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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

ChemCentre
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Curtin University

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 (< 80nm) behave more like gases

  Penetrate deep in the lungs

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

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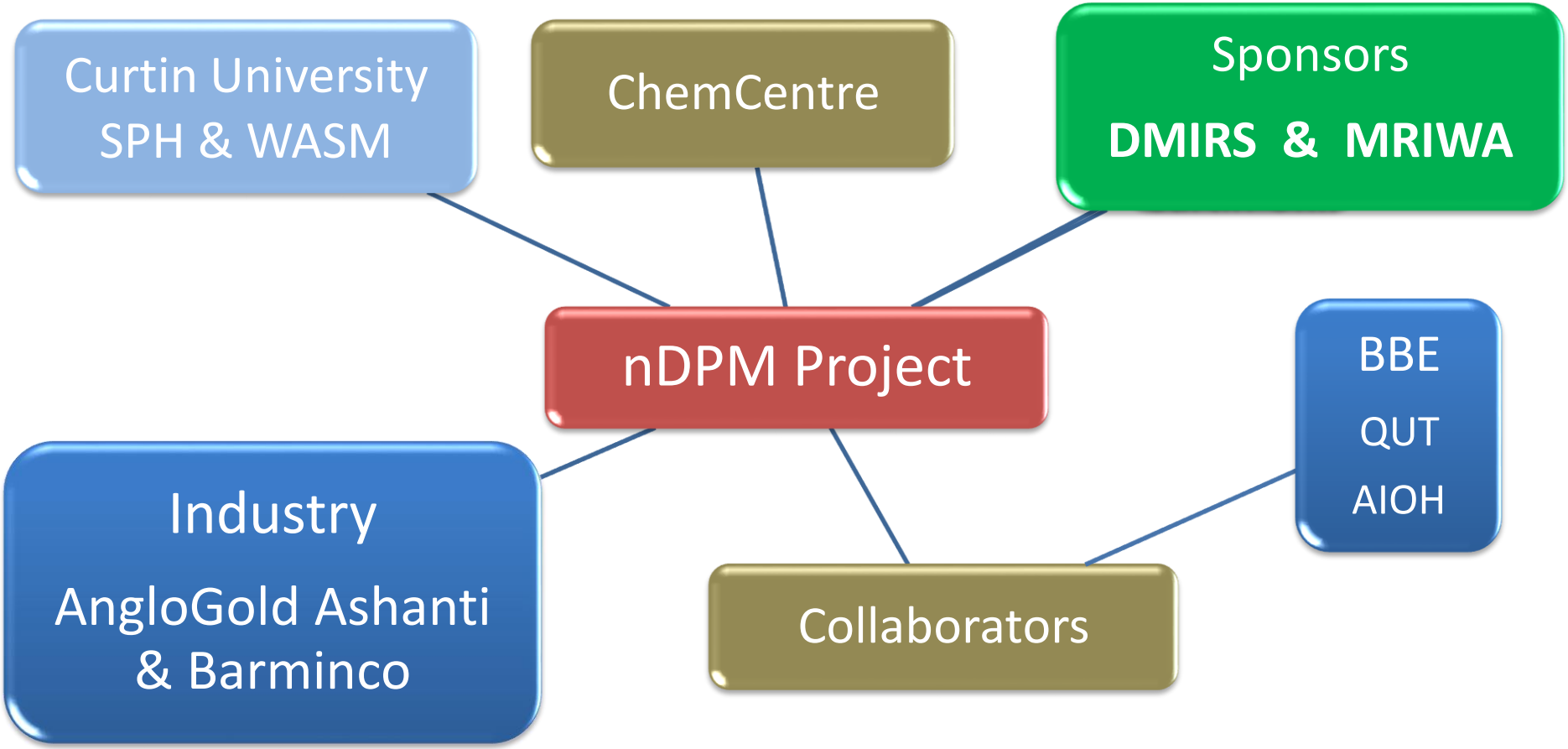
MRIWA M495: Project Objectives

- 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

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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, NOx, SOx, 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.

