Measurements of air quality during hydraulic fracturing in the Surat Basin

Erin Dunne | Research Scientist, CSIRO Climate Science Centre | December 2019

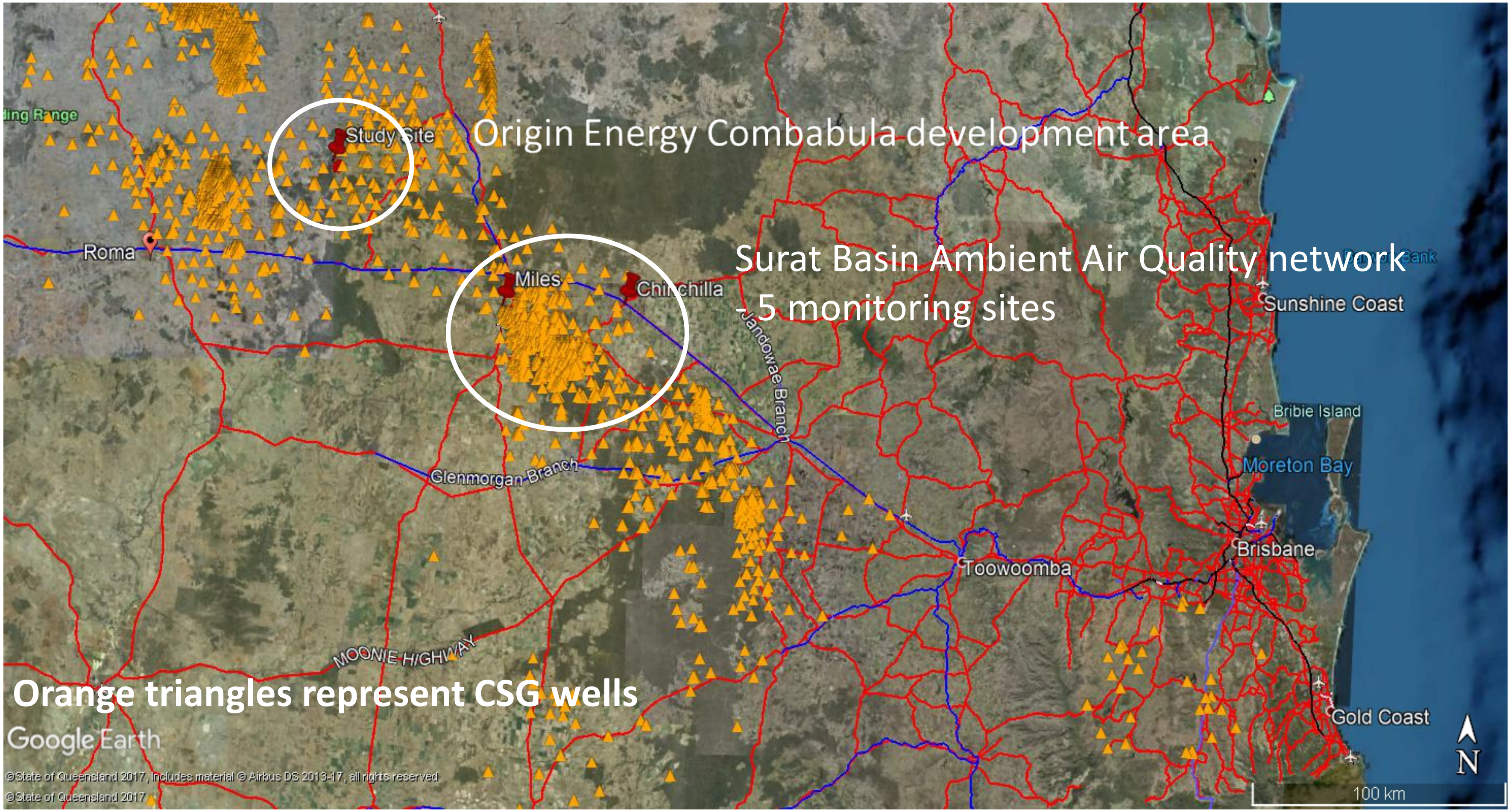
Potential sources of air pollutants

- **Vehicles & equipment – exhaust emissions & dust**
- **Fracturing fluids & flow back fluids – emissions during handling & storage**
- **Coal seam gas – fugitive emissions & venting**

Other air pollutant sources in the background atmosphere:

- **Biomass burning**
- **Long range transport**
- **Agriculture & farming**
- **Local traffic & domestic emissions**
- **Vegetation & soil**

Air quality study location



Source: Queensland Globe (2016). "Queensland Government CSG Globe"
Available: https://www.business.qld.gov.au/business/support-tools-grants/services/mapping-data-imagery/queensland-globe

Air quality measurement stations

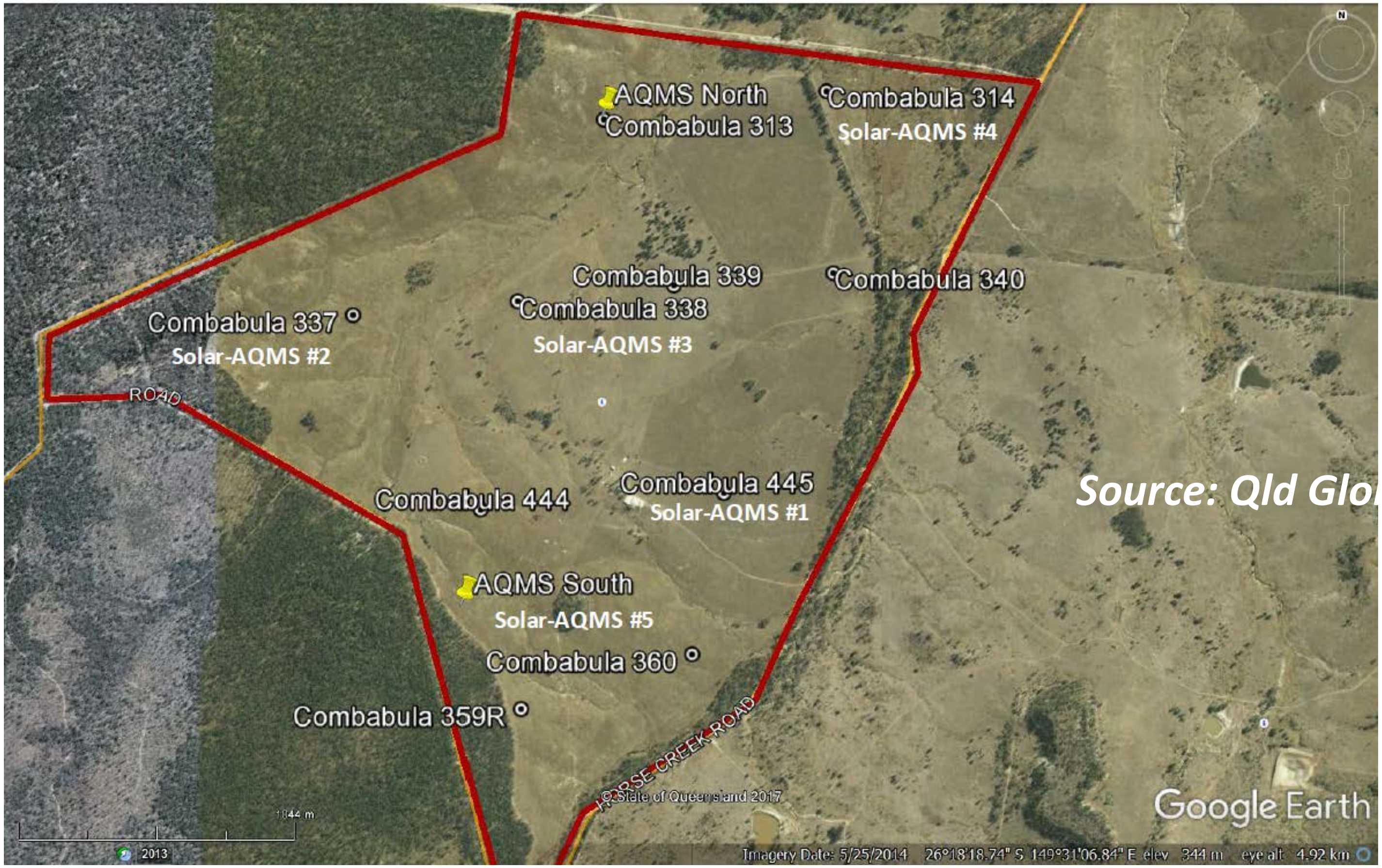
Two Ecotech Air Quality Monitoring Stations (AQMS North & South)

