# Air Monitoring Directive Chapter 6: Ambient Data Quality

Amends the original Air Monitoring Directive published June, 1989

## *DRAFT Version 2026*

Alberta

# Contents

# 1.0    Purpose

This Ambient Data Quality document forms a part (Chapter 6) of Alberta's Air Monitoring Directive (AMD; Alberta Environment and Parks 2016, as amended from time to time) and will hereafter be referred to as the Data Quality Chapter. Refer to the AMD Introduction (hereafter Chapter 1) for requirements and definitions that apply to all parts of the AMD, a list of what components constitute the AMD, and details on review of and revisions to the AMD.

The purpose of the Data Quality Chapter is to specify the requirements for collecting, verifying, and validating continuous ambient air quality and meteorological monitoring data.

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| *DQ 1-A* | *The person responsible must comply with the requirements set out in the Data Quality Chapter of the AMD on or before June 20, 2016, for all continuous ambient air monitoring* |

Figure 1 presents a flow chart of the suggested data collection and management process. The reporting aspect of the data process is described in the Reporting Chapter of the AMD (hereafter Chapter 9).

## 1.1    Amendments

2026 – As drafted here; will be updated and dated for final release.

1. Update to document design.
2. Amended Figure 1 to include annual data validation following Level 3.
3. Removed guidance under Section 2.1 referring to SOPs.
4. Minor terminology changes throughout the Chapter to be consistent across the AMD.
5. Amended clause DQ 3-A: minor wording changes, removed former bullet (a) (referencing scan rates for meteorological parameters) and amended bullet (b).
6. Amended guidance under Section 3.1.2 to reference other reporting intervals for comparison to Alberta Ambient Air Quality Objectives and Guidelines.
7. Removed former clause DQ 3-F under Section 3.1.3, referencing standard deviation of wind calculations. Clause numbering in Section 3 was adjusted accordingly.
8. Minor wording change to guidance under Section 4.1.1
9. Amended clause DQ 4-A to reference Ambient Air Quality Data Submitter's Guide and removed former bullets (a), (b), (c), and (d) as flagging requirements are specified in the Ambient Air Quality Data Submitter's Guide. Bullets (i), (ii), and (iii) under former bullet (a) were renumbered as bullets (a), (b), (c).
10. Added guidance under Section 4.1.3 to define analyzer operational time and describe how to calculate it.
11. Added clause DQ 4-D to provide exemption to meet analyzer operational uptime during station relocation or replacement. Clause letters in Section 4 were adjusted accordingly.
12. Added guidance under clause DQ 4-D to describe reporting when analyzer operational uptime is not met during station relocation or replacement.
13. Minor wording change to clause DQ 4-F (formerly E).
14. Minor wording changes were made in Section 4.3.4.
15. Former clause DQ 4-G was changed to guidance, as it is a requirement of Chapter 7. Clause letters in Section 4 were adjusted accordingly.
16. Added guidance to Table 2 under Section 4.3.7 to align with updated NAPS Criteria (2019).
17. Amended clause DQ 4-M (formerly DQ 4-L) to account for sub-hourly averages for certain parameters.
18. Amended guidance in Section 4.4 to describe invalid data investigations.
19. Former clause DQ 4-P was removed, as it is a requirement of Chapter 9.
20. Amended guidance in Section 4.5 to account for sub-hourly averages for certain parameters.

21. Amended guidance in Section 4.6 to remove duplication with Chapter 9 and describe the Regulator's review of annual data.
22. Updated references in Section 5.0.
23. Added Appendix A to describe the calculation of analyzer operational time and provide examples.
24. Added Table A.1 to describe scenarios for analyzer operational time calculations.

