Government of **Western Australia**
Department of **Water and Environmental Regulation**

Mapping dust plumes at Point Samson–Cape Lambert using a LiDAR

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Executive summary

This project was undertaken to determine the origins of dust causing nuisance or health impacts in Point Samson, a small community located in Western Australia's Pilbara region. As well as using standard dust monitoring equipment, a Windcube 200S Light Detection and Ranging (LiDAR) instrument was commissioned in the region for two months in the summer of 2016–17.

The National Environment Protection (Ambient Air Quality) Measure (NEPM) standard for particulate matter in air sized less than 10 micrometres in diameter (PM_{10}) of 50 micrograms per cubic metre ($\mu g/m^3$) averaged over one day was exceeded 10 times at one or more sites during the monitoring period. Of those exceedances, six were recorded at the Point Samson air quality monitoring station (AQMS) located 500 metres north-west of the Point Samson community. The PM_{10} NEPM exceedances were all caused by region-wide events but each had some contribution from Pilbara Iron Pty Ltd's Cape Lambert operations.

During the study period there were also several short-term PM_{10} spikes of between five and 60 minutes duration which recorded concentrations greater than 200 $\mu g/m^3$. The LiDAR captured a number of these spikes and indicated that in most cases, the spikes originated from the Cape Lambert operations.

This study confirmed that dust plumes from the Cape Lambert operations can reach the Point Samson township under certain meteorological conditions. Nevertheless, the extent to which these plumes impact on Point Samson is unknown, given that many of the plumes are narrow and affect only relatively narrow regions. At times, the plumes completely bypass Point Samson.

The LiDAR detected several ancillary sources (i.e. sources other than industry or regional particle load). These included the sand quarry, unpaved roads, beaches and salt spray. LiDAR traces for dust plumes generated from these sources, when compared with those from industry sources, resulted in an assessment that these ancillary sources only made a relatively small contribution to the overall dust levels in the region for both frequency of events and intensity of plumes.

This brief analysis did not find any specific meteorological conditions that caused the dust plumes from the Cape Lambert operations. The dust plumes seem to be more likely related to industry activity at Cape Lambert than a particular set of meteorological conditions.

The LiDAR has proven itself to be a valuable tool in tracking plume movements across large areas that have few to no dust monitoring instruments. Even in this time-limited study, the LiDAR has demonstrated its usefulness in assessing and pinpointing sources of dust which, in the past, have been the subject of dispute. Conventional dust monitoring instruments are still required to accurately determine concentrations of dust in the air, although this study has shown that narrow plumes can easily bypass these instruments.

1 Project purpose

This report provides an analysis of data obtained from a short-term air quality monitoring campaign in and around Point Samson, a small community located 1260 kilometres north of Perth in Western Australia's Pilbara region. The campaign monitored particle levels arising from sources near Point Samson, including the Cape Lambert port operations of Pilbara Iron Pty Ltd. The data were gathered using conventional particle monitoring methods and technology, such as Tapered Element Oscillating Microbalance (TEOM) instruments and a Beta Attenuation Monitor (BAM), along with a Light Detection and Ranging (LiDAR) instrument. The analysis covers a two-month period from mid-November 2016 to mid-January 2017.

2 Project objective

The project's objective was to determine the origins and movement of dust causing nuisance impacts in and around the Point Samson community. To do this, a Windcube 200S LiDAR instrument was installed at the Point Samson air quality monitoring site for two months in the summer of 2016–17. Additionally, the former Department of Environment Regulation (DER) sought to assess the suitability of applying LiDAR technology as a general tool to assess dust pathways and impacts on local communities. The former DER, Department of Water and the Office of the Environmental Protection Authority (OEPA) were amalgamated to form the Department of Water and Environmental Regulation (DWER) on 1 July 2017.

3 Background

Point Samson has a population of 300 people and is located on the eastern side of a small peninsula. The Cape Lambert operations are located about three kilometres north-west of Point Samson on the western side of the same peninsula. Pilbara Iron Pty Ltd and Robe River Mining Co. Pty Ltd, both wholly owned subsidiaries of Rio Tinto Limited (Rio Tinto), operate the facility under approvals issued through Parts IV and V of the *Environmental Protection Act 1986* (EP Act). The premises has two port areas, Cape Lambert Port A (CLA) and Cape Lambert Port B (CLB).

The DWER licence L5278/1973/13 issued under Part V of the EP Act allows Pilbara Iron to screen and process bulk material, maintain ore stockpiles and operate an export facility at Cape Lambert (see Figure 1). Infrastructure at the export facility includes iron ore stockpiles with loading and stockpiling operations occurring 24 hours a day.

Rio Tinto subsidiaries hold Ministerial Statements 741, 743, 840, 876, 1049 and 1050 issued under Part IV of the EP Act for the facility. Within Schedule 2 of Ministerial Statement 741, there is a requirement to monitor and investigate the real-time dust monitoring data for total suspended particulates (TSP) and particles with an aerodynamic diameter of 10 micrometres (PM_{10}) when the wind direction is within the defined arc of influence (CLA) of 290° to 20°. In addition, the *Cape Lambert dust management plan* (May 2014) incorporated an additional arc of influence (CLB) between 260° and 289°. Rio Tinto is to conduct real-time monitoring of TSP and PM_{10} ambient dust levels, together with wind speed and direction. Rio Tinto also has requirements under Ministerial Statements 741 and 840 to monitor and report dust exceedances within the local area.

CLA has an approved port capacity of 105 million tonnes per year through Ministerial Statement 741 and consists of a rail network, rail car dumping facilities, crushing and screening plants, stockpiles, conveyors, stackers, reclaimers and wharf and ship loading facilities.

CLB has an approved port capacity of 130 million tonnes per year through Ministerial Statement 741 and receives a blend of product railed from various mines. The facility includes a rail network, ore stockyards, screening and delivery systems, an access jetty/wharf fitted with two ship loaders and various associated ancillaries.

One of the provisions within Ministerial Statement 741 states that where the proponent makes a *'significant contribution'* to dust levels at Point Samson, the proponent shall report the dust event to the chief executive officer. The proposal's contribution to dust levels at Point Samson is considered to be a '*significant contribution*' when the wind direction is within the arc of influence of 290° to 20°, unless the proponent demonstrates by dust sample speciation or a method approved by the chief executive officer that more than 50 per cent of the dust was generated by other sources.

During the past few years, residents of Point Samson have complained to the former DER and OEPA (now DWER) and Rio Tinto about ongoing dust nuisance.

The NEPM standard for PM_{10} of 50 µg/m^3 over a 24-hour period is used as a standard guide for particle concentrations in the region. Several particle monitors installed and operated in the region – particularly the AQMS located at Point Samson – regularly exceed the NEPM standard. The source of these high particle levels has been unclear: one or a combination of sources are potential contributors, including Rio Tinto's port operations, local dust sources, regional events or some other unknown factors.

Figure 1 Point Samson and Rio Tinto Cape Lambert operations with particle monitors marked. The yellow circle represents the approximate extent of the LiDAR beam. Insets show regional location (top right) and a close-up of the sand quarry area (lower right).

4 Measurement instruments

As part of this project, DWER installed the following Australian Standard compliant instruments to measure PM_{10} concentrations from mid-November to mid-January 2016–17:

- a PM_{10} 1020 Beta Attenuation Monitor co-located with the Rio Tinto PM_{10} TEOM at Point Samson AQMS
- a PM_{10} 1400AB TEOM located at the Rio Tinto DS05 (Hatchery) monitoring site
- a PM_{10} 1400AB TEOM located at the Cove Holiday Village in Point Samson.

A Windcube® 200S LiDAR was also installed and operated by Ecotech Pty Ltd on behalf of DWER in the Point Samson AQMS for the two-month period.

LiDAR is a well-established technology developed in the 1960s. One of its first uses was by the US National Center for Atmospheric Research to measure cloud height.

The instrument sends out thousands of light pulses per second and measures the amount of time it takes for each pulse to bounce back after being reflected from a distant object. As light moves at a constant speed of 0.3 metres per nanosecond, the LiDAR instrument can precisely calculate the distance between itself and a target. By repeating this in quick succession and rotating through 360 degrees, the instrument essentially measures the backscattering of light from any particles in the atmosphere and is able to give a qualitative measure of these particles that are dispersed in the air. A measurement is taken of the average backscatter of particles within the beam length as recorded at every 20-metre interval along the beam.

For this project, the Windcube® 200S LiDAR was erected on a tower within the Point Samson AQMS and set to perform continuous circular scans, with each scan completed every 10 minutes. The ideal measurement range for the 200S is from 0.1 to six kilometres. In practice, a measurement range of about five kilometres is generally achieved. As the instrument can scan up to a distance of 6000 metres at 20-metre intervals, each 10-minute scan may theoretically contain more than 100,000 data points.

The LiDAR was positioned on cyclone-proofed scaffolding to allow a largely unimpeded view of the surrounding landscape.

Data were collected on a 10-minute cycle where the LiDAR scanned a full 360 degrees. During each scan, the LiDAR beam passed over each of the two DWER 1400AB TEOMs installed in the region. The information provided by the real-time feed from those TEOMs has the potential to allow the LiDAR to calibrate itself to the PM_{10} concentration. Use of this feature of the LiDAR is still under investigation and may be the subject of future reports.

5 Potential dust sources

The region has a number of potential dust sources. During the study, some of these sources were detected by the LiDAR at one time or another and were observed contributing to the general dust levels on the peninsula. Appendices A, B and C provide some analysis of selected events that best demonstrate these contributing dust sources.

5.1 Rio Tinto Limited operations

One of the region's major dust sources is the Rio Tinto Cape Lambert operations on the western edge of the peninsula. This facility operates 24 hours a day and has a licensed capacity for 230 million tonnes per year, but during the study period was only operating at 190 million tonnes per year (83%). Several dust sources within the facility have the potential to contribute dust to the region. These include the lump rescreening plant, crushing and screening areas, dumpers, reclaimers and ore stockpiles.

Between the facility and Point Samson are some additional sources which may influence dust levels within the region. These are outlined below.

5.2 Ancillary dust sources

Sand quarry

A sand quarry is located about one kilometre north-west of Point Samson and two kilometres east of the Rio Tinto facility. The 10-hectare site is occasionally used as a sand source, with most of the site being exposed and free of vegetation.

Beaches

Along the north-east coast of the peninsula there are two sandy beaches with the potential for dust lift-off or salt spray. In some cases, these beaches are within several tens of metres of the monitoring sites.

Roads

A number of sealed and unsealed roads crisscross the area and have the potential to generate dust during periods of high traffic.

6 Time series analysis

Traditionally, air quality in general and particles in particular have been assessed using point source monitors or monitors that record the concentration of a pollutant at one fixed location only. These methods generally have an Australian Standard or US Environmental Protection Agency method associated with application of the technology and positioning of the instrument, allowing the results to be used to assess compliance with a relevant NEPM or health standard.

While monitoring air pollution concentrations over time at one fixed location has been the mainstay of air quality monitoring, it still remains somewhat problematic to determine the origin of a particular event or trace the pathway of a pollution event back to a likely source. The general method used to trace these pathways has typically been a forward or back trajectory that modelled a pathway by tracing the movements of a pollutant using meteorological conditions recorded at one or several local sites. Notwithstanding the usefulness of these trajectory models, it is still the case that a point source monitor needs to be in the direct path of a plume to record an event.

Two TEOMs (located at the Hatchery and the Cove Holiday Village) and one BAM (located in the Point Samson air monitoring compound) were in operation continuously from 10 November 2016 to 26 January 2017, maintained in accordance with the manufacturer’s requirements and run in compliance with the relevant Australian Standards. During this period, the Caravan site TEOM experienced a number of failures from an intermittent logger/modem fault. This resulted in reduced data recovery from that site. Data recovery based on valid hourly data recovered from each site is shown in Table 1. A valid hourly average is one when the availability of data is 75 per cent or greater for that hour.

Table 1 Data recovery

Site	Data recovery
Hatchery (TEOM)	99.8%
AQMS (BAM)	97.6%
Caravan (TEOM)	76.9%

Daily (midnight to midnight) averages were calculated to enable comparisons with the NEPM standard. These have been displayed in Figure 2 for the total monitoring period. Averages were calculated in accordance with the NEPM convention requiring no less than 75 per cent valid data for that day’s average to be calculated. There were 10 days when the NEPM PM_{10} standard of 50 µg/m^3 averaged over one day was exceeded at one or more sites during the monitoring period. These exceedances occurred on 23 and 29 November 2016; 24, 26, 27 and 31 December 2016; and 1, 6, 7 and 13 January 2017. Each of these exceedances is summarised in Appendix A.

Figure 2 Daily PM_{10} averages for the Hatchery, AQMS and Caravan sites.

Figure 2 identifies a general trend where 24-hour averaged concentrations at the Hatchery site are on average 20 per cent greater than those at the AQMS site, which itself is on average six per cent higher than the Caravan site. This trend has several possible explanations. One major factor is the Hatchery's proximity to the port operations located two kilometres to the east and north. Other possible influences include the difference in human activity around each of the sites, the number of unsealed roads, and the amount and coverage of the vegetation.

This 'distance' effect is further illustrated in Figure 3, which displays the number of days where the 24-hour average exceeding a nominated concentration [C] is inversely proportional to the distance from the Cape Lambert operations. In other words, and as one may intuitively expect, the number of high events decreases as one moves further from the port operations.

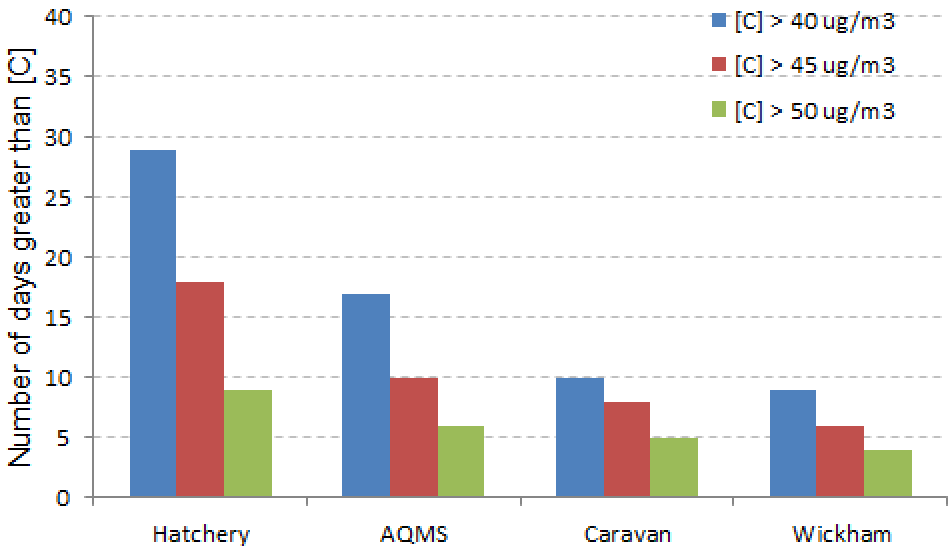


Figure 3 Number of days where the 24-hour average exceeded the nominated concentration for the Hatchery, AQMS and Caravan sites

Notwithstanding this general trend, several times the concentration at the Caravan site was slightly greater than that at either the Hatchery or the AQMS. Eight events resulted in concentrations greater than 40 µg/m^3. Of these, four (23 and 29 November 2016, 26 December 2016 and 7 January 2017) were associated with regional events and are explored in Appendix A. The remaining four events (9 to 12 January 2017) are essentially the same single event and have very similar profiles and concentrations to that recorded at Wickham, which matches the AQMS concentration to within four per cent.

While it is recognised that the current NEPM for particles is based on 50 µg/m^3 averaged over one day, it is also useful to look at whether the data collected can provide information on the potential for additional daily PM_{10} exceedances or, in other words, days when the NEPM standard was nearly exceeded.

Table 2 quantifies the number of PM_{10} exceedances at each site based on the current NEPM value of 50 µg/m^3, as well as two lower levels of 45 µg/m^3 and 40 µg/m^3 and one higher level of 70 µg/m^3. The two lower concentrations were included to indicate any ‘near miss’ events with the potential to exceed the current standard but for some reason failed to do so. The higher concentration level of 70 µg/m^3 is currently used in parts of Port Hedland and is shown for interest and comparison.

Table 2 Number of ‘near miss’ events

Site	Number of daily concentrations greater than				Monitoring period average (µg/m^3)
	40 µg/m^3	45 µg/m^3	50 µg/m^3	70 µg/m^3	
Hatchery (TEOM)	29 (37%)	18 (23%)	9 (12%)	1 (1%)	37.2
AQMS (BAM)	17 (22%)	9 (12%)	7 (9%)	1 (1%)	31.5
RTIO PS (TEOM)	19 (26%)	12 (16%)	6 (8%)	1 (1%)	33.6
Caravan (TEOM)	11 (21%)	8 (15%)	5 (9%)	1 (2%)	31.8
Wickham (TEOM)	9 (12%)	6 (8%)	4 (5%)	1 (1%)	27.5
Taplin Street (BAM)	25 (32%)	10 (13%)	5 (6%)	2 (3%)	33.0

Due to the lower data recovery for the Caravan site, percentages based on the number of valid readings recorded at each site are included, allowing a reasonable comparison to be made between sites. It is noteworthy from the 45 µg/m^3 column that each site had a relatively high number of days when there was a real potential to exceed the NEPM standard during the study.