mbabula development area

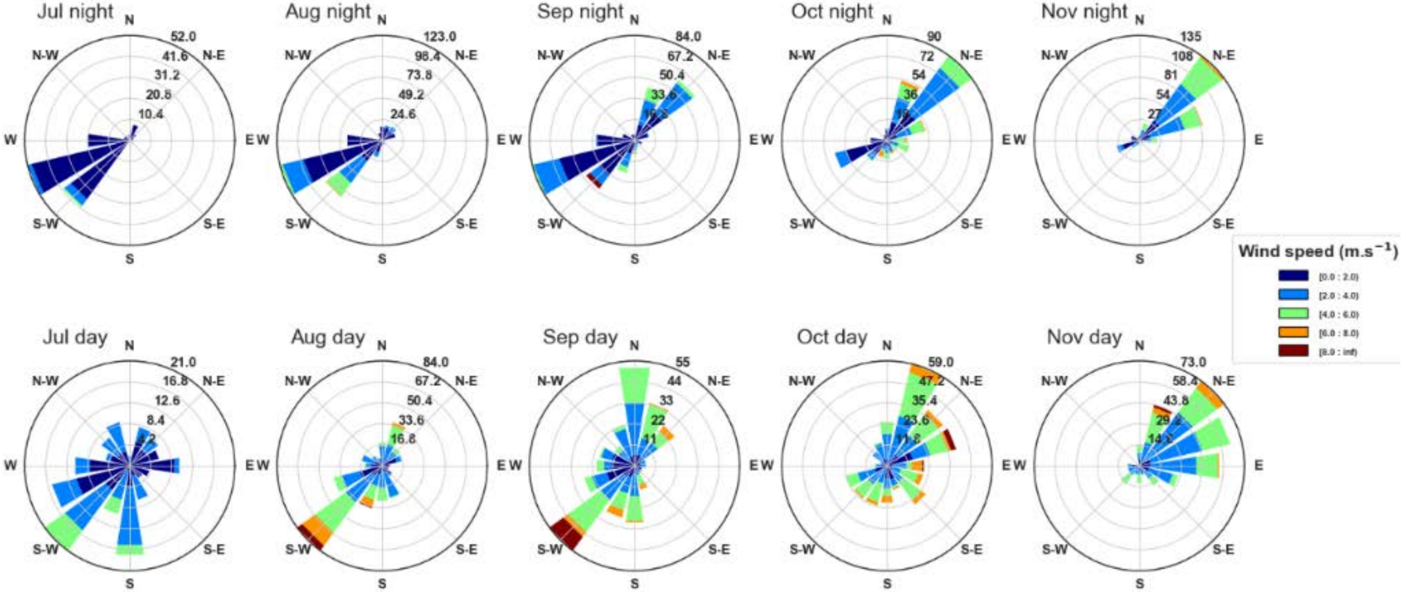
Five solar-powered air quality monitoring systems
- 4 located ~50 - 100m from well pads
-1 site co-located with South AQMS

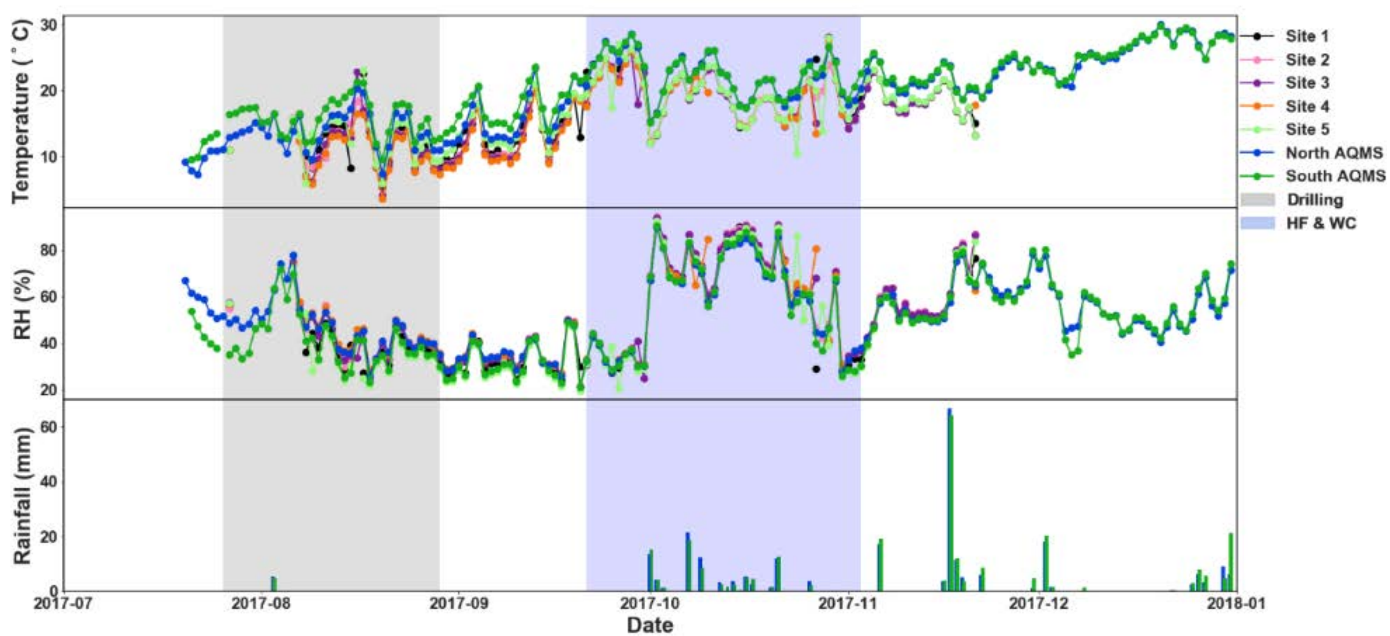
Measurement sites

Sites located according to:
proximity to wells; access to power; prevailing winds



Measurement sites





Target air pollutants & air quality objectives

National Environmental Protection Measure (NEPM) Ambient Air Pollutants

Nitrogen dioxide (NO_2)

Carbon monoxide (CO)

Sulfur dioxide (SO_2)

Ozone (O_3)

Particles – diameter less than 10 µm (PM_{10})

Particles – diameter less than 2.5 µm ($PM_{2.5}$)

