Prepared for:	Data and Information Committee
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Activity:	Governance Report
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PURPOSE

[1] This paper presents and discusses the results of a $PM_{2.5}$ air quality monitoring survey undertaken in 14 of Otago's airsheds during winter 2021.

EXECUTIVE SUMMARY

[2] $PM_{2.5}$ was monitored in 14 of Otago's airsheds during winter 2021 (July to September, inclusive) using low-cost sensors, ahead of the release of the new National Environmental Standard for $PM_{2.5}$. This was the first time in many years that some of these airsheds have been investigated and the concurrent monitoring allowed for direct comparisons between them.

[3] All airsheds except for Kingston recorded elevated $PM_{2.5}$ concentrations at night, with a secondary spike in the morning, indicating home heating emission sources. The $PM_{2.5}$ concentrations of the airsheds varied; Lake Hāwea, Luggate, Ranfurly and Oamaru had the highest mean concentrations for the monitoring period, and Lake Hāwea recorded the highest 24-hour average $PM_{2.5}$ concentration of 58 $\mu g/m^3$.

[4] Further monitoring and investigations should be considered to understand some of these airsheds in the context of our State of the Environment (SOE) monitoring network, the future NESAQ limits and for future air quality management.

RECOMMENDATION

That the Data and Information Committee*:*

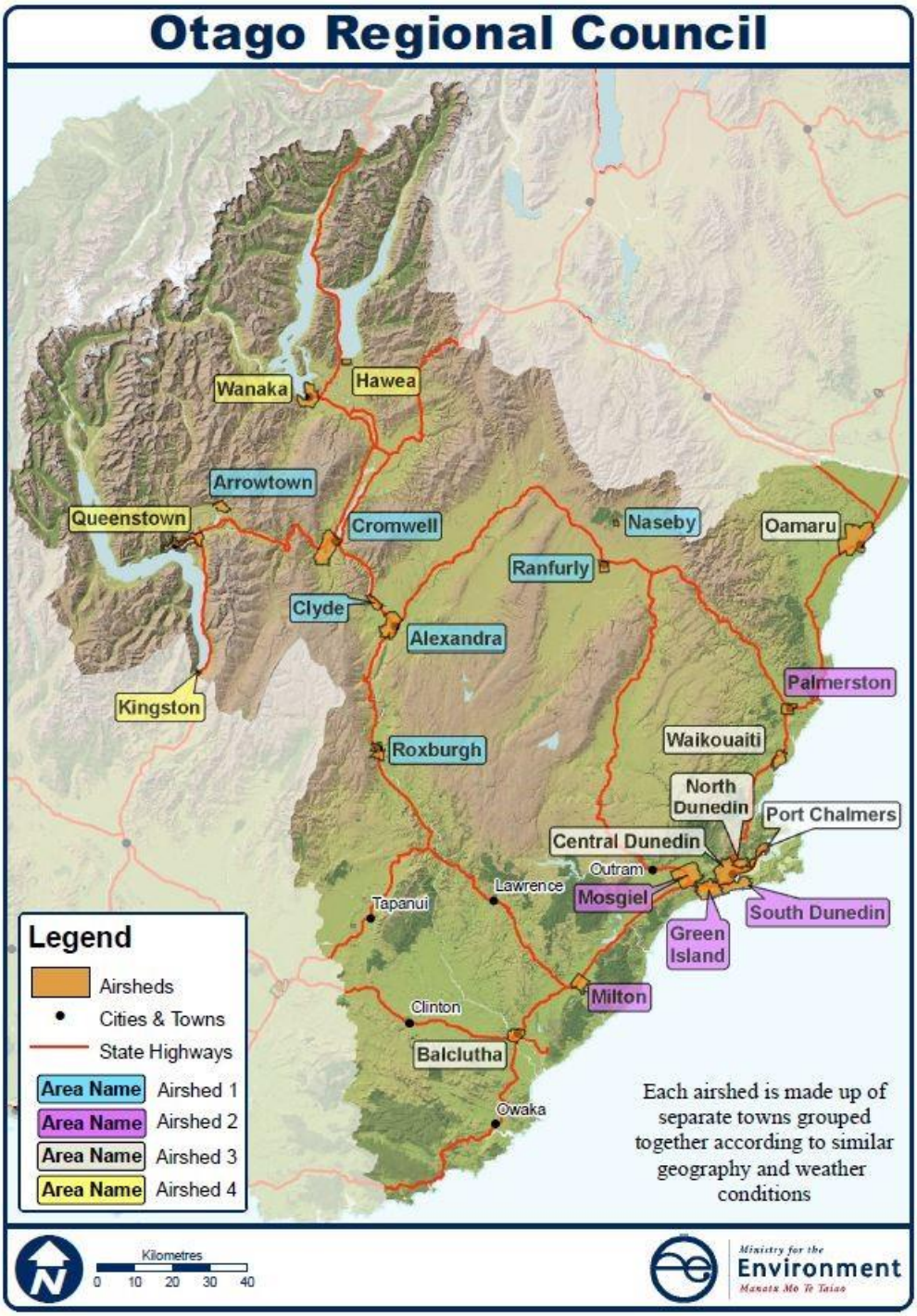
1) ***Notes** this report.*

INTRODUCTION

[5] The Otago Regional Council has 22 gazetted airsheds, seven of which are currently monitored for PM_{10} (particulate matter with a diameter of less than 10 micrometres). Particulate matter is the main pollutant of concern in Otago (Environet, 2019). Of the 22, there are 15 airsheds that have either not been monitored for many years, or at all, due to the high cost of standard method monitoring instruments. Under the National Environmental Standards for Air Quality (NESAQ), ORC is required to monitor any airshed that is likely to exceed any of the limits set out in the NESAQ.

[6] The 22 air sheds are currently organised into groups and given a rating from 1 – 4, indicating highest to lowest potential for degraded air quality (Figure 1). A fifth group encompasses the rest of Otago, rural areas and smaller towns.

Figure 1: Gazetted airsheds in Otago



[7] The grouping of airsheds across Otago allowed ORC to be able to assign key indicators from each category and monitor these as proxies for the rest in the group (currently Arrowtown, Central Dunedin and Mosgiel). The groupings were based on early monitoring data, and geographic or climatic similarities where monitoring data was unavailable. For the purposes of regulation, ORC also further categorised the airsheds into Air Zones (Air Zone 1 – 3). Air Zone 1 is the highest priority for air pollution management and has the strictest rules for wood burning appliances.

[8] Of the 22 airsheds, 12 have not been monitored in many years, and a further three ungazetted airsheds (Lawrence, Luggate and Middlemarch) were added to the study. Lawrence has been the subject of air quality investigations in the past which indicated regular occurrences of PM_{10} exceedances. Luggate is at risk due of air quality issues due to recent urban growth.

Table 1: Otago's airsheds and monitoring history