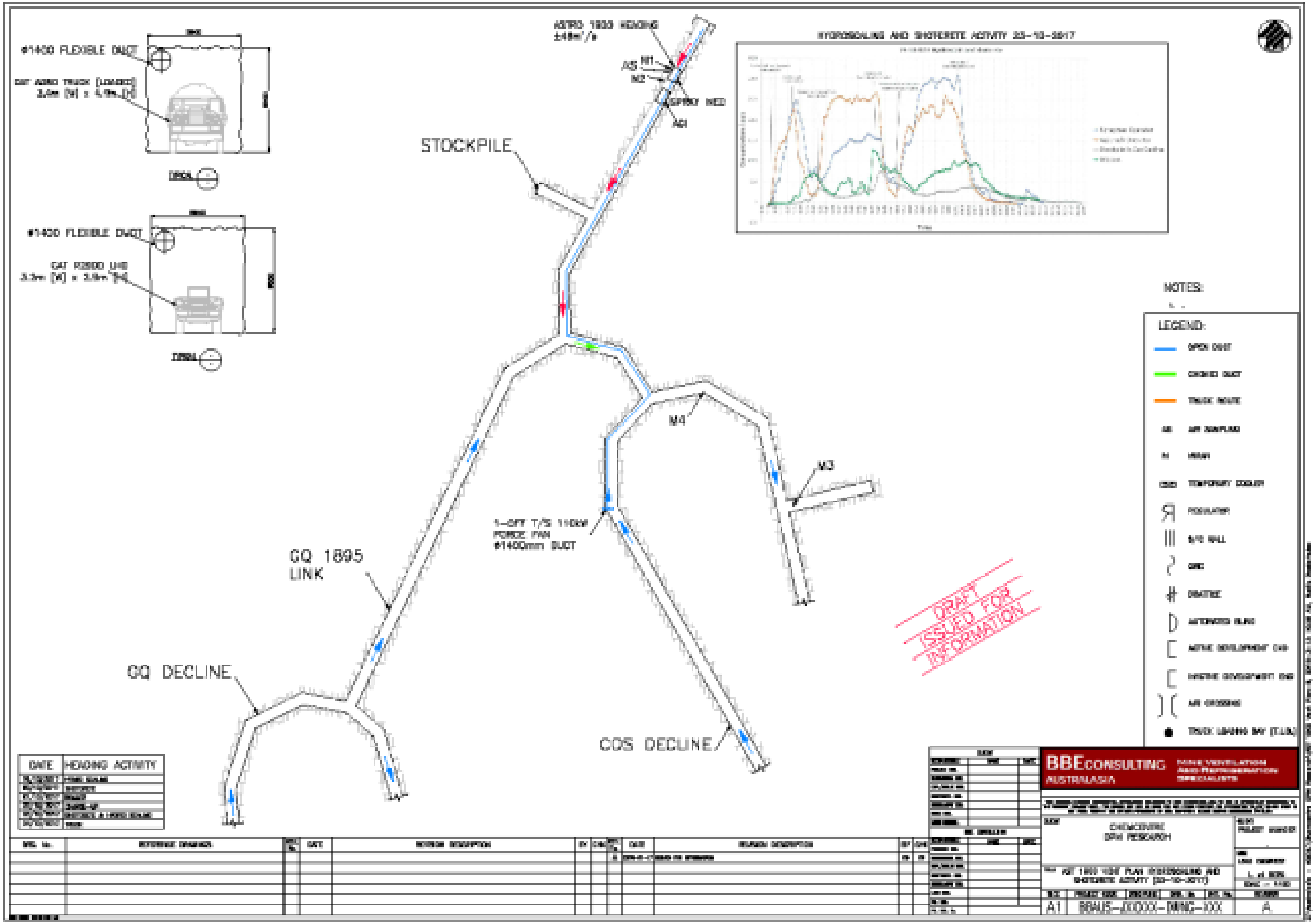
Tracer Gas Study

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



#1400 FLEXIBLE DUCT
STOCKPILE
HYDROSEALING AND SHOTCRETE ACTIVITY 23-10-2017
