

Please read this before using presentation



- This presentation is based on the content presented at the 2019 Nano diesel particulate matter (nDPM) in July 2019.
- Department of Mines, Industry Regulation and Safety (DMIRS) supports and encourages reuse of its information (including data), and endorses use of the Australian Governments Open Access and Licensing Framework (AusGOAL)
- This material is licensed under Creative Commons Attribution 4.0 licence. We request that you observe and retain any copyright or related notices that may accompany this material as part of attribution. This is a requirement of Creative Commons Licences.
- Please give attribution to Department of Mines, Industry Regulation and Safety, 2019.
- For resources, information or clarification, please contact:
SafetyComms@dmirs.wa.gov.au or visit
www.dmirs.wa.gov.au/ResourcesSafety



2019 Nano diesel particulate matter (nDPM) Forum

MRIWA Project M495: A Study of Nano Diesel Particulate Matter (nDPM) Behaviour and Physico-chemical Changes in Underground Hard Rock Mines of Western Australia.

Silvia Black and Ben Mullins

DMIRS, July 2019

Why?

- Diesel exhaust linked to significant health impacts – both acute and chronic – carcinogen (WHO).
- Conventional monitoring (EC / NIOSH 5040) less relevant to modern engines?
- Need to study generation and propagation of nDPM in WA mines
- Ensure WA underground mines stay ahead of emissions issues and future standards
- Pave the way for deeper mines

What is nDPM? nano Diesel Particulate Matter

- Diesel engines generate Ultrafine particles (even Tier3 and Tier4)

not all captured by filtration

- nDPM - Ultrafine particles ($< 80\text{nm}$) behave more like gases

Penetrate deep in the lungs

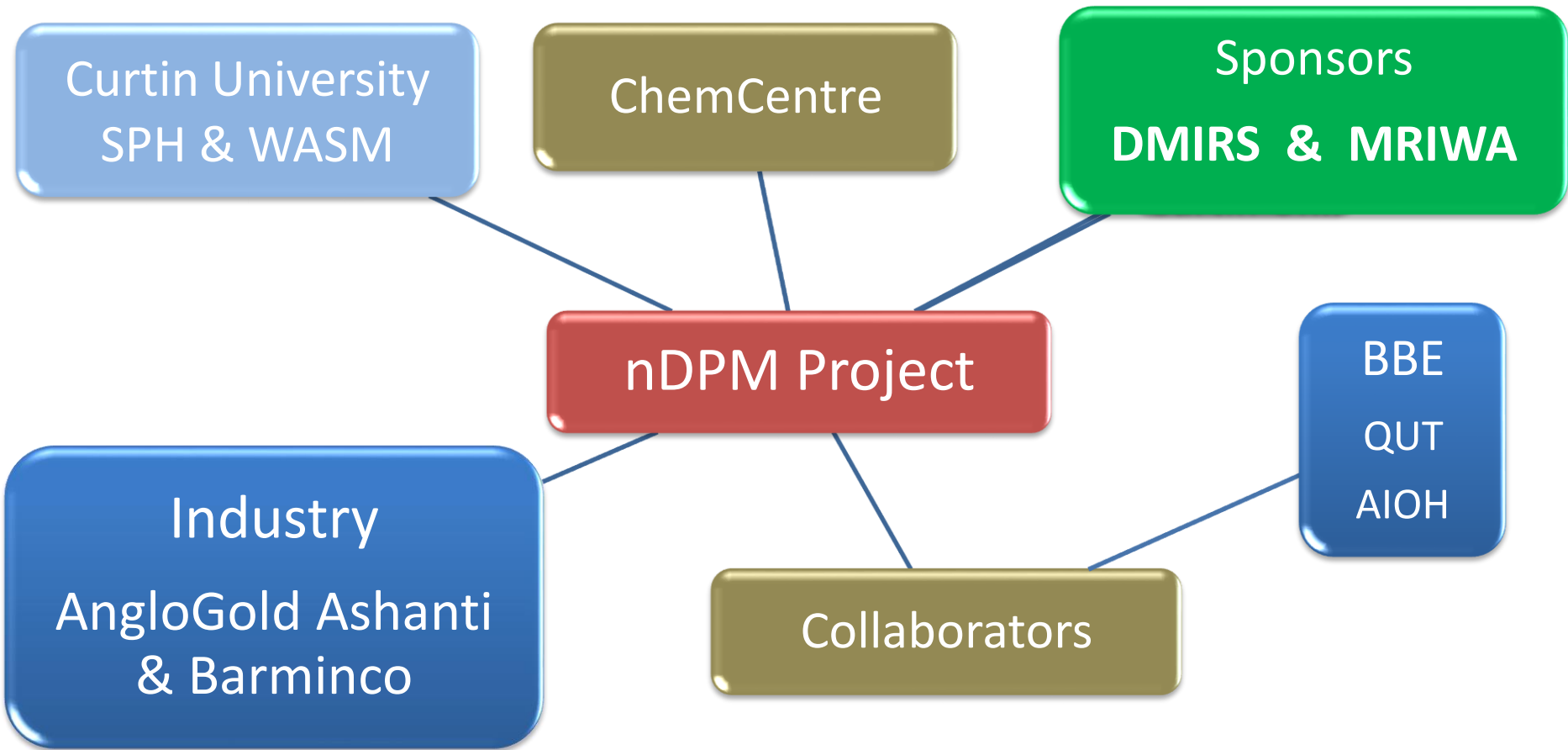
- **Can use Tracer Gas technology to understand the flow behaviour of Ultrafine particles**