Airshed	Airshed Number	Air Zone Number	Most recent year of monitoring
Alexandra	1	1	Current
Arrowtown			Current
Clyde			Current
Cromwell			Current
Naseby		2	2007
Ranfurly			2008
Roxburgh			2007
Palmerston	2		2014
Mosgiel			Current
South Dunedin			2009
Green Island			2002
Milton			Current
Balclutha	3		2018
North Dunedin			2007
Central Dunedin			Current
Oamaru			2009
Port Chalmers			NA
Waikouaiti			NA
Hāwea	4		NA
Kingston			NA
Queenstown			To be installed
Wānaka			To be installed
Middlemarch	Not gazetted	3	NA
Lawrence			2012
Luggate			NA

[9] The development of low-cost sensors for air quality monitoring provided a useful opportunity to undertake more widespread monitoring ahead of proposed changes to the NESAQ. These sensors can be used in networks of multiple units to understand spatial patterns and movements of air pollution to a very local level, which is something a single standard method instrument cannot do. However, these instruments are less reliable and have less accuracy than standard method monitoring and must be corrected to a reference instrument. The data quality and reliability issues associated with low-cost sensors need to be considered when interpreting data, but

these drawbacks are offset by the cost of these sensors, and the large number of them which can be deployed. As such, they are well suited to screening studies to determine if an area may have degraded air quality.

METHODS

[10] The study that this paper informs used Outdoor Dust Information Nodes (ODINs), developed by NIWA. ODINs are less accurate than the instruments used in our SOE network, but when used as a network they agree with each other within a range of 20% (NIWA, 2020). Once the data is corrected, it can represent 90% of the variability in $PM_{2.5}$ concentrations from woodsmoke sources (Olivares *et. al*., 2014). ODINs have been used in New Zealand in recent years to investigate variation in particulate matter from home heating emissions, and there were enough of them available to monitor ORC's large number of airsheds simultaneously.

[11] A total of 47 ODINs were installed within 15 airsheds (Figure 2), with at least three ODINs in each airshed. In most cases the ODINs were attached to lampposts at a height of 3 metres, but in towns that didn't have lampposts, alternative mounting structures such as fences were used.

Figure 2: Monitoring locations

[12] The ODINs were installed for a three-month period from the start of July until the end of September 2021. Data were recorded by the ODIN's dataloggers and were downloaded twice: during a mid-campaign retrieval at the start of August, and at the end of the campaign. All the ODINs were placed at the Alexandra air quality SOE site for two weeks during October 2021 as a co-location to compare the instruments and correct the data. The ODIN data was accordingly corrected[1] to the reference instrument (MetOne ES642).

Figure 3: ODIN attached to a lamppost. Source: Bodeker Scientific, 2021

RESULTS

[13] Of the 47 ODINs, 29 of them returned at least 50% valid data; and 28 returned over 95% valid data. Consequently, except for Waikouaiti where no valid data was available, every airshed was monitored for the full monitoring period (Table 2). The reasons for missing data included failure to log data either during the monitoring period or the co-location, technical issues with the instruments, or theft/vandalism of the instruments.

