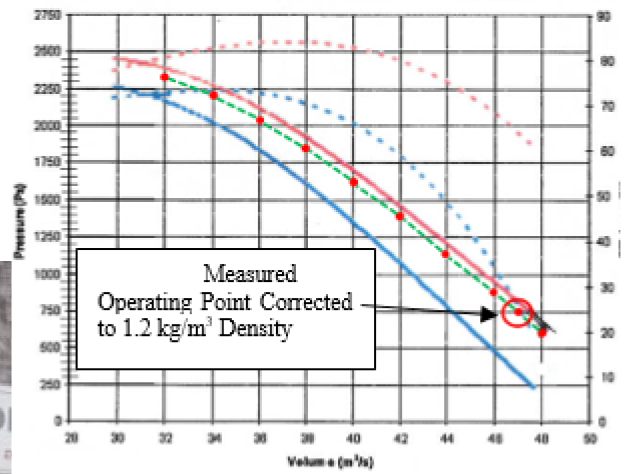
Site Visits



- In order to develop confidence in design assumptions the Phase 1 ventilation system was examined during a series of site visits.
- The resistance of ventilation infrastructure was determined and calculated
- Actual fan performance of the portal fans were examined
- Leakage rates were measured

4 x CC1400 Fans

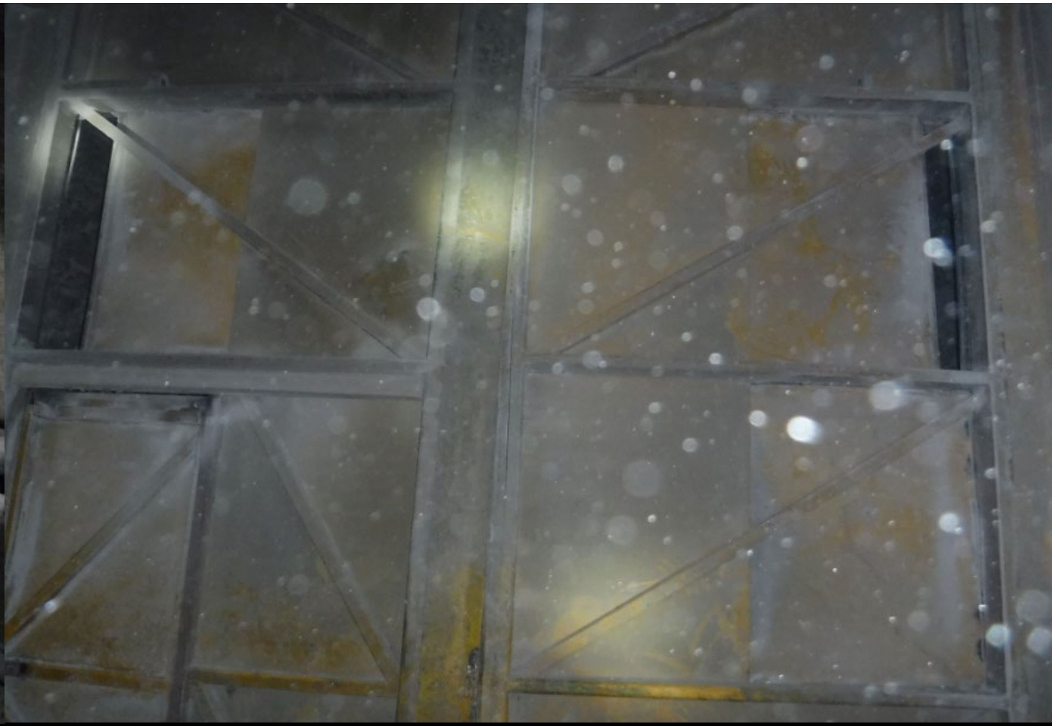




Controls and Infrastructure

Closed Regulator on Abandoned Level

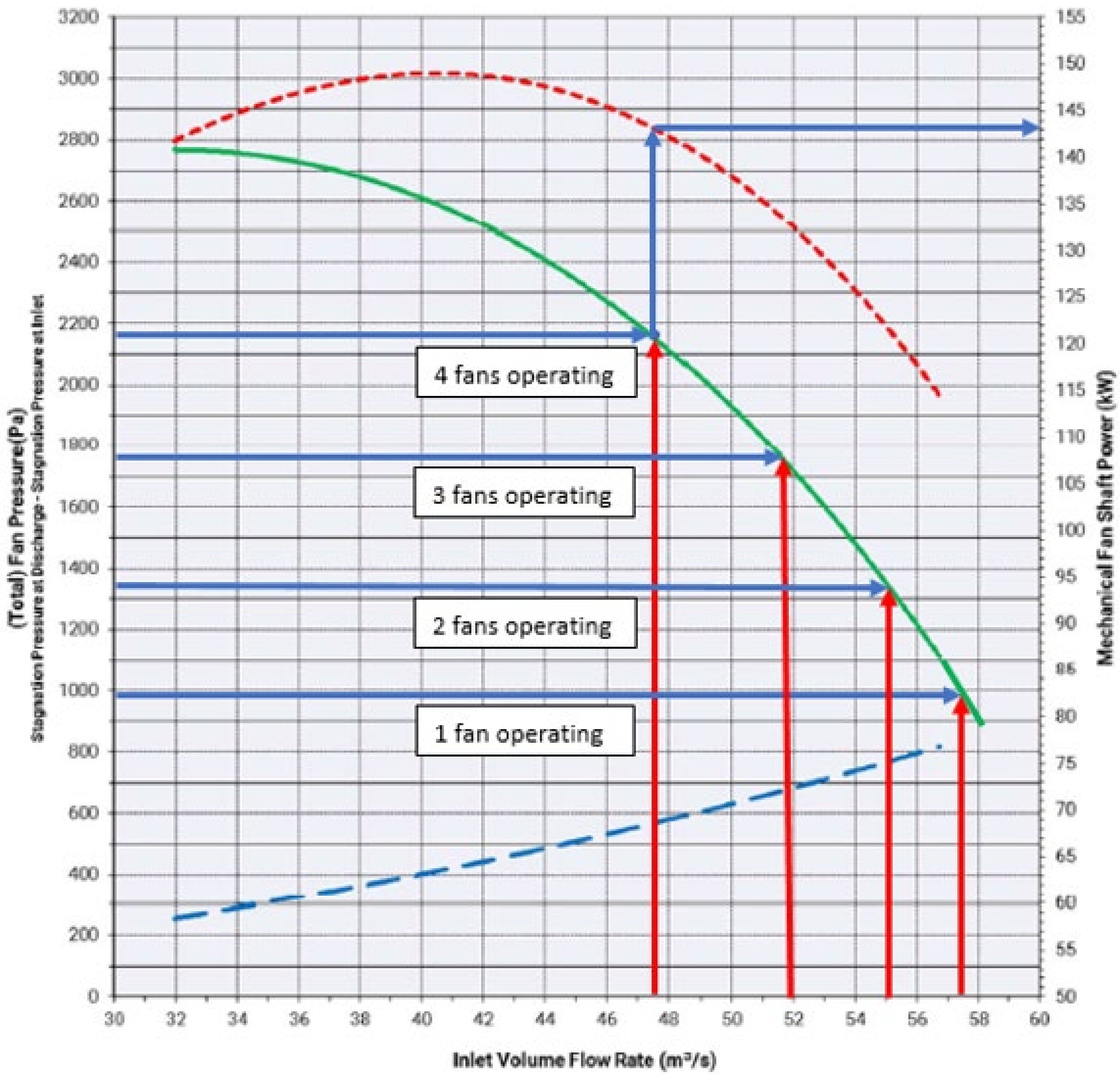
Single Equipment Door Between Fresh Air and Exhaust with Openings