MRIWA M495: Project Objectives

- Improve the understanding of the impact of nDPM on air quality from diesel exhaust emissions
- Establish best methods for characterising exposure and health effects of diesel exhaust
- Study the implications of deeper mines

Project Stakeholders



MRIWA M495: Project Plan

- Detailed characterisation (number, size, surface area, composition) of (nano)particulate and gaseous emissions throughout the ventilation system
- Use of tracer gas to assess transport and surrogate nDPM concentration for representative tasks in the mine
- Chamber study of heavy diesel emission “ageing” at higher pressures (deeper mines) than currently exist

MRIWA Project M495: A Study of Nano Diesel Particulate Matter (nDPM) Behaviour and Physico-chemical Changes in Underground Hard Rock Mines of Western Australia.

- Part A (ChemCentre-Led Component)

Dr Silvia Black, ChemCentre

DMIRS, 29 July 2019

Aim

The overall aim of this component of the study was to assess the applicability of tracer gas technology as a tool to study diesel exhaust flow behaviour and source contribution in an underground hard rock mine.

Objectives

- Study the dispersal of gaseous and ultrafine particulate emissions from diesel exhaust, particularly nDPM, and the dilution efficiency of the mine ventilation with particular focus on the auxiliary ventilation at the face of development headings;
- Measure Real-Time concentration of gaseous components (CO, CO₂, NO_x, SO_x, VOCs) at the tracer gas monitoring sites;

Objectives

- Determine the impact of ventilation practises on the exposure levels; and
- Improve the understanding of the impact of nano-diesel particulate matter (nDPM) on air quality from diesel exhaust emissions.

Tracer Gas Study

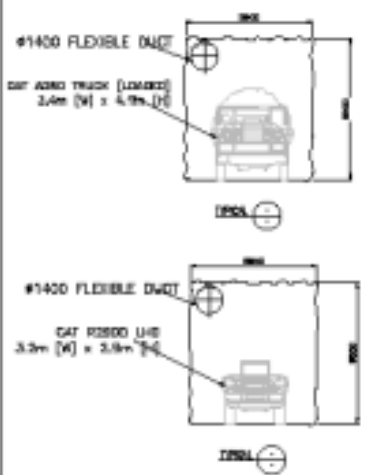
Use of tracer gas (SF_6) to Study localized air flow and contribution of nDPM from various sources

Development Heading - Astro 1900

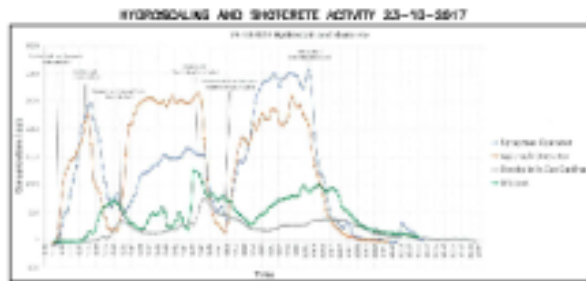
- Charge-up
- Bogger
- Hydro-scaling, Spraymec
- Shotcreting
 - Spraymech; and
 - Agi-truck
- Truck
- Traverse study
- WATU WSX Portal interaction

nDPM Study – Agi-truck





ASTRO 1000 HEADING
±48m / s



STOCKPILE

GQ 1895 LINK
GQ DECLINE

1-OFF T/S 110KW
FORCE PWA
#1400mm DUCT

CDS DECLINE

**DRAFT
ISSUED FOR
INFORMATION**

NOTES:

LEGEND:

- OPEN DWCT
- CLOSED DWCT
- TRUCK ROUTE
- AS AIR SWAP
- N NVAH
- ODD TEMPORARY COOLER
- REGULATOR
- S/O WALL
- ORC
- ORATEC
- ALTERED FLAG
- ACTIVE DEVELOPMENT CHD
- INACTIVE DEVELOPMENT CHD
- AIR CROSSING
- TRUCK LOADING BAY (TLA)

DATE	HEADING ACTIVITY
25/10/2017	TRUCK ROUTE
26/10/2017	TRUCK ROUTE
27/10/2017	TRUCK ROUTE
28/10/2017	TRUCK ROUTE
29/10/2017	TRUCK ROUTE
30/10/2017	TRUCK ROUTE