Wickham is located eight kilometres south-west of Point Samson and thus provides a reasonable background site with which to compare PM_{10} concentrations. While the number of 24-hour concentrations exceeding the indicated levels listed in Table 2 show that Wickham and the Caravan site were somewhat comparable, this is due to the lower data recovered from the Caravan site. The percentage of valid readings shows the number of Wickham exceedances represent around half compared with the other sites.

Taplin Street, a site located in Port Hedland, is included in Table 2 for comparative reasons using data compiled for the same period as for the study sites. Port Hedland is also located in Western Australia’s Pilbara region and is about 1300 kilometres north of Perth. Port Hedland is one of the largest export ports, by tonnage, in Australia. It has similarities with Point Samson due to the close proximity of the export facilities to sensitive receptors.

As expected, Table 2 shows that the number of exceedances decreases the further east the site is located. There is a large drop from the Hatchery site to the AQMS site for each concentration listed and a further drop from AQMS to the Caravan site. In the case of the 40 µg/m^3 concentration, these drops were greater than 35 per cent at each site.

Table 2 also identifies an average concentration over the period of monitoring. In all cases the average PM_{10} concentration at each of the study sites was greater than

30 µg/m^3. Notwithstanding that the data does not cover a full year, these exceed the NEPM PM_{10} calendar year averaged standard of 25 µg/m^3.

A cumulative frequency of one-hour-averaged concentrations was produced by calculating the number of times a particular concentration occurred together with all concentrations that were greater than that concentration and placing it into an ordered frequency distribution. Figure 4 shows the cumulative frequency graph for four PM_{10} particle monitoring sites for the complete period and total suspended particulates (TSP) as measured by an industry site at the AQMS. The plot has log-normal axes to better display features of interest at the higher concentrations.

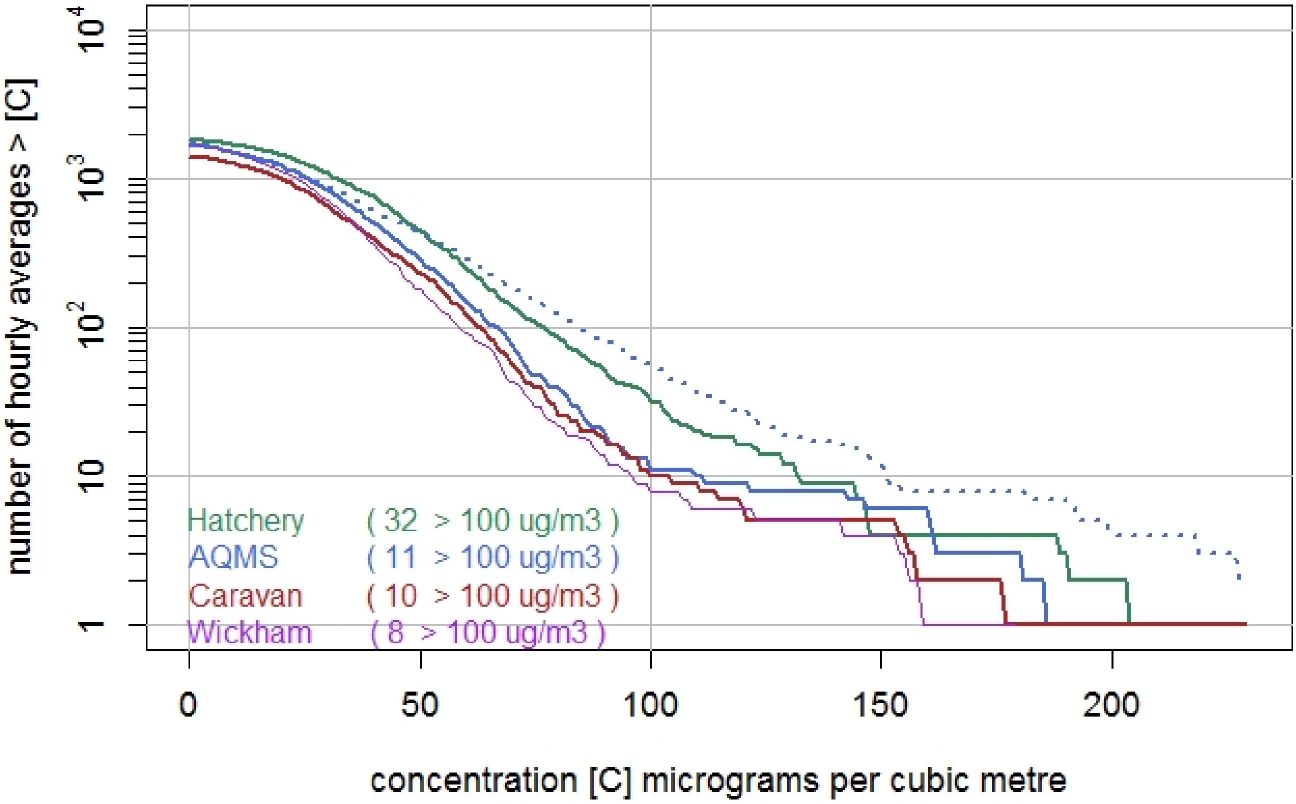


Figure 4 *Hourly averaged cumulative frequency plot for PM_{10} from Hatchery (green), AQMS (blue), Caravan (Red) and Wickham (purple) sites with the 100 µg/m^3 concentration marked as a grey vertical line. The dotted line represents TSP concentration at the AQMS site*

Notations on Figure 4 indicate the number of times the hourly averaged PM_{10} concentration exceeded 100 µg/m^3 during the monitoring period. This particular concentration has been chosen to illustrate the number of moderately high, but relatively short-term events that occurred during the study. The 100 µg/m^3 concentration has no basis in a standard and in fact many of these occurred on days when the NEPM 24-hour PM_{10} standard was not exceeded. The plot origin for the Caravan site starts from a lower position than either the Hatchery or the AQMS. This is due to the logger and communication issues experienced by the Caravan TEOM that resulted in a lower overall data recovery for that site.

The overall lower concentrations at Wickham are clearly demonstrated in Figure 4. One possibility for this is the site being located eight kilometres south-west of Point Samson and thus having a reduced likelihood of being influenced by port operations. It has been assumed the surrounding landscape in Wickham is somewhat similar to that which exists on the peninsula, other than the existence of an iron ore export facility and a coastal outlook.

7 Weather and meteorology

Given the LiDAR depends on the backscatter of light on intervening particles to determine relative dust concentrations, rainfall has the potential to be misinterpreted as particles in the atmosphere. While a complete weather station was not included in the meteorological suite at Point Samson, the Bureau of Meteorology (BoM) maintains a weather station at Roebourne Airport located 18 kilometres south-southwest of Point Samson that provides rainfall and weather observations. Figure 5 summarises the weather data obtained from BoM for November 2016 to January 2017. The full record of BoM daily weather observations is provided in Appendix D.

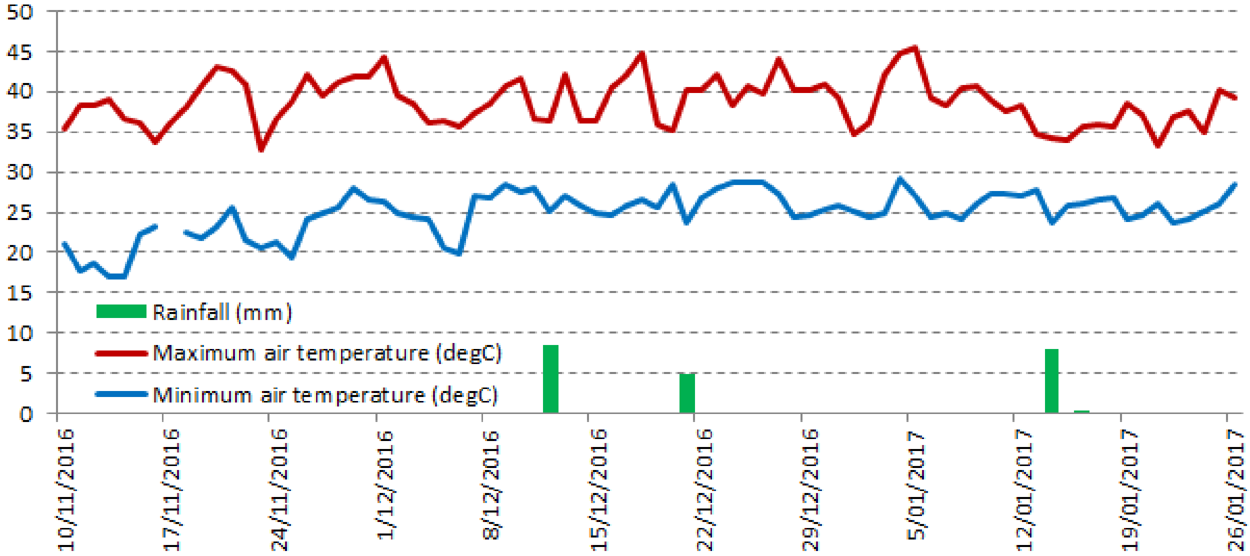


Figure 5 Roebourne weather data including daily rainfall (green) and maximum (red) and minimum temperature (blue). (Source: Bureau of Meteorology)

During the study period from 10 November 2016 to 26 January 2017, rainfall was recorded at the BoM weather station on five days: 8 December (0.2 mm), 12 December (8.4 mm) and 21 December 2016 (4.8 mm); and 14 January (8 mm) and 16 January 2017 (0.4 mm).

Figure 6 shows the occurrence of a particular wind speed and wind direction throughout the study period divided into day time and night time. Each wind speed and direction segment of the plot shows the percentage contribution of that segment to the complete dataset.

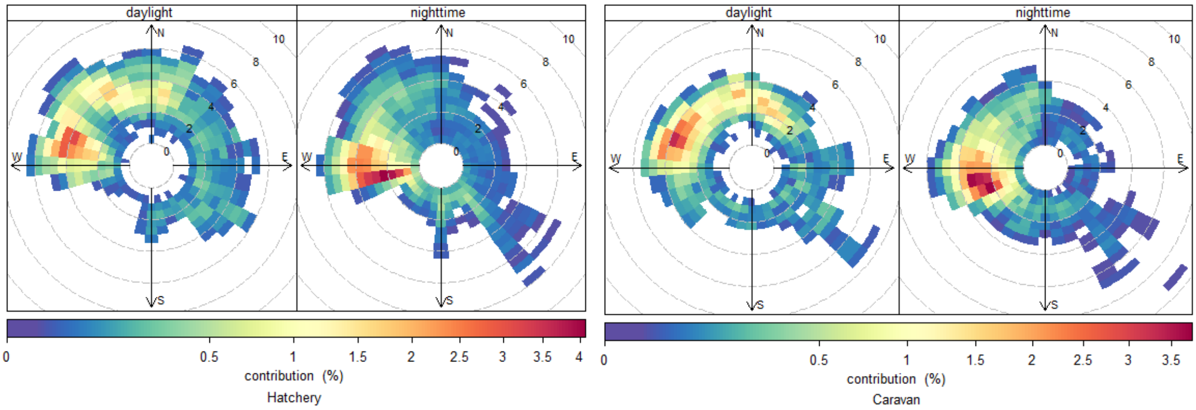


Figure 6 Polar frequency plot of wind speed and direction during the period of the study for the Hatchery (left) and Caravan (right) sites

Notable from Figure 6 is the similarity of the percentage ocurrences of wind directions for the two sites flanking the AQMS site with a difference between the day-time profile, which is dominated by west-northwest winds, and night-time profile, which has more west-southwesterly winds. In both cases, for a sizeable portion of the study period, the wind arriving at Point Samson has come from within the arc of influence of the Cape Lambert operations.

8 LiDAR assessment

As part of this study, LiDAR was evaluated as a tool for determining the origins of dust contributing to nuisance impacts in the Point Samson community. Appendix B summarises selected short-term events which, while not exceeding any NEPM standards, were captured by the LiDAR. The use of a LiDAR as part of a robust monitoring network proved valuable in confirming dust pathways and origins.

Figure 7 shows a heat map of one of these short-term events recorded on 4 January 2017 at 11:50 am. Plumes travelling in a south-east direction are clearly visible extending from the crushing and screening areas and the CLA and lump rescreening plant. These plumes can be seen traveling the complete width of the peninsula. Winds were coming from a bearing of 326 degrees at the time.

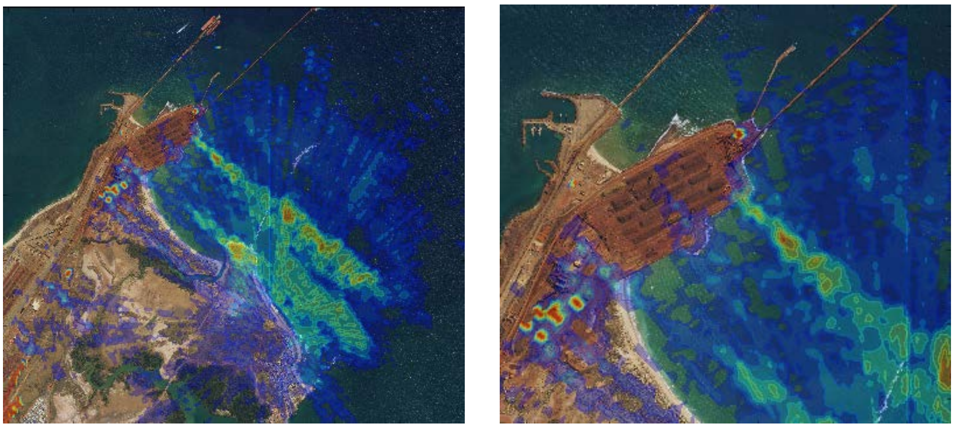


Figure 7 LiDAR event record on 4 January 2017 at 11:50 am (left) with a closeup of CLA (right) showing activities at the dumper and crushing and screening areas

Figure 8 is another example where a plume from ship loading and other various activities can be clearly seen moving in a north-east direction. Winds at the time were coming from a bearing of 230 degrees.

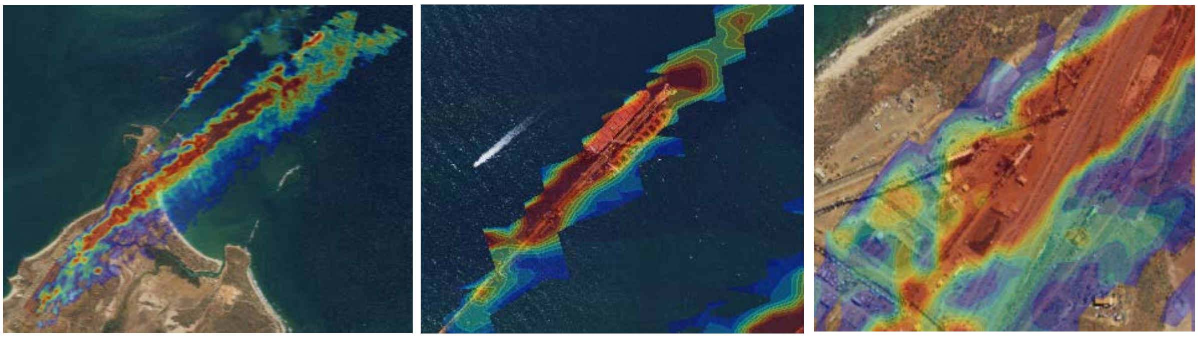


Figure 8 LiDAR event record on 8 December 2016 at 6:40 am (left) showing ship loading (centre) and screenhouse (right) activities.

The event depicted in Figure 8 was also captured on a camera and shown in Figure 9. The sequence of images in the figure captures the ship loading facility at 6:40 am on 8 December 2016 together with an image for both the previous and next day for the same time. The centre image shows a plume extending to the right of the ship loading activity. The images are not altered other than expanded to focus on the ship loader. The dynamic range for each image is not the same due to altered conditions such as varying cloud cover restricting the available light.

Figure 9 Ship loading plume recorded on 8 December 2016 at 6:40am (centre image) showing dust from port activities

LiDAR recordings were also assessed against Rio Tinto boundary monitoring. Figure 10 shows an example of an event recorded by the LiDAR at 9 am on 19 November 2016 which is further detailed in Appendix B. The LiDAR clearly shows some red areas indicating elevated particle levels occuring at various locations on Cape Lambert. While PM_{10} concentrations recorded at Rio Tinto's dust monitors DM01, DM02 and DM04 at the time were less than 30 µg/m^3, the DM03 monitor recorded 139 µg/m^3 averaged over 10 minutes. Winds were coming from a bearing of 349 degrees (NNW) at two metres per second.