Table 2: Data capture results

Airshed name	Number of ODINs installed	Number with data
Green Island	3	3
Hāwea	3	3
Kingston	3	1
Lawrence	3	2
Luggate	3	2
Middlemarch	3	1
Naseby	3	2
North Dunedin	3	2
Oamaru	4	2
Palmerston	3	1
Port Chalmers	3	2
Ranfurly	3	3

[1] This process is described in Bodeker Scientific, 2021.

Roxburgh	3	3
South Dunedin	4	2
Waikouaiti	3	0
Total	**47**	**29**

[14] For the airsheds where two or more ODINs returned complete data sets, the set with the highest average concentration was chosen to represent that airshed for the purposes of comparing between airsheds. Most airsheds showed elevated 24-hour average concentrations of $PM_{2.5}$ during the winter months of July and August (Figure 4). The Lake Hāwea site recorded the highest 24-hour average $PM_{2.5}$ concentration of 58 µg/m³, followed by Green Island with 54 µg/m³ (Table 3). The sites with the lowest median concentrations were in Kingston, followed by Middlemarch and Roxburgh (Figure 5).

Figure 4: $PM_{2.5}$ timeseries at each airshed (24-hour average)

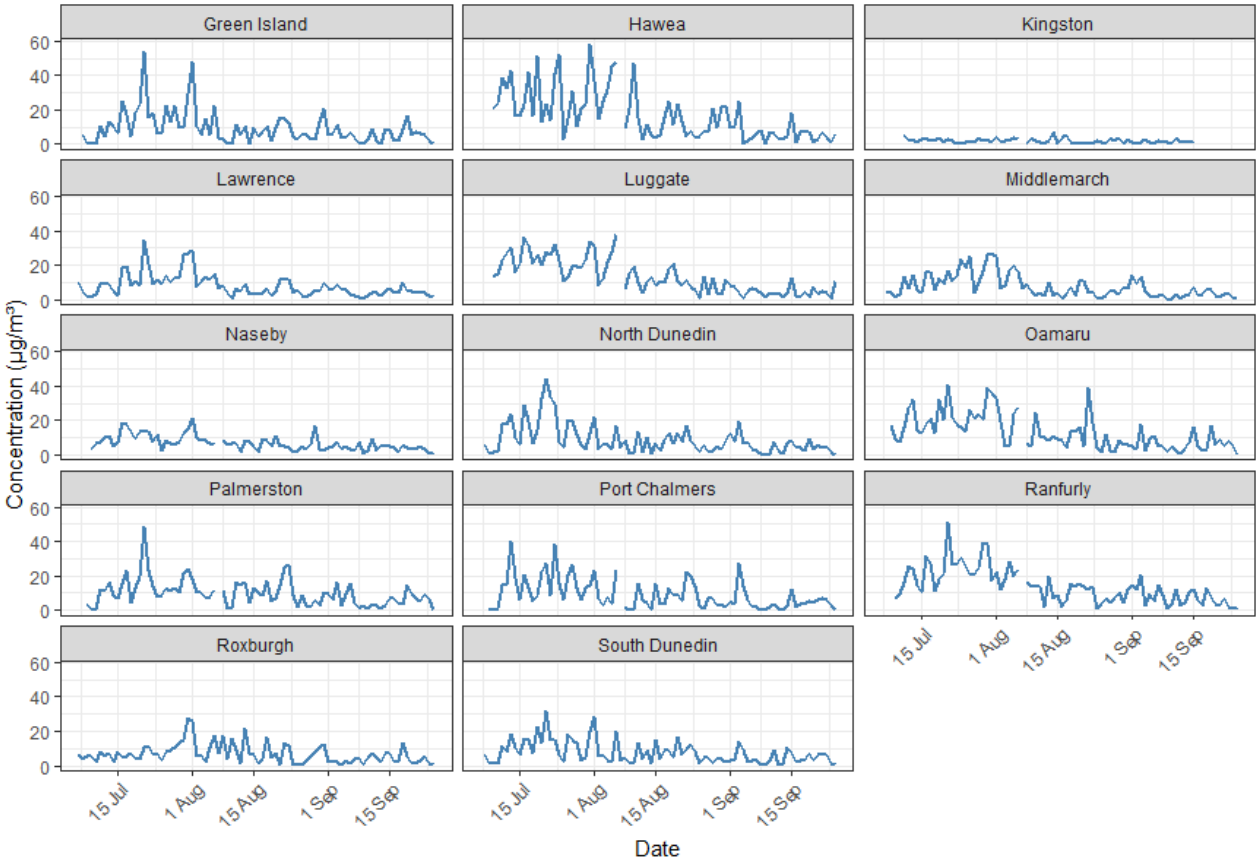
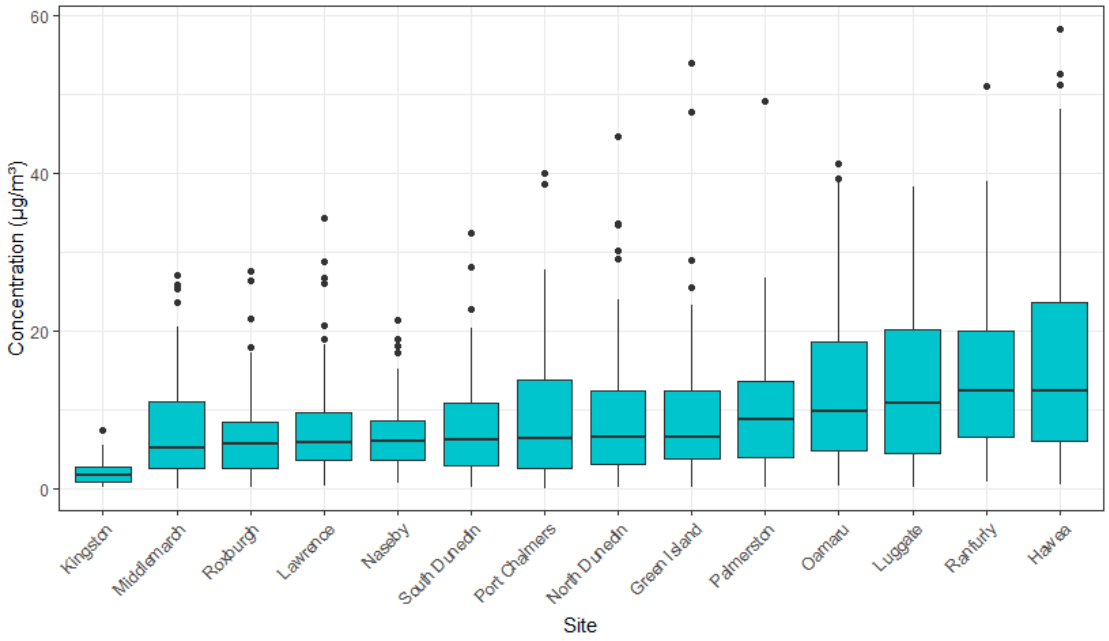


