# Vortex Air Quality Sensor Performance - Southwark

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## 1 Background

This is a summary report for Vortex IoT for the period 01/04/2021 to 12/07/2021 assessing the performance of particulate matter ($PM_{10}$ and $PM_{2.5}$) sensors. The sensors form part of a small network in Southwark, London and provide data at a time averaged resolution of 5-minutes. Nearby reference sites, which provide 15-minute average data, were used for comparison to the sensors. Sensor system data is aggregated to 15-minute, hourly and daily averages for the comparisons with reference data. Analyses have been carried out using sensor data as supplied by Vortex IoT - no further adjustments have been carried out by Ricardo.

## 2 Monitoring stations

The map below (Figure 1) shows the sensor network (blue markers) and reference sites (red markers) used for this assessment. Further details of the sites are summarised in Table 1.

Southwark Borough Council operate five automatic air quality monitoring sites (reference), in addition to the six sensor sites. The closest of these reference sites to the sensor network is Southwark - Lower Road with SW-AQM-01 co-located within 5 m of the site.

***Figure 1: Location map of air quality monitoring sites***


***Table 1: Site information summary***

| Site Name | Type | Pollutants Measured | Latitude | Longitude |
|---|---|---|---|---|
| SW-AQM-01 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49664 | -0.05256 |
| SW-AQM-02 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49702 | -0.05091 |
| SW-AQM-03 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49784 | -0.04952 |
| SW-AQM-04 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49562 | -0.05155 |
| SW-AQM-05 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49451 | -0.04993 |
| SW-AQM-06 | Sensor | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | 51.49741 | -0.05394 |
| Southwark - Lower Road | Reference | $NO_2$, $PM_{10}$, $PM_{2.5}$ | 51.49656042 | -0.053050447 |
| Southwark - Vicarage Grove | Reference | $NO_2$, $PM_{10}$, $PM_{2.5}$ | 51.47358035 | -0.087781854 |
| Southwark - A2 Old Kent Road | Reference | $NO_2$, $PM_{10}$, $PM_{2.5}$ | 51.48049949 | -0.059552893 |
| Southwark - Elephant and Castle | Reference | $PM_{10}$, $PM_{2.5}$ | 51.4931557 | -0.101527038 |
| Southwark - Tower Bridge Road | Reference | $NO_2$, $PM_{10}$, $PM_{2.5}$ | 51.50139067 | -0.078203437 |

## 2.1 Air Quality Strategy Objectives

The European Air Quality Directive and Fourth Daughter Directive set out legal limits for different pollutants as Limit Values (LV), Target Values or Long Term Objectives to protect human health and have been transposed into UK law. Table 2 summarises the air quality strategy objectives for England for $PM_{10}$ and $PM_{2.5}$ and shows the objectives in units of micrograms per cubic metre (µg $m^{-3}$) with the number of exceedances in each year that are permitted (where applicable).

***Table 2: Air quality objectives, England***

| Pollutant | Metric | Type | Legal Value (µg $m^{-3}$) |
|---|---|---|---|
| $PM_{10}$ | 24-hr mean | LV | 50 (35 allowed) |
| $PM_{10}$ | Annual mean | LV | 20 |
| $PM_{2.5}$ | Annual mean | LV (Stage 1) | 25 |
| $PM_{2.5}$ | Annual mean | LV (Stage 2) | 20 |

# 3 Data Analysis

## 3.1 Summary statistics

Tables 3 and 4 present pollutant statistics for the period 01/04/2021 to 12/07/2021 for $PM_{10}$ and $PM_{2.5}$, respectively. Note that at a data capture rate of at least 85% over a calendar year is required in order to directly compare statistics to the air quality objectives. However, the objectives do provide a useful reference point for the purposes of this assessment. It is also important to note that all data from reference sites were provisional at the time of carrying out this assessment and that statistics were calculated using hourly average data.

Sensor data capture rates for $PM_{10}$ and $PM_{2.5}$, SW-AQM-01 and SW-AQM-05, achieved a data capture rate of 63.7% and 79% with all others achieving greater than 90%. In general data coverage was comparable to what is seen in the provisional reference data sets. Measured mean $PM_{10}$ and $PM_{2.5}$ concentrations by the sensor network are again lower than that measured by the reference network. However, hourly maximum concentrations are consistent with what was seen at Southwark - Lower Road. In terms of numbers of daily $PM_{10}$ exceedances, 1 to 2 exceedances were measured at the sensor sites compared to 0 by the reference network.

***Table 3: Summary of statistics for $PM_{10}$***

| Site | Mean (µg $m^{-3}$) | Data Capture (%) | Hourly Maximum (µg $m^{-3}$) | Days Exceeding |
|---|---|---|---|---|
| SW-AQM-01 | 12.9 | 63.7 | 183.7 | 2 |
| SW-AQM-02 | 10.5 | 91.2 | 118.6 | 0 |
| SW-AQM-03 | 13.6 | 91.3 | 157.9 | 2 |
| SW-AQM-04 | 10.9 | 91 | 154.4 | 2 |
| SW-AQM-05 | 13.2 | 79 | 191.6 | 2 |
| SW-AQM-06 | 10.2 | 90.5 | 168.7 | 1 |
| Southwark - Lower Road | 13.6 | 98.6 | 209.5 | 0 |
| Southwark - Vicarage Grove | 14.7 | 98.6 | 98.9 | 0 |
| Southwark - A2 Old Kent Road | 16.5 | 98.6 | 136.2 | 0 |
| Southwark - Tower Bridge Road | 17.1 | 98.5 | 109 | 0 |
| Southwark - Elephant and Castle | 13.9 | 93.4 | 102.2 | 0 |