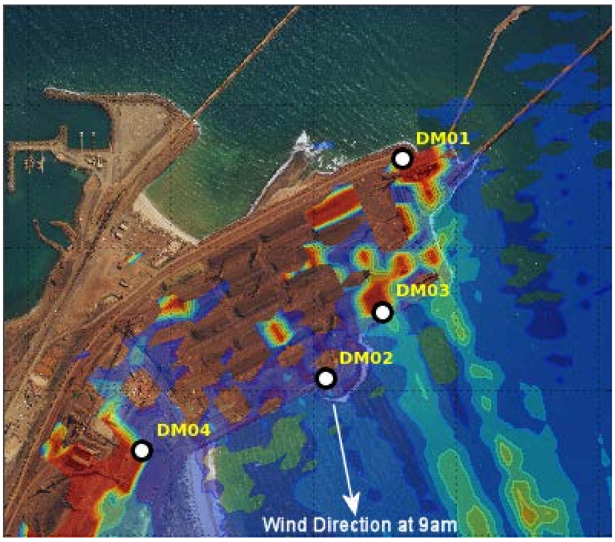


Figure 10 LiDAR event record on 19 November 2016 at 9 am showing a number of active areas on Cape Lambert and locations of dust monitoring equipment

The features to note in Figure 10 include the lack of a plume at DM02 and a plume developing to the south-east of DM01 which, due to the prevaling north-northwest winds, failed to influence the dust monitor. DM04 appears to be at the eastern edge of a plume, which also failed to register on the monitor due to the prevailing wind direction that at the time was at 349 degrees rotating to north over the next 30 minutes. This prevented the plume from influencing DM04. DM03, being in the direct path of the plume, recorded this event with a concentration of 139 µg/m^3 averaged over 10 minutes.

Some of the confounding influences on assessing the performance of this LiDAR when compared with the existing dust network include:

a) Interval lengths along the beam were set at 20 metres for this project with some overlap providing an effective radial (i.e. along the beam) resolution of 50 metres. Additionally, as these dust monitors were about 3000 metres from the LiDAR, every degree scan of the LiDAR swept approximately 50 metres. Each LiDAR scan point at that distance is therefore allocating its reading to an area of around 2500 square metres.

b) Placement was atop a three-metre scaffold (raised to eight metres on 28 November 2016) within a compound, with ground level about 22 metres above sea level. Due to this elevated outlook, scans were set at zero degrees (i.e. pointing to the horizon) which generally provided an unobstructed beam that managed to pass over ground-level objects. This means the levels the LiDAR recorded at the coastal dust monitors will have initially been those recorded at about 25 metres above these instruments, which are sited only a few metres above sea level. Later LiDAR scans were set at various times to between zero and one degree from horizontal. At these times the beam height above sea level at a distance of 3000 metres would be between 30 and 80 metres.

c) LiDAR beams measure backscatter from particles. There is no distinction between classes of particles – such as TSP, PM_{10}, $PM_{2.5}$ or smaller – other than generally, all things being equal, the smaller the particle, the higher its light scattering efficiency. As the existing dust monitoring network monitors only the size fraction of PM_{10}, this may be the cause of some inconsistencies with the LiDAR reading.

Notwithstanding these limitations, the LiDAR technology provides some excellent insight into particle plume movement. The technology is able to provide unambiguous information on the relative levels of dust at a specific location, although its ability to provide absolute concentrations is still being assessed.

Summary

There were 10 days when the NEPM PM_{10} standard of 50 µg/m^3 averaged over one day was exceeded at one or more sites during the period of monitoring. Of those exceedances, six days were recorded at the Point Samson AQMS. The PM_{10} NEPM exceedances were all caused by region-wide events but each had some contribution from the Cape Lambert operations.

Several short-term PM_{10} spikes of between five and 60 minutes duration, recording concentrations greater than 200 µg/m^3 during the period of the study, were noted. The LiDAR captured some of these spikes and indicated that, in most cases, the spikes originated from Rio Tinto's Cape Lambert operations.

This study confirmed that dust plumes from the Cape Lambert operations can reach the Point Samson township under certain meteorological conditions. Nevertheless, the extent to which these plumes impact on Point Samson is unknown, given that many of the plumes are narrow and affect only relatively narrow regions. At times, the plumes completely bypass Point Samson.

Several ancillary sources (i.e. sources other than industry or regional particle load) were detected by the LiDAR. These included the sand quarry, unpaved roads, beaches and salt spray. LiDAR traces for dust plumes generated from these sources, when compared with those from industry sources, resulted in an assessment that these ancillary sources made only a relatively small contribution to the overall dust levels in the region for both frequency of events and intensity of plumes.

This brief analysis did not find any specific meteorological conditions that caused the dust plumes from Cape Lambert operations. The dust plumes seem to be more likely related to industry activity at Cape Lambert than a particular set of meteorological conditions.

LiDAR has proven itself to be a valuable tool in tracking plume movements across large areas. It has demonstrated its usefulness in assessing sources of dust and may also become a helpful tool to assess the effectiveness of dust mitigation strategies.

Appendices

Appendix A — PM_{10} 24-hour NEPM exceedances

The following pages contain information specific to each site exceeding the NEPM standard of 50 µg/m^3 averaged over one day during the Point Samson study. Each analysis is provided in date order and may include one or more of a wind spiral, concentration table and concentration plots. Where known, possible sources are indicated. Included in the graphics are data related to concentrations of PM_{10} particles reached at the three sites installed by DWER for this study, as well as Rio Tinto's TEOM in Wickham which is located eight kilometres south-west of Point Samson. For the purposes of this study, it is considered that the distance and direction of the Wickham TEOM when compared with the Point Samson instruments allows it to be used as an indicator of region-wide events.

Wind spirals are a representation of wind data recorded throughout the day. The wind speeds are represented by the size of the marker while PM_{10} concentrations are represented by the colour of the marker. The radial axis of each wind spiral represents the time of day extending out from the centre, while the angular axis represents the direction from where winds were arriving when recorded by the meteorological instrument. Wind spirals are a visual representation useful to demonstrate the way wind direction changes throughout the day.

Where used within the text, wind direction refers to the direction from where the wind originated. The following short-hand nomenclature used throughout this document:

N – 0 degrees	E – 90 degrees	S – 180 degrees	W – 270 degrees
NNE – 30 degrees	ESE – 120 degrees	SSW – 210 degrees	WNW – 300 degrees
ENE – 60 degrees	SSE – 150 degrees	WSW – 240 degrees	NNW – 330 degrees

The Caravan site suffered from intermittent communication and logger failures that reduced data recovery. Where relevant, any missing data have been noted as such in the following pages.

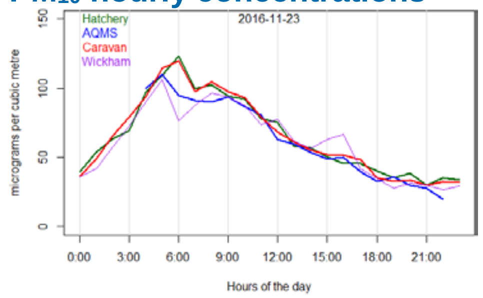
Summary of findings

For most days when the NEPM PM_{10} daily standard was exceeded at one or more of the monitoring sites, the following were generally observed:

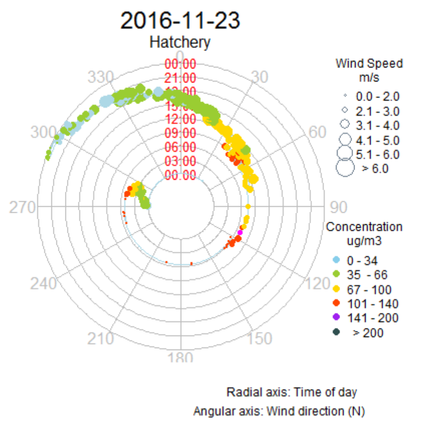
a) The Hatchery PM_{10} concentration was greater than either the AQMS or Caravan sites
b) The hourly averaged PM_{10} profile was broadly consistent across all sites
c) Wickham recorded lower concentrations than the other listed sites
d) The PM_{10} NEPM exceedances were caused by a combination of region-wide events with some contribution from the Cape Lambert operations
e) Wind speed and direction were consistent between sites with wind speed slightly higher at the AQMS site due to its elevated location

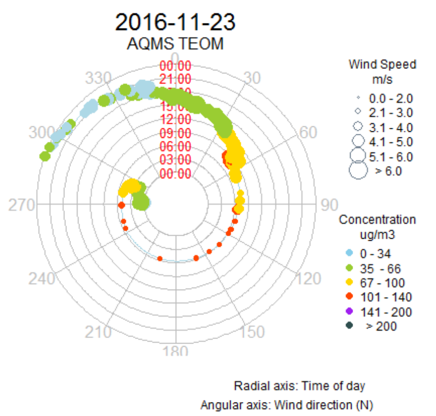
23 November 2016

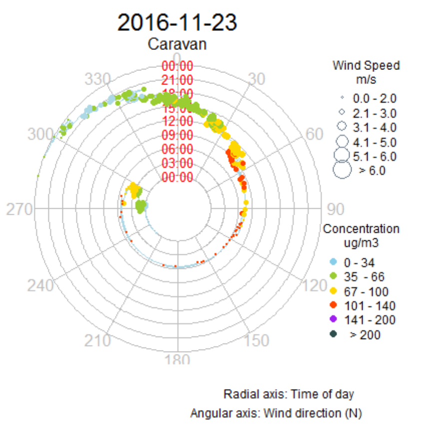
PM10 hourly concentrations



Wind speed and direction







PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	65.6 μg/m^3	52.8%
AQMS	61.8 μg/m^3	31.9%
Caravan	65.1 μg/m^3	48.9%
Wickham	61.2 μg/m^3	N/A

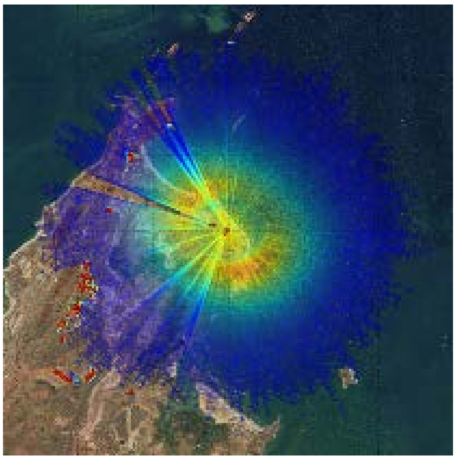
* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Low early morning winds were westerly moving anticlockwise and freshening throughout the day to end the day from the west.

The majority of the particle load was from 3 am to 3 pm with the bulk originating from the S through to the NE during light wind conditions.

The similarity of the concentrations across all sites tends to exclude local events as the cause.

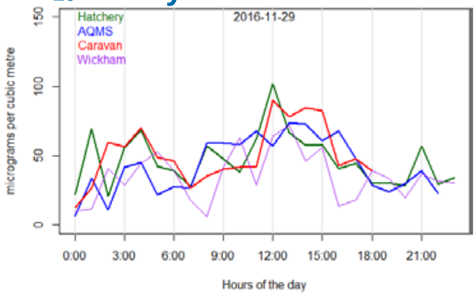


LiDAR image at 6 am showing the extent of the event captured by the LiDAR.

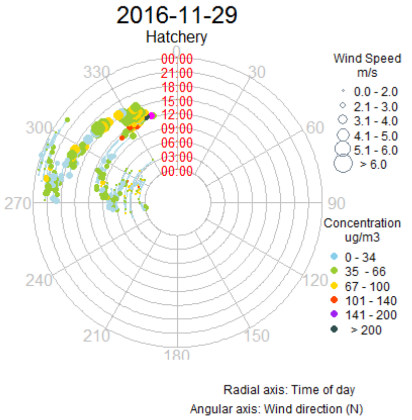
Assessment of the Rio Tinto instrument which monitors TSP, PM10 and PM2.5 within the PS AQMS compound found the particles had a ratio of 1.04 : 1.00 : 0.23 – indicating the particles were likely of a crustal nature or from a mechanical process.

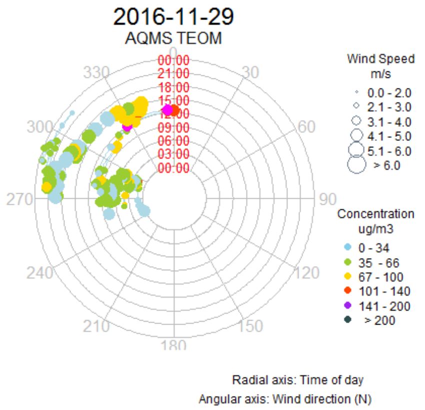
29 November 2016

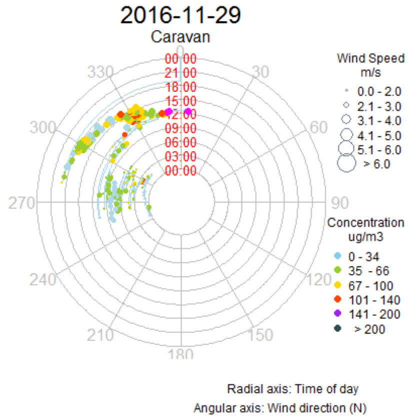
PM_{10} hourly concentrations



Wind speed and direction







PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	47.0 µg/m^3	98.5%
AQMS	41.9 µg/m^3	97.5%
Caravan	51.4 µg/m^3	98.5%
Wickham	35.4 µg/m^3	N/A

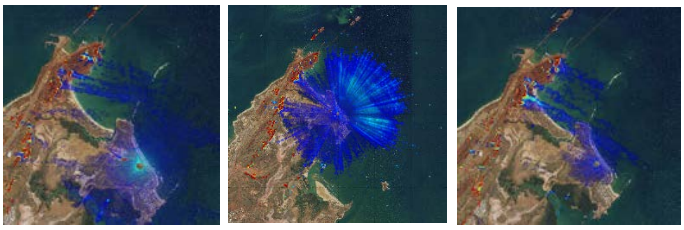
* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Low early morning winds were westerly swinging clockwise to N and freshening through midday, returning to westerly in the evening.

The majority of the particle load was from 9 am to 6 pm with the bulk originating from the NW through to N during light wind conditions.

The similarity of the concentrations across all sites tends to exclude local events as the major cause.



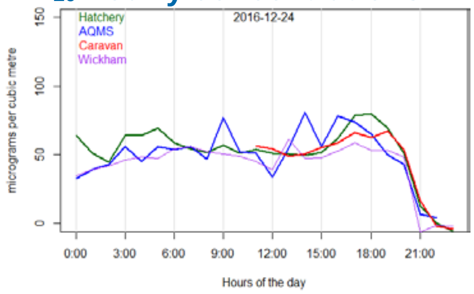
LiDAR image at 6 am, 12 pm and 6 pm

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.04 : 1.00 : 0.24 – indicating the particles were likely of a crustal nature or from a mechanical process.

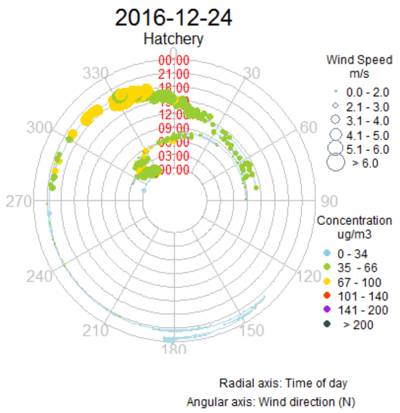
Given the majority of peninsula PM_{10} monitors recorded values greater than Wickham by more than 30 per cent and the winds were predominantly from within the AOI, it is assessed that Cape Lambert operations influenced the exceedance recorded at the Caravan monitor.

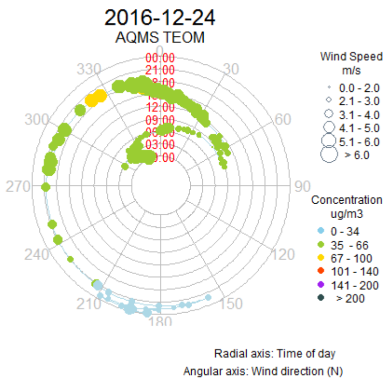
24 December 2016

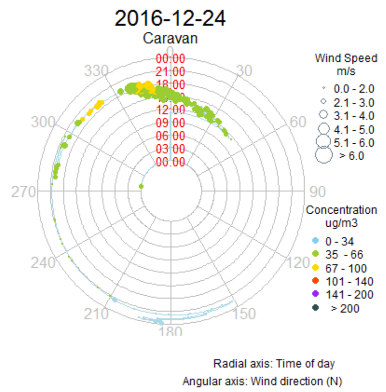
PM_{10} hourly concentrations



Wind speed and direction







PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	51.4 µg/m^3	82.8%
AQMS	48.0 µg/m^3	68.1%
Caravan	N/A	N/A
Wickham	42.5 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Concentrations were similar throughout the day with morning winds from WNW clockwise to E and then returning to W in the evening. The particle load was evenly distributed throughout the day.

Morning wind data from the Caravan site is missing.

The similarity of the concentrations across all sites tends to exclude local events as the cause.

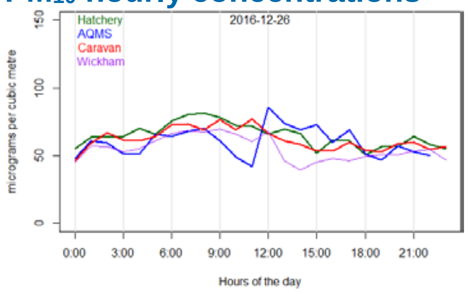
LiDAR was shut down from 21 December 2016 to 3 January 2017 due to cyclone warnings.

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 0.97 : 1.00 : 0.31 – indicating the particles were likely of a crustal nature or from a mechanical process. (It is noted the TSP concentration is lower than the PM_{10} concentration, indicating an issue with the monitoring instrument.)