December 16, 2016

1. Update to title page – reference to 1989 AMD.

August 3, 2016

1. Update to document design/branding.
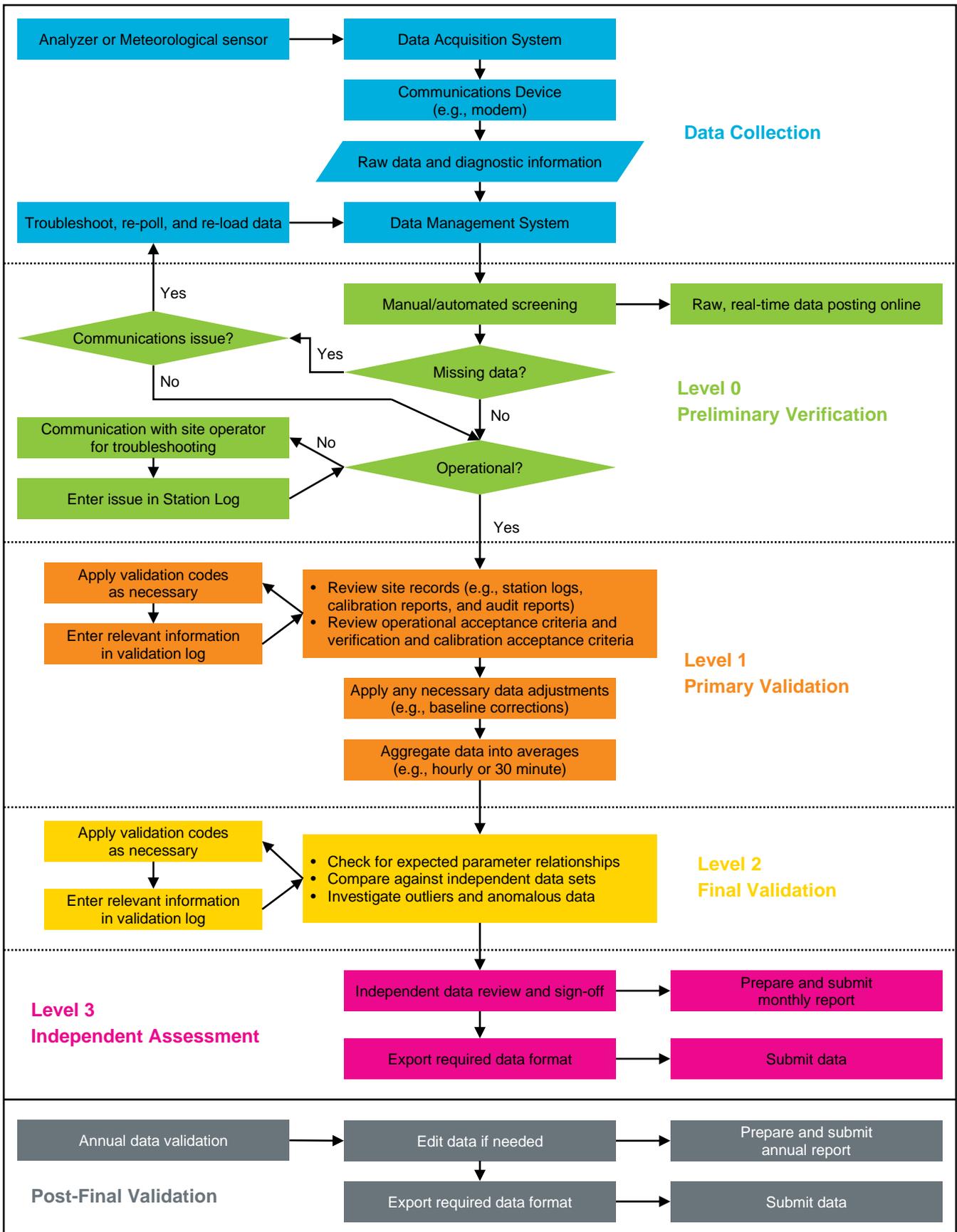
*DQ 1-B      Figure 1      Data Collection and Management Process Flow Chart*

Classification: Public

# 2.0    Documents and Records

Minimum requirements for documents, records and maintaining a Quality System are given in the Quality System Chapter of the AMD (hereafter Chapter 5).

All documents and records should be easily accessible. The majority of documents and records referred to in this section should be in electronic format to ensure accessibility and long-term storage.

## 2.1    Project Specific Documents

Documents required for continuous ambient data quality and handling include, but are not limited to, procedures relevant to data collection, verification, validation, and reporting. These documents become part of the person responsible's Quality Assurance Plan (QAP).

## 2.2    Field Records

Recording of field data is necessary for ambient air monitoring and serves as valuable input for the data validation process.