National Environmental Protection Measure (NEPM) Air Toxics

Formaldehyde

Benzene

Toluene

Xylenes

Benzo(a)pyrene as a marker for PAHs

Additional Pollutants in Qld Environmental Protection Policy for Air

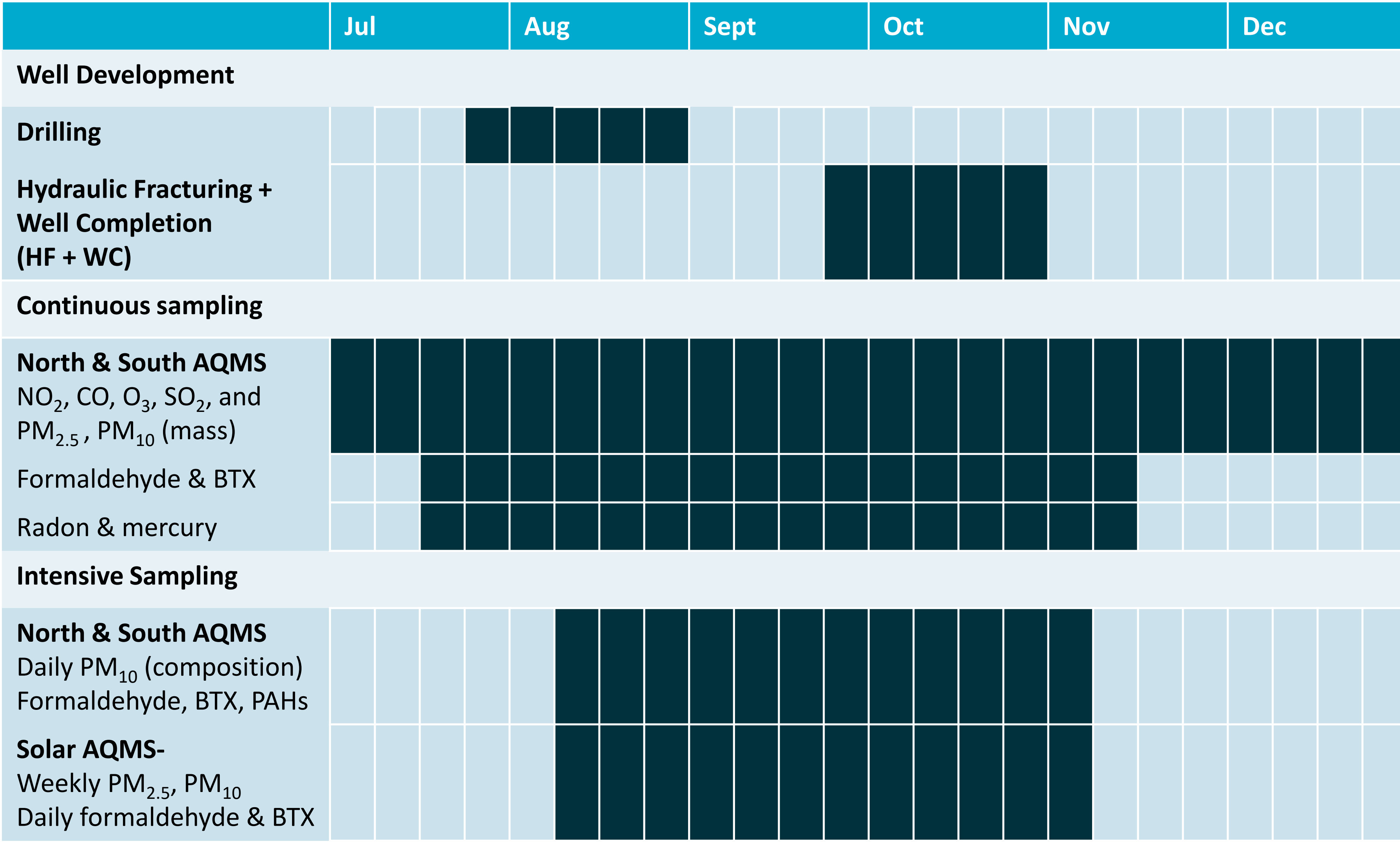
Components in PM_{10} – Arsenic, Manganese, Nickel, Sulfate

Gases - Mercury, Hydrogen Sulfide, Styrene, 1,2,-Dichloroethane, Tetrachloroethylene

Australian Radiation Protection & Nuclear Safety Agency (ARPANSA) Recommendations for Limiting Exposure to Ionizing Radiation

Radon-222

Measurements before, during & after hydraulic fracturing



Objective 1

- *Provide comparisons of the air quality observed at a hydraulic fracturing (HF) site with Australian federal and state air quality objectives*

- *Provide comparisons with data from other air quality studies undertaken in areas not directly impacted by HF operations both within the Surat Basin and in other locations in Australia.*

NEPM Ambient air pollutants – air quality index values

			Proportion of total observations in each AQ index category					
AQ Index categories			Very Good	Good	Fair	NEPM Ambient Air Quality Objective	Poor	Very Poor
Location	Pollutant	AQ objective						
North AQMS	NO_2	NEPM 1h	100%	0%	0%		0%	0%
	CO	NEPM 8h	100%	0%	0%		0%	0%
	O_3	NEPM 1h	68%	32%	0%		0%	0%
		NEPM 4h	45%	55%	**1%**		0%	0%
	SO_2	NEPM 1h	100%	0%	0%		0%	0%
		NEPM 24h	100%	0%	0%		0%	0%
	$PM_{2.5}$	NEPM 24h	85%	13%	**2%**		0%	0%
	PM_{10}	NEPM 24h	88%	12%	**1%**		0%	0%
	TSP	EPP 24h	81%	17%	**1%**		**1%**	0%
South AQMS	NO_2	NEPM 1h	100%	0%	0%		0%	0%
	CO	NEPM 8h	100%	0%	0%		0%	0%
	O_3	NEPM 1h	62%	38%	0%		0%	0%
		NEPM 4h	34%	65%	**1%**		0%	0%
	$PM_{2.5}$	NEPM 24h	86%	13%	**1%**		0%	0%
	PM_{10}	NEPM 24h	83%	13%	**3%**		**1%**	0%
	TSP	EPP 24h	70%	23%	**4%**		**2%**	**2%**

NEPM pollutants – comparison with other locations

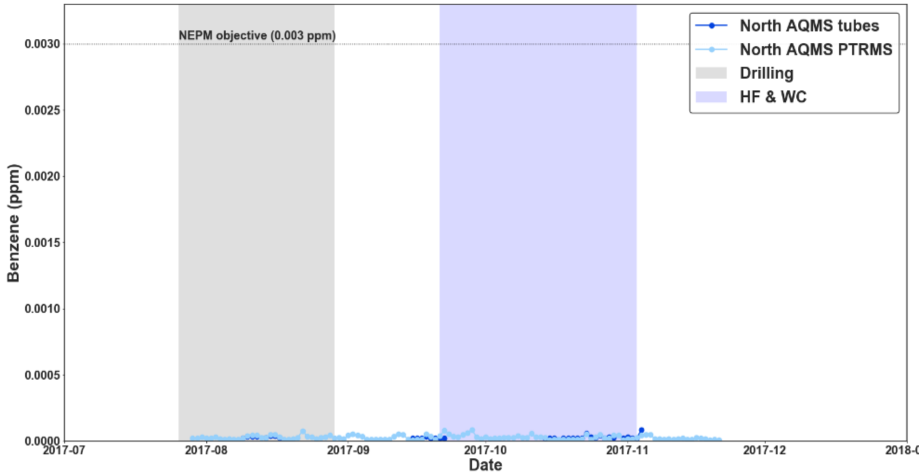
NEPM pollutants (NO_2, CO, O_3, $PM_{2.5}$, PM_{10}) and TSP levels were similar to those at Surat Basin sites not directly impacted by HF activities, during the same period.