Table 3: Average and maximum concentrations of $PM_{2.5}$ by airshed

Airshed	ODIN number	PM 2.5 Concentration (µg/m³)		
		Monitoring average	July-August (winter) average	Maximum 24-hour average
Green Island	ODIN013	9	11	54
Hāwea	ODIN032	17	22	58
Kingston	ODIN015	2	2	7
Lawrence	ODIN167	8	9	34
Luggate	ODIN172	13	17	38
Middlemarch	ODIN050	8	9	27
Naseby	ODIN155	7	8	21
North Dunedin	ODIN042	9	11	45
Oamaru	ODIN017	13	16	41
Palmerston	ODIN045	10	12	49
Port Chalmers	ODIN020	9	11	40
Ranfurly	ODIN170	14	17	51
Roxburgh	ODIN065	7	8	28
South Dunedin	ODIN041	8	9	32

Figure 5: Distribution of $PM_{2.5}$ concentrations (24-hour average)

The box represents the interquartile range, with the median represented by the horizontal bar. The whiskers represent the smallest/largest values plus 1.5 times the interquartile range, and outliers are outside the whiskers.



[15] The regional variation of $PM_{2.5}$ concentrations are plotted spatially in Figures 6 and 7. Lake Hāwea, followed by the Luggate, Ranfurly and Oamaru sites had the highest average $PM_{2.5}$ concentrations during the winter months (Figure 6). The highest maximum 24-hour averages occurred in Lake Hāwea, Ranfurly, Palmerston and Green Island (Figure 7).