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| *DQ 2-A* | *The person responsible must (a) maintain field records for each continuous ambient air monitoring station (b) containing:*<br>*(i)   analyzer-specific information regarding all maintenance activities;*<br>*(ii)  quality control checks;*<br>*(iii) troubleshooting activities;*<br>*(iv) site visits; and*<br>*(v)  any other relevant information pertinent to analyzer performance in accordance with the Data Quality Chapter.* |

Field records should be used for validation purposes. Field records include station logs, which are chronological records of all of the events that occurred at a monitoring site. Paper copies of log notes can be maintained on-site, but electronic or web-based logging systems should be used so that information is better organized and readily available for the data validation process.

Requirements for retention and accessibility of documents and records are given in Chapter 5.

The following are types of information that may be recorded in a station log entry:

- technician name;
- date and time;
- the manufacturer's name, equipment type identification, and serial number or other unique identification;
- information about all routine and non-routine maintenance activities;
- a record of any damage, malfunction, modification, or repair to station systems and equipment;
- brief description of any corrective actions performed;
- any quality control information, including "as-found" and "as-left" information for analyzer verification or calibration activities;
- information relevant to analyzer-specific performance specifications and acceptance criteria (e.g., leak checks, flow checks, etc.); and
- any other pertinent information.

# 3.0    Data Collection and Management

Data acquisition is the process of collecting data, while data management refers to the process of organizing, storing, verifying, validating, and reporting data.

## 3.1    Data Collection

Data collected includes raw ambient data and also quality control data such as zero and span tests, multi-point as found verification and calibration data, and analyzer diagnostics.

Data output options for continuous analyzers generally include both analog and digital signals.

Either analog or digital data are acceptable, but if analog data collection is implemented, quality assurance measures should confirm that data collected match the output from the analyzer.

Adoption of digital data acquisition is encouraged because it eliminates any noise that may be introduced with signal translation and can improve analyzer sensitivity. Digital data acquisition can provide more analyzer diagnostic information than is available through analog channels.

### 3.1.1    Data Acquisition System Scan Rates

A Data Acquisition System (DAS) is a system used to collect and transfer data from ambient analyzers and meteorological sensors to a data management system – it can include digital or analog hardware, software, or both. As the DAS may comprise many components, any requirements imposed on the DAS must be interpreted as extending to any relevant integrated hardware or software component thereof.

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| *DQ 3-A* | *For collection of continuous ambient air monitoring data, the person responsible must implement the following for the DAS:*<br>*(a) scan rates at least as fast as actual analyzer or sensor response times; or*<br>*(b) 1-second scan rates, at a minimum, for analog systems with analyzer or sensor response time less than 1 second.* |

Scan rates are the intervals at which a DAS retrieves an analyzer value, which are subsequently used in calculations performed by the DAS.

### 3.1.2    Data Averaging Intervals

Scanned data are the raw, unaveraged data retrieved from an analyzer by a DAS. DAS scan rates determine the level of data incorporated into an average value, where the minimum time resolution selected for averaging is the base average. Any subsequent averaging begins with the base average.

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| *DQ 3-B* | *The person responsible must (a) collect and (b) store 1-minute base average intervals for QA/QC data, including zero/span and multi-point as found verification or calibration data.* |
| *DQ 3-C* | *Base averages collected by the person responsible must include at least 75% of scanned data.* |
| *DQ 3-D* | *The person responsible must (a) calculate and (b) retain final averages that:*<br>*(i) are less than or equal to 1-hour; and*<br>*(ii) include at least 75% of base averages.* |

Final data are reported as hourly average values. Final data may also be averaged and reported over other intervals to allow for comparison to Alberta Ambient Air Quality Objectives and Guidelines. Data averaged over shorter intervals may be stored and used for validation. Refer to Chapter 5 for data retention requirements.

### 3.1.3 Wind Direction

Because wind direction is a circular variable, the calculation of statistics for wind is not as straight-forward as calculating statistics for linear variables like concentrations.

Average wind speed and wind direction must be computed and reported as resultant vector averages of either the base averages or other short-term averages, not simple scalar averages of these quantities. This can be done automatically by most modern DAS if the appropriate selections are made. See Appendix B for more information.