		Proportion of total observations in each AQ index category				
AQ Index categories		Very Good	Good	Fair	Poor	Very Poor
NO_2 1-hour average	North-AQMS	100%	0%	0%	0%	0%
	South-AQMS	100%	0%	0%	0%	0%
	Hopeland	100%	0%	0%	0%	0%
	Miles Airport	100%	0%	0%	0%	0%
	Burncluith	100%	0%	0%	0%	0%

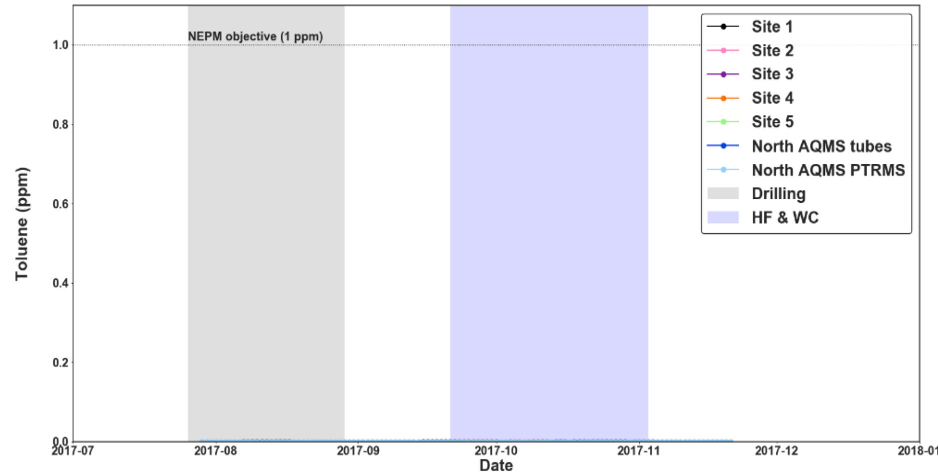
		Proportion of total observations in each AQ index category				
AQ Index categories		Very Good	Good	Fair	Poor	Very Poor
PM_{10} 24-hour average	North-AQMS	88%	12%	1%	0%	0%
	South-AQMS	83%	13%	3%	1%	0%
	Hopeland	93%	7%	0%	0%	0%
	Miles Airport	87%	11%	2%	0%	0%

Air toxics – comparison with NEPM objectives

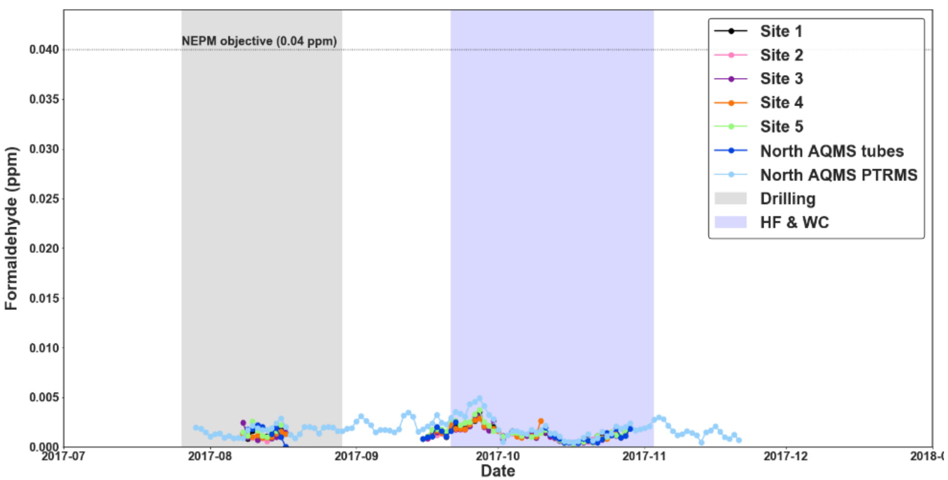
Benzene



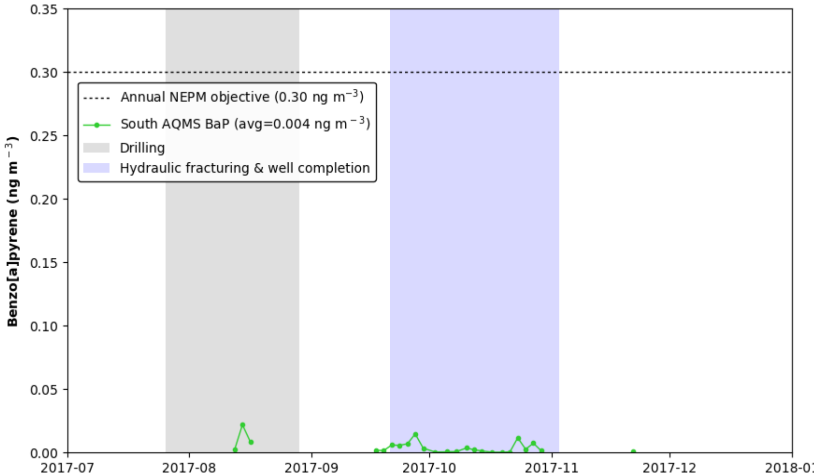
Toluene



Formaldehyde



Benzo(a) pyrene as a marker for polyaromatic hydrocarbons (PAHs)



Air toxics – comparison with other locations

	HF site (this study)		HF Sites 2016/17[a]		Regional sites[b] (>10km from CSG)		Gas-field sites[b]	
	Roma-Yuleba region		Miles-Condamine region		Tara region & Burncluith		Wilgas, Hopeland	
	Range (ppb)	DF (%)	Range (ppb)	DF (%)	Range (ppb)	DF (%)	Range (ppb)	DF (%)
Benzene	0.02 – 0.07	18%	0.01 – 0.09	21%	0.02 – 0.05	25%	0.01 – 0.09	29%
Toluene	0.01 – 0.03	18%	0.01 – 0.18	29%	0.01 – 0.04	21%	0.01 – 0.04	43%
m & p-xylenes	0.01 – 0.06	12%	0.01 – 0.08	9%	0.01 – 0.06	13%	0.01 – 0.03	19%
o-Xylene	< 0.02	0 %	0.01 – 0.03	4%	0.01 – 0.03	4%	0.01 – 0.04	5%
Formaldehyde	0.04 – 1.30	94%	0.33 – 2.12	100%	0.04 – 1.30	83%	0.39 – 1.30	100%

DF% = detection frequency (%)- the number of observations above the detection limit of the method

[a] Dunne et al (2018) available :https://gisera.csiro.au/project/air-water-and-soil-impacts-of-hydraulic-fracturing/
[b] Lawson et al (2018) available: https://gisera.csiro.au/project/ambient-air-quality-in-the-surat-basin/

Air toxics – comparison with other locations

	Benzo(a)pyrene (BaP) as a marker for PAHs ($\mu g/m^3$)			
	This study (rural)	Mutdapilly (rural) Summer [a]	Mutdapilly (rural) Winter [a]	Woolloongabba[b] (urban)
Max	**0.022**			**0.051**
Average	**0.005**	**<0.006**	**0.007**	**0.028**

a (Kennedy et al 2010a)
b (NEPC 2017)

Mercury & Radon – comparison with air quality objectives & levels observed at other locations

Mercury

Location	Average & standard deviation	Air Quality Objective	
This study	0.57 ± 0.12 ng/m^3	1100 ng m^{-3}	Annual Qld EPP
Near Darwin, NT 2015[a]	0.93 ± 0.12 ng/m^3		
Southern Ocean, Tasmania, 2013	0.85 ± 0.11 ng/m^3		
Inland site, Hunter Valley NSW 2019	0.8 - 1.0 ng/m^3		
Snowy Mountains, NSW 2017	0.59 ± 0.10 ng/m^3		

Radon

	Average	Max	Air Quality Objective	
South-AQMS	4.44 Bq m^{-3}	9.96 Bq m^{-3}	200 Bq m^{-3}	Long term ARPANSA objective for households
Tara region (Surat Basin)	9.2 Bq m^{-3}	34.2 Bq m^{-3}		

Objective 1 – findings

- *Provide comparisons of the air quality observed at a HF site with Australian federal and state air quality objectives.*

→ Levels of most air pollutants were well below relevant air quality objectives for the entire duration of the study period.