NOTES:
LEGEND:
OPEN DUCT
TRUCK ROUTE
M4
M3
1-OFF T/S 110kW
FORCE FAN
Ø1400mm DUCT
GQ 1895
LINK
GQ DECLINE
COS DECLINE
DRAFT
ISSUED FOR
INFORMATION
DATE
HEADING ACTIVITY
BBE CONSULTING
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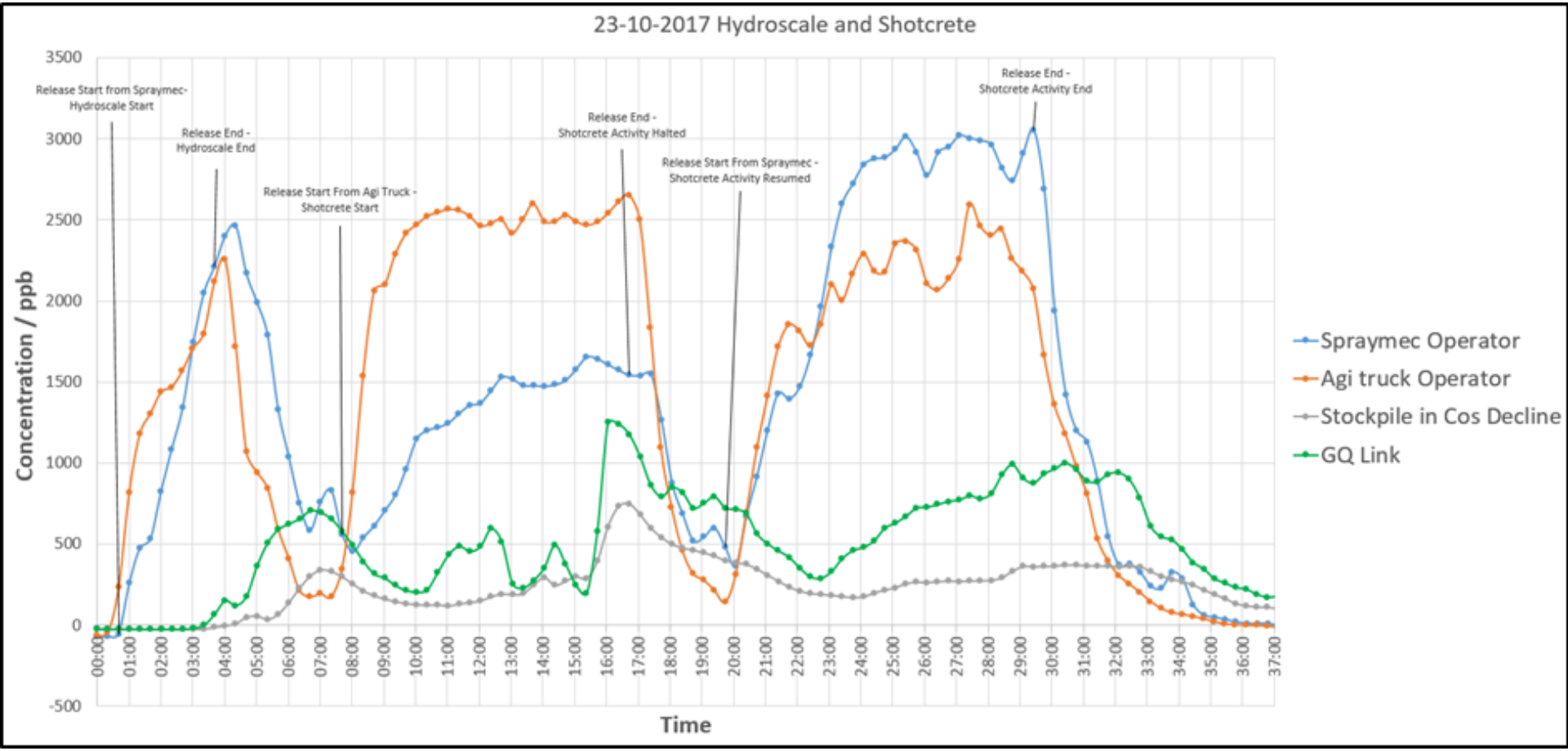
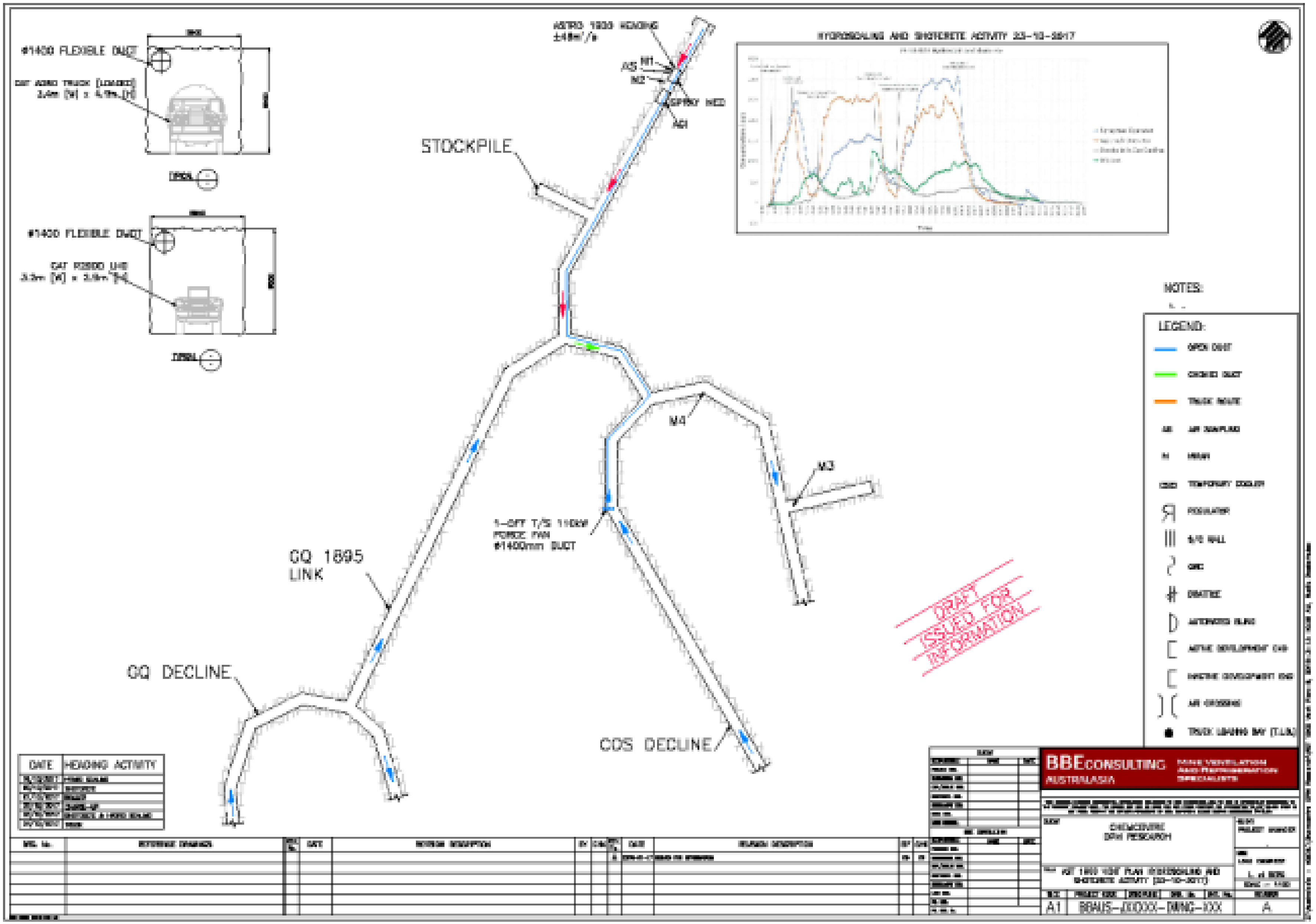
nDPM Study – Shotcrete