The standard deviation of wind direction is a calculated parameter primarily used to model dispersion in the atmosphere. The United States Environmental Protection Agency (US EPA) has provided guidance for calculating the standard deviation of wind direction, and these calculation procedures are built into modern DAS as standard calculation algorithms. Most DAS use the Yamartino method, which complies with US EPA guidelines for use with straight line Gaussian dispersion models to model plume transport.

| DQ 3-E | *The person responsible must either (a) collect hourly averages of standard deviation of wind direction from DAS using US EPA approved algorithms, or (b) calculate hourly averages of standard deviation of wind direction externally using US EPA approved algorithms, unless an alternate algorithm has been documented and authorized in writing by the Director prior to implementation.* |
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### 3.1.4 Analog Output Verification

It is important to ensure that DAS output matches digital output directly from the analyzer.

| DQ 3-F | *When analog data collections systems are used, the person responsible must verify analog output by comparing to digital data output, at a minimum:*<br>*(a) upon commencement of continuous ambient air monitoring; and*<br>*(b) after any changes to the data collection system.* |
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Additional periodic checks (e.g., monthly) should be performed on analog output to ensure that time drifts or other data collection issues have not affected the data.

To report data correctly, a time adjustment may be necessary to ensure that the time associated with the sample accurately represents the period that was sampled.

Differences in time stamps may occur when comparing analog and digital output due to delayed analyzer responses (e.g., for a semi-continuous analyzer measurement cycle). Any specific methods used to correct for lag times in semi-continuous analyzer output should be documented in the QAP and SOPs.

An external DAS overrides an analyzer's internally logged digital time stamp, which may result in a disagreement between the DAS and the analyzer. For logged digital data, the DAS will access the analyzer's internal time stamp.

Examples of semi-continuous analyzers which may require special analog data collection setup considerations include the Beta Attenuation Monitor (BAM), the FDMS version of the Tapered Element Oscillating Microbalance (TEOM), and continuous Gas Chromatography (GC) based analyzers.

Classification: Public

## 3.2 Data Management

It is important that data storage maintain the integrity of raw data. Additional records that should be stored with data include any data flags, analyzer diagnostics, data verification results, and multi-point as found verification and calibration results.

> DQ 3-G    *The person responsible must archive raw data collected from continuous ambient air monitoring stations separate and distinct from the validated data.*

# 4.0 Data Verification and Validation

Data verification and validation techniques are used to accept, reject, or qualify data in an objective and consistent manner. Data verification is primarily an evaluation of analyzer or system performance, and is usually performed during or shortly after data collection activities, while data validation consists of actual qualification of data validity.

Software systems used to support data review and validation should have both graphical and tabular display and validation support capabilities. Tabular data review is valuable for identifying actual start and end times for data issues, but graphical displays can show behavior, relationships among parameters, outliers, and subtle changes that can be easily overlooked in tabular displays.

Basic steps involved in the data verification and validation process are presented here according to the following progressive levels:

- Level 0 - Preliminary Verification;
- Level 1 - Primary Validation;
- Level 2 - Final Validation;
- Level 3 - Independent Data Review; and
- Post-Final Validation.

## 4.1 Validation Process Records

During data validation, a number of decisions are made regarding whether data are valid, if data adjustments are necessary to obtain valid data, or if data do not meet acceptance criteria and are considered invalid. Data are identified as invalid using data validation codes.

### 4.1.1 Data Validation Codes

A data validation code (also referred to as a flag, flag code, or data flag) is an indicator of validity or an indicator of the fact and reason that a data point is invalid or missing. Organizations may utilize a variety of different data validation codes internally, but it is necessary that the codes are consistent for submission of all data to Alberta's Ambient Air Quality Data Warehouse. Data validation codes (both flags and qualifiers) are provided in the Ambient Air Quality Data Submitter's Guide.

A data flag is a code added to explain why a data point is missing (e.g., "C" for calibration or "P" for power failure). A data qualifier is a code added to a data point, which may or may not be valid, to describe the quality or characteristics of the data point (e.g., "GT" for over range, or "L" for local interference).

> DQ 4-A    *For all continuous ambient air data, the person responsible must assign data validation codes, in accordance with the Ambient Air Quality Data Submitter's Guide to:*
> *(a) flag missing data;*

> *(b) qualify data that fall outside the analyzer's normal operating range; and*
>
> *(c) qualify anomalous data that are deemed to be valid after review.*

## 4.1.2 Data Validation Logs

Data validation logs are used to provide a record of the validation process by summarizing and justifying decisions regarding application of validation codes. Record of any data adjustments, deletions, or modifications create an audit trail for all flagged and edited data and can save time and effort if questions arise about specific data at a later date. To ensure a defensible audit trail, suspect or invalid data should not be deleted.