Figure 6: Mean winter $PM_{2.5}$

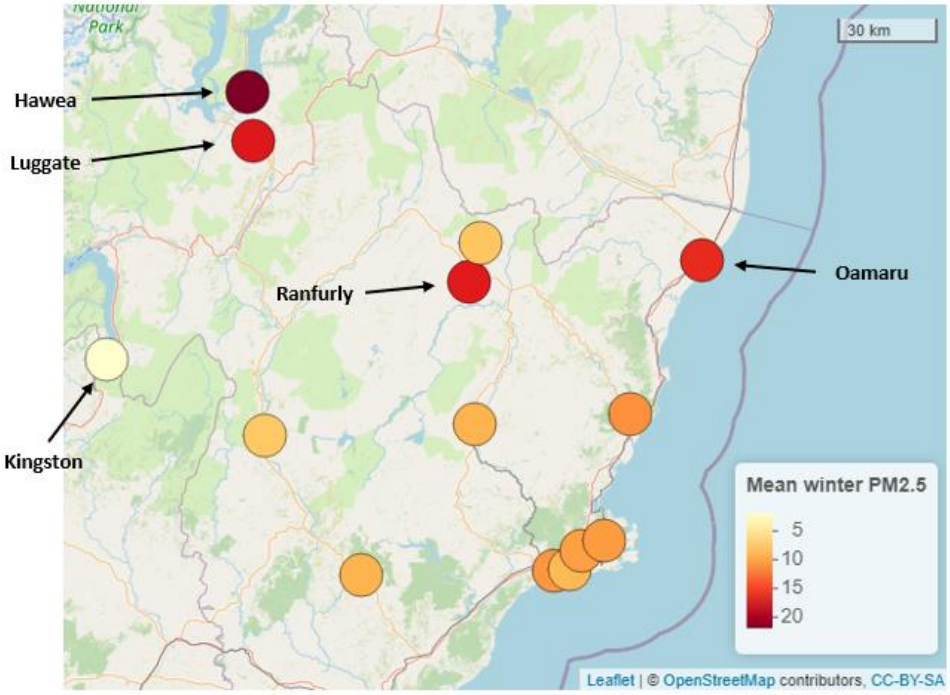
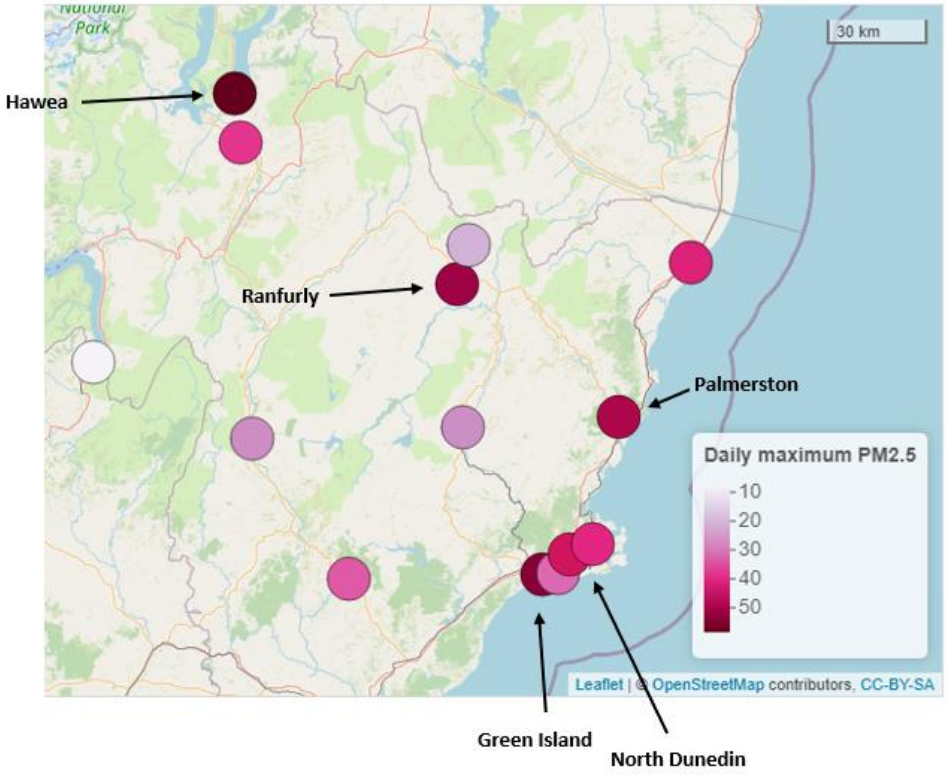


Figure 7: Daily maximum $PM_{2.5}$ concentration



[16] The relationship with wind speed and ambient temperature was examined at the four sites where meteorological data was available (Figures 8 and 9): Middlemarch, Oamaru, Ranfurly and South Dunedin. This data shows that wind speed has a stronger relationship with $PM_{2.5}$ than ambient temperature does for all four sites. Higher concentrations occurred on days with low wind speeds and less dispersion, which aligns with observations made within the SOE network (ORC, 2021). The relationship

with ambient temperature is the least strong at South Dunedin, which is similar to the pattern shown at Central Dunedin (ORC, 2021) and may indicate the presence of other sources of particulate matter, however more data would be needed to confirm this.