***Table 4: Summary of statistics for $PM_{2.5}$***

| Site | Mean (µg $m^{-3}$) | Data Capture (%) | Hourly Maximum (µg $m^{-3}$) |
|---|---|---|---|
| SW-AQM-01 | 3.9 | 63.7 | 72.4 |
| SW-AQM-02 | 3.3 | 91.2 | 47.3 |
| SW-AQM-03 | 5.2 | 91.3 | 77.2 |
| SW-AQM-04 | 4.1 | 91 | 62.6 |
| SW-AQM-05 | 4.1 | 79 | 75.1 |
| SW-AQM-06 | 3.3 | 90.5 | 71.2 |
| Southwark - Lower Road | 7.8 | 98.6 | 80 |
| Southwark - Vicarage Grove | 8.7 | 98.6 | 86.2 |
| Southwark - A2 Old Kent Road | 8.7 | 98.6 | 86.2 |
| Southwark - Tower Bridge Road | 9.7 | 98.5 | 95.3 |
| Southwark - Elephant and Castle | 8.3 | 93.4 | 91.7 |

## 3.2 Time series plot

The plots in Figures 2 to 7 show the time series of 15-min, hourly and daily average PM concentrations. These plots provide a good method for comparing trends in pollutant concentrations at different sites. The time series plots for $PM_{10}$ and $PM_{2.5}$ show that the sensor measurements trend closely with the nearby reference sites. In general, the sensors measure lower PM concentrations than the reference sites and is more apparent for $PM_{2.5}$.