> *DQ 4-B    The person responsible must keep a validation log that describes the basis or justification for all data validation activity for each continuous ambient air monitoring station.*

Data Validation Log entries should include the following information:

- who performed the validation action;
- when the validation action was completed;
- the parameter(s) affected;
- the identification of, and justification for, any data adjustments or invalidations;
- a brief description of any corrective action performed to address data issues;
- the identification of, and justification for, the validity of anomalous data or outliers; and
- any additional entries for post-validation changes.

## 4.1.3 Analyzer Operational Time

> *DQ 4-C    The person responsible must maintain, at a minimum, 90% operational time for each continuous ambient analyzer and accompanying data recording system, on a monthly basis for each parameter monitored.*

Operational time refers to the percentage of time in the month, after discounting routine, pre-planned QA/QC activities, that the analyzer monitored ambient air (i.e., the percentage of time it was in operation and performing its primary function). Time for routine QA/QC is subtracted from the total time in the month so that what is counted against operational time is downtime due to non-routine events.

Operational time for each ambient analyzer, as represented in Equation 1 is a ratio of quality assured hours (during which the analyzer measured ambient air) to the total possible hours over a calendar month less any hours of scheduled, routine, pre-planned QA/QC activities.

$$\text{Operational time} = \frac{t_m - t_q - t_d}{t_m - t_q} \times 100\% \qquad \text{Equation 1}$$

Where:

$t_m$ = total hours in the calendar month;

$t_q$ = total hours that routine, pre-planned analyzer maintenance or replacement took place in the month, including any associated multi-point as found verification, calibration and analyzer warmup/stabilization; and

$t_d$ = total hours of downtime resulting from analyzer malfunction or failure, power outage or station shelter replacement or relocation, including any associated multi-point as found verification, calibration and analyzer warmup/stabilization.

The numerator ($t_m$-$t_q$-$t_d$) represents the total hours during the month for which the analyzer was operationally available (in control and meeting AMD specifications) and captured valid, quality assured data while the

denominator ($t_m$-$t_q$) represents the total possible hours in the month less any hours of scheduled, routine, pre-planned QA/QC activities.

Note: operational time may be determined using higher-resolution time periods (e.g., minutes).

Quality assured data means data generated from an analyzer that is representative of ambient conditions when the analyzer is in control and meets all AMD specifications.

Planned, routine quality assurance and maintenance activities (as documented in the QAP) for proper operation of the analyzer are part of normal operation (i.e., there are no issues with the analyzer). The time for these activities, including all activities that surround this work (multi-point as found verification, startup and stabilization, calibration), is considered routine QA/QC. As these are needed for normal operation to ensure quality assured data, they are not counted against operational time. These hours are therefore removed from both the denominator (total possible hours) and the numerator (quality assured data that is representative of ambient conditions).

Examples of planned, routine QA/QC activities include (but are not limited to): routine multi-point as-found verifications (not in response to analyzer malfunction or repairs); daily zero/span tests; manifold cleaning; planned preventative maintenance as per QAP (e.g., pump replacement, lamp replacement); audit checks; equipment installation, start-up and stabilization for planned, preventative analyzer replacement.

Any maintenance or analyzer repairs that are not regular, planned activities, but are conducted in response to analyzer failure or malfunction are not included as operational time. This includes any activities that surround this work (multi-point as found verification, startup and stabilization, calibration). Power outage and station relocation or station shelter replacement are also not counted as operational time. The time for these activities is subtracted from the numerator, but does remain in the denominator.

Examples of periods that would not count as operational time include (but are not limited to): analyzer malfunction; data impacted by zero/span; failure to meet multi-point as found verification or calibration acceptance criteria; additional zero/spans, multi-point as found verifications, or calibrations that result from analyzer malfunction; audit failure; power outages; analyzer repairs, troubleshooting or replacement in response to analyzer malfunction; equipment installation, start-up and stabilization in response to analyzer malfunction; station relocation or station shelter replacement.

Example analyzer operational time calculations and guidance on which QA/QC activities fall under the allotment for operational time are given in Appendix A.