- *Provide comparisons with data from other air quality studies undertaken in areas not directly impacted by HF operations both within the Surat Basin and in other locations in Australia.*

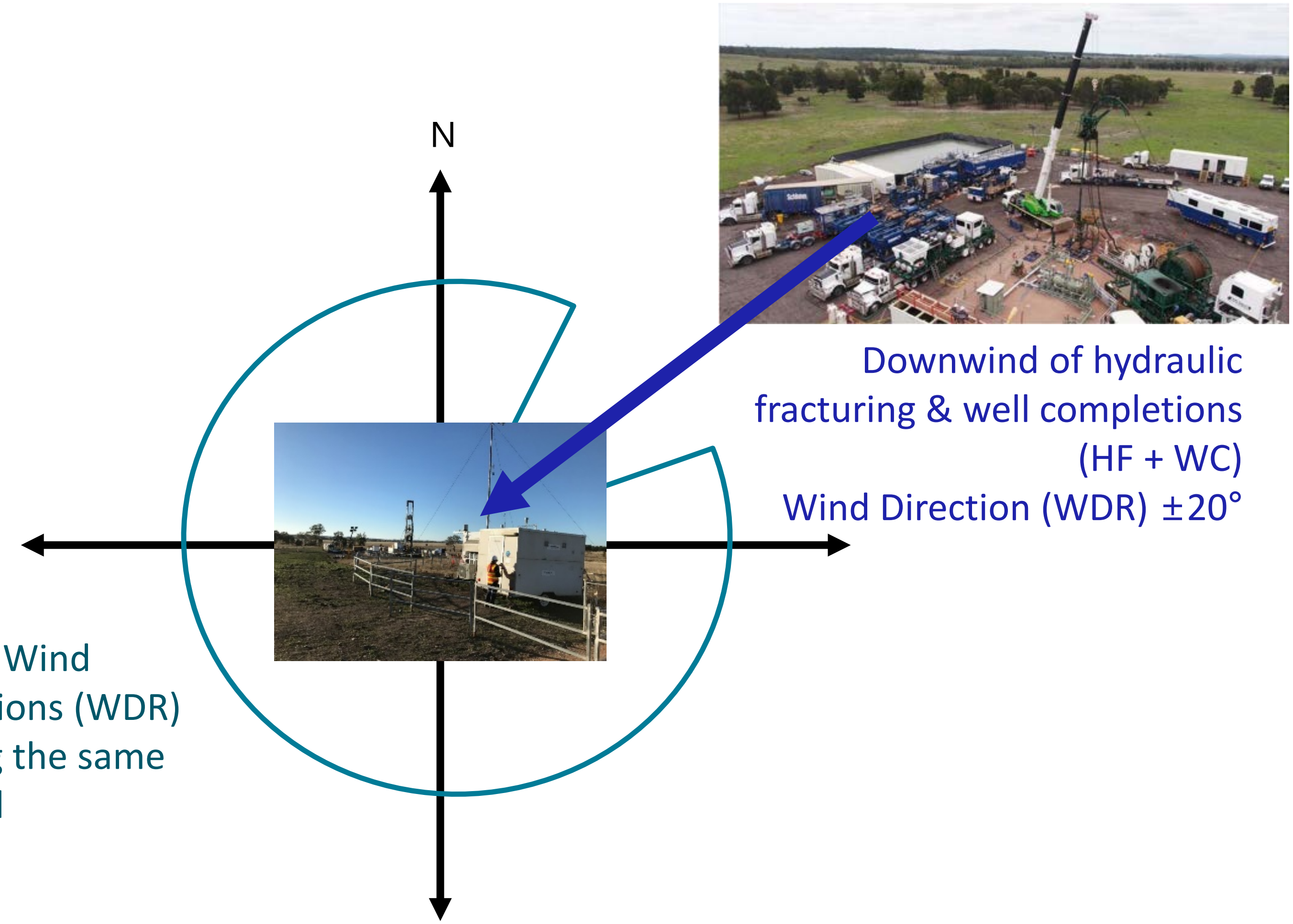
→ Range of concentrations observed (including exceedances of PM_{10} & TSP) were not distinctly different to those observed at other sites in the Surat Basin and in Australia that were not directly impacted by HF activity.

Objective 2

Quantify increases in air pollutant levels above background that occur during HF operations.

- Potential increases in pollutant concentrations above background due to well development activity were assessed using higher time resolution (5-10 minute) pollutant concentration and wind direction data.