***Figure 2: Time series plot of 15-minute $PM_{10}$ concentrations***

***Figure 3: Time series plot of hourly $PM_{10}$ concentrations***

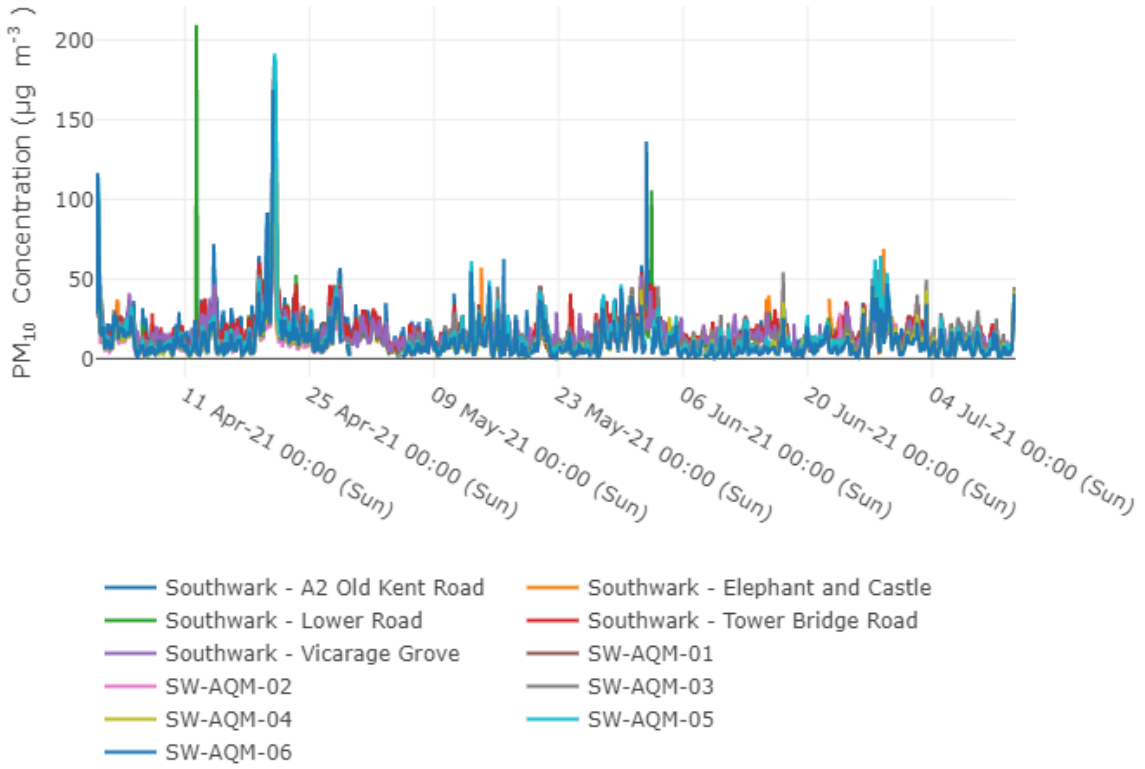



***Figure 4: Time series plot of daily $PM_{10}$ concentrations***

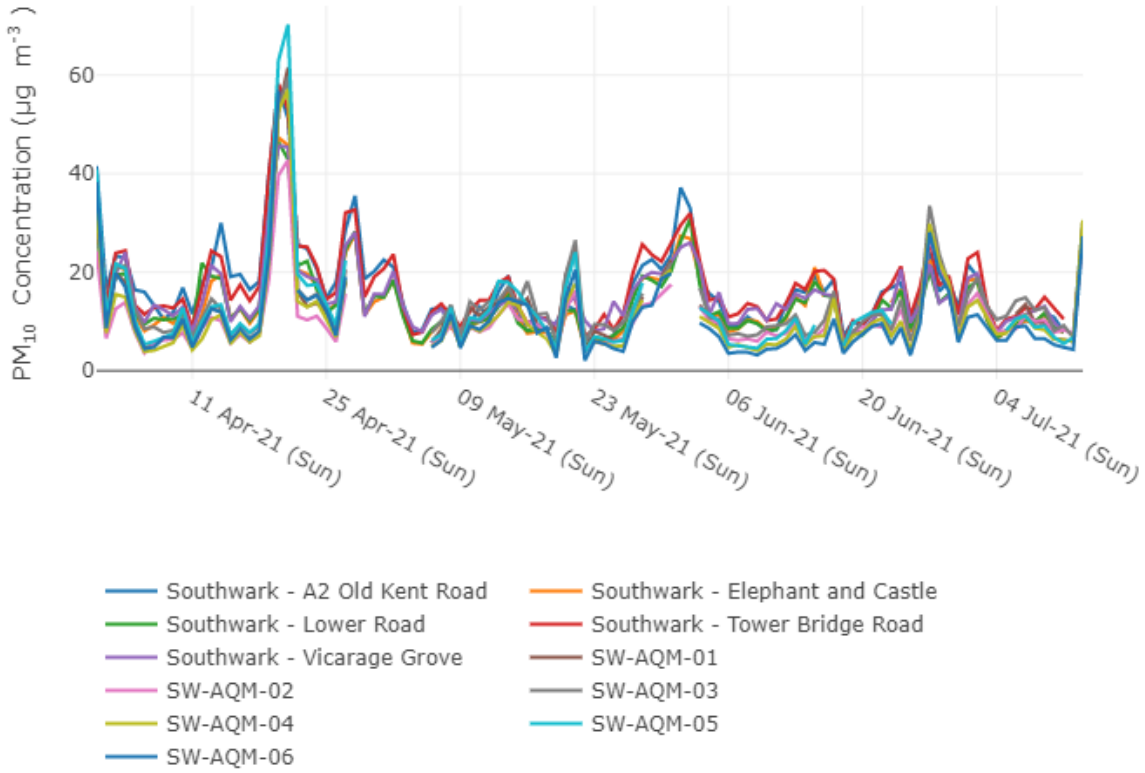