Figure 8: Relationship between $PM_{2.5}$ and wind speed

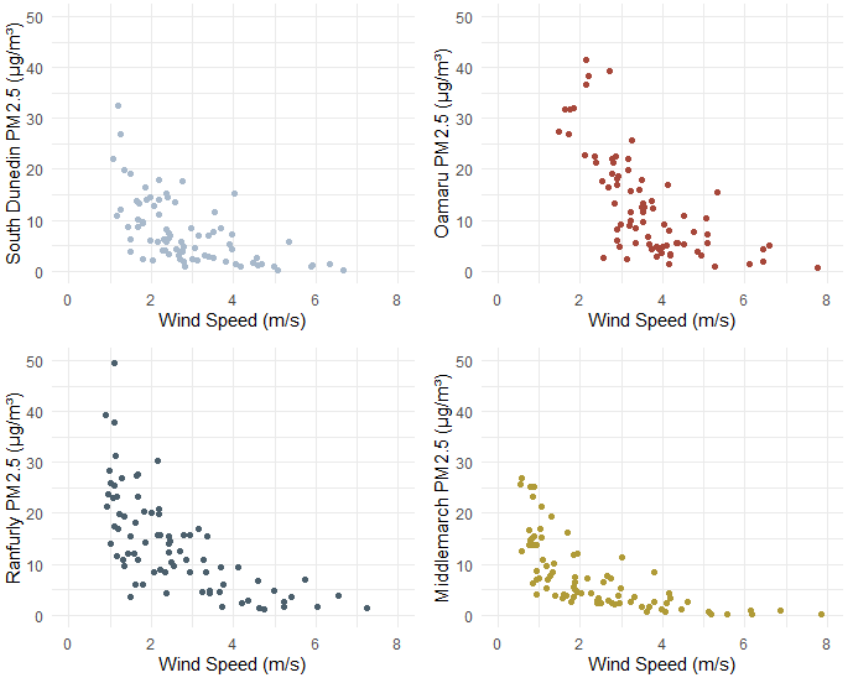
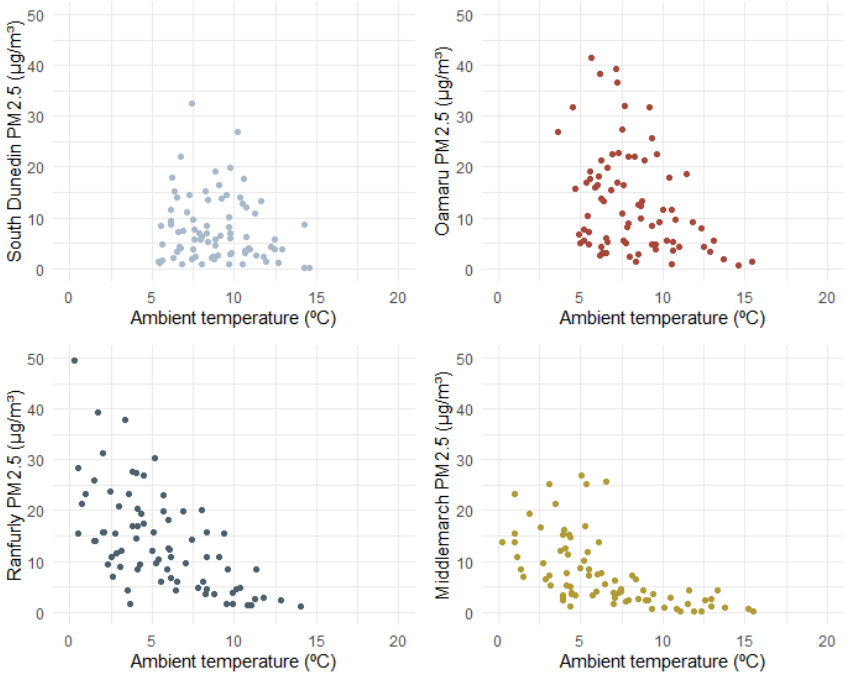


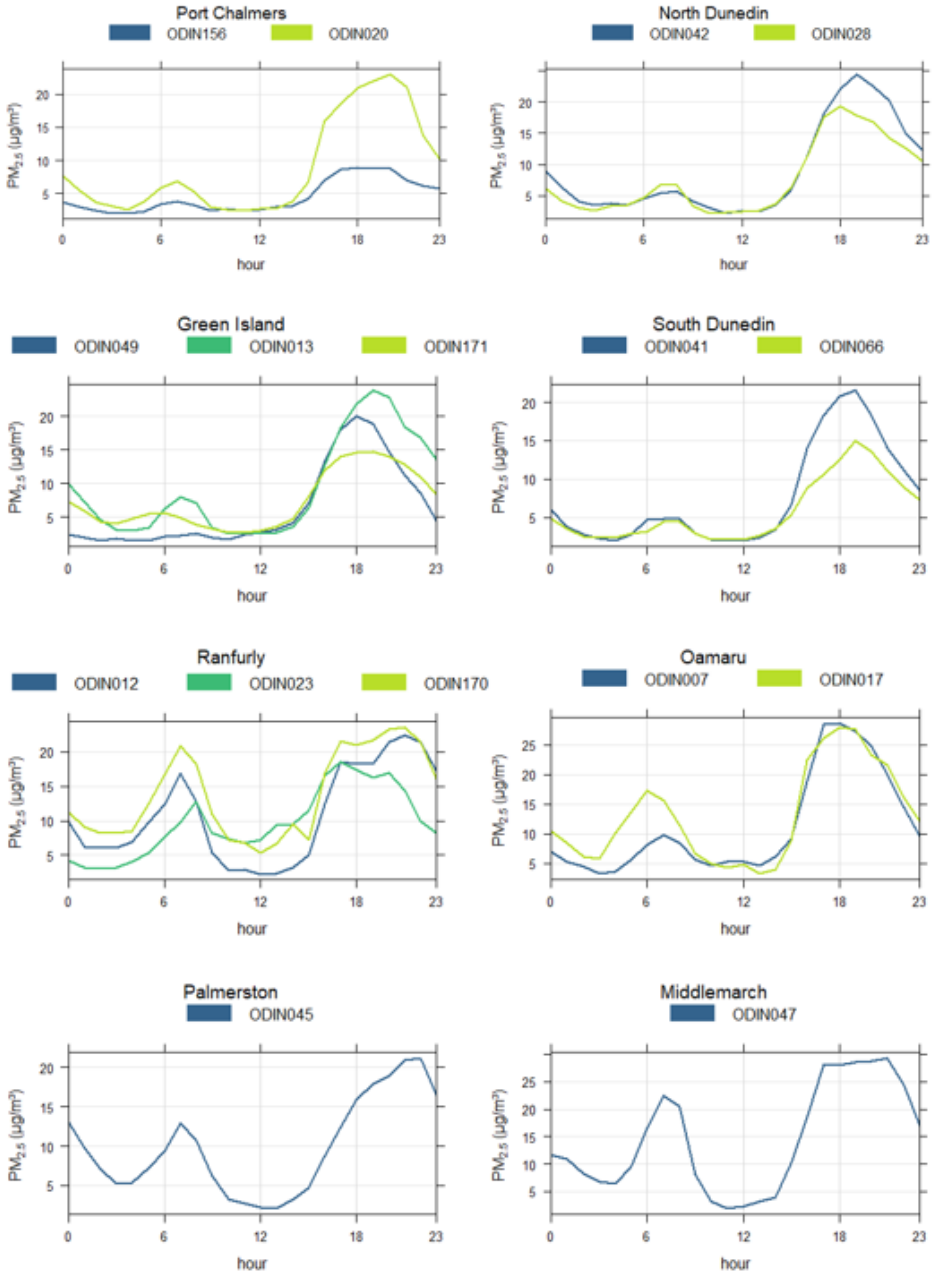
Figure 9: Relationship between $PM_{2.5}$ and ambient temperature