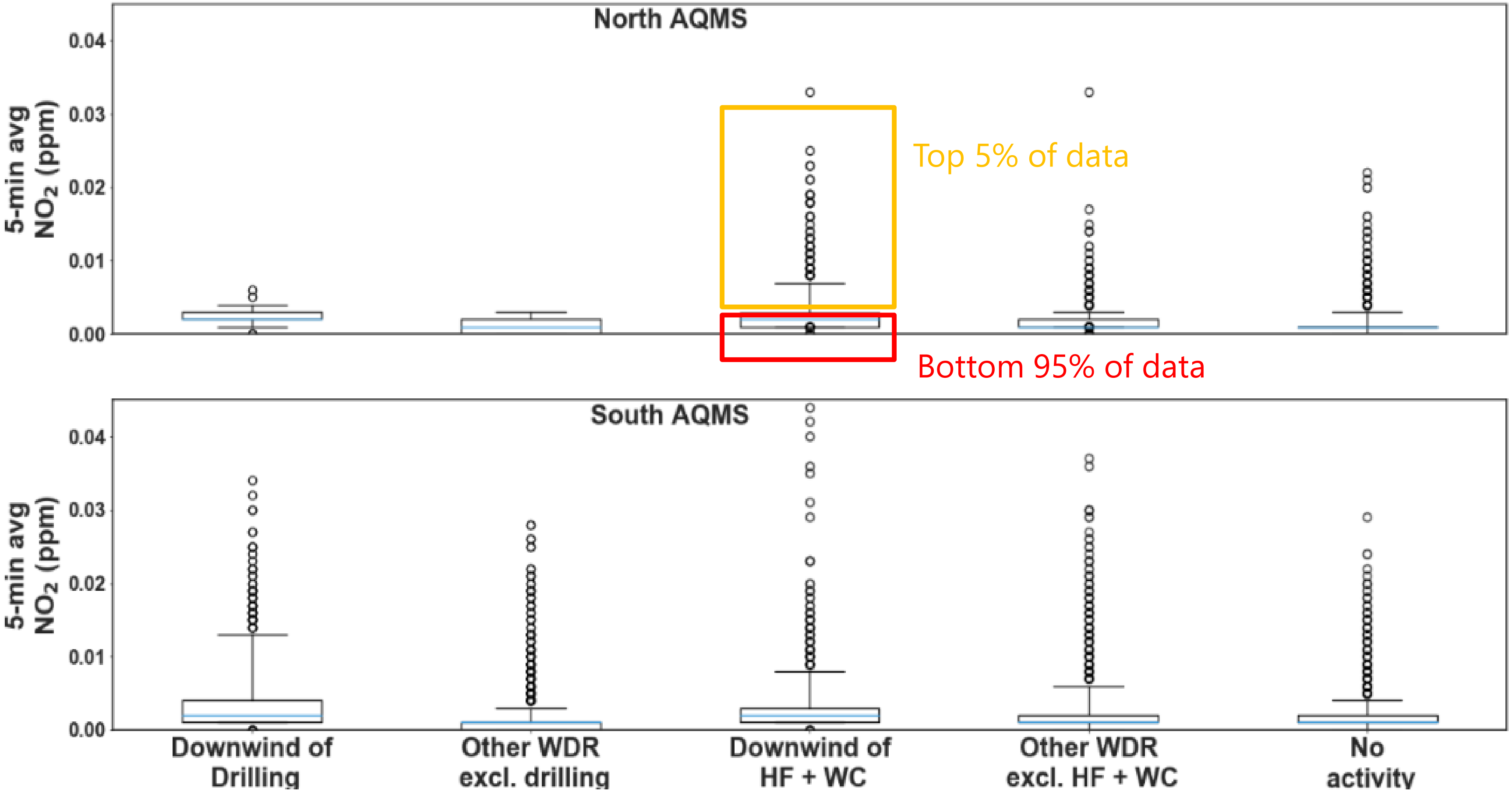
Quantifying changes in pollutant levels



Were pollutant levels higher downwind of HF + WC than they were when sampled:

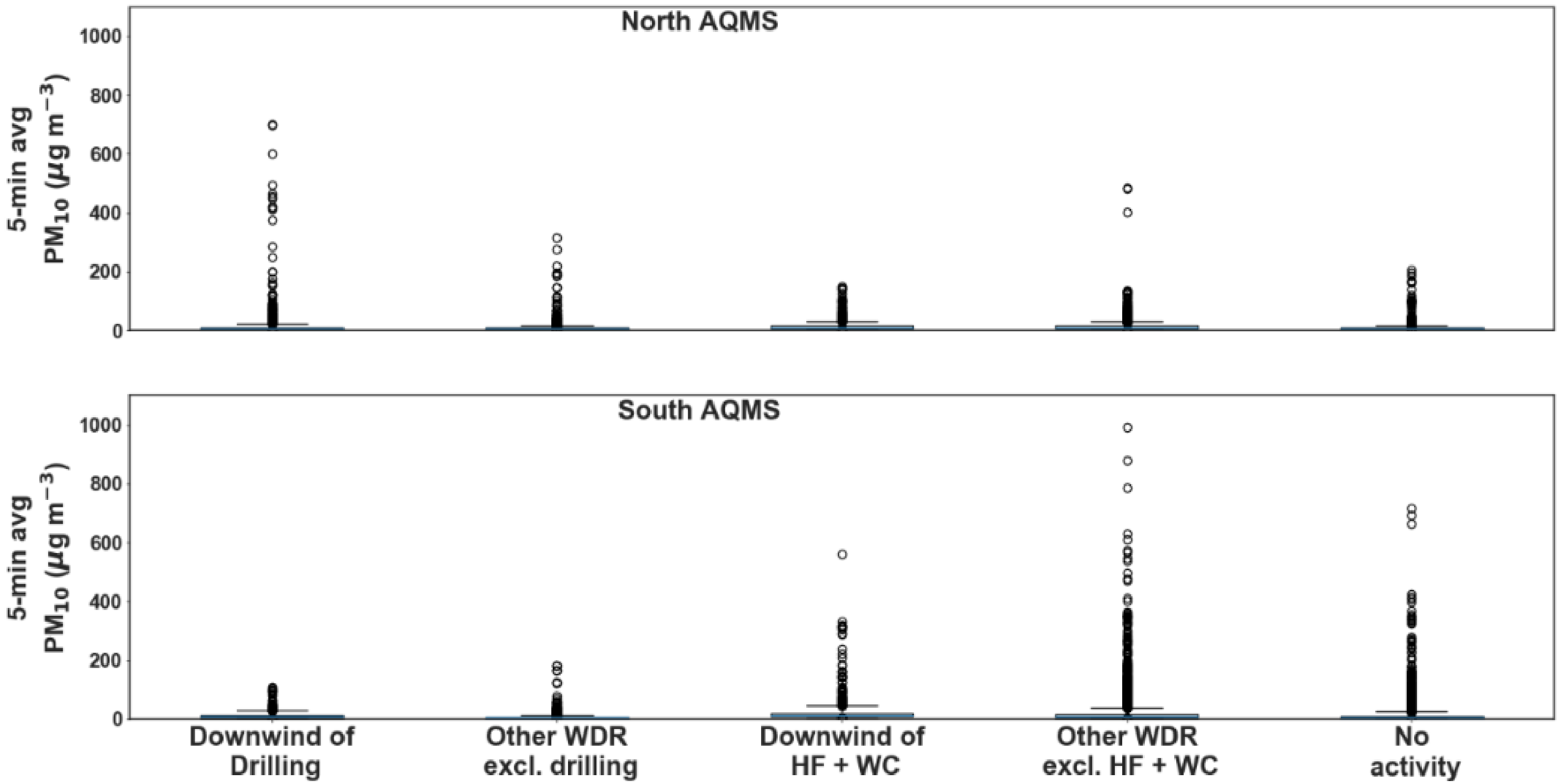
- from other wind directions during the same period?
- during periods when no HF + WC was occurring on site?

Quantifying changes in pollutant levels – NO_2



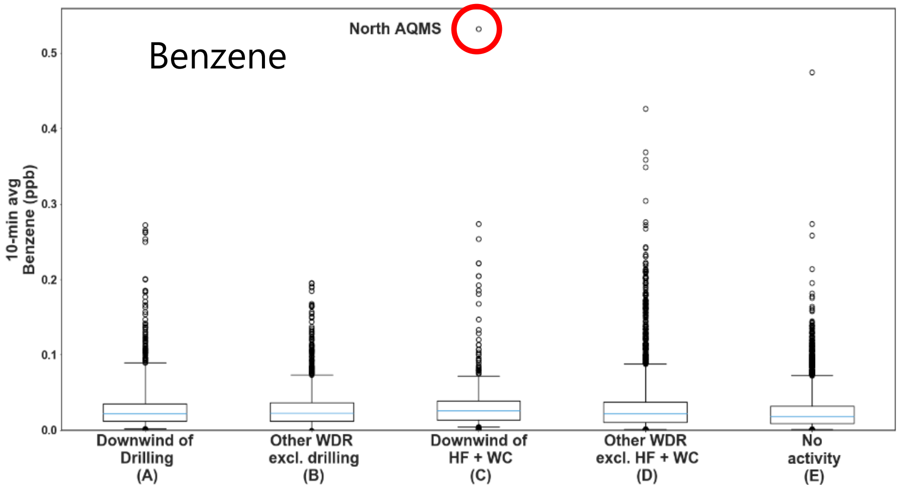
- NO_2 levels were low for a majority of the time (95%) for all activity and non-activity periods.
- The top 5% of NO_2 observations were slightly higher when measuring downwind HF + WC.