***Figure 5: Time series plot of 15-minute $PM_{2.5}$ concentrations***

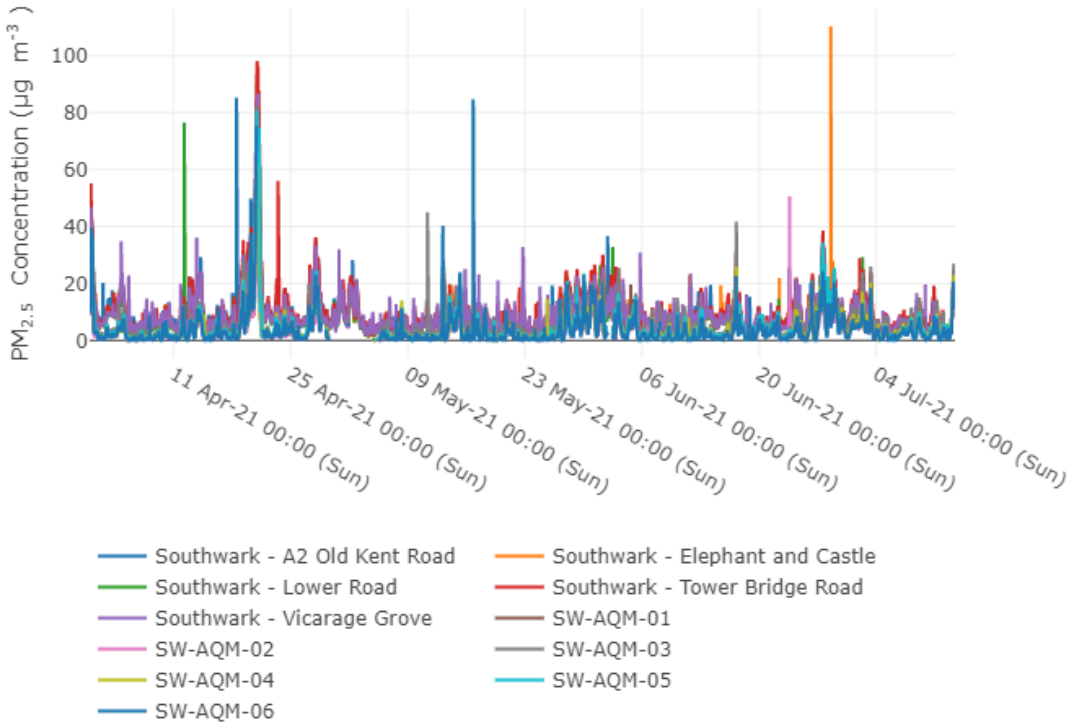



***Figure 6: Time series plot of hourly $PM_{2.5}$ concentrations***

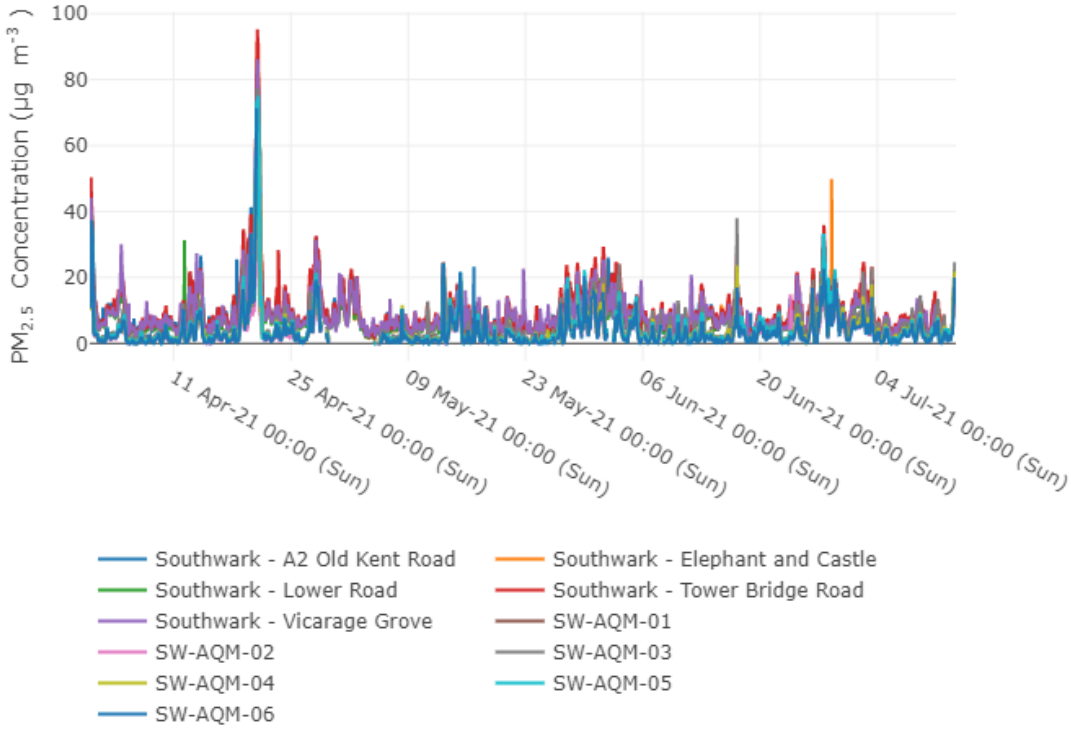
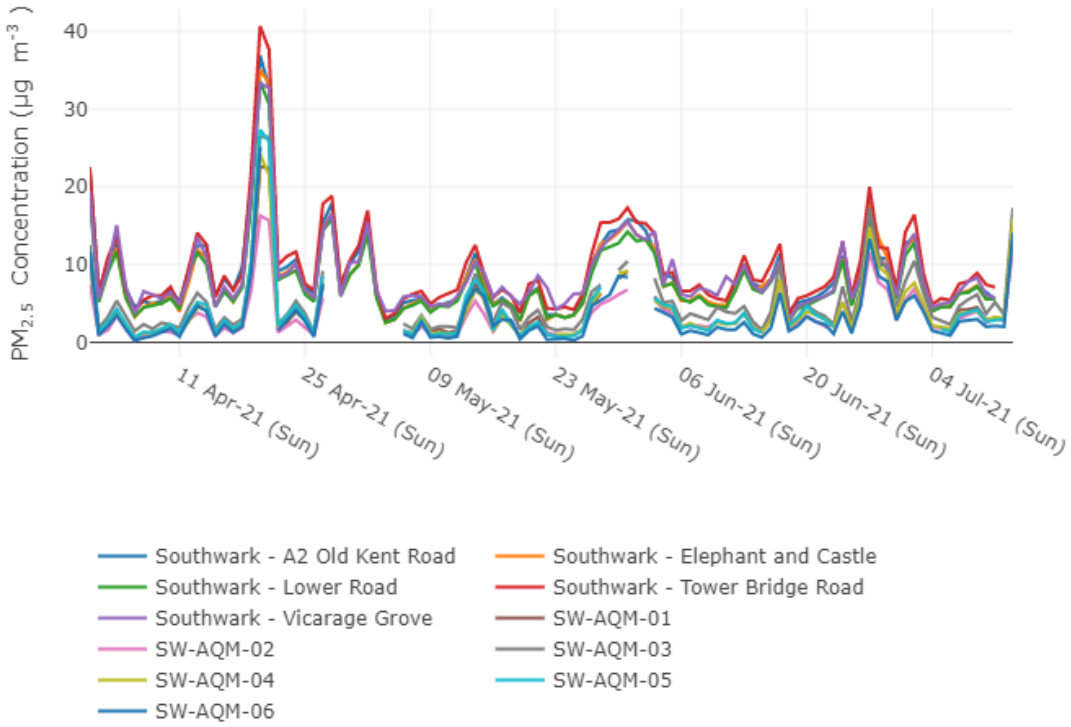


***Figure 7: Time series plot of daily $PM_{2.5}$ concentrations***




## 3.3 Correlation

The plots shown in Figures 8 to 13 are correlation plots of the relationships between the Vortex sensors and nearby Southwark Borough Council or AURN reference sites for $PM_{10}$ and $PM_{2.5}$. These plots quickly highlight patterns in the relationships between the sensor and reference sites.