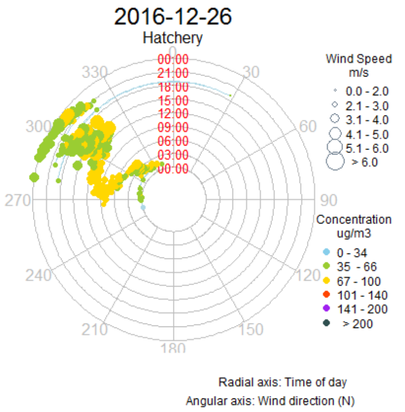
Given the Hatchery recorded values greater than Wickham by more than 20 per cent and the winds were predominantly from within the AOI, it is assessed that Cape Lambert operations influenced the exceedance recorded at the Hatchery monitor.

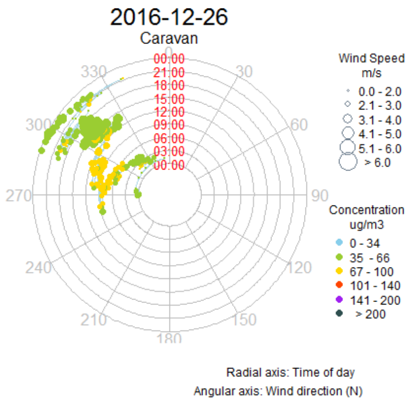
26 December 2016

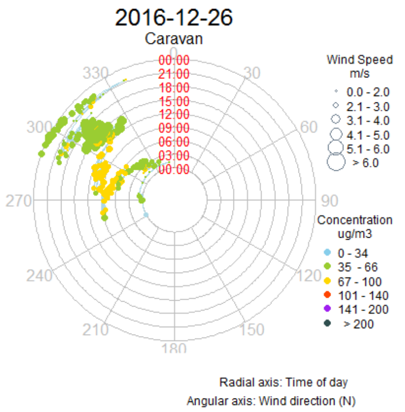
PM_{10} hourly concentrations



Wind speed and direction







PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	64.8 µg/m^3	99.7%
AQMS	59.9 µg/m^3	100%
Caravan	61.8 µg/m^3	98.9%
Wickham	55.1 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

W to NNW winds dominated throughout the day with the particle load evenly distributed.

The similarity of the concentrations across all sites tends to exclude local events as the cause.

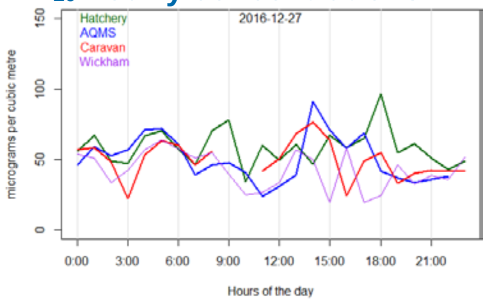
LiDAR was shut down from 21 December 2016 to 3 January 2017 due to cyclone warnings.

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 0.97 : 1.00 : 0.33 – indicating the particles were likely of a crustal nature or from a mechanical process. (It is noted the TSP concentration is lower than the PM_{10} concentration indicating an issue with the monitoring instrument.)

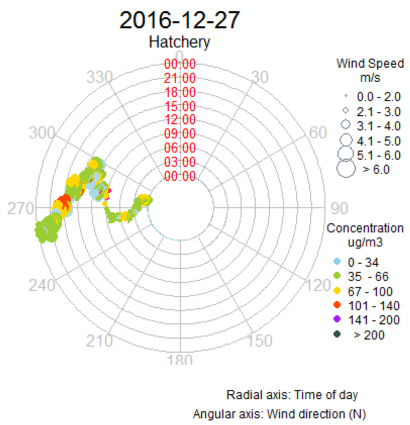
All sites exceeded the NEPM daily standard for PM_{10}, with the peninsula monitors recording concentrations between 8 and 18 per cent greater than Wickham's. As the winds were predominantly from within the AOI, it is assessed that Cape Lambert operations influenced the magnitude of exceedances recorded at all the peninsula monitors.

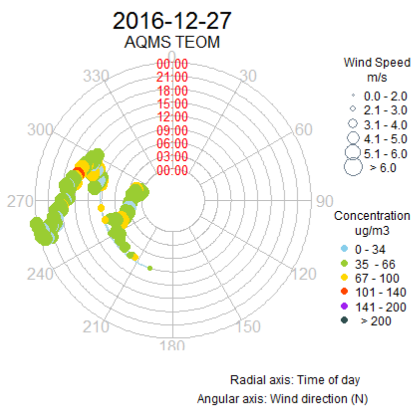
27 December 2016

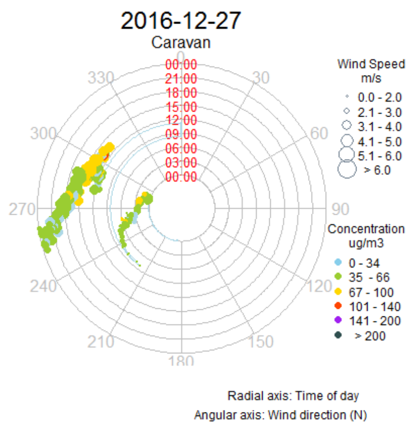
PM10 hourly concentrations



Wind speed and direction







PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	58.5 µg/m^3	81.0%
AQMS	50.2 µg/m^3	76.3%
Caravan	49.5 µg/m^3	69.5%
Wickham	42.8 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

WSW to WNW winds dominated throughout the day with the particle load evenly distributed.

The similarity of the concentrations across all sites tends to exclude local events as the cause.

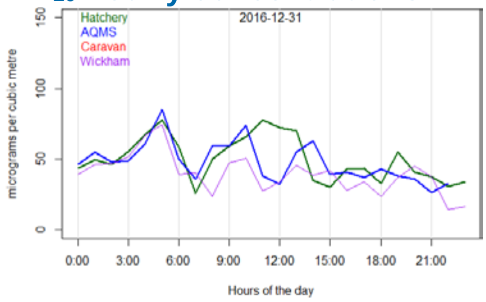
LiDAR was shut down from 21 December 2016 to 3 January 2017 due to cyclone warnings.

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.13 : 1.00 : 0.31 – indicating the particles were likely of a crustal nature or from a mechanical process.

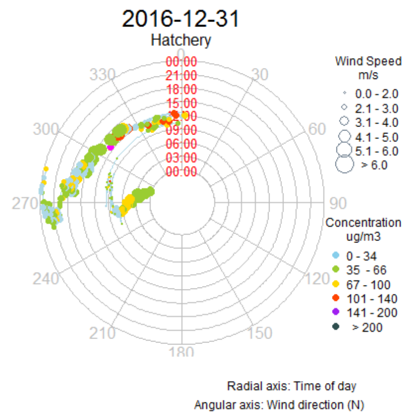
The Hatchery and AQMS site PM_{10} concentrations were greater than Wickham's by more than 20 per cent. Additionally, winds were predominantly from within the AOI for both sites. Cape Lambert operations influenced the exceedances recorded at the Hatchery and AQMS monitors.

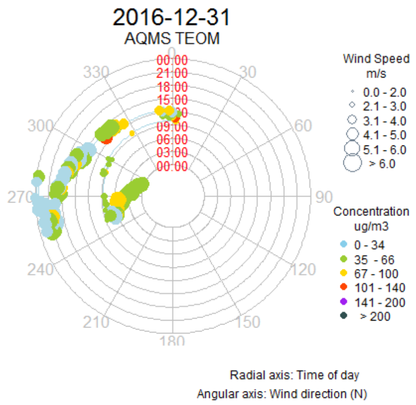
31 December 2016

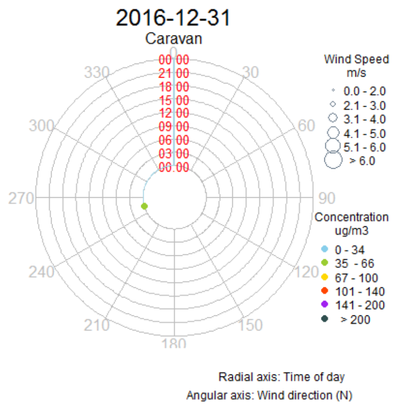
PM10 hourly concentrations



Wind speed and direction







PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	50.2 µg/m^3	96.3%
AQMS	47.4 µg/m^3	92.5%
Caravan	N/A	N/A
Wickham	39.6 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Early morning W winds swinging clockwise to N by midday, returning to westerly throughout the afternoon and evening with the particle load evenly distributed.

Wind data from the Caravan site is missing.

The similarity of the concentrations across the two sites tends to exclude local events as the cause.

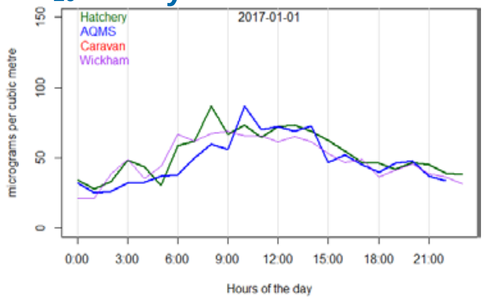
LiDAR was shut down from 21 December 2016 to 3 January 2017 due to cyclone warnings.

Assessment of the Rio Tinto instrument which monitors TSP, PM10 and PM2.5 within the PS AQMS compound found the particles had a ratio of 1.01 : 1.00 : 0.22 – indicating the particles were likely of a crustal nature or from a mechanical process.

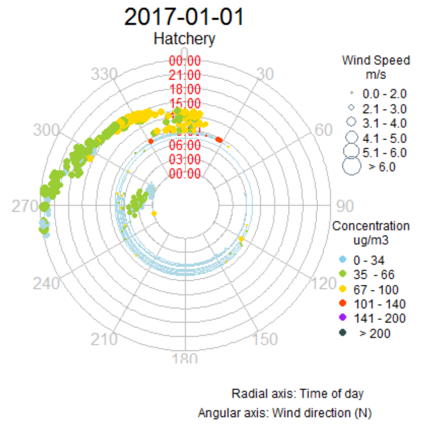
Given the Hatchery recorded values greater than Wickham by more than 25 per cent and the winds were predominantly from within the AOI, it is assessed that Cape Lambert operations influenced the exceedance recorded at the Hatchery monitor.

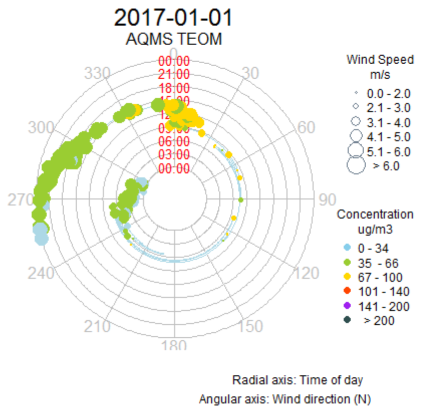
1 January 2017

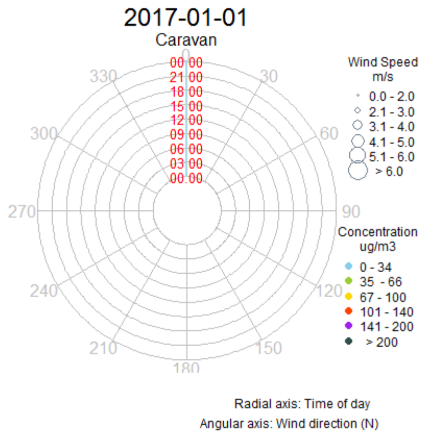
PM10 hourly concentrations



Wind speed and direction







PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	52.6 µg/m^3	88.5%
AQMS	47.7 µg/m^3	67.1%
Caravan	N/A	N/A
Wickham	48.9 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Early morning winds were westerly swinging clockwise to N around midday, returning to westerly throughout the afternoon and evening with the particle load concentrated between 6 am to 3 pm when winds were from a northerly vector.

Wind data from the Caravan site is missing.

The similarity of the concentrations across the two sites tends to exclude local events as the cause.

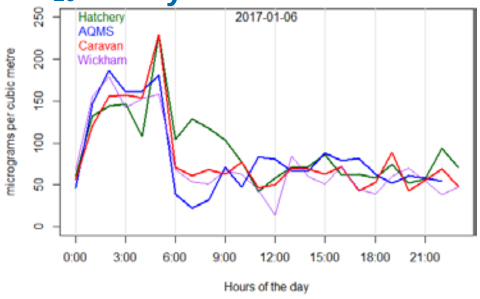
LiDAR was shut down from 21 December 2016 to 3 January 2017 due to cyclone warnings.

Assessment of the Rio Tinto instrument which monitors TSP, PM10 and PM2.5 within the PS AQMS compound found the particles had a ratio of 0.92 : 1.00 : 0.27 – indicating the particles were likely of a crustal nature or from a mechanical process. (It is noted the TSP concentration is lower than the PM10 concentration indicating an issue with the monitoring instrument.)

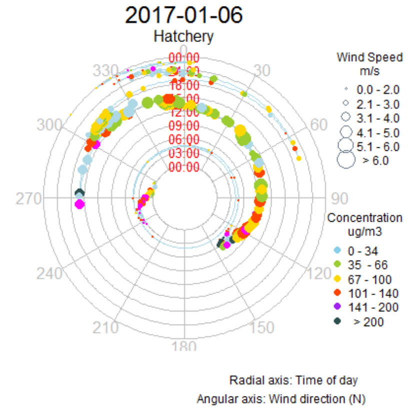
The Hatchery recorded values slightly greater than Wickham. With winds predominantly from within the AOI, it is assessed that Cape Lambert operations influenced the exceedance recorded at the Hatchery monitor.

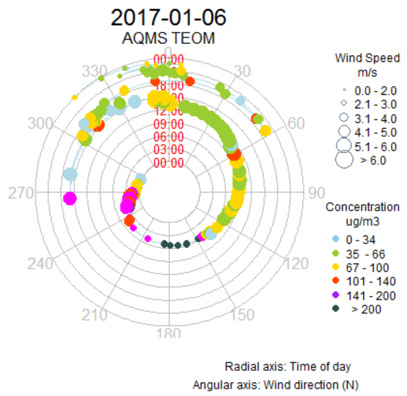
6 January 2017

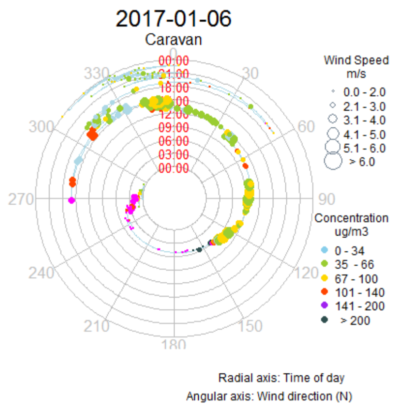
PM10 hourly concentrations



Wind speed and direction







PM10 24-hour averages

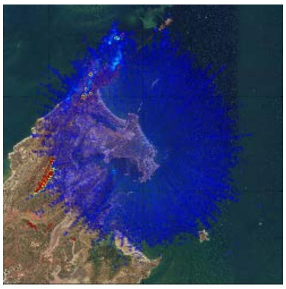
Site	Concentration	% within AOI*
Hatchery	92.4 µg/m^3	47.5%
AQMS	82.7 µg/m^3	52.5%
Caravan	82.1 µg/m^3	43.5%
Wickham	75.6 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Early morning winds were from the W swinging anticlockwise to W in the afternoon, then moving to N in the evening.

The majority of the particle load was from 1 am to 6 am with a large portion originating from the W between 3 am and 6 am and some very high concentrations from the SSW at around 6 am. The similarity of the concentrations across all sites tends to exclude local events as the cause.



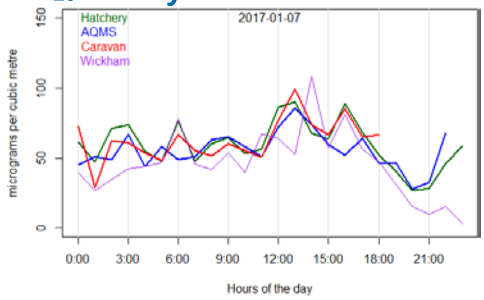
LiDAR image at 5 am

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.04 : 1.00 : 0.22 – indicating the particles were likely of a crustal nature or from a mechanical process.

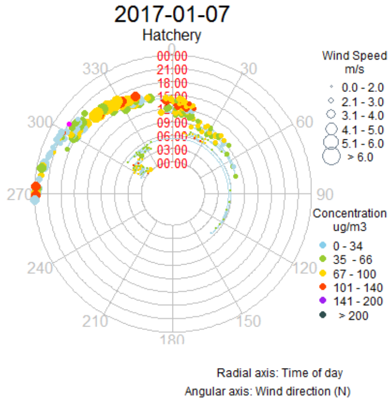
All sites exceeded the NEPM daily standard for PM_{10}, with the peninsula monitors recording concentrations between 9 and 22 per cent greater than Wickham's. The morning winds bearing a greater particle load were predominantly from within the AOI. It is assessed that Cape Lambert operations influenced the magnitude of exceedances recorded at all the peninsula monitors.