WEL. NO.	REFERENCE DRAWING	DATE	REVISION DESCRIPTION	BY	CHECKED	DATE	REVISION DESCRIPTION	BY	CHECKED	DATE

NO.	DATE	BY	DESCRIPTION

BBE CONSULTING AUSTRALASIA

NAME: CHEMISTRE
DPIH RESEARCH

PROJECT: GAT 1000 LHD PLAN HYDROLOGICAL AND SHOYEBRETE ACTIVITY (25-10-2017)

SCALE: 1:1000

DATE: 25/10/2017

BY: A1

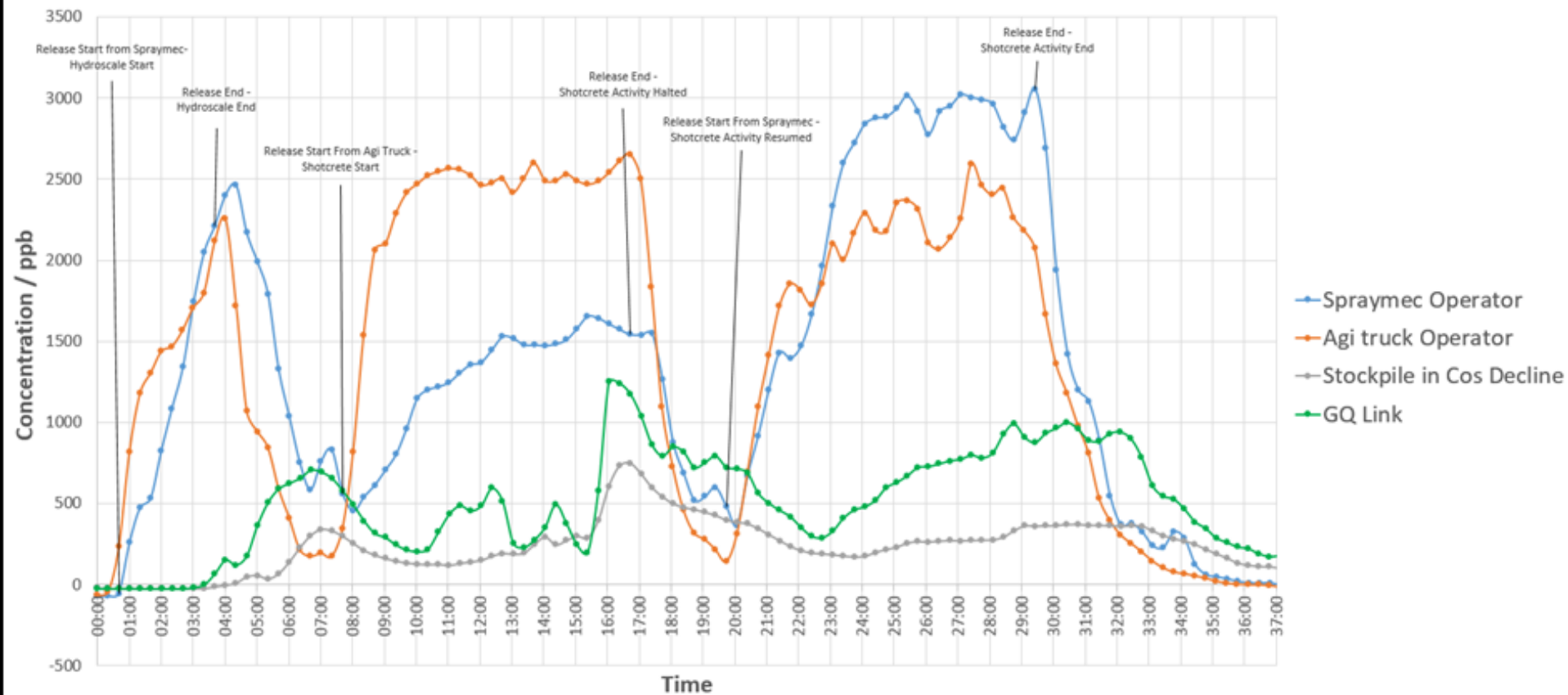
PROJECT NO: BBAUS-XXXX-DMC-XXX

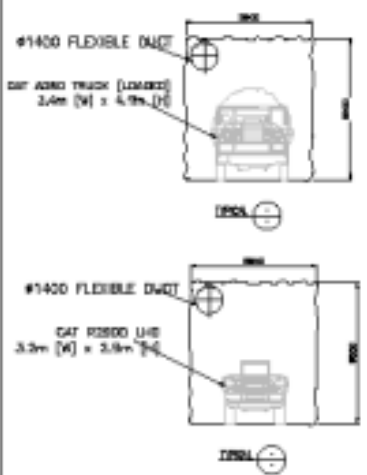
SCALE: A

nDPM Study – Shotcrete



23-10-2017 Hydroscale and Shotcrete





ASTRO 1800 HEADING
±48m / s



STOCKPILE

GQ 1895 LINK
GQ DECLINE

1-OFF T/S 110KW
FORCE PWA
#1400mm DUCT

CDS DECLINE

DATE	HEADING ACTIVITY
23/10/17	CONC. RAMP
24/10/17	CONC. RAMP
25/10/17	CONC. RAMP
26/10/17	CONC. RAMP
27/10/17	CONC. RAMP
28/10/17	CONC. RAMP
29/10/17	CONC. RAMP
30/10/17	CONC. RAMP