Observations

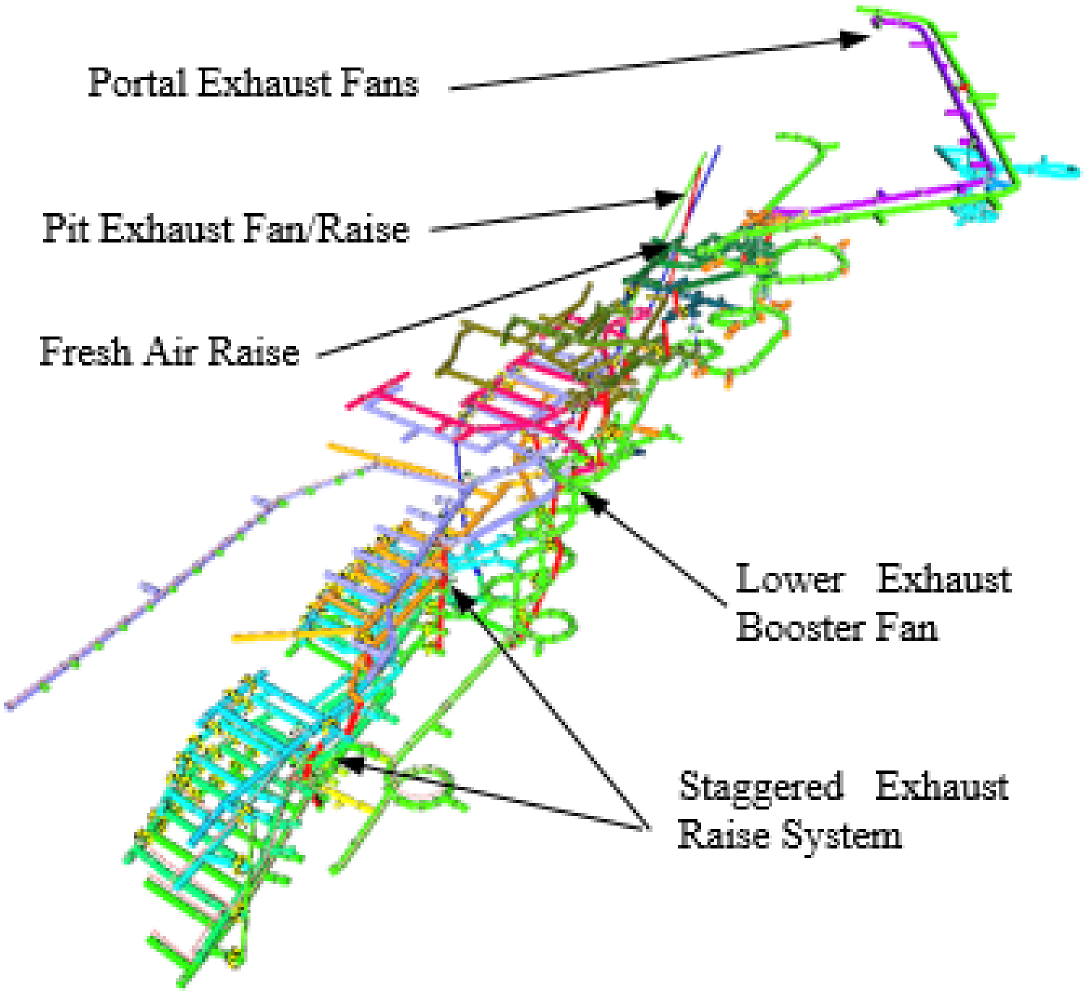
- The average fan system efficiency measured for the temporary Phase 1 exhaust system was measured at 62%. The entry and exit losses associated with the four parallel fans are significant.
- Until the new exhaust ventilation raise is in, the mine will have no more than 170 m^3/s at a delivered pressure of under 250 Pa (at roughly the 795 Level)
- There is significant leakage in the Link 3 access door (non-airlocked).
- The future mine plans need to include the drive to the new raise location
- The mining time and new fan commissioning needs to be evaluated
- The new ventilation system will need an exhaust fan to pull more air than the current 190 m^3/s (roughly 350 m^3/s)
- The fan needs to be sized based on long range ventilation needs
- A ventilation plan is needed on how to convert the existing system to the new system – this includes how to intake the current exhaust system and how to connect to the new exhaust raise.
- Leakage resistances and fan pressures were modified in the ventilation model to achieve a correlation error of less than 10%.