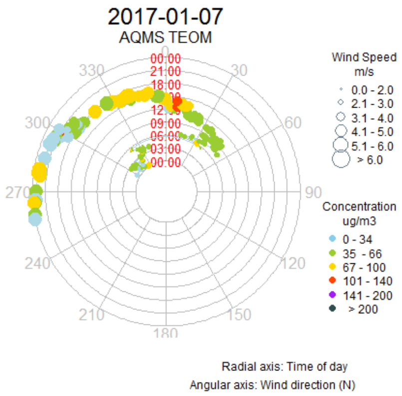
7 January 2017

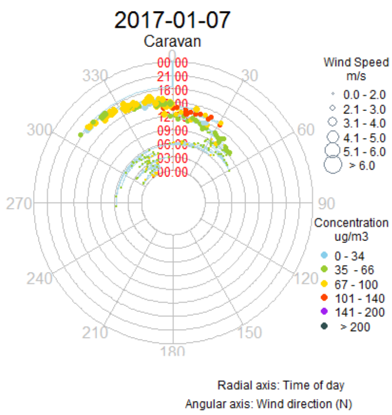
PM_{10} hourly concentrations



Wind speed and direction







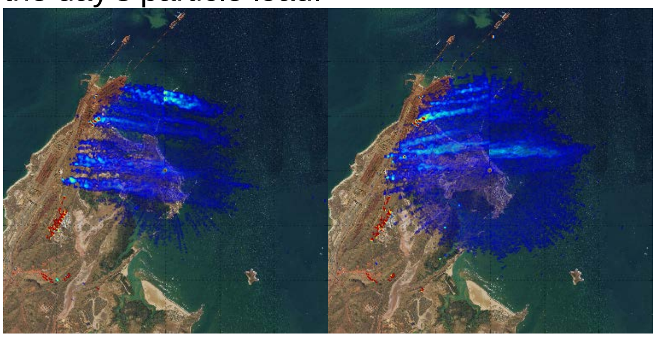
PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	59.2 µg/m^3	82.6%
AQMS	55.5 µg/m^3	63.0%
Caravan	62.8 µg/m^3	72.1%
Wickham	46.1 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Light early morning winds were WNW swinging clockwise to E, freshening and returning to W from mid-morning through to the evening.
The majority of the particle load was from 12 pm to 3 pm with the bulk originating from the N. Caravan data is missing from 6 pm.
The similarity of the concentrations across all sites tends to exclude local events as the cause, although there was some activity at Cape Lambert from 9 pm that contributed to the day's particle load.

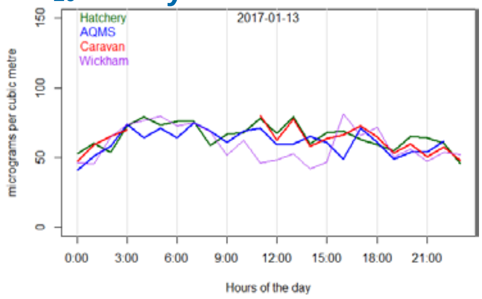


7/1/2017 22:30 (left) and 7/1/2017 23:30 (right)

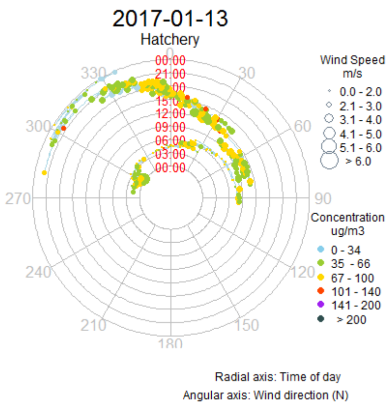
Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.09 : 1.00 : 0.25 – indicating the particles were likely of a crustal nature or from a mechanical process.

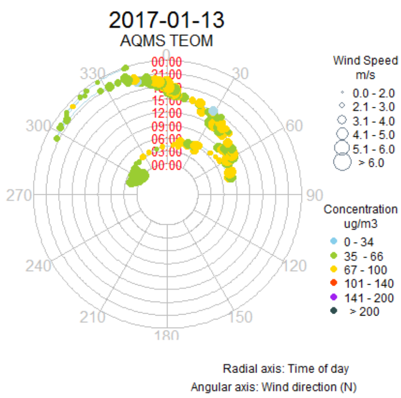
13 January 2017

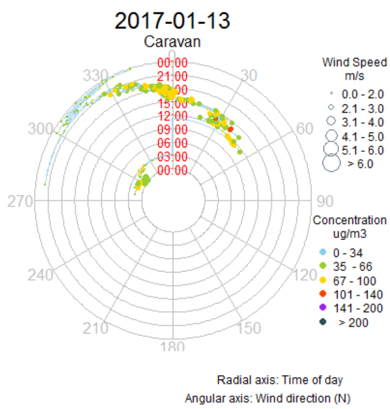
PM_{10} hourly concentrations



Wind speed and direction







PM_{10} 24-hour averages

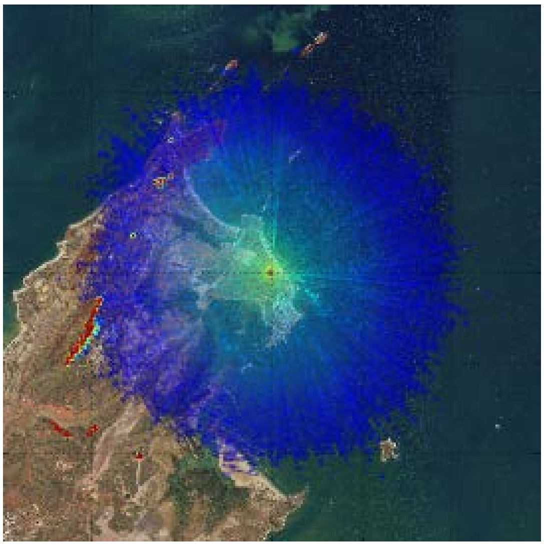
Site	Concentration	% within AOI*
Hatchery	65.5 µg/m^3	62.4%
AQMS	61.0 µg/m^3	45.8%
Caravan	N/A	N/A
Wickham	59.6 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Low early morning winds were westerly swinging clockwise to ENE and freshening through midday, returning to WNW in the evening.

The particle load was evenly distributed throughout the day. Caravan data was missing between 3 am and 11 am.
The similarity of the concentrations across all sites tends to exclude local events as the cause.



LiDAR image at 3 am

Assessment of the Rio Tinto instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.01 : 1.00 : 0.27 – indicating the particles were likely of a crustal nature or from a mechanical process.

Appendix B – Short-term elevated concentrations recorded by both the LiDAR and monitors

The following pages contain information on specific events which, while not exceeding any NEPM standards, were captured by both the LiDAR and the monitoring sites. The choice of events was limited to days when there was a five- or 10-minute averaged recording of PM_{10} greater than 200 µg/m^3 somewhere in the network. Choosing a PM_{10} concentration greater than 200 µg/m^3 has no basis other than to limit the number of short-term events investigated. It is noted that Ministerial Statement 741 states a short-term TSP dust impact occurs when dust emissions exceed 200 µg/m^3 averaged over 10-minute intervals.

The LiDAR records backscatter from particles in the atmosphere. Where the particle density is high, the backscatter (or amount of light reflecting off the particles) returning to the LiDAR is also high. Correspondingly, when the particle density is low, the backscatter returning to the LiDAR is also low.

The images presented within this Appendix use a standardised colour pallet called ‘jet’ to overlay the amount of light being reflected back to the LiDAR onto a map of the region.

The colours used to display a qualitative assessment of backscatter from the LiDAR range from dark blue – representing a low amount of backscatter due to airborne particles, through to dark red – representing a high amount of backscatter. Dark red shading is also used to represent solid objects.

Summary of findings

There were several short-term PM_{10} spikes of between five and 60 minutes duration which recorded concentrations greater than 200 µg/m^3 during the study period.

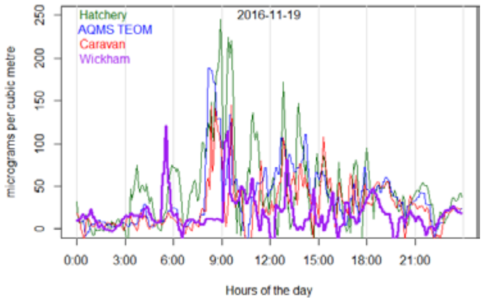
The LiDAR captured some of these spikes and indicated their origin as the Rio Tinto Cape Lambert operations.

The potential exists for dust plumes from Cape Lambert to reach Point Samson under some meteorological conditions. The extent to which these plumes impact on Point Samson is, however, not fully understood given the narrow shape of the plumes and the possibility that they may only affect relatively narrow pathways.

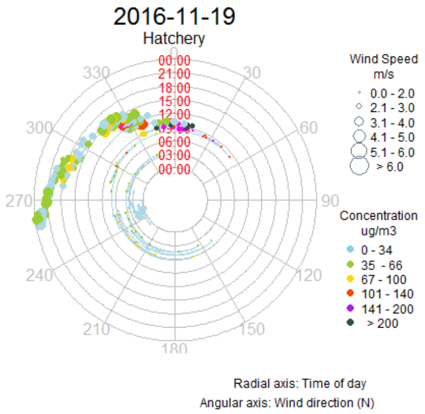
On the basis of this brief analysis, no specific meteorological conditions seem to give rise to these plumes, which appear to be more related to activity than meteorology.

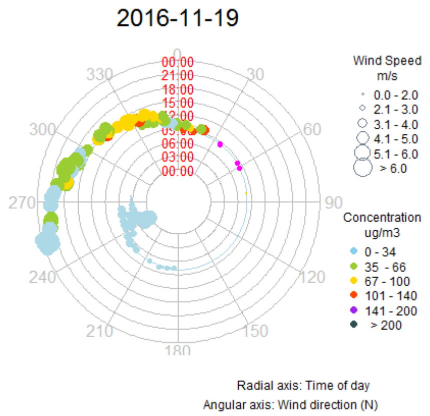
19 November 2016

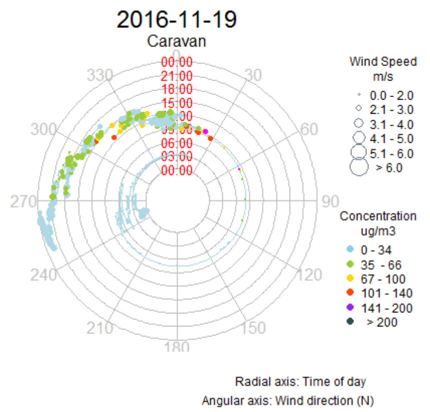
PM10 concentrations



Wind speed and direction

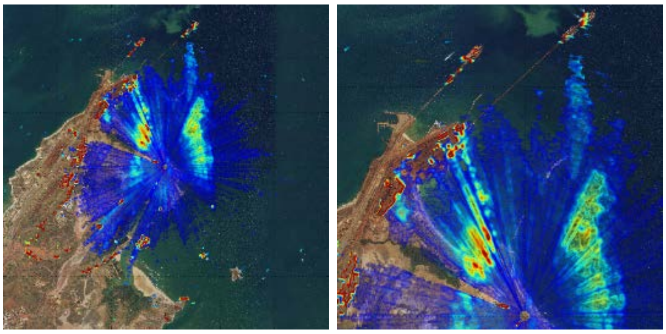






Event description

Winds were from the N at 9 am with activity indicated at the ship loading facility as seen by the LiDAR.



LiDAR image at 9 am (left) with close-up of 9 am image (right) showing possible contribution from ship loading

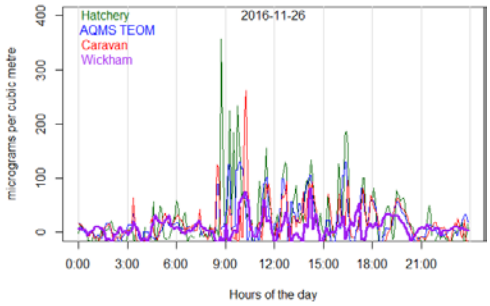
There is also some possible dust from the sand quarry, however given this facility is located to the SE of the Hatchery site and winds were from the N during the event, it is unlikely that there was any great contribution by the sand quarry to the dust levels recorded at the Hatchery.

PM10 24-hour averages

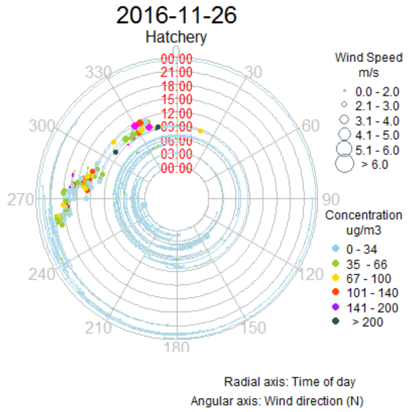
Site	Concentration
Hatchery	46.2 µg/m^3
AQMS	35.2 µg/m^3
Caravan	27.3 µg/m^3
Wickham	18.2 µg/m^3

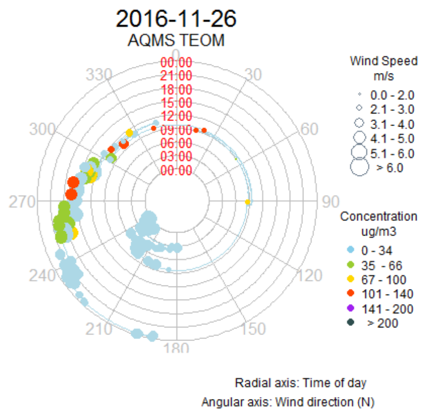
26 November 2016

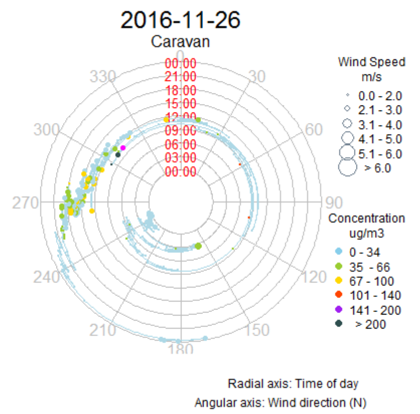
PM_{10} concentrations



Wind speed and direction

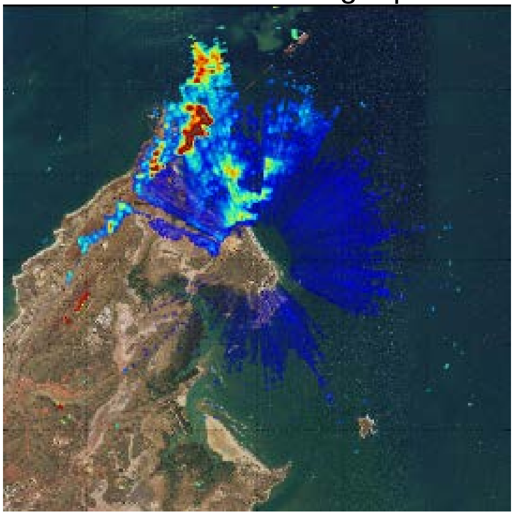






Event description

Low early morning winds were westerly swinging N by midday and freshening WNW in the afternoon.
The Hatchery recorded a five-minute averaged PM_{10} concentration of 357.6 µg/m^3 at 8:45 am with winds from 344 degrees. This coincided with the LiDAR recording a plume in the area.



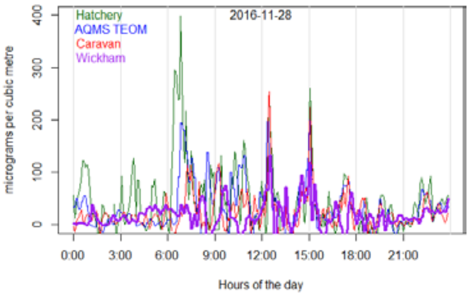
LiDAR image at 8:50 am

PM_{10} 24-hour averages

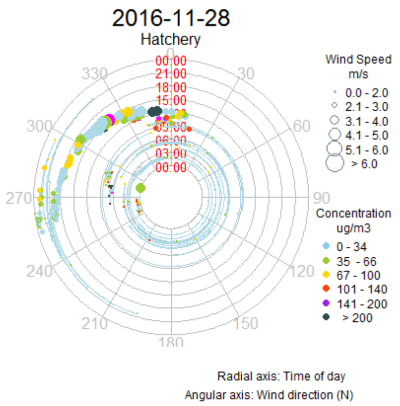
Site	Concentration
Hatchery	25.3 µg/m^3
AQMS	19.2 µg/m^3
Caravan	16.4 µg/m^3
Wickham	8.6 µg/m^3

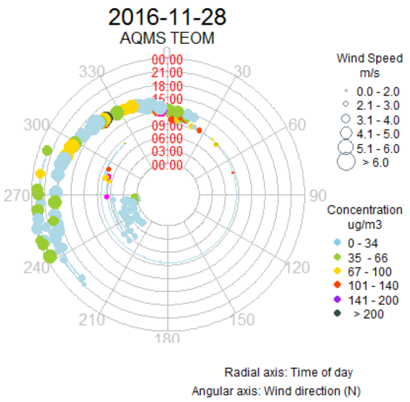
28 November 2016

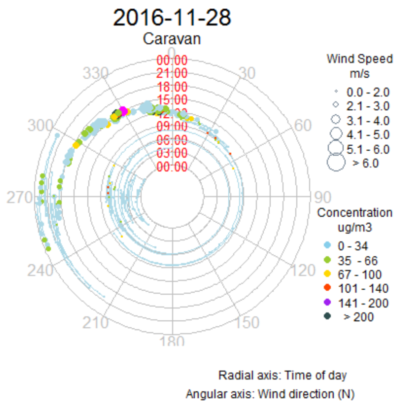
PM$_{10}$ concentrations



Wind speed and direction



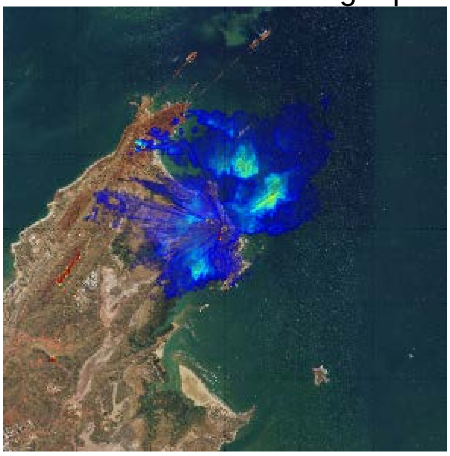




Event description

Low early morning winds were westerly swinging N by midday and freshening WNW in the afternoon.