NO.	DATE	DESCRIPTION	BY	CHKD	STATUS	REVISION

**DRAFT
ISSUED FOR
INFORMATION**

NOTES:

- LEGEND:**
- OPEN DUCT
 - CLOSED DUCT
 - TRUCK ROUTE
 - AS AIR SHAFER
 - N NVAH
 - COO TEMPORARY COOLER
 - REGULATOR
 - S/O WALL
 - ORC
 - ORATEC
 - ALTERED PLAN
 - ACTIVE DEVELOPMENT CH
 - INACTIVE DEVELOPMENT CH
 - AIR CROSSING
 - TRUCK LOADING BAY (TLB)

NO.	DATE	DESCRIPTION	BY	CHKD	STATUS

BBE CONSULTING AUSTRALASIA

NAME: CHEMISTRE
DPM RESEARCH

PROJECT: GQ 1895 LINK HYDROLOGICAL AND SHOYEBRETE ACTIVITY (23-10-2017)

DATE: 23/10/17

BY: A1

CHKD: []

STATUS: []

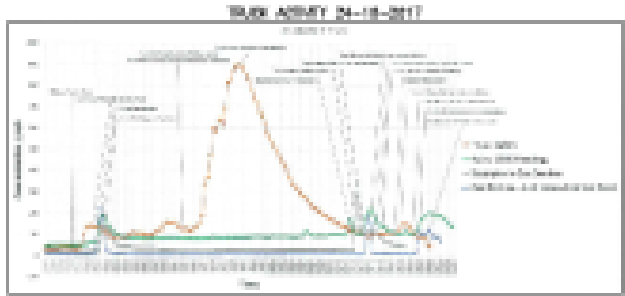
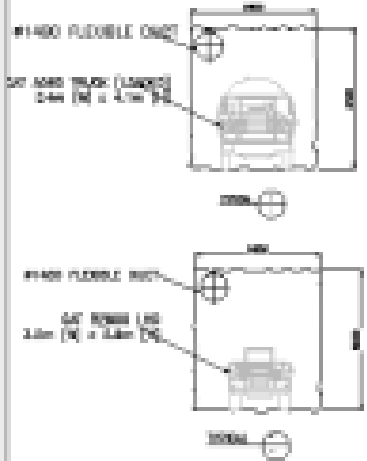
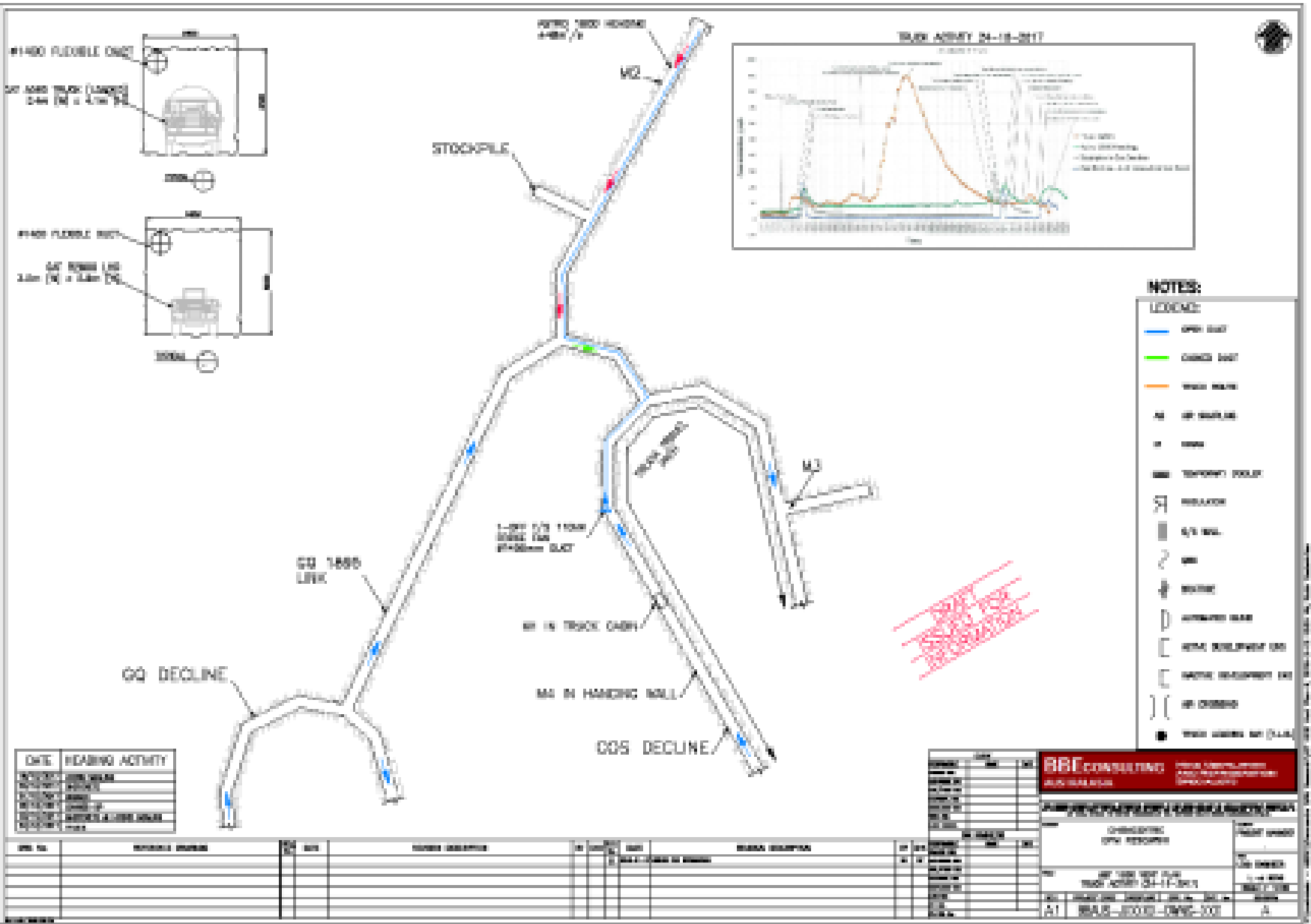
Tracer Gas Study - Outcomes