> **DQ 4-D**    *The person responsible is exempt from meeting the operational time requirement in DQ 4 C for a planned replacement or relocation of a continuous ambient air monitoring or meteorological sensor station shelter during the month the replacement or relocation occurs, for a maximum of 1 month.*

The person responsible has time allotted to complete the replacement or relocation of a station shelter. If the operational time requirement cannot be met during the transition, the person responsible still needs to calculate and report percent availability (in monthly reporting according to Chapter 9), however, the operational time requirement in DQ 4-C does not need to be met for that month as per DQ 4-D. The reason for not meeting the operational time requirement would be explained in the monthly report. The time for station shelter replacement is not counted as operational time (i.e., is not included in $t_q$ in Equation 2 and Equation 3). Planned replacement of a station shelter should be expedited to minimize data loss whenever possible.

> **DQ 4-E**    *When continuous ambient monitoring periods cover three months or less, the person responsible must:*

> (a) *maintain at a minimum 90% operational time for each analyzer for the overall monitoring period,*
> (b) *extend monitoring to meet 90% operational time for each analyzer, or*
> (c) *if an analyzer is operational for less than 75% of the time in any calendar month, monitor for a new 30 day monitoring period.*

In the condition described in DQ 4-E (b), monitoring would be extended to meet the 90% operational time based on the total number of hours lost in the monitoring period.

Monitoring should be scheduled to commence at the beginning of a calendar month, when possible, in order to collect a full month of data.

To minimize the risk of data loss when a DAS goes down, some sort of back up (whether electronic, chart recorder or internal analyzer memory) should be used.

## 4.2 Level 0 – Preliminary Verification

Level 0 data are raw data obtained directly from the DAS or directly from the analyzer. Under preliminary verification, these data may undergo a certain amount of manual or automated screening and flagging. Typical screening checks should include the following:

- identification of periods of missing data;
- verification of time stamps against reference time;
- verification that analyzer diagnostics/DAS flags indicate normal operation;
- comparison of data to upper and lower limits (e.g., physical limits, such as analyzer thresholds, or limits established based on experience or historical data);
- rate-of-change flagging indicating that data changed too rapidly or not at all; and
- verification that zero, span, and multi-point as found verifications are within specifications.

Most DAS have the capability to automatically flag and log comprehensive sets of analyzer diagnostic data. Collection of analyzer diagnostic parameters can be a very effective way to quickly identify and mitigate data quality problems.

Manual review of data graphs by experienced personnel is also recommended, as human judgment may compel reversal of an automated screening decision. This review should be carried out promptly after data collection and should take into account any field observations available at that time.

Frequent data review (e.g., daily) and prompt troubleshooting of any observed operational problems is recommended to help avoid data loss.

> DQ 4-F    *If the quality of any recorded ambient data is suspect, the person responsible must:*
> (a) *document any data identified as suspect during the preliminary verification process;*
> (b) *investigate the root cause and identify period of invalid data;*
> (c) *immediately begin any necessary corrective action upon determination of a root cause;*
> (d) *document root cause and any corrective action taken; and*
> (e) *verify the effectiveness of corrective action taken to resolve the root cause.*

Investigation of suspect data may indicate that corrective action is not necessary (e.g., root cause was a brief power failure) or that corrective action is necessary to resume normal operation. Corrective action may involve remote systems adjustments, troubleshooting and repair on-site, or removal of analyzers for repair. All data issues identified and corrective action taken should be documented in station log notes.

Organizations conducting ambient air monitoring activities are increasingly making data available to the public in near real-time on websites. Data available in real-time have generally only undergone preliminary verification (e.g., Level 0 data). Disclaimers should be included with all real-time data available to the public indicating that data are not fully validated. In some cases, public feedback may actually assist in data screening by alerting data providers to possible issues.

## 4.3       Level 1 – Primary Validation

Data validation begins with the outputs from data verification and involves more thorough evaluation and documentation of issues identified during data screening, along with appropriate application of data validation codes. This level of validation should be performed on a weekly or monthly basis. Recommended validation actions include the following:

- review of all screening flags assigned during preliminary verification;
- review of all supporting site information and documentation;
- review of operational acceptance limits for each parameter/analyzer;
- review of daily zero/span and routine calibration results for all gaseous parameters; and
- application of any necessary adjustments to data (e.g., baseline adjustments).

### 4.3.1       Review of Supporting Information and Documentation

All analyzer status information, including any analyzer diagnostics and DAS flags applied during screening, should be reviewed carefully to determine data validity implications. In some cases, data that were identified as suspect during manual or automated screening may be determined to be valid following further investigation.