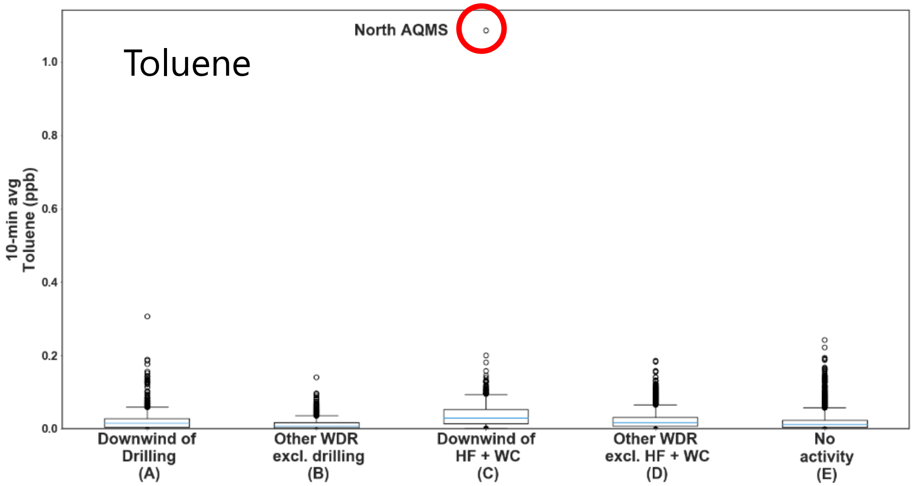
Quantifying changes in pollutant levels – airborne particles (PM_{10})



- PM_{10} levels were similar for a majority of the time (95%) across all activity and non-activity periods
- Measurements downwind of HF + WC activity did not coincide with the highest peaks in PM_{10} at either the North or South-AQMS.

Quantifying changes in pollutant levels – BTEX





With the exception of one peak event during HF + WC activity, the top 5% of BTEX values when measuring downwind of HF + WC were within the range of:

- the top 5% of values when measuring air masses from other WDRs during the same period
- during non-activity periods.

Objective 2 - findings

Quantify enhancements in air pollutant levels above background that occur during HF operations.

- Short-term increases in the concentrations of NO_2, CO, PM_{10}, $PM_{2.5}$, TSP, BTEX and formaldehyde above background.

- These impacts occurred at levels below air quality objectives, with the exception of infrequent dust events.

- Well development activity was not associated with measurable enhancements in O_3, SO_2, mercury and radon.

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Objective 3

Provide information on the contribution of HF and non-HF related sources of air pollutants to local air quality at the study site.

Enhancements above background were observed for:

- NO_2, CO – not components of HF fluids/flowback and dominant source was diesel exhaust
- $PM_{2.5}$, PM_{10} , TSP, Formaldehyde and BTEX

→ may be emitted from HF fluids/flowback and further assessment of sources was undertaken

- Use of statistical techniques for source apportionment – PM
- Identification of tracers from known source profiles – air toxics

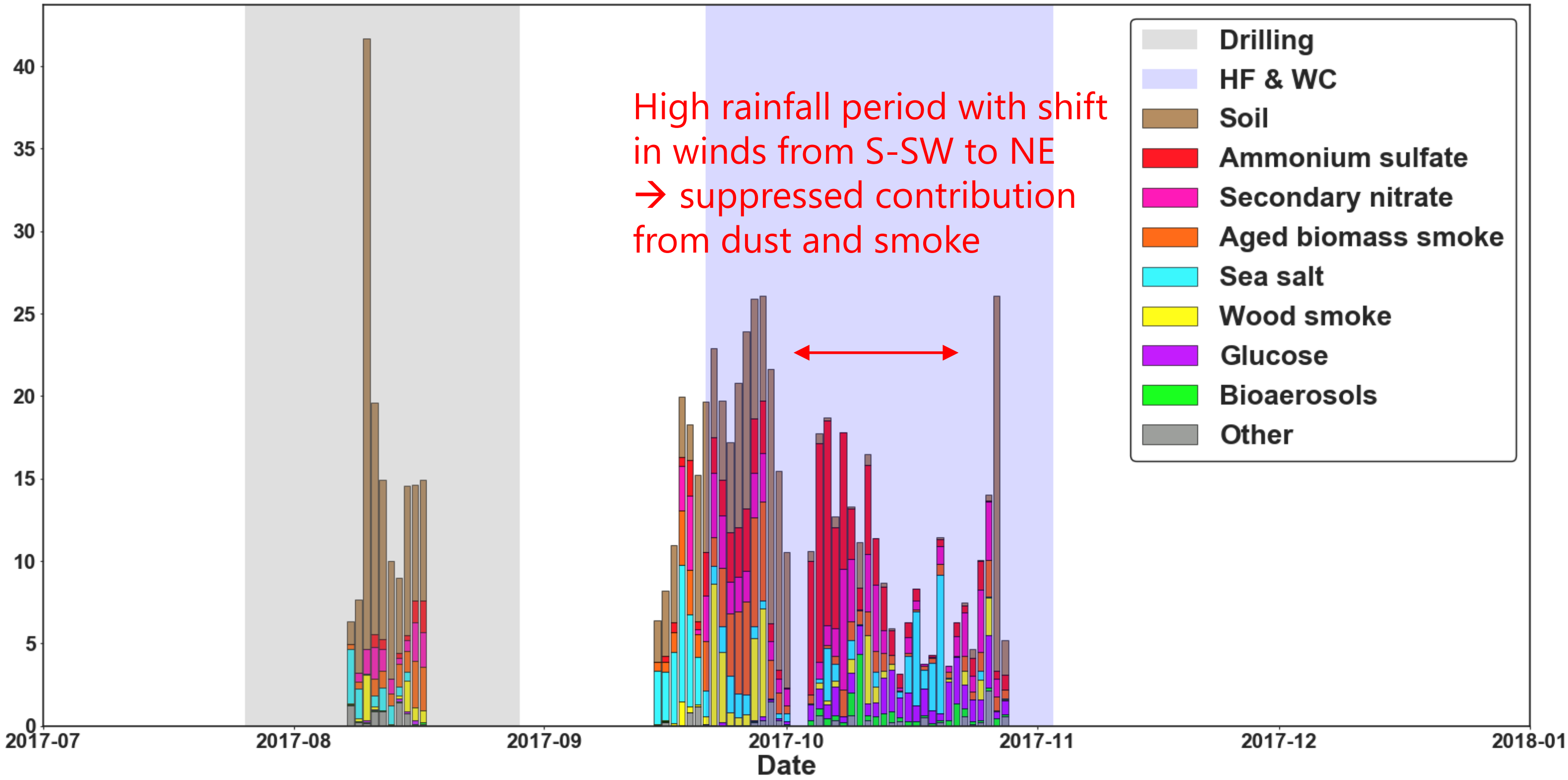
Sources of airborne particles (PM_{10}, $PM_{2.5}$, TSP)

- Chemical composition analysis of particle samples was undertaken
- A statistical model (positive matrix factorisation PMF) applied to the PM_{10} chemical composition data
- Eight dominant factors that contributed to PM identified.