During shotcreting, the Agi truck operator experienced approximately the same exposure of SF₆ from the Agi truck and spraymech exhaust. In contrast, the spraymech operator received almost twice the exposure from the spraymech exhaust than from the Agi truck exhaust. The Agi operator in this instance was at greater risk.

Hence, because the spraymech is the more significant contributor of exhaust to the operators it is recommended that a focus on improving systems around the spraymech will give the greatest initial return on investment.

nDPM Study – Truck





- NOTES:**
- LEGEND:**
- OPEN CHUTE
 - CLOSED CHUTE
 - TRUCK PAUSE
 - M1 M2 M3 M4
 - TEMPORARY CHUTE
 - ISOLATION
 - S/S WALL
 - GRP
 - BENT
 - HANGING ROLL
 - WITH ROLLER/CHUTE
 - WITH ROLLER/CHUTE
 - CHUTE
 - TRUCK PAUSE (S.S.)

DRAFT
 ISSUED FOR
 INFORMATION

DATE	HEARING ACTIVITY
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE
10/24/17	TRUCK PAUSE

LINE NO.	REVISION NUMBER	DATE	REVISION DESCRIPTION	BY	CHKD BY	DATE	REVISION DESCRIPTION

BRE Consulting
 CONSULTING ENGINEERS ARCHITECTS

PROJECT: **TRUCK ACTIVITY 24-10-2017**

DATE: **24-10-2017**

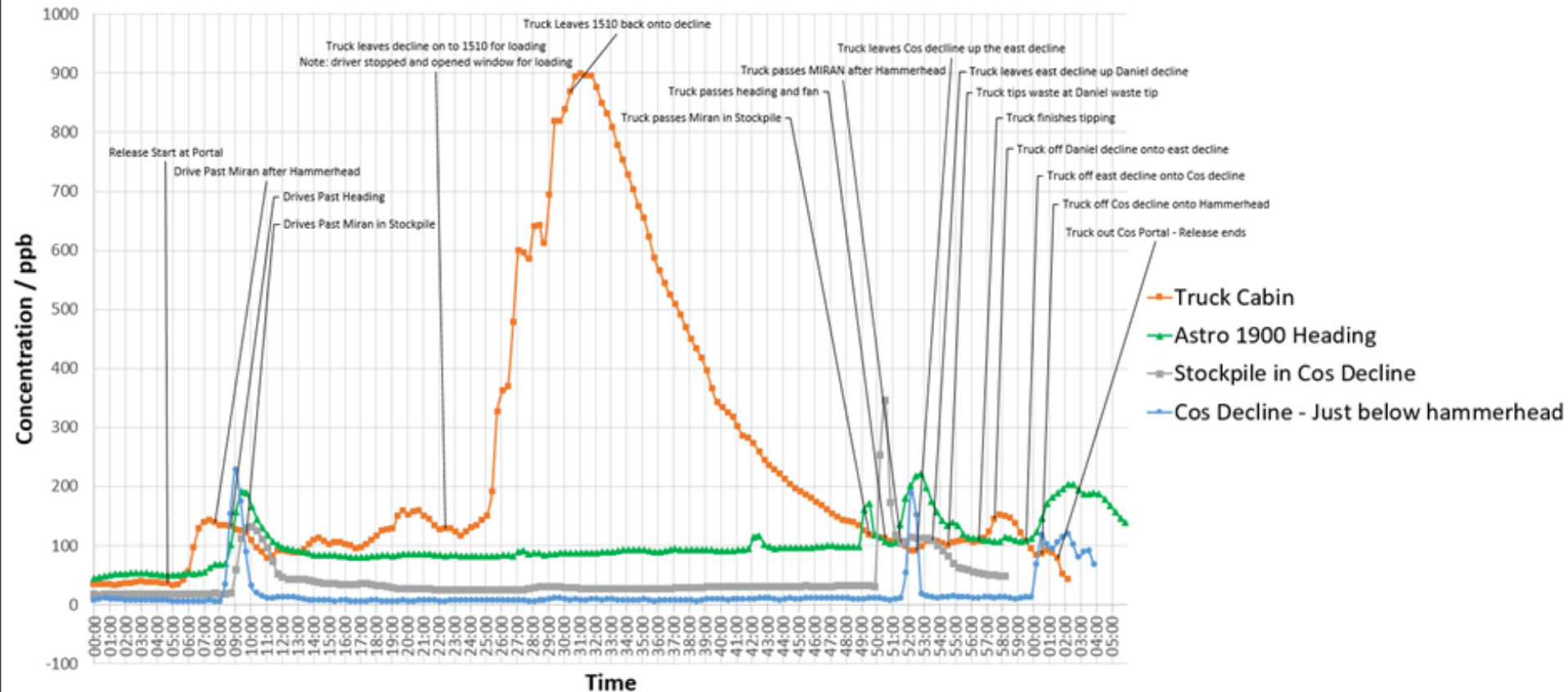
BY: **...**

APP: **...**

SCALE: **...**

PROJECT NO: **...**

24-10-2017 Truck



Tracer Gas Study - Outcomes

The SF6 results from the **truck** study suggest that the enclosed airconditioned cabin is very effective in managing exposure levels. However, the level of SF6 exposure to the truck driver increases significantly when a window is opened (a 9 fold increase). Once the window is closed the clearance time is very slow. Thus, the opening of the window not only results in increased levels but also results in prolonged exposure to higher levels once the SF6 is inside the cabin. The benefits of ensuring the cabin remains isolated is clear and some administrative control needs to be considered.

A recommendation from this study is that the truck driver should keep the window closed while stationary during loading. However, if the truck driver needs to open the window to communicate with the loader driver it is best that the window is left open while driving away for a certain amount of time to ensure faster clearance of exhaust from the cabin.

nDPM Study – Charge-up



nDPM Study – Charge-up



nDPM Study – Bogger



nDPM Study – Bogger



Tracer Gas Study - Outcomes

The tracer gas study of a number of underground mining activities, such as charging, bogging, hydro-scaling, shotcreting and truck driving, demonstrated that during those activities there were consistently **higher SF6 concentrations measured during the hydro-scaling and shotcreting activities.**