The Hatchery recorded a five-minute averaged PM$_{10}$ concentration of 399.5 µg/m^3 at 6:50 am, with winds from 271 degrees. This coincided with the LiDAR recording a plume in the area.



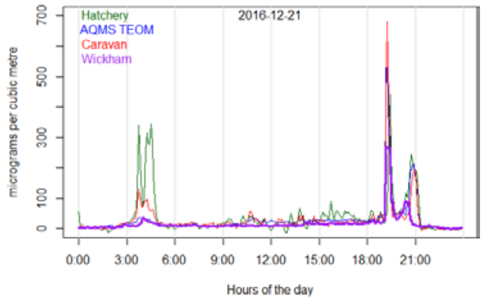
LiDAR image at 7 am

PM$_{10}$ 24-hour averages

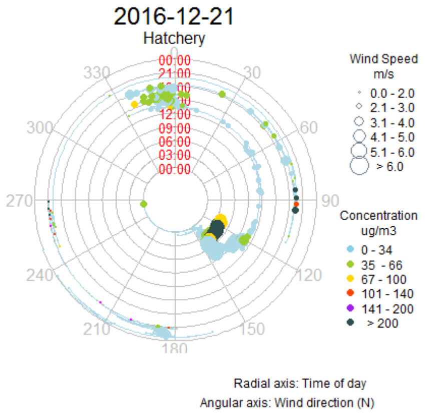
Site	Concentration
Hatchery	46.6 µg/m^3
AQMS	31.6 µg/m^3
Caravan	24.7 µg/m^3
Wickham	18.0 µg/m^3

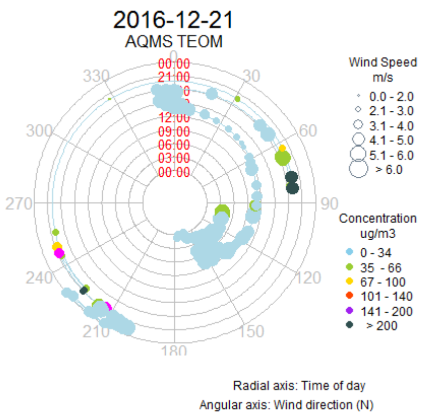
21 December 2016

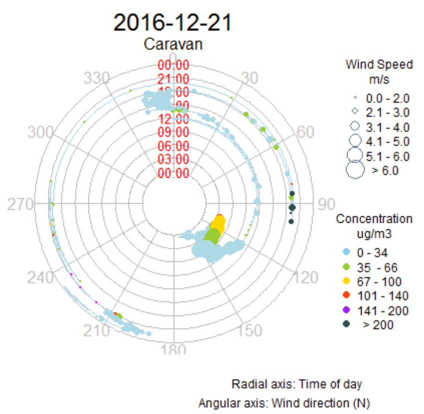
PM10 concentrations



Wind speed and direction



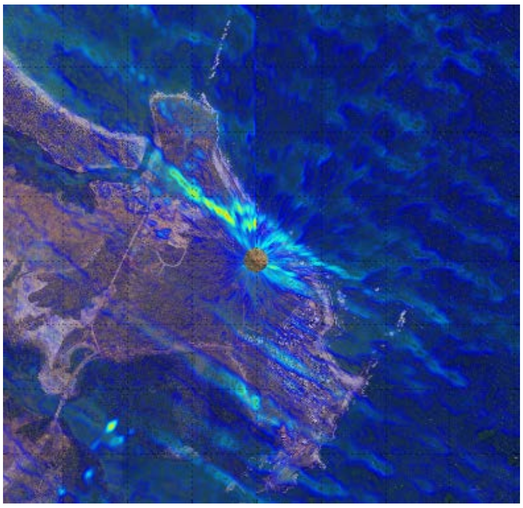




Event description

Moderate winds up to 11 m/s in the morning from the SE caused elevated particle levels at the Hatchery. Similarly, in the evening the elevated particles at all sites originated from the east. In both cases, these were outside the arc of influence.

A cyclone warning was issued for this period and the LiDAR was shut down from 11am on 21 December 2016 to 2 January 2017.



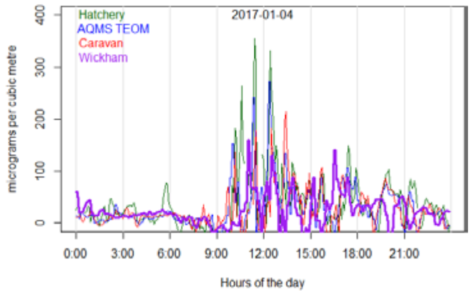
LiDAR image at 4:20 am on 21 December 2016 shows a plume originating from the coast crossing the Hatchery site during a period of strong south easterlies.

PM10 24-hour averages

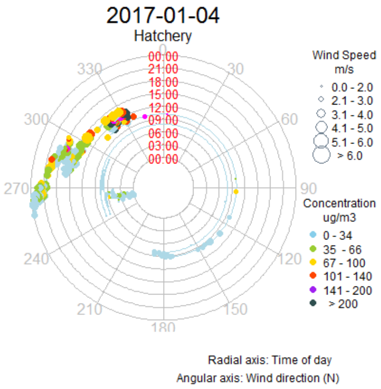
Site	Concentration
Hatchery	38.7 µg/m³
AQMS	29.6 µg/m³
Caravan	29.9 µg/m³
Wickham	17.9 µg/m³

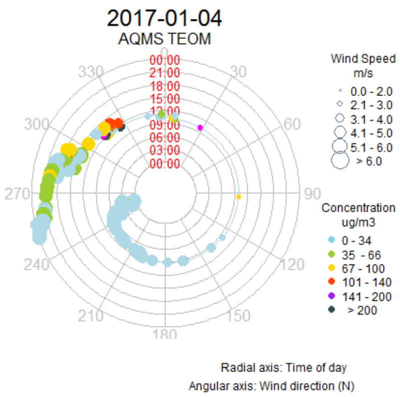
4 January 2017

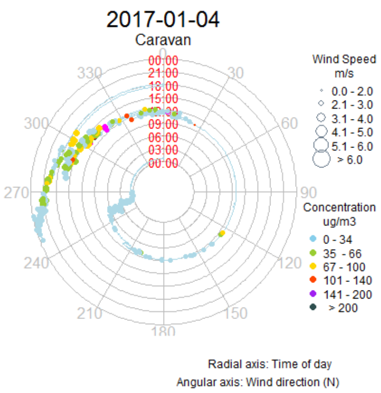
PM_{10} concentrations



Wind speed and direction



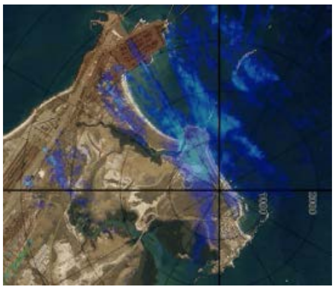
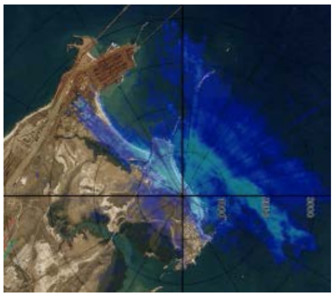




Event description

Low early morning winds were westerly swinging N by midday and freshening WNW in the afternoon.

The Hatchery recorded a five-minute averaged PM_{10} concentration of 264 µg/m^3 at 10:35 am, 354.9 µg/m^3 at 11:25 am with winds from 333 degrees, followed by 331.5 µg/m^3 at 12:25 pm. This coincided with the LiDAR recording a plume in the area.

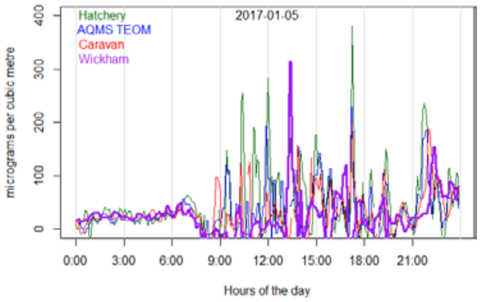
11:20 am (left) and 12:20 pm (right)

PM_{10} 24-hour averages

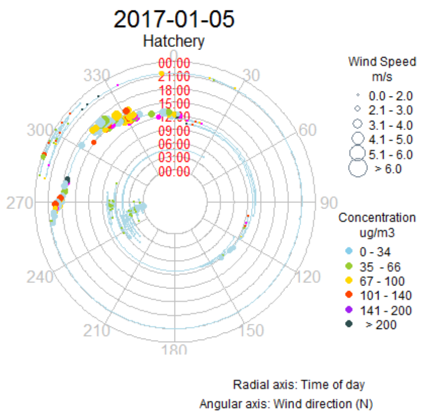
Site	Concentration
Hatchery	38.8 µg/m^3
AQMS	35.9 µg/m^3
Caravan	24.6 µg/m^3
Wickham	23.7 µg/m^3

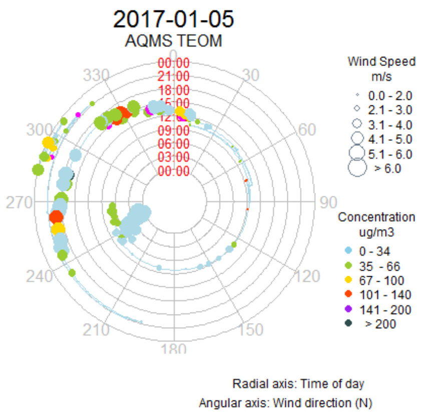
5 January 2017

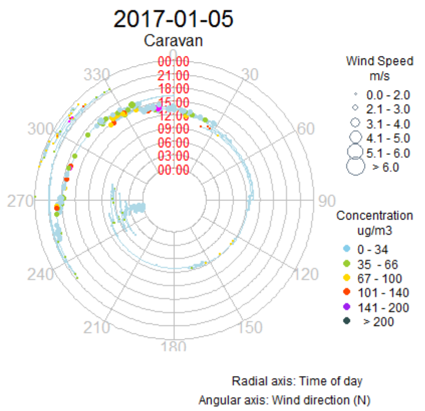
PM_{10} concentrations



Wind speed and direction



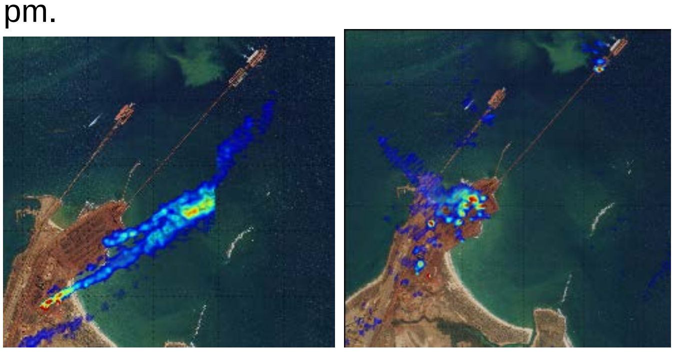




Event description

Light early morning winds from the SE at around 9am freshening around to N by midday and continuing to freshen to the NW during the afternoon.

The Hatchery recorded a five-minute averaged PM_{10} concentration of 255 µg/m^3 at 10:25 am, 283 µg/m^3 at 12 noon and 380 µg/m^3 at 5:15 pm.



LiDAR recorded activity on the peninsula at 6:20 am and some shipping activities at 9:20 am

PM_{10} 24-hour averages

Site	Concentration
Hatchery	46.7 µg/m^3
AQMS	31.1 µg/m^3
Caravan	32.1 µg/m^3
Wickham	24.9 µg/m^3

Appendix C – Selected events recorded by the LiDAR

The following pages contain information on a selection of specific events that neither exceeded any NEPM standards nor in some cases were recorded on the particle monitors, but were nevertheless captured by the LiDAR.

The LiDAR records backscatter from particles in the atmosphere. Where the particle density is high, the backscatter (or amount of light reflecting off the particles) returning to the LiDAR is also high. Correspondingly, when the particle density is low, the backscatter returning to the LiDAR is also low.

The images presented within this Appendix use a standardised colour pallet called ‘jet’ to overlay the amount of light being reflected back to the LiDAR onto a map of the region.

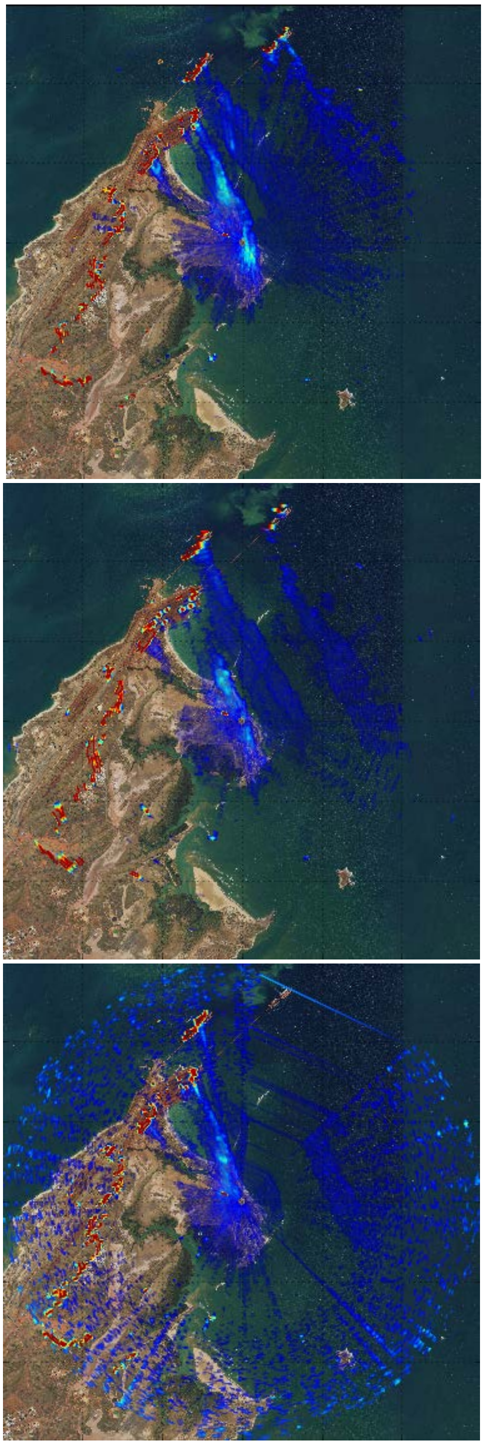
The colours used to display a qualitative assessment of backscatter from the LiDAR range from dark blue – representing a low amount of backscatter due to airborne particles, through to dark red – representing a high amount of backscatter. Dark red shading is also used to represent solid objects.

Summary of findings

The potential exists for dust plumes from Cape Lambert to reach Point Samson under some meteorological conditions. The extent to which these plumes impact on Point Samson is, however, not fully understood given the narrow shape of the plumes and the possibility that they may only affect relatively narrow pathways.

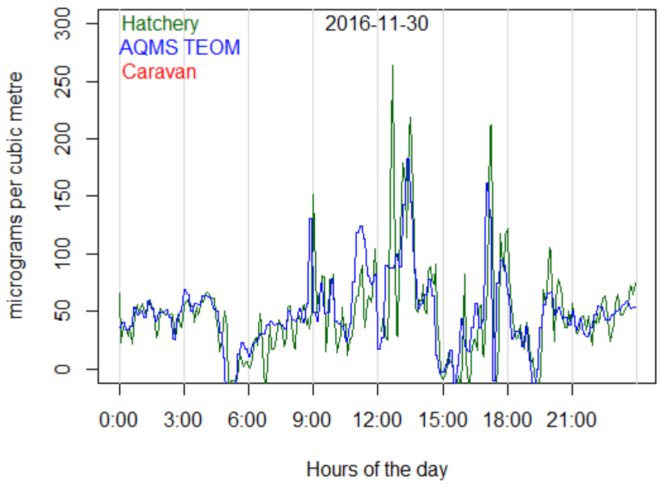
On the basis of this brief analysis, no specific meteorological conditions seem to give rise to these plumes, which appear to be more related to activity than meteorology.