23-10-2017 Hydroscale and Shotcrete
Release Start from Spraymec-Hydroscale Start
Release End - Hydroscale End
Release Start From Agi Truck - Shotcrete Start
Release End - Shotcrete Activity Halted
Release Start From Spraymec - Shotcrete Activity Resumed
Release End - Shotcrete Activity End
Concentration / ppb
Time
Spraymec Operator
Agi truck Operator
Stockpile in Cos Decline
GQ Link



#1400 FLEXIBLE DUCT
#1400 FLEXIBLE DUCT
ASTRO 1930 HEADING
STOCKPILE
HYDROSCALING AND SHOTCRETE ACTIVITY 23-10-2017
GQ 1895
LINK
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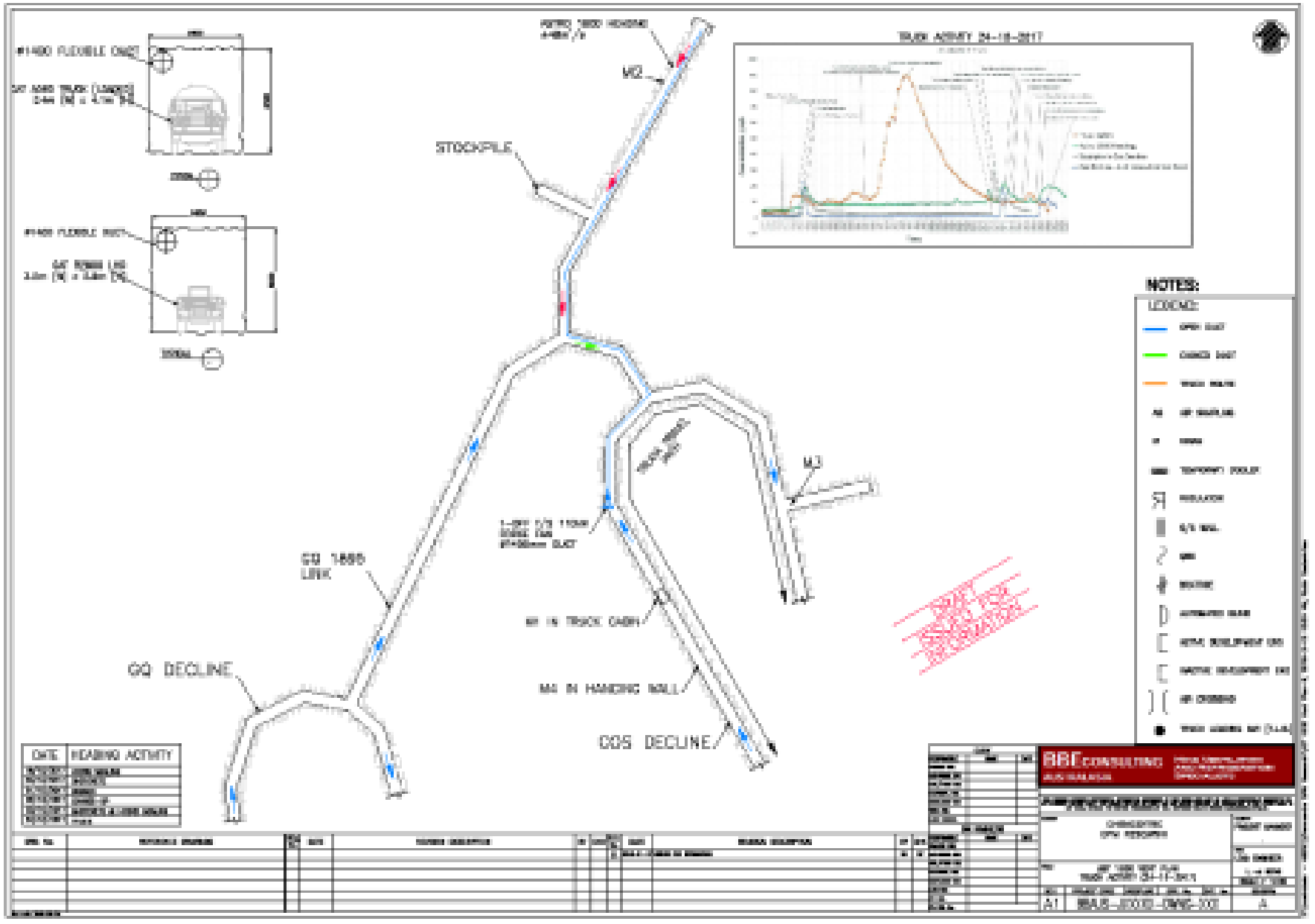
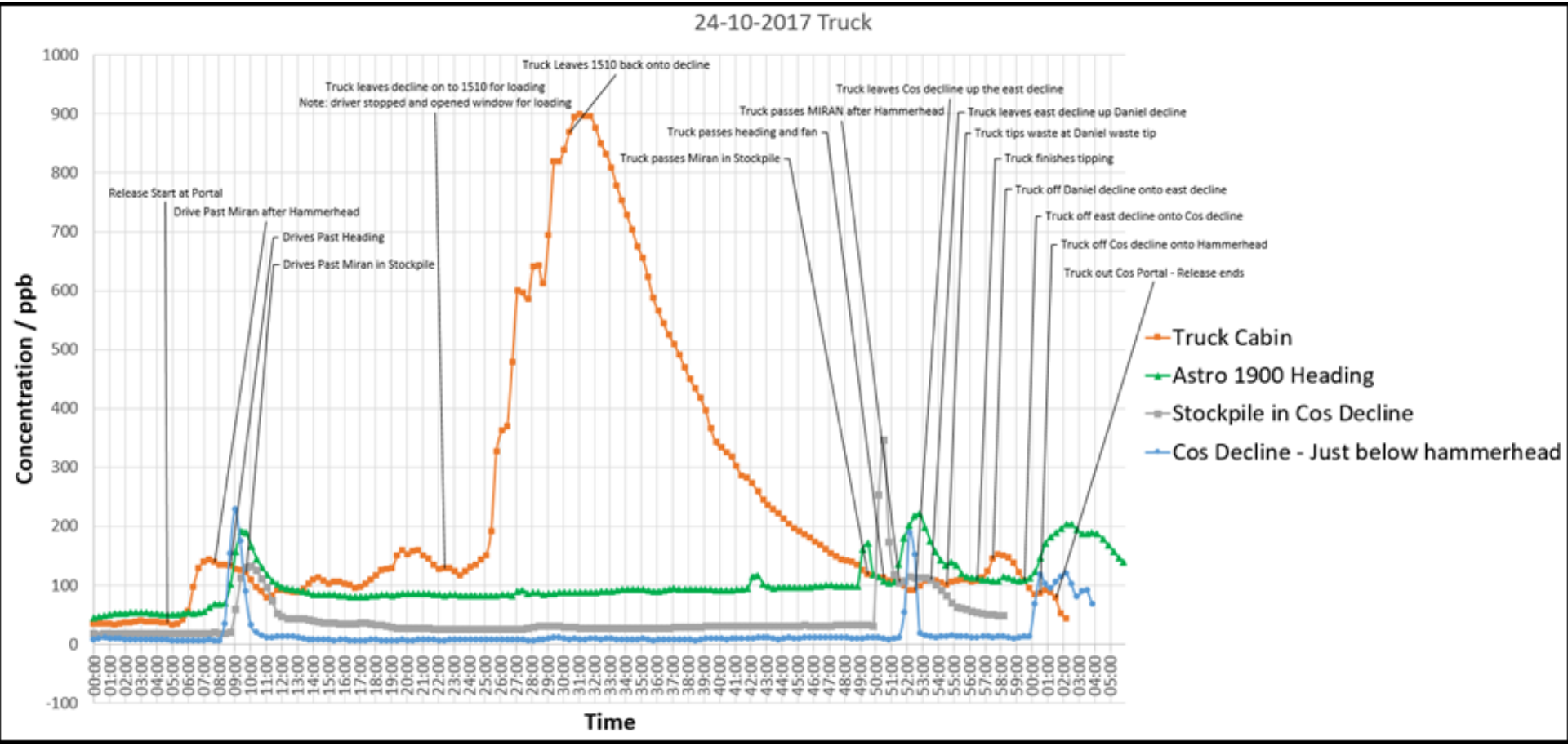
Tracer Gas Study - Outcomes