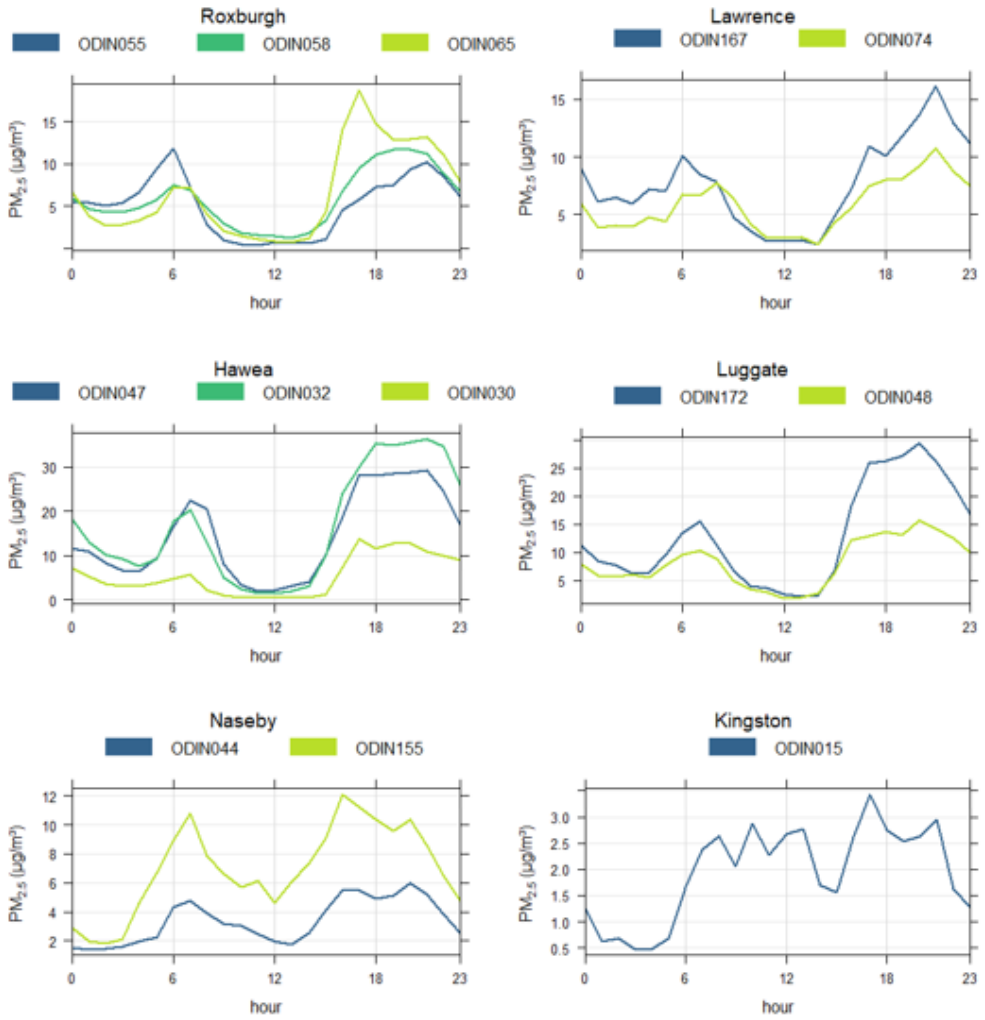


[17] The diurnal data from all ODINs display typical home heating signatures, represented by a large evening peak, and a smaller morning peak (Figure 10). The only site that does not display this pattern is the Kingston site. Further investigation would be needed to confirm this however possible reasons include Kingston has very few