$PM_{10}$ and $PM_{2.5}$ sensor measurements correlate very well with reference sites and is particularly strong in the daily averages. Again, two distinct groups can be seen in the plots with sensors and reference sites correlating more strongly in the intra-comparisons than with each other, but this confirms what was seen in the time series plots that the sensors are capturing the variation in PM concentrations with good precision.

***Figure 8: Correlation plot of 15-minute $PM_{10}$ concentrations***

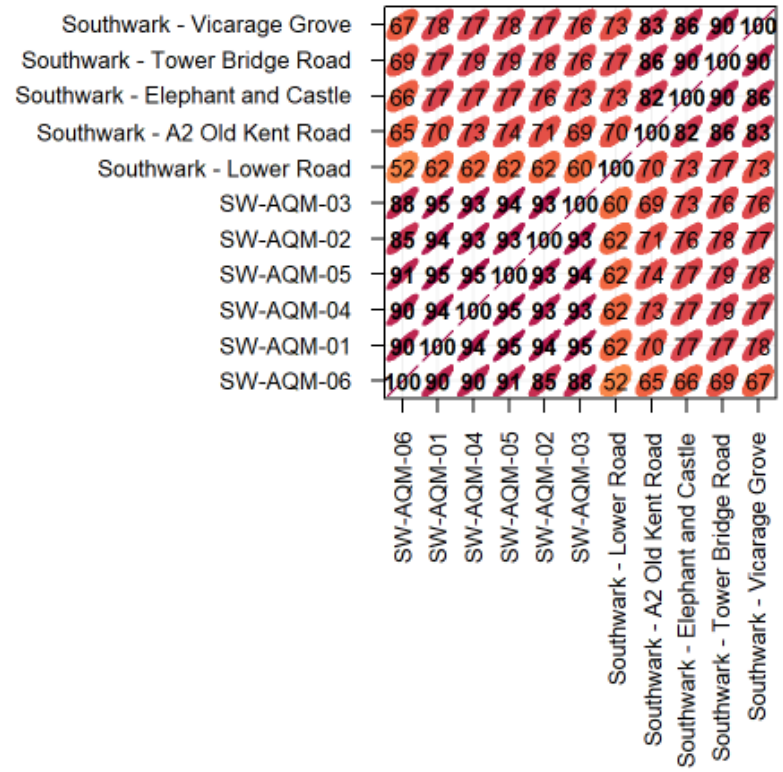



***Figure 9: Correlation plot of hourly $PM_{10}$ concentrations***

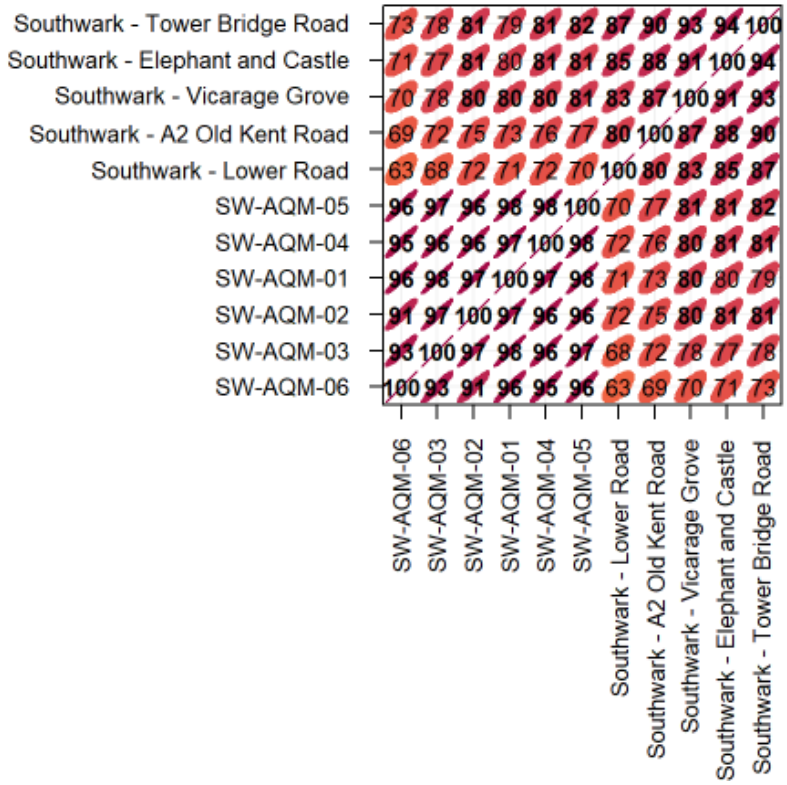


***Figure 10: Correlation plot of daily $PM_{10}$ concentrations***

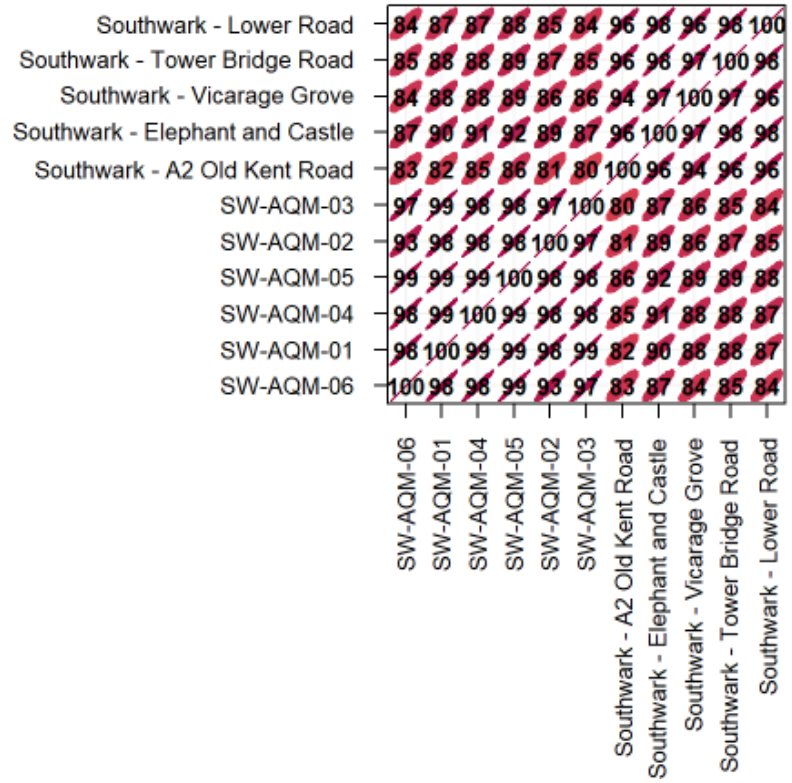



***Figure 11: Correlation plot of 15-minute $PM_{2.5}$ concentrations***

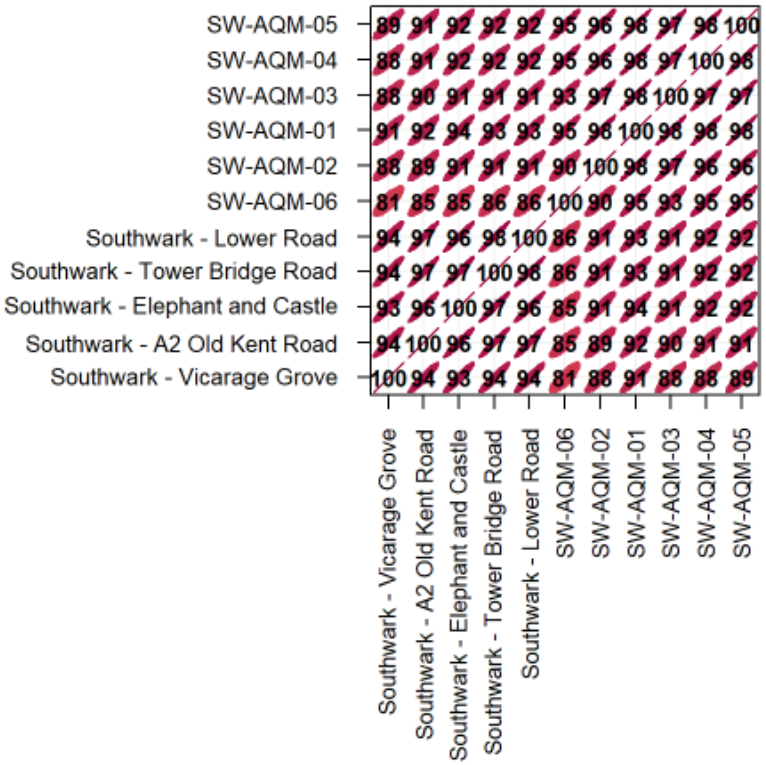