Any additional documentation or analyzer diagnostics that were not available at the time of data collection, including station log notes and any calibration and audit records, should be reviewed and evaluated for data validity implications.

### 4.3.2       Operational Acceptance Criteria

Data validation should consider any analyzer specific limitations that may invalidate data.

> *DQ 4-G       The person responsible must document the operational acceptance limits used during validation in a QAP or associated SOPs.*

Operational acceptance limits are specified in the Monitoring Chapter of the AMD (hereafter Chapter 4).

Data which violate acceptance limits should be considered invalid unless other quality control information demonstrates otherwise.

Examples of analyzer-specific limitations that may invalidate data include, but are not limited to, temperature tolerances, converter efficiency for $NO_2$ measurements, and unacceptable ranges of flow rates for particulate analyzers with size-cut inlets (e.g., $PM_{2.5}$ and $PM_{10}$ measurements).

### 4.3.3       Verification or Calibration Acceptance Criteria

Multi-point verifications and calibrations are used to maintain measurement uncertainty within established acceptance criteria. Verification and calibration acceptance criteria are listed in the Verification and Calibration Chapter of the AMD (hereafter Chapter 7).

### 4.3.4       Over-Range Values

Instrument operating ranges should be configured according to Chapter 4. Most analyzers are capable of output ranges far exceeding the required ranges, but actual analyzer output may be limited by analog data signal

translations. If over-range values occur regularly, the analyzer range should be adjusted to be appropriate for the monitoring situation.

Analyzer operating ranges are specified in Chapter 4.

Values outside of required operating ranges should be invalidated (for example relative humidity values > 100% or wind direction values > 360 degrees) and analyzer ranges may need to be adjusted.

Values outside of required operating ranges, which appear otherwise valid and indicative of anomalously high events (e.g., nearby wildfire), should remain valid.

For over-range values which are kept valid, data validation logs should be used to indicate that an exceptional event occurred and that the over-range value likely underestimates the actual concentration.

### 4.3.5      Baseline Adjustments

Analyzer zero drift is common in many continuous air quality analyzers, and may be evident when the daily minimum concentration, often referred to as the baseline concentration, tends to increase or decrease from normal over a period of days or weeks. Analyzer drift can generally be confirmed by review of zero/span tests. A zero offset may be estimated from the lowest ambient measurements at a site, since concentration levels are often low for some pollutants at certain times during a day. Review of data graphs and tabulations allow for detection of uncorrected drift in the zero baseline of a continuous analyzer.

Generally, data affected by analyzer drift can be corrected by adjusting the data accordingly (e.g., a verified +2 ppb drift can be accounted for by subtracting 2 ppb from all data during the affected period). The degree of baseline shift may vary from day to day. Common adjustment approaches include applying a constant offset to all data during the period between adjacent zero tests (e.g., a step-wise adjustment), or interpolating zero adjustments between verified zero tests (e.g., gradually adjusting on a linear basis). These adjustments can be applied automatically by the DAS or manually applied during the data validation process.

Maintaining continuous ambient analyzers within the calibration specifications set out in Chapter 7 or the manufacturer's specifications will minimize the need for zero adjustments.

> *DQ 4-H      When applying data adjustments based on zero test data, the person responsible must (a) review, then (b) accept or reject the data being adjusted, to ensure that erroneous data adjustments are not applied.*

Data adjustments based on span test results should not be applied between analyzer multi-point as found verifications or calibrations.

All zero test results should be accepted or rejected individually to ensure appropriate data adjustments are made. If adjustments are small, either adjustment approach is acceptable.

Adjustments based on span test results are not recommended.

Upscale adjustments should be limited to actual full calibration adjustments, which are based on multiple upscale checks against a reference standard (see Chapter 7).

The most appropriate zero baseline adjustment approach should be determined so as to not negatively affect the reported ambient concentration values. Some zero test results may be unreliable due to equipment failure or other issues, and application of automated zero adjustments introduces the risk that erroneous adjustments may be applied to data.

## 4.3.6        Derived Parameter Relationships

Some continuous parameters are not measured directly by sensors or analyzers, but rather are derived based on measurements of other parameters.