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


STOCKPILE
M2
M3
M4 IN TRUCK CABIN
M4 IN HANGING WALL
GQ DECLINE
GQS DECLINE
NOTES:
LEGEND:


24-10-2017 Truck
Concentration / ppb
Time
Truck Leaves 1510 back onto decline
Truck leaves decline on to 1510 for loading
Note: driver stopped and opened window for loading
Truck leaves Cos decline up the east decline
Truck passes MIRAN after Hammerhead
Truck leaves east decline up Daniel decline
Truck passes heading and fan
Truck tips waste at Daniel waste tip
Truck passes Miran in Stockpile
Truck finishes tipping
Release Start at Portal
Drive Past Miran after Hammerhead
Truck off Daniel decline onto east decline
Drives Past Heading
Truck off east decline onto Cos decline
Drives Past Miran in Stockpile
Truck off Cos decline onto Hammerhead
Truck out Cos Portal - Release ends
Truck Cabin
Astro 1900 Heading
Stockpile in Cos Decline
Cos Decline - Just below hammerhead

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

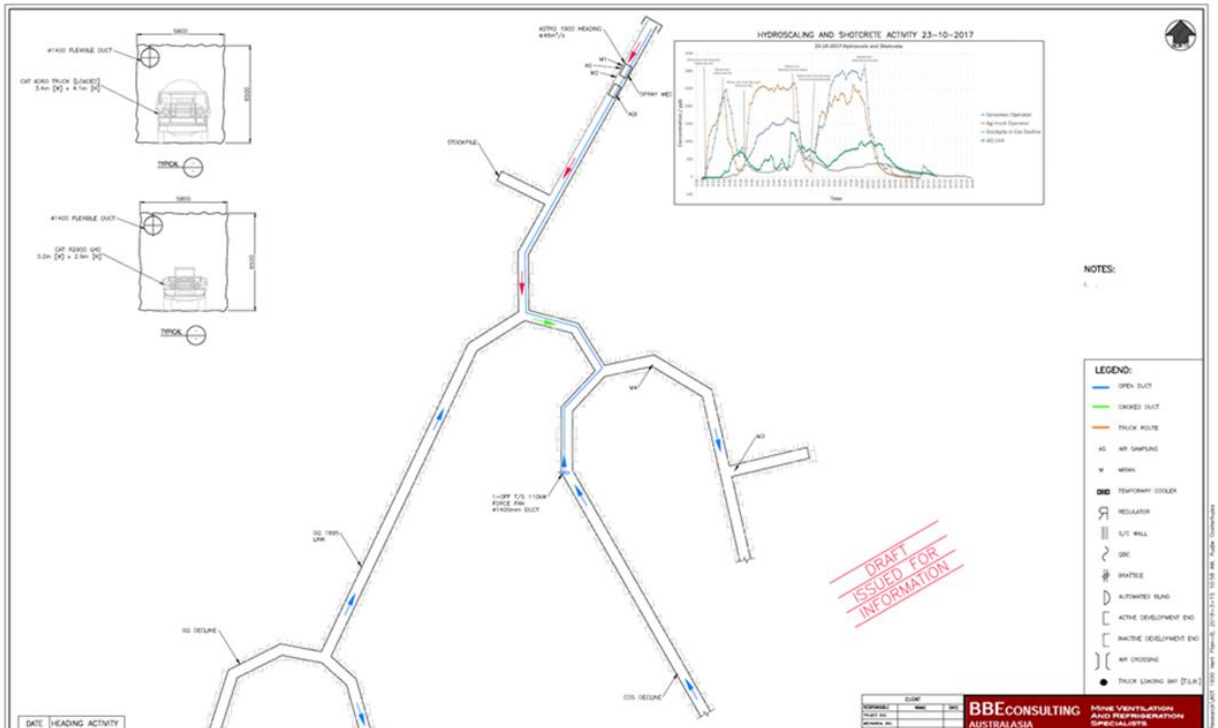
Development Heading - Astro 1900

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

The levels measured for VOCs, CO, CO_2, NH_3, NO_2 and SO_2 were below both the Occupational Exposure Guidelines for both the Short Term Exposure Limit (STEL) and the Time Weighed Average (TWA) levels, **except for CO during hydro-scaling and NO_2 during the shotcreting and bogger activities**.