Factors	Average contribution	Potential sources
Soil	37%	• Soil dust from vehicles & equipment was the only PM source attributable to well development • 7 days when dust from vehicles and equipment on site resulted in exceedances in PM_{10} and TSP. • Frequency and extent of dust events dependent on meteorology, especially rainfall.
Secondary ammonium sulfate	16%	
Secondary nitrate aged sea salt	13%	
Aged biomass smoke	11%	
Fresh sea salt	9%	
Woodsmoke	7%	
Glucose	5%	
Primary biological aerosols	2%	

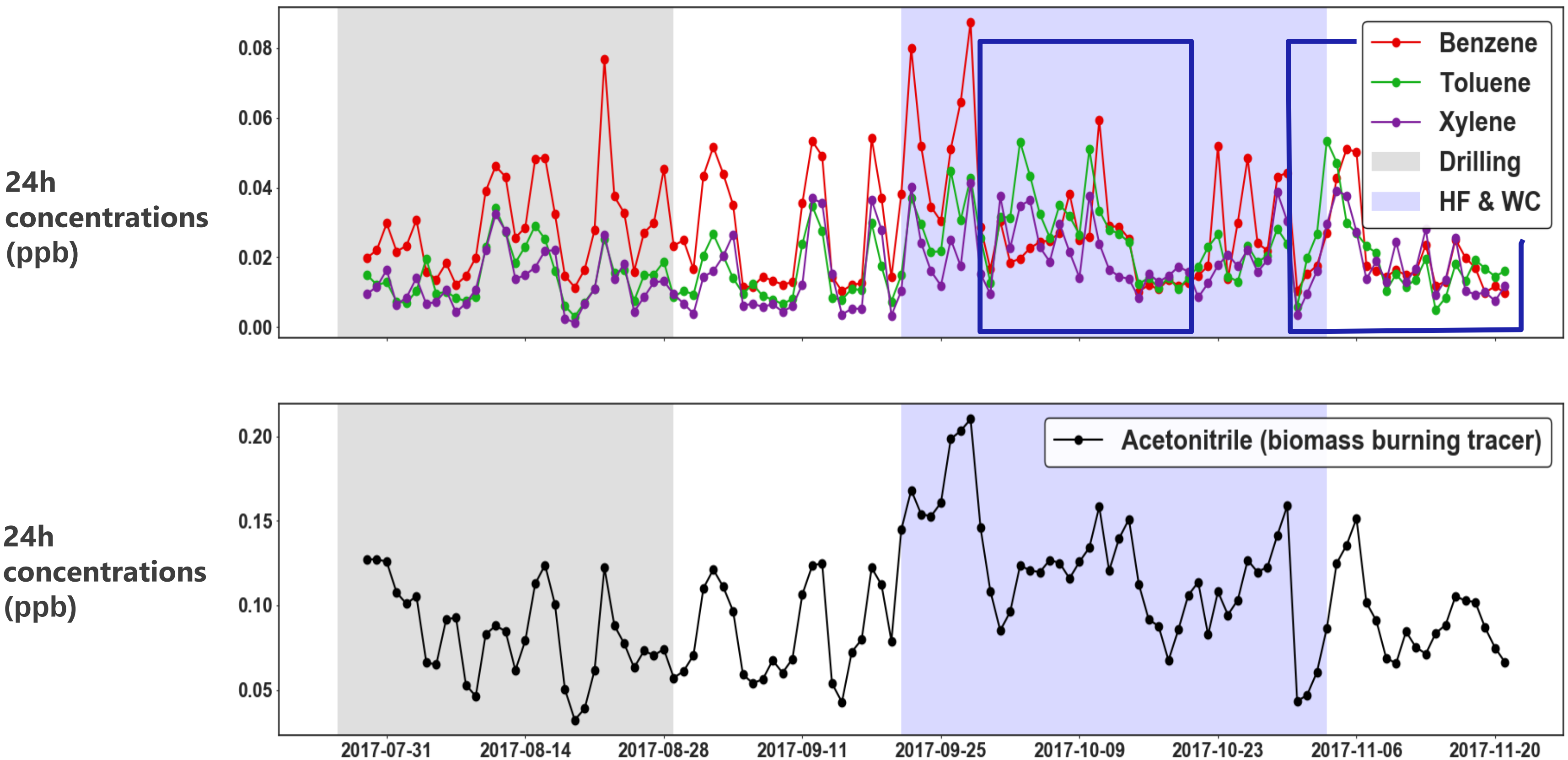
Sources of airborne particles (PM_{10}, $PM_{2.5}$, TSP)

24h concentration ($\mu g\ m^{-3}$)



Sources of air toxics – BTEX

- Relationship with acetonitrile, a smoke tracer, indicates smoke was a significant contributor to BTEX at the study site.
- Benzene > Toluene is typical of smoke → background air pollution from region
- Toluene ≥ Benzene typical of vehicle exhaust → emissions from well pad



Source composition analysis

- HF fluids, drilling fluids – well-completion reports, safety data sheets, NICNAS (2017)
- Flowback/produced waters – this project (Apte et al 2019), NICNAS (2017)
- CSG – Day *et al.* (2016), NICNAS (2017), GISERA Project G.3 (Lawson *et al.* 2017)

→ These HF-specific sources did not contain high levels of contaminants which have low solubility/ high volatility & therefore may impact air quality e.g. BTEX, PAHs, mercury, radon

→ Due to the low levels in gas & fluids, direct emissions of pollutants to the air from these HF-specific sources was unlikely to have contributed significantly to airborne concentrations.

Objective 3 – findings

Provide information on the contribution of HF and non-HF related sources of air pollutants to local air quality at the selected study site.

→ Soil dust was identified as the source of the exceedance of PM_{10} and TSP

→ Dust events were associated with the movement of vehicles and equipment on unsealed roads on site

→ Emissions from diesel powered vehicles and equipment on well pad the most likely source of small enhancements in:

- Air toxics - BTEX, formaldehyde, PAHs and
- NEPM ambient air pollutants – NO_2, CO, $PM_{2.5}$

which were still well within relevant ambient air quality objectives.

→ Analysis of available data on composition of HF fluids, flowback fluids and CSG indicates direct emissions of pollutants to the air from HF-specific sources were unlikely to have contributed significantly to air pollutant levels.

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Summary and conclusion

- In this study, hydraulic fracturing activity made a minor but measurable impact on the levels of air pollutants.
- The exception was occasional dust events associated with vehicle movements.

In general, the impacts of hydraulic fracturing on ambient air quality are likely to be minor depending on:

- well integrity
- the safe storage, handling & transport of HF chemicals, flowback fluids & CSG at the surface
- dust suppression.

Air Quality Reports

Phase 1 Air Quality Reports available: https://gisera.csiro.au/project/air-water-and-soil-impacts-of-hydraulic-fracturing	
Task 4	Design of a study to assess the potential impacts of hydraulic fracturing on air quality in the vicinity of well sites in the Surat Basin, Queensland (Revised study design for Combabula site) - Nov 2017
Task 6	Measurements of VOCs by passive Radiello sampling at a hydraulic fracturing site in the Surat Basin, Queensland – June 2018
Phase 2 Air Quality Reports available: https://gisera.csiro.au/project/air-water-and-soil-impacts-of-hydraulic-fracturing-phase-2/	
Task 1	Air Quality Measurement report - March 2018
Task 3	Measurements of air quality at a hydraulic fracturing site in the Surat Basin, Queensland- Final Report – expected publication late 2019-early 2020

Thank you

Erin Dunne
Research Scientist

t +61 3 9239 4434
e erin.dunne@csiro.au
w gisera.csiro.au

Air Quality Project contributors:

CSIRO Climate Science Centre
Erin Dunne, Melita Keywood, Jason Ward, James Harnwell, Jennifer Powell, Paul Selleck, Maximilien Desservettaz, Suzie Molloy, Min Cheng, Scott Henson

ANSTO
Alistair Williams, Sylvester Werczynski, Ot Sisoutham
Armand Atanacio

Macquarie University
Grant Edwards, Anthony Morrison

Queensland Alliance for Environmental Health Sciences (QAEHS)
Fisher Wang

Ecotech and SGS Leeder

Origin Energy