emissions or the site was not located near the source of any emissions and was recording background concentrations. The plots below also demonstrate the spatial variation present in most airsheds, particularly between ODINs placed in Port Chalmers, Lake Hāwea and Luggate. This means these airsheds have more variability of emissions and/or pollutant dispersion. An interesting feature of the Lake Hāwea, Ranfurly and Luggate sites is the presence of a third peak in the late evening. A similar pattern occurs at the SOE site at Alexandra, where the atmospheric processes allow for a brief period of vertical temperature mixing and pollution dispersion before resuming stability for the rest of the night (ORC, 2021).

Figure 10: Diurnal $PM_{2.5}$ concentrations for each ODIN, separated by airshed





DISCUSSION

[18] The results of this study show that there are elevated concentrations of $PM_{2.5}$ in most airsheds in Otago, including non-gazetted airsheds such as Luggate, Middlemarch and Lawrence. The $PM_{2.5}$ data showed higher concentrations during winter months, as well as a diurnal pattern that characterises home heating emissions. These temporal patterns were present in all 29 monitoring locations that returned valid data, except for the site in Kingston.

[19] The $PM_{2.5}$ concentrations varied between and within airsheds, with the highest averages for both the monitoring period and the winter months being measured in Lake Hāwea, Luggate, Ranfurly and Oamaru. Spatial variation of the particulate matter was displayed in many of the airsheds where more than one ODIN returned data. This helped identify areas of high concentrations and/or low dispersion and will be helpful for guiding site locations for future investigations.

[20] The NESAQ is currently being updated to include a limit for $PM_{2.5}$. The proposed 24-hour limit is 25 µg/m³, and the current limit for PM_{10} is 50 µg/m³. The World Health Organization now recommends the $PM_{2.5}$ and PM_{10} limits to be set at 15 and 45 µg/m³ respectively, for 24-hour averages (WHO, 2021).

[21] The uncertainty associated with the higher recorded $PM_{2.5}$ concentrations mean that the data cannot be confidently compared to the proposed limits for the NESAQ. However, considering this uncertainty it is still clear that some of these airsheds are at risk of exceeding the proposed $PM_{2.5}$ limit of 25 µg/m³.

[22] The results of this study will be useful when assessing our existing gazetted airsheds and Air Zones for the upcoming review of the Regional Air Plan. The data supports the need to assess the airsheds to reflect current particulate matter concentrations, and future monitoring would be beneficial to confirm the extent of $PM_{2.5}$ issues and the likelihood of future exceedances of the NESAQ.

[23] The main limitations of this study were timing the co-location and type of reference instrument. The co-location was undertaken in October, with only low concentrations measured. Consequently, the higher concentrations in the dataset from this study have higher uncertainty. The reference instrument used was a hired non-reference method instrument (MetOne ES642), which means the collected data cannot be compared to relevant guidelines and limits, however this correction did allow for the accurate comparison between all ODINs. These limitations can be improved upon in future, by conducting two co-locations instead of one, and making sure one of them occurs during typical winter weather. Another improvement would be to correct the ODINs to an ORC SOE instrument, to be able to best compare with our SOE sites, and to relevant standards and guidelines.

REFERENCES

Bodeker Scientific, 2021. *2021 Otago Airsheds Particulate Matter Survey.*

Environet, 2019. *Wanaka, Cromwell and Clyde Air Emission Inventory – 2019.*

Olivares, G., Edwards, C., Longley, I., 2014. *The Outdoor Dust Information Node - ODIN Development and first tests.* NIWA, 41 Market Place, Auckland, NZ

ORC, 2021. *State and Trends of Air Quality in the Otago Region 2010-2019.*

World Health Organization, 2021. *WHO global air quality guidelines. Particulate matter (PM_{10} and $PM_{2.5}$), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.*

CONSIDERATIONS

Strategic Framework and Policy Considerations

[24] This information may be useful for the assessment and comparison of airsheds and emission reduction scenarios modelling.

Financial Considerations

[25] NA

Significance and Engagement Considerations

[26] NA

Legislative and Risk Considerations

[27] NA

Climate Change Considerations

[28] NA

Communications Considerations

[29] NA

NEXT STEPS

[30] Further monitoring or investigations should be considered for Lake Hāwea, Ranfurly, Luggate, Oamaru and the Dunedin airsheds.

ATTACHMENTS