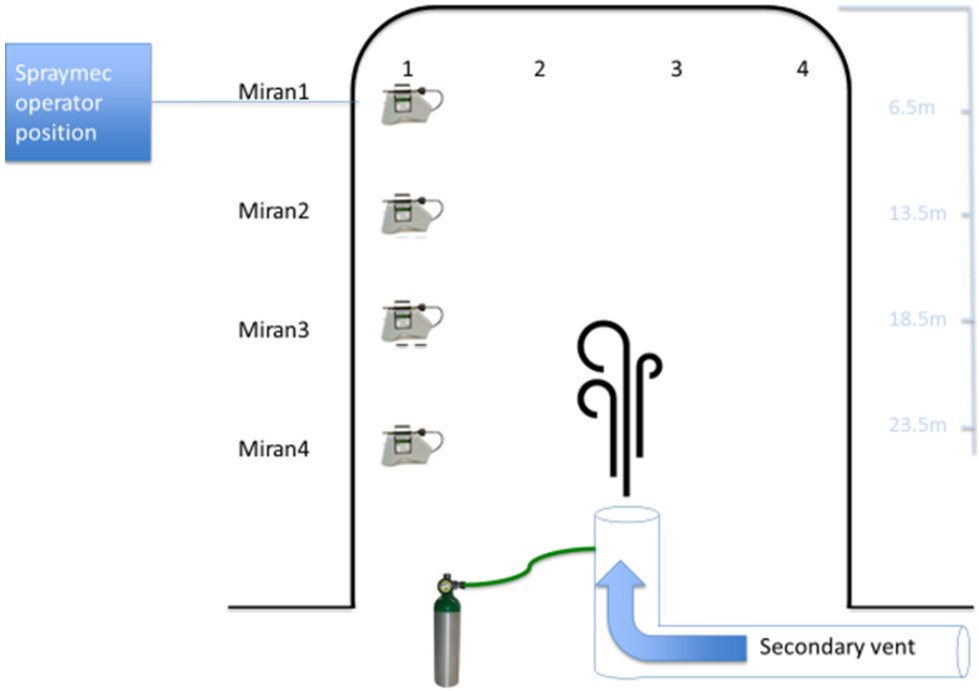
Tracer Gas Study - Outcomes

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.



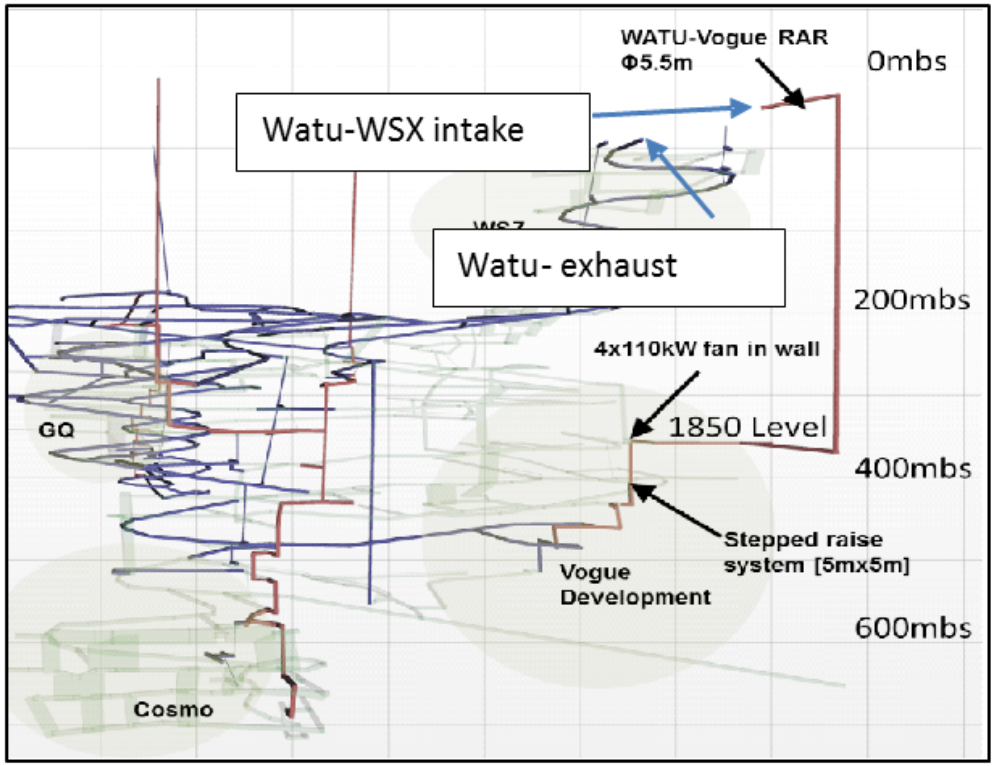
Tracer Gas Study - Outcomes

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:

- *SF6 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 SF_6 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 & Barminco - On site staff
- BBE Consulting Australasia (Leon van den Berg & Katie Manns)
- Curtin Uni. (Ben Mullins, Abishek Sridhar, Guang Xu)
- Sandvik, Perth.


OVERHEAD
CRANE


PELICAN

Acknowledgments

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- Curtin Uni. (Ben Mullins, Abishek Sridhar, Guang Xu)
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Sandvik Visit – Truck