First Step to Increase Airflow



- Increase fan motor and advance the blade settings / increase blade pitch angle
- Increases the airflow from 165 m^3/s to 249.8 m^3/s
- Operating four parallel fans at a higher pressure can cause issues upon starting (fourth fan may likely stall)

Second Step – Full Upgrade



- Maximized portal exhaust fans
- Exhaust fans on new pit exhaust raise providing increased exhaust capacity
- New fresh air raise developed to alleviate high air velocities in the ramp system.
- Booster fan in lower exhaust transfer balances pressures and minimizes leakage

Phased Modeling Results

Time Phase	Number Operating Stopes							
Existing	745P	720D	695D	ramp				
	40	40	63	by 695				
2017 Q4	745P	720P	695P	670D	ramp			
	30	30	30	by ramp	50			
2018 Q1	695	670-1	670-2	645D	ramp			
	40	40	40	by ramp	85			
2018 Q2	670-1	670-2	645	620D	ramp			
	40	40	80	by ramp	74			
2018 Q3	670-2	645-1	645-2	620D	595D	ramp		
	40	40	45	33	by ramp	50		
2018 Q4	645	645	620	620	595	570D	545D	ramp
	45	30	40	40	40	by ramp	by ramp	62
2019 Q1	645	620	620	595	570D	545D	520D	Ramp
	95	45	40	45	28	by ramp	by ramp	50
2019 Q2	620	620	595	520	645D	545D	495D	ramp
	35	35	35	35	30	20	by ramp	56
2019 Q3	620	595	570	545	520	645D	495D	by ramp
	35	40	40	40	40	25	by ramp	56
2019 Q4	620	570	545	520	645D	495D	470D	ramp
	40	40	45	50	30	by ramp	by ramp	56

Control of leakage will be critical (Existing – 2018 Q1)

Step Change (2018 Q1)

Step Change (2018 Q3 – 2018 Q4)

Issue with timing of Intake/Exhaust Raises in Q1, perhaps reschedule 695 to finish in Q4, and only mine 670 in Q1? (2017 Q4 – 2018 Q1)

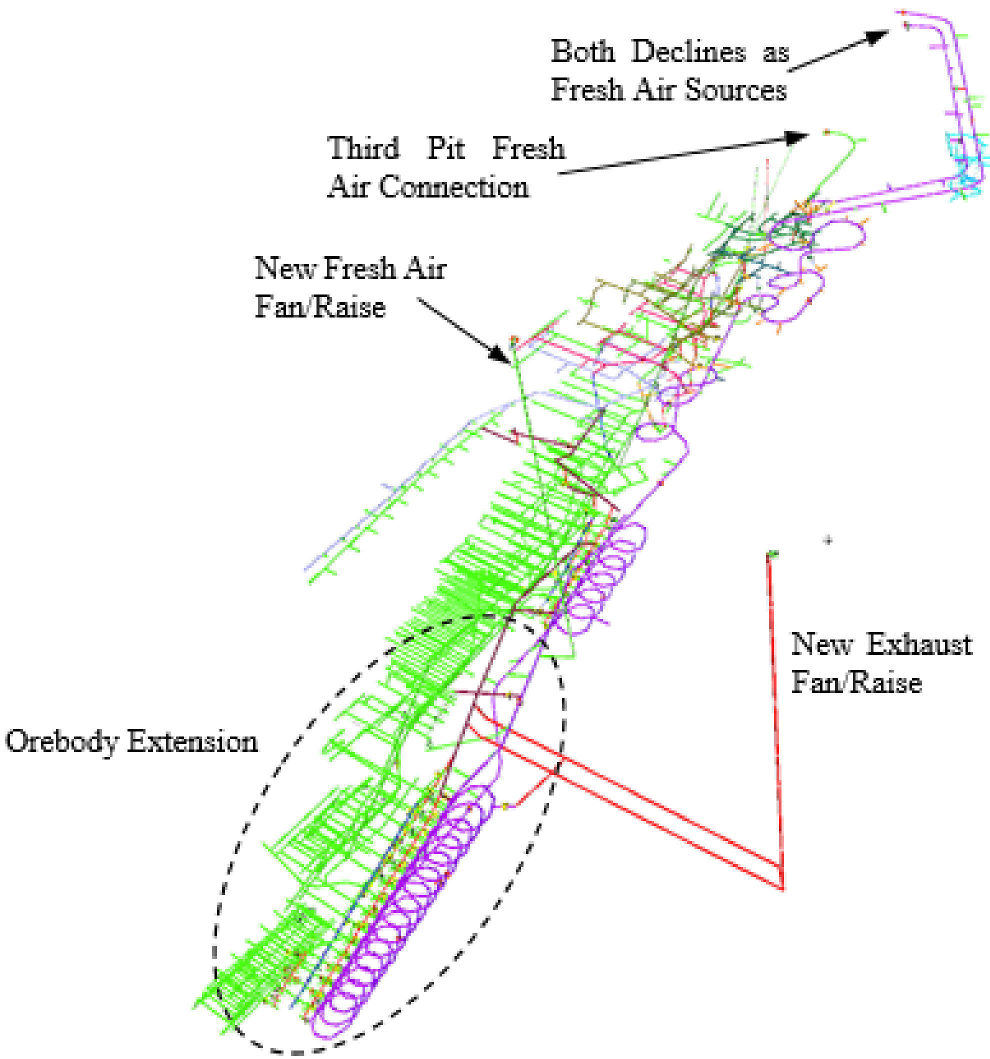
The airflow allocation was developed for each of the mining areas for each quarter and incorporated into the ventilation models