30 November 2016



Series of pictures spanning from 11:10 am (top), 11:30 pm (middle), 11:50 pm (bottom)

PM10 concentrations



PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	48.1 µg/m^3	85.1%
AQMS	48.2 µg/m^3	75.6%
Caravan	N/A	N/A
Wickham	30.7 µg/m^3	N/A

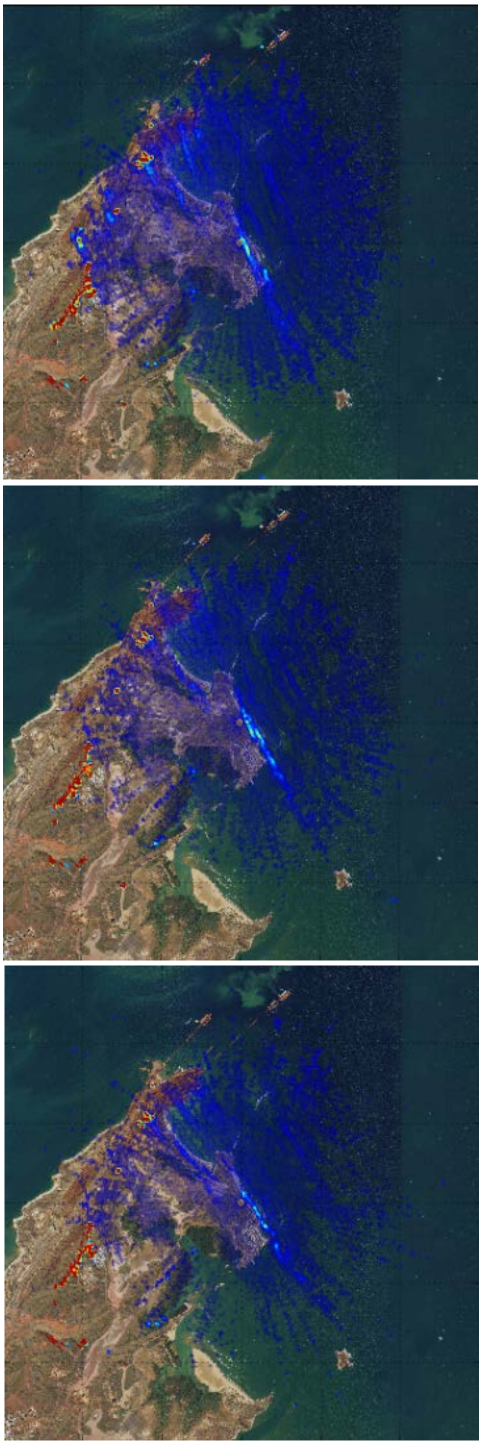
* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Shiploading activities showed plumes extend southward towards Point Samson and the monitoring sites during periods when winds were at 5 m/s from a bearing of between 350 degrees to due N.

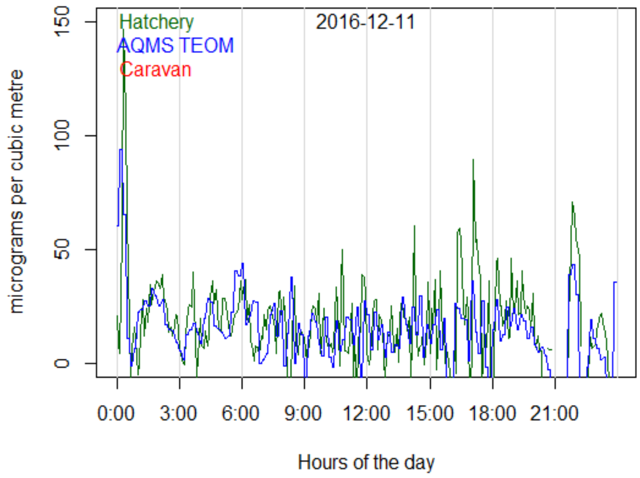
Assessment of the RTIO instrument which monitors TSP, PM_{10} and $PM_{2.5}$ within the PS AQMS compound found the particles had a ratio of 1.34 : 1.00 : 0.20 – indicating the particles were likely of a crustal nature with a high proportion of coarse particles greater than PM_{10} size.

11 December 2016



Series of pictures spanning from 6:10 pm (top), 6:30 pm (middle), 6:50 pm (bottom)

PM_{10} concentrations



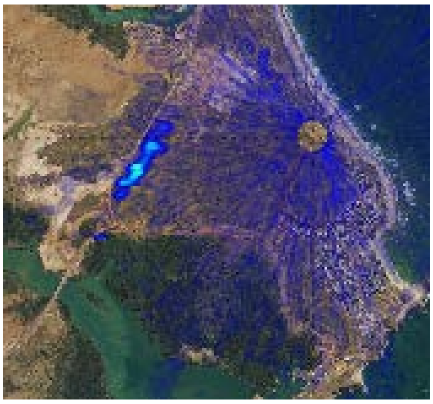
PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	17.5 µg/m^3	63.5%
AQMS	13.1 µg/m^3	42.3%
Caravan	N/A	N/A
Wickham	16.1 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

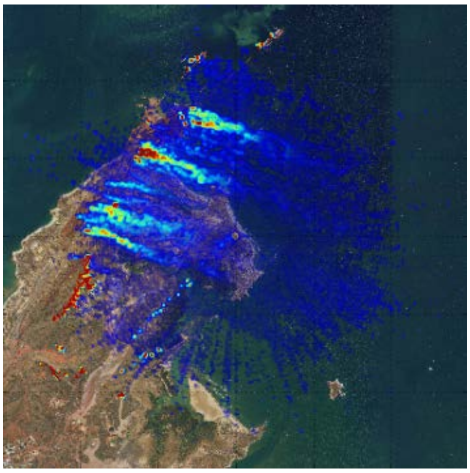
Event description

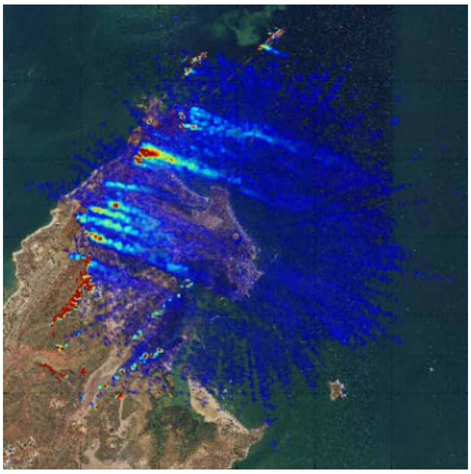
The dust was recorded by the LiDAR and indicated its origin as the beach. At the time, winds were around 6 m/s between 320 and 330 degrees or essentially running parallel to the beach.

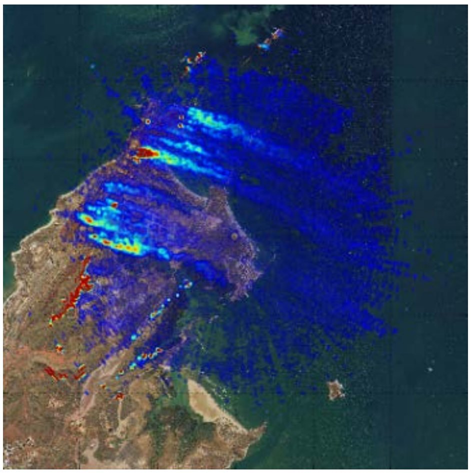


Track dust at approximately 9:40 am. At the time, winds were around 4 m/s between 30 and 35 degrees or essentially running parallel to the track.

13 December 2016

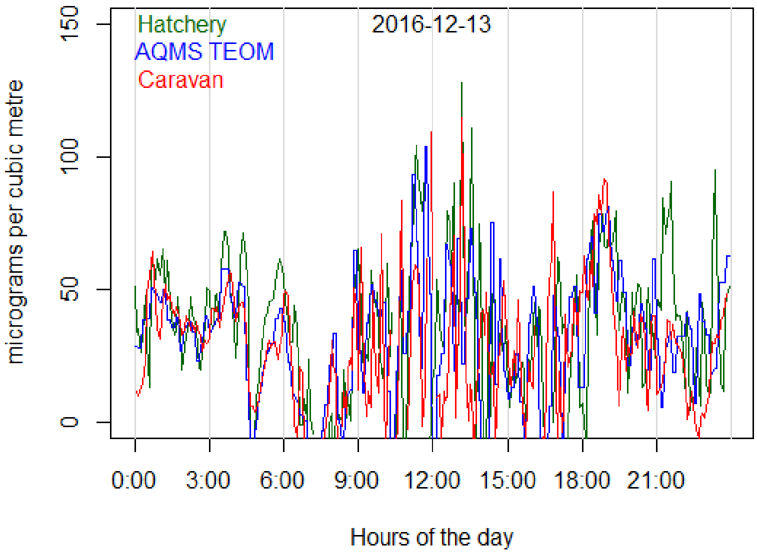






Series of pictures spanning from 5:10 pm (top), 5:30 pm (middle), 5:50 pm (bottom)

PM$_{10}$ concentrations



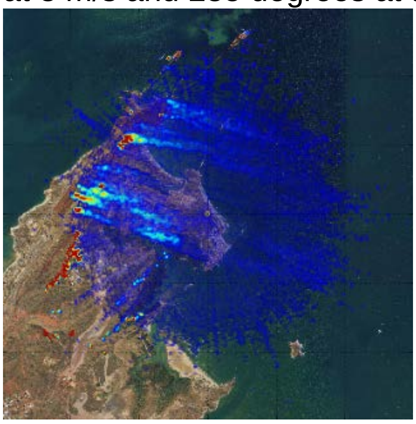
PM$_{10}$ 24-hour averages

Site	Concentration	% within AOI*
Hatchery	35.4 µg/m^3	86.5%
AQMS	34.1 µg/m^3	75.0%
Caravan	27.8 µg/m^3	80.5 %
Wickham	20.0 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

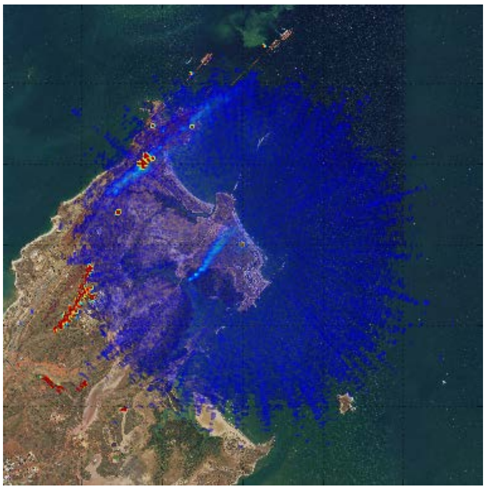
Event description

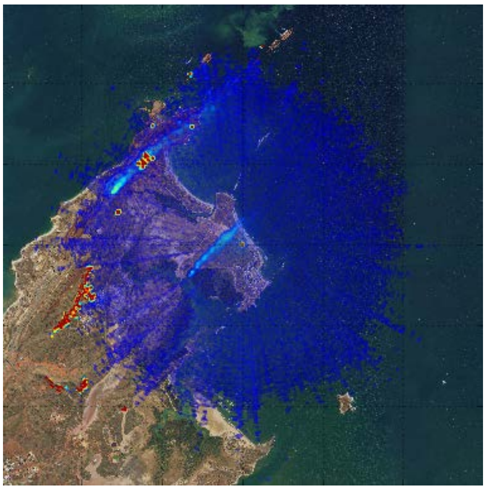
Activity from the Cape Lambert operations with winds at 8 m/s and 285 degrees at the time.

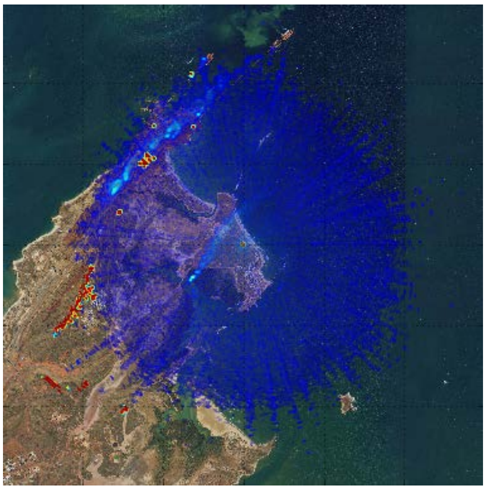


6:30 pm with activity in both CLA and CLB

15 December 2016

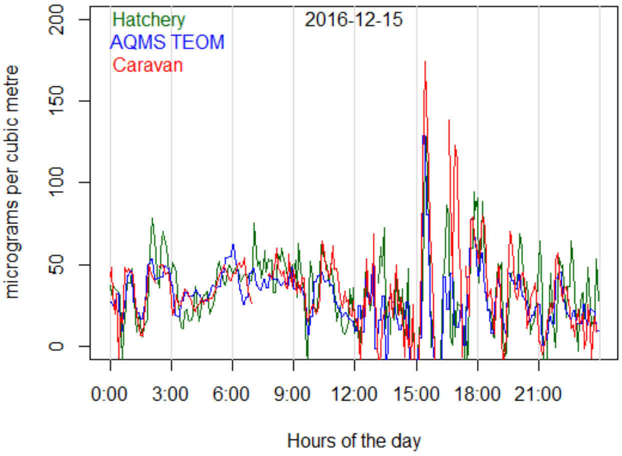






Series of pictures spanning from 3:50 pm (top), 4 pm (middle) and 4:10 pm (bottom)

PM_{10} concentrations



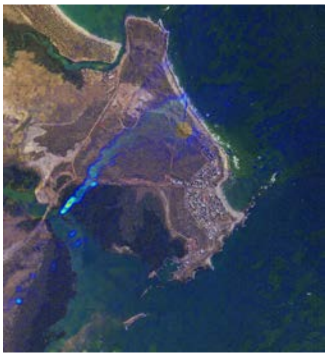
PM_{10} 24-hour averages

Site	Concentration	% within AOI*
Hatchery	33.6 µg/m^3	70.8%
AQMS	28.9 µg/m^3	61.8%
Caravan	33.6 µg/m^3	57.1%
Wickham	27.5 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

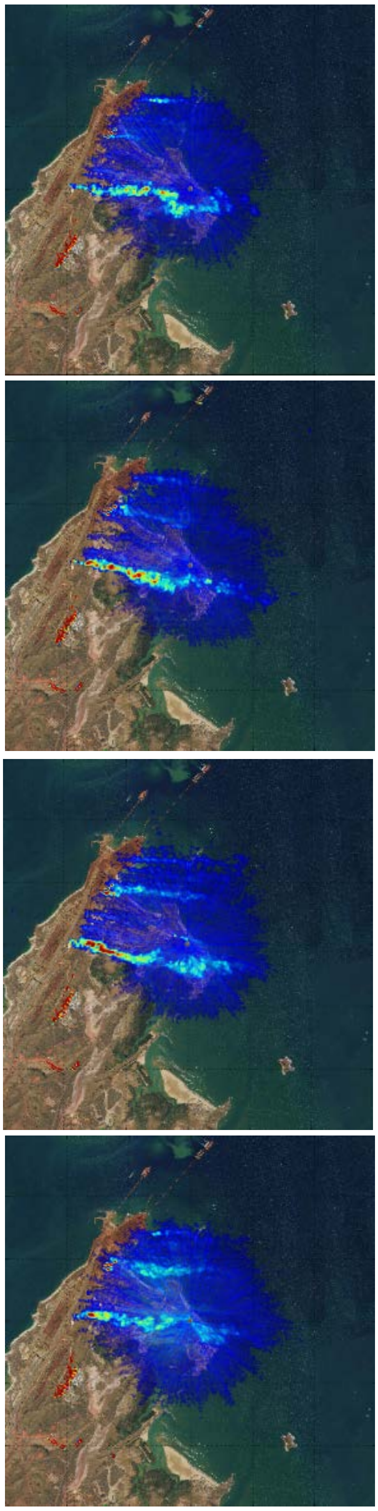
Event description

Smoke or dust is visible from the inlet SW of Point Samson. At the time, winds were around 2.5 m/s at 220 degrees.