***Figure 12: Correlation plot of hourly $PM_{2.5}$ concentrations***

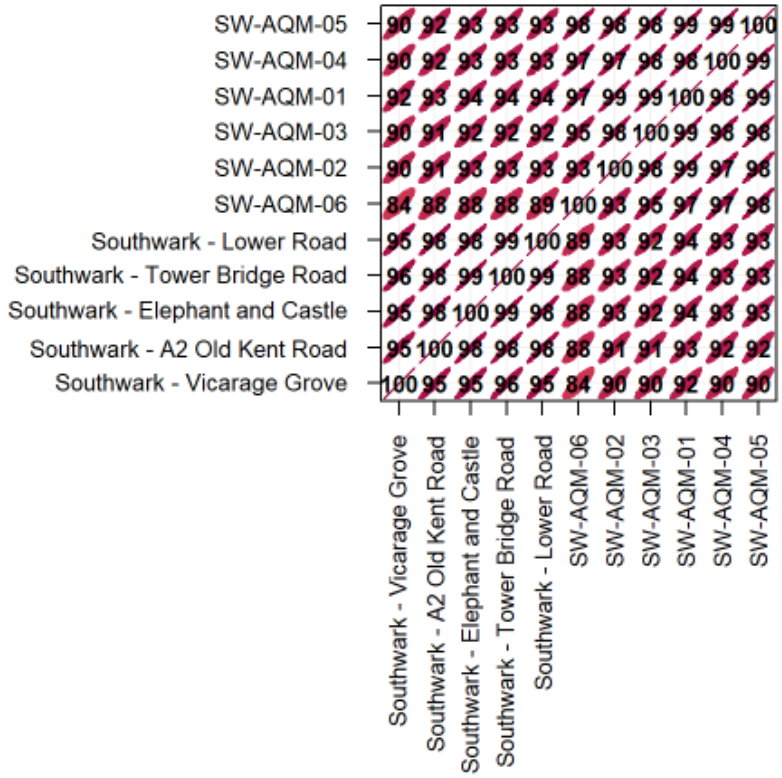
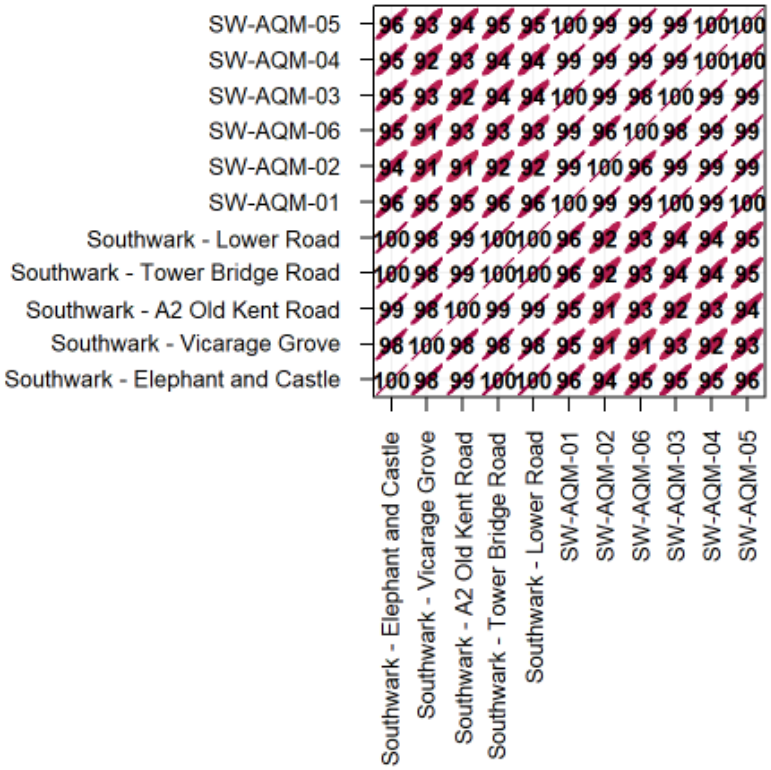



***Figure 13: Correlation plot of daily $PM_{2.5}$ concentrations***



## 3.4 Concentration Distributions

Figures 14 and 15 show the concentration distributions of 15-minute averages as measured by the Vortex sensor network and the nearby reference sites. The $PM_{10}$ concentration distributions mirror closely what is seen at the reference sites. When compared to the Southwark Lower Road reference measurements, the $PM_{10}$ plots indicate that an offset and/or span correction of the sensor measurements would improve the accuracy of the $PM_{10}$ sensors. The $PM_{2.5}$ distribution plots follow the shape seen at the reference sites; however, the plots indicate that the accuracy of the sensor measurements could be improved by the application of a further offset correction and/or span correction.