Air Sampling

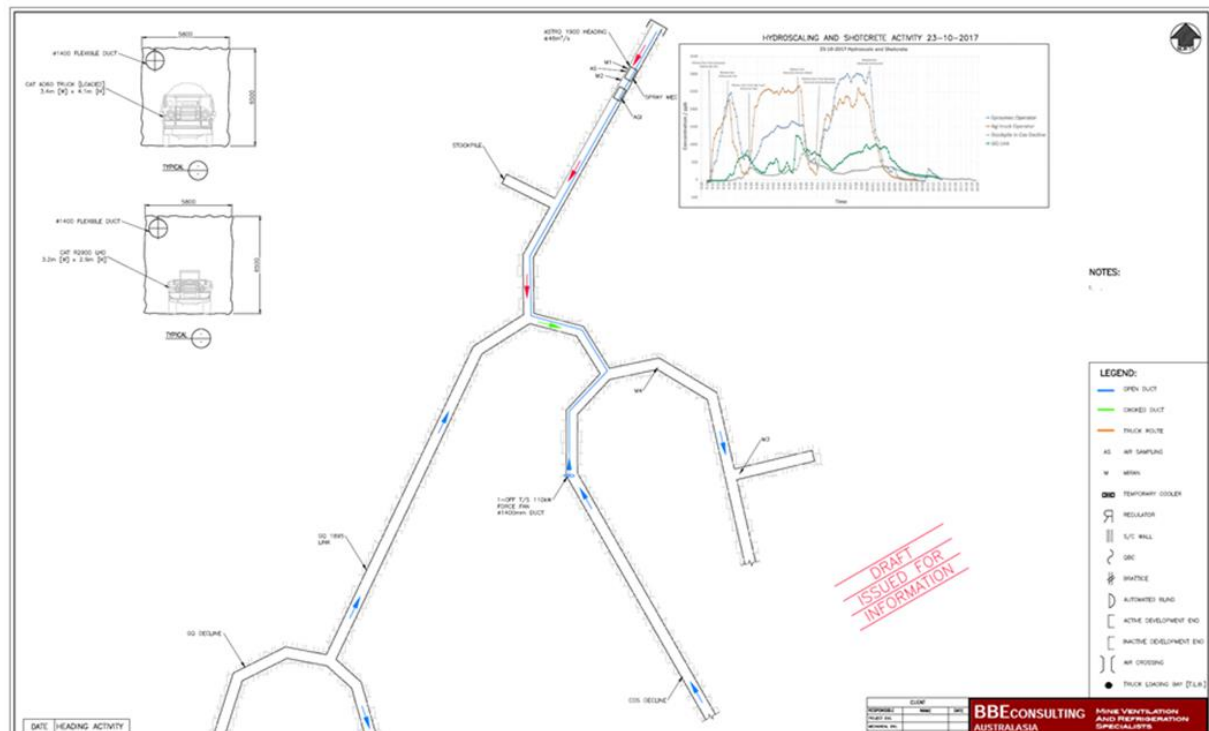
Development Heading - Astro 1900

- Bogger
- Hydro-scaling, Spraymec
- Shotcreting
 - Spraymech; and
 - Agi-truck

The levels measured for VOCs, CO, CO₂, NH₃, NO₂ and SO₂ were below both the Occupational Exposure Guidelines for both the Short Term Exposure Limit (STEL) and the Time Weighted Average (TWA) levels, **except for CO during hydro-scaling and NO₂ during the shotcreting and bogger activities.**

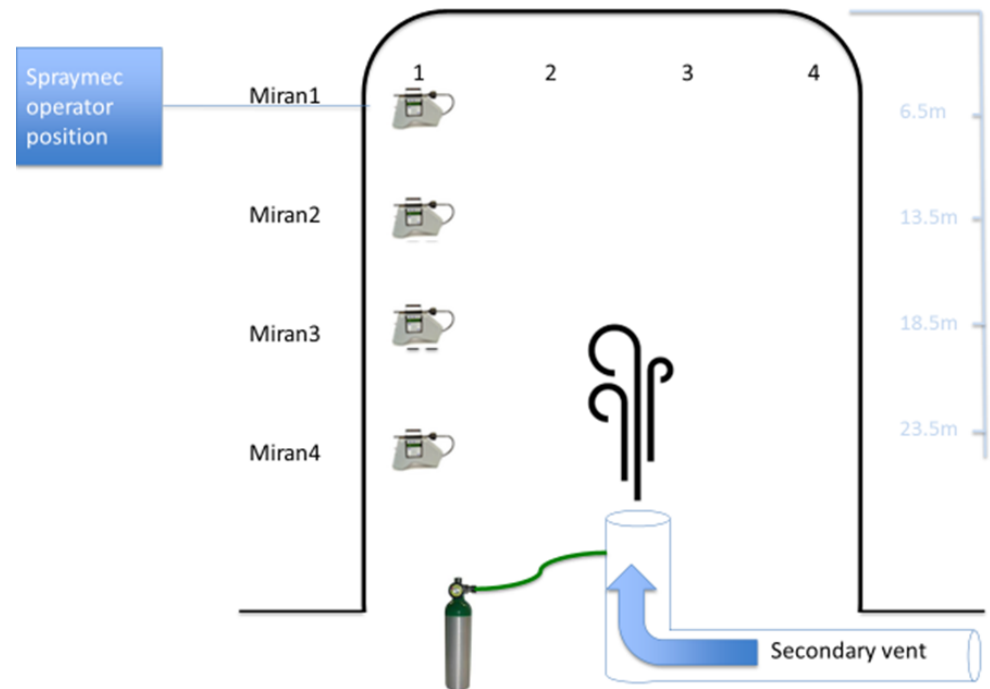
Tracer Gas Study - Outcomes

During a short duration activity in a development heading, an **unventilated cuddy** (as represented by the stockpile in this study) could be a natural 'place of safety' or shelter area for personnel that are in the general area but not involved with the actual activity at a development heading. This information can be utilised to better inform the planning of administrative controls to manage activities around other major diesel activities.