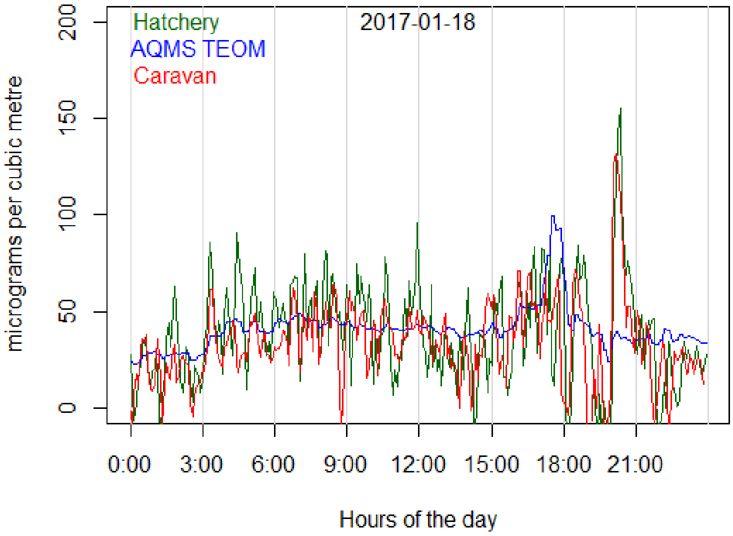
15 December 2017 3:50 am LiDAR image (left) showing close-up of inlet at left with a similar event on 14 January 2017 at 7 am (right)

18 January 2017



Series of pictures spanning from
4 pm (top), 4:20 pm (second from top), 4:40 pm (second from bottom) to 5 pm (bottom)

PM10 concentrations



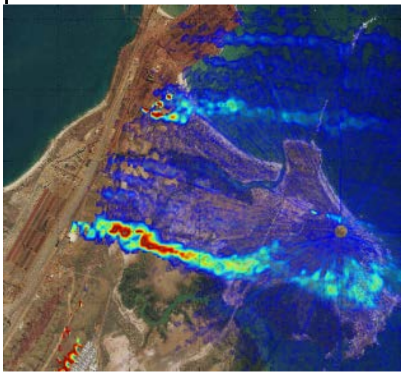
PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	38.3 µg/m^3	85.7%
AQMS	40.6 µg/m^3	71.50%
Caravan	33.5 µg/m^3	67.6 %
Wickham	36.6 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

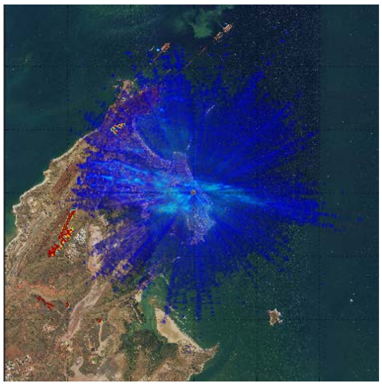
Event description

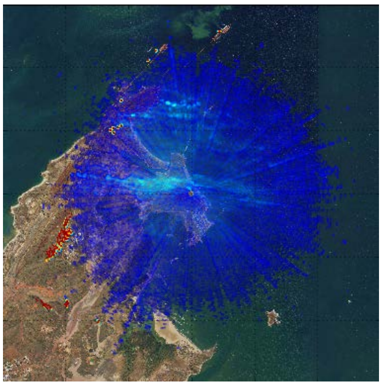
Dust was recorded by the LiDAR and the LiDAR indicates its origin as from the CLB area reclaimers. The dust is tracked by the LiDAR to Point Samson from 4 pm to after 5 pm. The plume has effectively bypassed all monitors in the area as indicated by the plot.

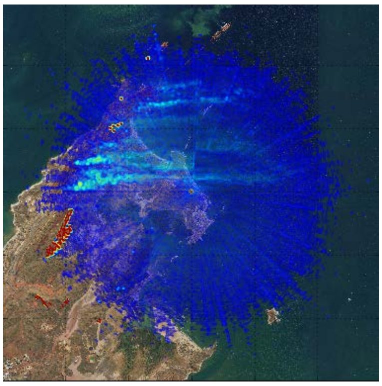


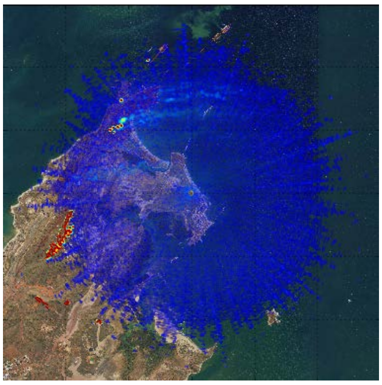
Close-up of Rio Tinto stockpiles at 4:40 pm. Winds were at 9 m/s and bearing of 285 degrees

19 January 2017



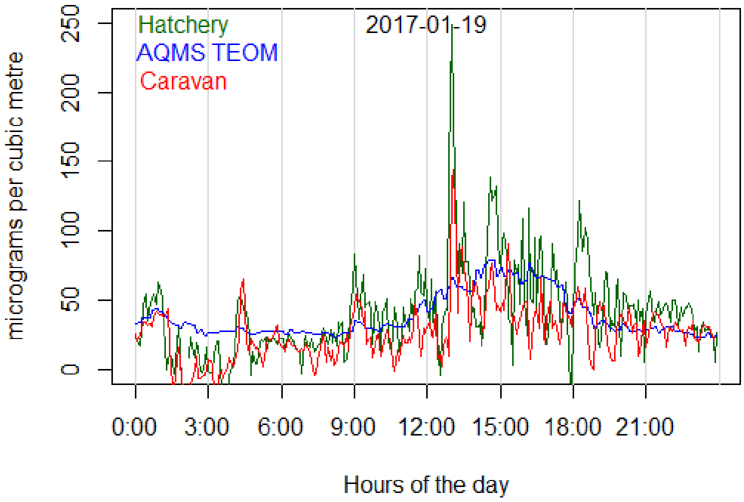






Series of pictures spanning from 2 pm (top), 4 pm (second from top), 6 pm (second from bottom) to 8 pm (bottom)

PM10 concentrations



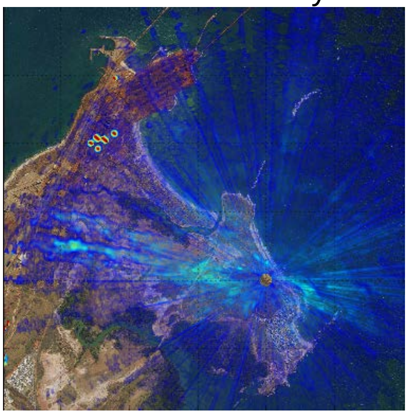
PM10 24-hour averages

Site	Concentration	% within AOI*
Hatchery	40.5 µg/m^3	81.2%
AQMS	37.2 µg/m^3	50.7%
Caravan	27.3 µg/m^3	58.5 %
Wickham	28.4 µg/m^3	N/A

* Arc of Influence is based on actual particle contribution within the arc 260° to 20°

Event description

Westerly winds were greater than 10 m/s and continued from midday for the rest of the day.



Close-up of region at 1 pm when the Hatchery recorded 248 µg/m3. At the time, winds were gusting over 12 m/s bearing 274 degrees

Appendix D – Bureau of Meteorology weather data

Date	Day	Temps		Rain	Max wind gust			9:00 AM						3:00 PM				
		Min	Max		Dir	Spd	Time	Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Dir	Spd	MSLP
		°C	°C	mm		km/h	local	°C	%	8th		km/h	hPa	°C	%		km/h	hPa
10/11/2016	Th	21.1	35.5	0	WNW	59	16:46	28.6	25		WSW	20	1010.7	33	28	WNW	41	1006
11/11/2016	Fr	17.7	38.2	0	NW	50	16:22	31.4	19		S	15	1011.5	37.9	9	SW	19	1006.8
12/11/2016	Sa	18.6	38.3	0	ESE	44	8:46	33	23		ESE	33	1010.8	36	24	N	30	1007
13/11/2016	Su	16.9	38.9	0	NW	37	18:10	32.1	45		NNE	6	1011.4	36.3	17	N	22	1008.7
14/11/2016	Mo	17.1	36.7	0	N	46	15:21	33.2	20		NE	24	1011.3	34.7	24	N	35	1007.8
15/11/2016	Tu	22.3	36.1	0	W	48	22:35	29.7	49		SSW	13	1010.6	34.8	36	NW	30	1007.3
16/11/2016	We	23.2	33.7	0	SW	50	14:59	29.4	42		WSW	28	1011	30.9	36	SW	35	1009.9
17/11/2016	Th		36.1					30.1	38		SSW	15	1013.4	35	30	NNW	20	1009.8
18/11/2016	Fr	22.4	38	0	N	39	13:42	35	23		ENE	15	1010.3	36.2	27	NW	28	1007.7
19/11/2016	Sa	21.8	40.6	0	NNW	39	15:44	37.7	13		SSE	9	1009.4	38.6	16	N	28	1006.4
20/11/2016	Su	23.2	43.2	0	WNW	50	14:25	37.5	17		SW	11	1008.2	38.9	26	WNW	39	1004.3
21/11/2016	Mo	25.7	42.7	0	WNW	50	17:56	38.6	9		SE	20	1007.6	40	12	NW	33	1003.6
22/11/2016	Tu	21.5	40.9	0	NW	52	16:32	37	14		ESE	15	1006.2	38.8	16	NW	35	1003
23/11/2016	We	20.6	32.9	0	ENE	43	10:11	29.2	60		ENE	30	1009.2	32	39	N	28	1006.8
24/11/2016	Th	21.2	36.7	0	N	39	14:10	29.3	56		ENE	13	1010.8	34.7	24	N	22	1007.1
25/11/2016	Fr	19.3	38.8	0	W	43	21:59	32.4	32		N	6	1010.6	38.1	10	NNW	20	1008.1
26/11/2016	Sa	24.2	42.1	0	NNE	35	11:56	38.2	11		SSE	15	1010.6	40	13	NW	17	1007.6
27/11/2016	Su	24.9	39.5	0	ENE	46	10:18	38.1	20		ESE	20	1010	38.4	25	NNE	24	1007.6
28/11/2016	Mo	25.6	41.2	0	N	43	14:00	38.6	21		SE	9	1009.4	37.5	27	N	35	1006.8
29/11/2016	Tu	28.1	42	0	N	41	13:16	35.4	37		SW	9	1009.3	37.8	26	NNW	28	1006.4
30/11/2016	We	26.6	42	0	WNW	48	16:25	35	39		SSE	9	1007.7	40.7	26	NW	28	1004.6
1/12/2016	Th	26.3	44.2	0	WNW	52	14:44	38.5	11		S	11	1007.2	40.5	15	WNW	43	1003.2
2/12/2016	Fr	24.8	39.6	0	WNW	50	15:59	34	32		W	20	1006.4	37.4	33	WNW	35	1004.2
3/12/2016	Sa	24.4	38.5	0	NW	46	13:09	31.9	41		W	17	1007.6	35.6	30	WNW	30	1005.8
4/12/2016	Su	24.3	36.2	0	WNW	44	15:59	30.6	38		W	15	1008.5	32.1	44	NW	28	1006.8
5/12/2016	Mo	20.5	36.4	0	N	37	15:40	29.8	53		NNW	13	1009.3	34.8	26	NNW	22	1006.4
6/12/2016	Tu	19.8	35.6	0	NNW	33	13:52	28.9	65		NNE	13	1010.2	34.9	30	N	20	1007.5
7/12/2016	We	27	37.3	0	NNE	39	12:51	32.2	52		NE	11	1011	35.9	36	N	24	1007.8
8/12/2016	Th	26.7	38.5	0.2	N	35	17:49	34.9	34		NNE	7	1009.5	37.5	30	NNE	19	1006.4
9/12/2016	Fr	28.4	40.8	0	E	46	19:33	34.6	39		ESE	17	1009.8	39	27	SSW	9	1006.2
10/12/2016	Sa	27.6	41.7	0	E	48	9:38	38.6	24		E	26	1009.8	38.4	32	N	33	1006.4
11/12/2016	Su	28.1	36.7	0	N	46	14:45	32.9	65		NNE	15	1009.7	35.1	53	N	33	1006.1
12/12/2016	Mo	25.2	36.4	8.4	NW	43	15:52	32.5	63		N	2	1009.7	35	53	NW	28	1007
13/12/2016	Tu	27	42.1	0	NW	50	14:43	36.4	33		SSW	9	1008.2	38.4	25	NW	37	1004.3
14/12/2016	We	25.8	36.3	0	ESE	48	7:29	34.2	37		E	31	1009	34.5	47	N	30	1006.3
15/12/2016	Th	24.8	36.4	0	NNE	37	12:51	32.2	56		N	9	1010.2	34.9	38	N	22	1007.3
16/12/2016	Fr	24.6	40.5	0	NW	44	13:08	34.5	28		WSW	13	1007.9	39.2	22	WNW	30	1004.9
17/12/2016	Sa	25.8	42.2	0	W	41	21:20	34.8	30		SW	15	1007.9	38.6	28	NW	31	1005.1
18/12/2016	Su	26.6	44.8	0	NW	43	16:02	38.3	24		SE	11	1006.1	40.3	25	NNW	31	1002.8
19/12/2016	Mo	25.6	36	0	N	43	9:30	33.1	49		N	31	1005.6	35.5	53	N	24	1004.2
20/12/2016	Tu	28.4	35.3	0	NNE	44	13:41	31.9	63		ENE	24	1006.1	33.1	62	NNE	30	1002.9
21/12/2016	We	23.7	40.2	4.8	ESE	57	4:25	33.5	50		SE	24	1004.1	37.4	39	N	28	1000.5
22/12/2016	Th	26.9	40.1	0	NE	33	14:39	34.5	45		ENE	9	1001.5	38.7	36	N	22	998.5
23/12/2016	Fr	28.1	42.1	0	NW	39	18:10	36.9	34		NE	9	998.8	39.9	32	NW	24	994.9
24/12/2016	Sa	28.8	38.2	0	N	43	15:34	33.3	65		ENE	15	999.5	36.3	47	N	31	996.4
25/12/2016	Su	28.7	40.8	0	NNW	44	13:32	34.7	47		WNW	9	1001.1	39.3	36	NNW	28	998
26/12/2016	Mo	28.8	39.7	0	NNW	44	14:31	32.7	62		W	19	1001.4	37.6	45	NW	31	997.7
27/12/2016	Tu	27.2	44	0	NW	52	14:29	34.2	48		WSW	13	1000.6	40.2	28	WNW	43	997.2
28/12/2016	We	24.4	40.3	0	NW	50	14:50	36	16		S	11	1003.5	37.4	20	NW	33	1000.8
29/12/2016	Th	24.7	40.2	0	W	43	0:04	34	25		S	9	1004.7	38.7	19	NW	22	1002
30/12/2016	Fr	25.3	40.9	0	WNW	50	16:50	32.1	27		W	20	1003.7	37.9	27	WNW	33	1000.3
31/12/2016	Sa	25.8	39.2	0	N	39	13:29	34.3	33		SSW	9	1004	37.6	35	NW	26	1001
1/01/2017	Su	25.1	34.8	0	W	39	23:43	31.3	58		N	9	1005.1	33.1	53	N	24	1002.9
2/01/2017	Mo	24.5	36.1	0	ESE	43	19:17	31.8	58		WSW	6	1006.8	34.4	41	N	22	1004.2
3/01/2017	Tu	24.8	42.1	0	WNW	41	16:28	33.6	41		W	17	1006.8	40.6	25	NNW	24	1002.7
4/01/2017	We	29.1	44.8	0	N	44	13:42	39.8	25		S	20	1003.7	40.9	27	NNW	26	1000.2
5/01/2017	Th	27	45.5	0	NNE	54	14:10	38.7	20		ESE	22	1001.8	42.5	13	NNE	24	998.5
6/01/2017	Fr	24.5	39.2	0	E	50	10:11	36.8	43		ESE	26	998.4	36.8	44	N	37	996
7/01/2017	Sa	25	38.2	0	NNW	39	14:05	32.6	57		NE	19	1001.4	35.1	47	NNW	24	998.6
8/01/2017	Su	24.2	40.5	0	NW	48	16:30	33.8	50		E	17	1002.1	38.2	35	NW	30	999.3
9/01/2017	Mo	26.1	40.7	0	NW	46	15:28	32.8	48		SSW	13	1004	38.2	38	NW	28	999.9
10/01/2017	Tu	27.2	38.9	0	NW	48	17:05	32.2	51		W	15	1004.9	37.3	43	NW	35	1001.3
11/01/2017	We	27.4	37.5	0	WNW	46	18:38	32.8	54		SSW	9	1004.6	36.2	47	WNW	26	1000.6
12/01/2017	Th	27	38.2	0	NW	46	14:40	31.4	59		W	19	1002.6	36.3	43	WNW	35	998.4
13/01/2017	Fr	27.7	34.6	0	NNE	37	12:18	28.2	85		E	19	1004	32.4	57	NNE	19	1002.4
14/01/2017	Sa	23.6	34.3	8	SSE	41	1:49	29.4	76		SE	19	1005.6	33.2	57	ESE	22	1003.2
15/01/2017	Su	25.9	34.1	0	NNE	39	10:49	30.6	66		NE	17	1006.4	32.2	61	NNE	26	1004.7
16/01/2017	Mo	26	35.6	0.4	N	35	12:59	31	65		WNW	2	1006.8	34	53	N	24	1004.2
17/01/2017	Tu	26.5	35.8	0	NW	43	13:31	30.6	55		WNW	13	1006.3	34.2	49	NW	30	1003.9
18/01/2017	We	26.7	35.7	0	NW	46	14:02	30.2	66		WNW	17	1007.2	34.2	51	WNW	33	1003.8
19/01/2017	Th	24.3	38.5	0	WNW	57	16:55	29.4	48		WSW	28	1006.3	35.7	37	WNW	35	1002.1
20/01/2017	Fr	24.6	37.1	0	NW	54	14:34	30	49		W	24	1004.3	34.3	46	WNW	39	1001.1
21/01/2017	Sa	26	33.2	0	WNW	46	17:13	29.2	62		WSW	19	1006.7	30.3	58	WNW	31	1004.8
22/01/2017	Su	23.7	36.8	0	WNW	59	14:57	29.2	55		W	30	1009.2	34.5	43	WNW	39	1005.6
23/01/2017	Mo	24.1	37.5	0	NW	50	15:09	29.3	57		WSW	19	1007.5	34.1	47	NW	39	1004.6
24/01/2017	Tu	25.1	35	0	NW	39	15:55	29	64		WNW	17	1009.3	33.8	49	NW	28	1006.4
25/01/2017	We	26.2	40.2	0	NNW	48	14:41	34.2	49		SSE	13	1010.1	38.1	38	NNW	24	1004.8
26/01/2017	Th	28.4	39.2	0	SW	78	15:42	32.5	65		W	13	1007.4	36.5	45	NW	28	1003.1

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