Fan Operating Duty Points

	Portal Fans		Pit Fans		Lower Fans	
Time Phase	(m^3/s)	(kPa)	(m^3/s)	(kPa)	(m^3/s)	(kPa)
Existing	174.4	1.185				
2017 Q4	174.0	1.198				
2018 Q1	168.0	1.386	80.0	1.753		
			surface loss	0.257		
2018 Q2	167.0	1.390	80.0	1.753	regulated intake	
			surface loss	0.257		
2018 Q3	175.8	1.144	80.0	1.413	regulated intake	
			surface loss	0.257		
2018 Q4	161.0	1.567	80.0	1.985	114.0	3.241
			surface loss	0.257	surface loss	0.522
2019 Q1	156.6	1.690	80.0	2.162	150.0	5.101
			surface loss	0.257	surface loss	0.896
2019 Q2	158.4	1.638	80.0	2.118	150.0	4.991
			surface loss	0.257	surface loss	0.896
2019 Q3	157.3	1.669	80.0	2.165	150.0	5.043
			surface loss	0.257	surface loss	0.896
2019 Q4	155.1	1.730	80.0	2.247	150.0	5.096
			surface loss	0.257	surface loss	0.896

- The combination of the portal exhaust fans, pit exhaust fans, and lower exhaust booster fans were modeled on a time phased approach
- The staged ventilation models identified when the new fans were required and how they were required to be ramped up

Third Step - Expansion



- Expansion of the equipment fleet and the addition of an increased ore body in the lower areas requires an elevated airflow.
- The increased depth and linear development required additional shafts for the ventilation system.
- The new exhaust raise would replace all exhaust fans, all other raises and portals would provide fresh air and a flow through system
- The new fresh air raise would be used if a refrigeration system was to be incorporated if the mine is developed deeper or the equipment load is further increased

Refrigeration Review

The ventilation model was adjusted develop a 6.5 MW(R) bulk air cooler at the top of the new proposed fresh air raise to minimize air temperatures in the mine if a refrigeration system were to be incorporated

- The heat load associated with auto-compression with all mining in the deeper reserves is calculated at approximately 1.9 MW
- The heat load associated with the mobile equipment load is approximately 8.5 MW
- The heat load associated with the rock mass was not separately calculated but with a VRT in the range of 33º C it was not projected to be significant for this depth.
- The natural cooling provided by fresh air circulating through the ventilation system was calculated at approximately 7.8 MW.
- There is a deficit of 2.8MW which indicates that the mine temperatures will either be elevated, a smaller operating equipment fleet is required, or that refrigeration is required.

Closing Comments

- The design of the ventilation system is an iterative process.

Scenario	Airflow	Refrigeration
Original Phase 1	170	n/a
Original Phase 2	235	n/a
Increased Phase 2	540	2.8 to 6.5 MW
Future	Further Production Increases at Greater Depths Will Require Additional Airflow and Refrigeration	

Closing Comments

- The initial design assumptions must be checked against the infrastructure and control devices developed at the mine because not all mines utilize the same construction techniques and methodologies.
- The ventilation plan must be updated at the mine plan is further refined and new production areas are opened up
- Time staged modeling is useful to determine the sequencing of fans, raises, and electric power loads.

Thank you!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MAIN DECLINE
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