***Figure 14: $PM_{10}$ concentration distributions***

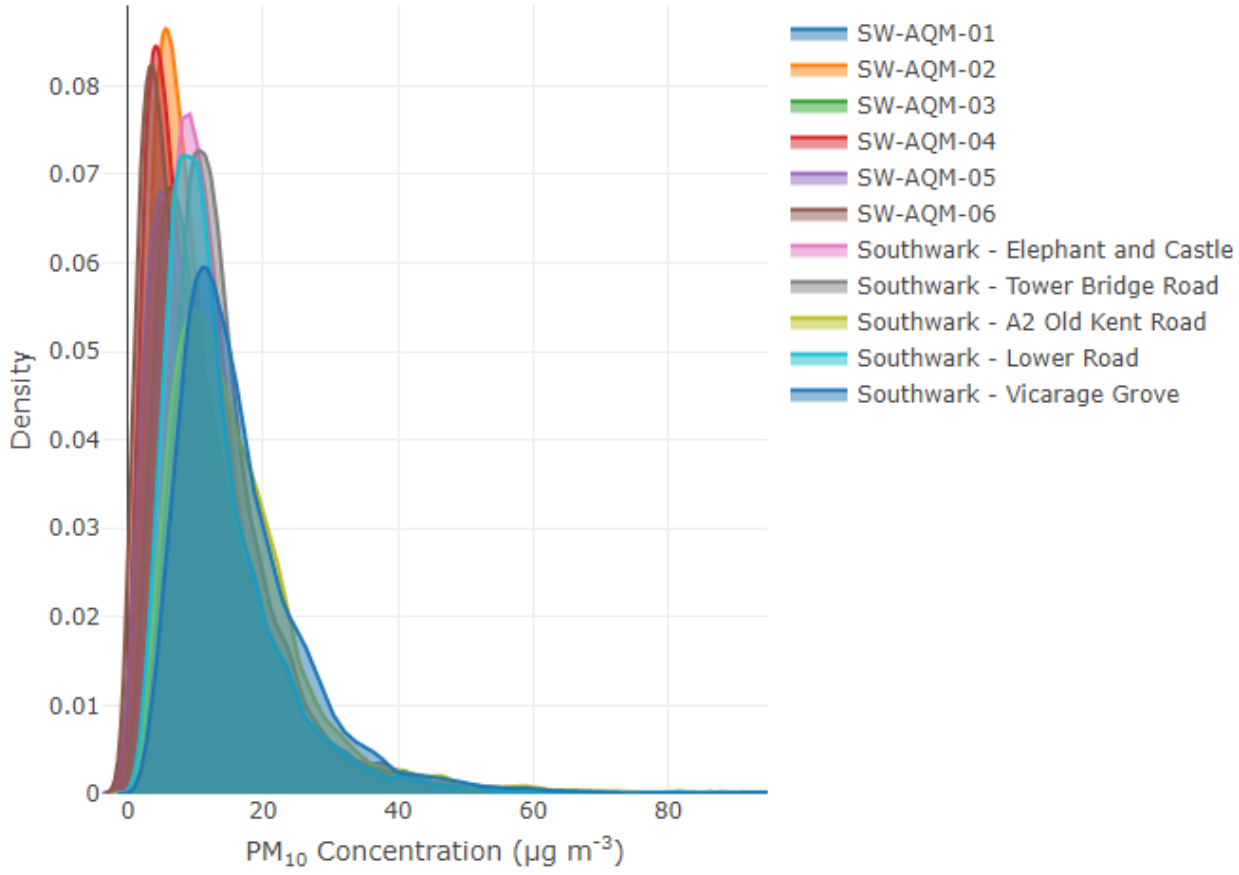
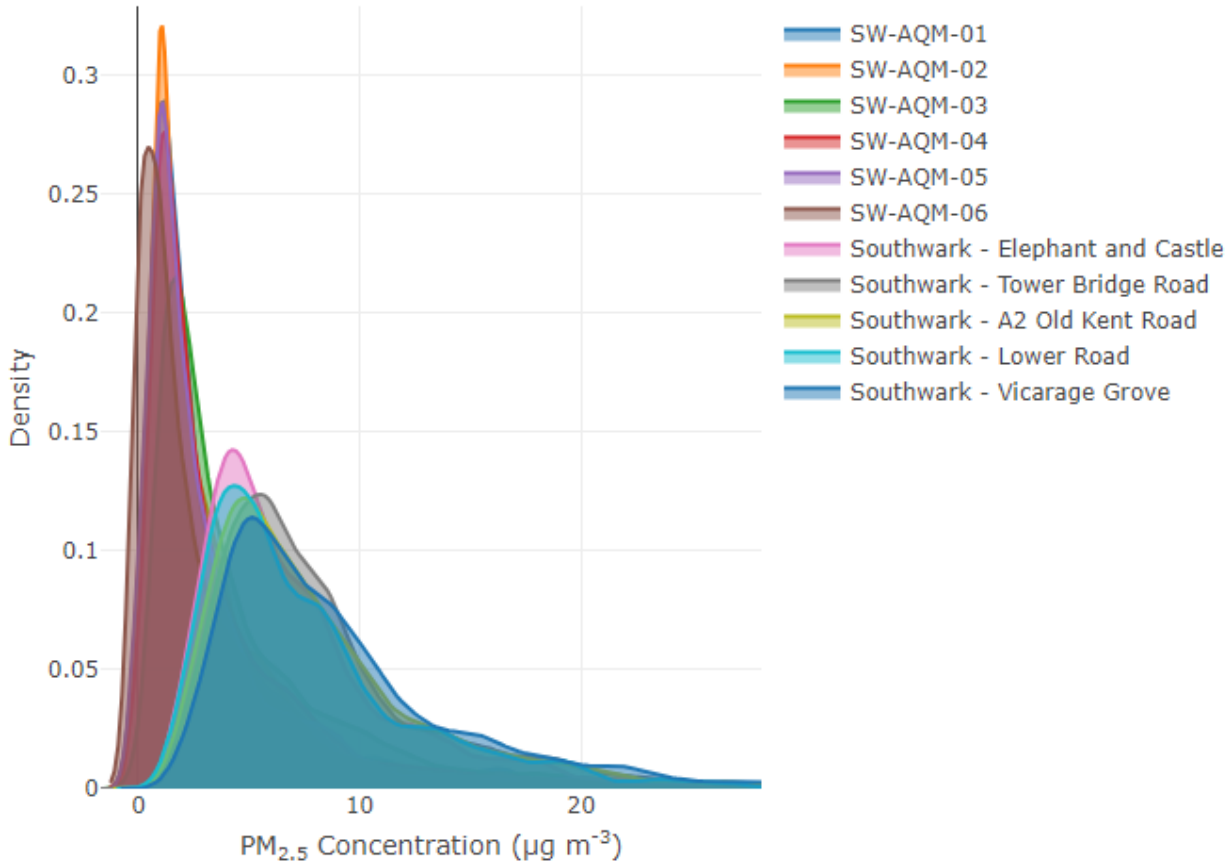


***Figure 15: $PM_{2.5}$ concentration distributions***




# 4 Summary

***$PM_{10}$ sensors:***

- The intra-comparability between sensor sites and precision is excellent.
- The inter-comparability between sensor sites and reference sites is excellent.
- Sensor accuracy could be improved with the application an offset and/or span correction.

***$PM_{2.5}$ sensors:***

- The intra-comparability between sensor sites and precision is excellent.
- The inter-comparability between sensor sites and reference sites is excellent.
- Sensor accuracy could be improved with the application an offset and/or span correction.