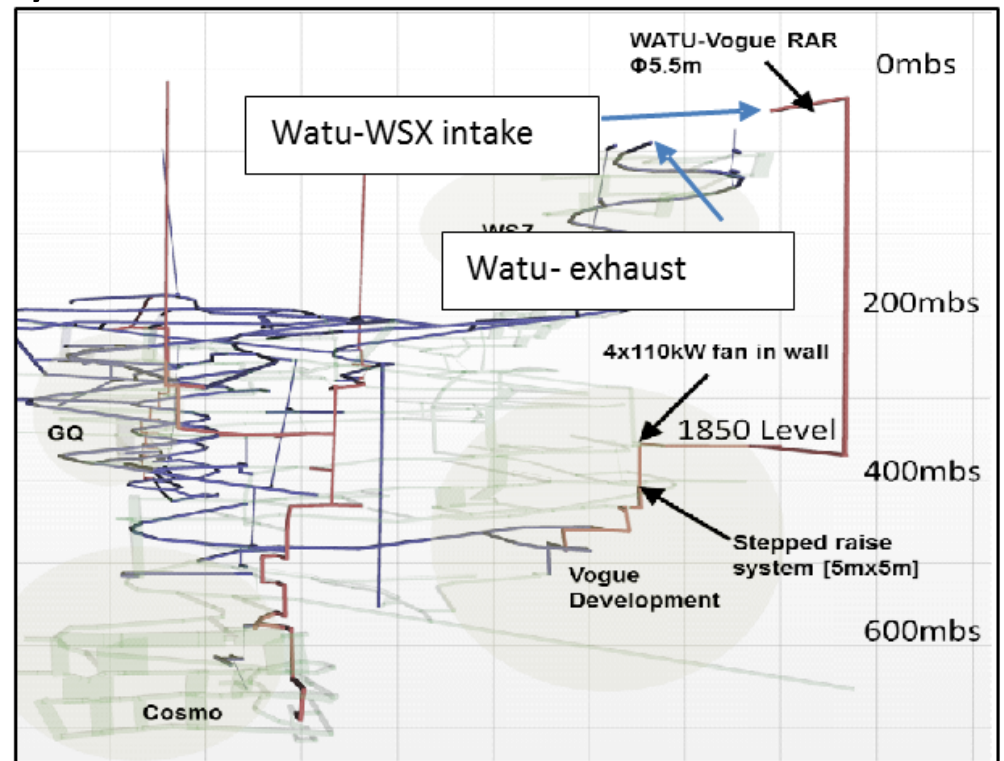
Tracer Gas Study - Outcomes

A **traverse exercise** performed in a well ventilated development heading demonstrated that there was little horizontal stratification across the heading despite the vent bag being near the right hand side of the heading wall. However, there was a very rapid drop-off in ventilation flow between 11.5m from the face and 6.5m from the face which means that areas much closer to the face will probably have far less effective ventilation.



Tracer Gas Study - Outcomes

At the **portals** where the experiment was undertaken, it showed no material significant contamination of the intake portal by the exhaust portal. However, there are other portals at Sunrise Dam where the intake and exhaust are closer and thus it would be worthwhile repeating the portal interaction experiment for these sections of the mine to identify if there is any material contamination of the intake portal by the exhaust portal.



Summary

Tracer gas (SF_6) technology was applied successfully to better understand and inform the following:

- SF_6 flow behaviour as a surrogate for diesel exhaust and relative source contribution to exposure of nearby equipment operators;*
- The dispersal of gaseous and ultrafine particulate emissions from diesel exhaust, i.e. particularly nDPM, and the dilution efficiency of the mine ventilation with particular focus on the auxiliary ventilation at the face of a development heading;*
- The impact of ventilation practises on the exposure levels; and*
- The potential impact of nano-diesel particulate matter (nDPM) on air quality.*

Tracer Gas Technology vs. CFD

Some of the “in the field” tracer gas study data (steady state levels) was utilised by the Curtin Uni. (WASM) research team to better inform the application of Computational Fluid Dynamics (CFD) modelling of DPM.

Two different Tools:

- CFD is a predictive tool*
- SF6 tracer gas is a measurement tool*

Tracer Gas Study – Recommendations for Future Work

- Controlled experimental set-ups with different secondary ventilation configurations should be considered to allow comparative studies that will enable ventilation optimisation.
- It would be possible to correlate SF₆ tracer gas measurements with dispersal of nanoparticles if particle characterisation data is available from the sites studied using tracer gas. This would require particle analysers to be co-located with the tracer gas detectors.
- It is recommended that future research on nDPM in underground mines includes both tracer gas study and particle characterisation at the same location.

Acknowledgments

- Anglo Gold Ashanti/SDGM & Barmenco - On site staff
- BBE Consulting Australasia (Leon van den Berg & Katie Manns)
- Curtin Uni. (Ben Mullins, Abishek Sridhar, Guang Xu)
- Sandvik, Perth.



Acknowledgments

- Anglo Gold Ashanti/SDGM & Barmenco - On site staff
- BBE Consulting Australasia (Leon van den Berg & Katie Manns)
- Curtin Uni. (Ben Mullins, Abishek Sridhar, Guang Xu)
- Sandvik, Perth.

Sandvik Visit – Truck