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| *DQ 4-I* | *For continuous ambient air parameters not directly measured by sensors or analyzers, the person responsible must apply adjustments equally to all parameters during validation procedures in order to preserve the relationship between the measured and derived parameters.* |

In the case of $NO/NO_2/NO_x$, any adjustments applied to NO (e.g., baseline or zero adjustments) need to be applied equally to $NO_x$.

Chemiluminescence $NO_x$ analyzers detect only NO, where $NO_2$ is converted to NO for measurement purposes. $NO_2$ is reported as the difference between $NO_x$ and NO. An analyzer can either report these concentrations directly or concentrations can be calculated external to the analyzer. If parameters are reported directly from an analyzer, any rounding after the calculation or translation of signal noise may affect the exact stoichiometry for composite parameters.

Examples of quantitative parameter relationships, along with validation considerations, are listed in Table 1.

**Table 1  Validation Considerations for Parameter Relationships**

| Parameter | Validation Consideration |
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| $NO/NO_2/NO_x$ | The sum of nitrogen oxide (NO) and nitrogen dioxide ($NO_2$) should equal $NO_x$. When making data adjustments to any of these parameters (such as a baseline adjustment based on zero results) the relationship between these parameters must be preserved. |
| $CH_4$/NMHC/THC | The sum of methane ($CH_4$) and non-methane hydrocarbons (NMHC) should equal total hydrocarbons (THC). When making data adjustments to any of these parameters (such as a baseline adjustment or an adjustment to zero) the relationship between these parameters must be preserved. |
| $PM_{10}$ and $PM_{2.5}$ | If $PM_{10}$ flow is split for measurement of $PM_{2.5}$ (e.g., $PM_{10}$ is split into Coarse Particulate Matter (PMC) and $PM_{2.5}$), $PM_{10}$ is calculated as the sum of PMC and $PM_{2.5}$. |
| VWS, VWD and SDWD | Vector wind speed (VWS) or vector wind direction (VWD) and standard deviation of wind direction (SDWD) should be invalid during the same time periods. If scalar parameters are collected in addition to vector parameters, invalidated scalar wind speed (SWS) or scalar wind direction (SWD) should result in invalid VWS, VWD and SDWD for the same period. |
| SWS and VWS | SWS can be equal to, but never less than VWS. |
| Delta Temperature | Delta temperature is calculated as the difference between temperatures measured at two levels. If the temperature is invalid at either level, delta temperature is also invalid. |

## 4.3.7        Below Zero Adjustments

Analyzers are subject to precision and zero noise limitations. The precision of an analyzer is the degree of variation about the mean of repeated measurements of the same pollutant concentration. Zero noise is more specifically a measure of the deviations from zero while sampling constant zero air input.

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| *DQ 4-J* | *The person responsible must adjust the continuous ambient hourly averages of all valid negative gas and particulate concentrations to zero pursuant to Table 2 prior to reporting this data.* |

For example, a valid -1 ppb ozone reading should be reported as 0 ppb ozone.

It is important to distinguish normal noise from operational issues, as operational issues should be invalidated.

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| *DQ 4-K* | *Zero adjustments must not be applied to sub-hourly intervals prior to aggregation into 1-hour averages.* |

All adjustments of negative values to zero should be applied after baseline adjustments are made.

Table 2 lists the applicable reporting requirements, including lower acceptable limits defined for 1-hour $PM_{2.5}$ data adopted from the Canada-wide National Air Pollution Surveillance (NAPS) program.

**Table 2  Zero Adjustment Criteria**

| Aggregation Level | Pollutant | Validation Criteria |
|---|---|---|
| < 1-hour | All parameters | All negative values determined valid must remain negative prior to aggregation into hourly averages |
| 1-hour | $PM_{2.5}$* | -3 ≤ $PM_{2.5}$ < 0 adjusted to 0; $PM_{2.5}$ < -3 invalid |
| | All gases | Below zero values determined valid are adjusted to zero (values < -3 should be further investigated prior to adjusting) |

*Adopted from NAPS criteria (Canadian Council of Ministers of the Environment (CCME), 2019).

## 4.4    Level 2 – Final Validation

The purpose of Level 2 validation is to verify that there are no inconsistencies among related data, or among regional data measured at nearby sites. Level 2 validation is a level of review where some general knowledge of pollutant and meteorological behavior can be used to determine if data are suspect.

Dependent data, or additional parameters measured at the same site, can be used to determine if expected parameter relationships exist. Independent data, or data from one or more nearby sites, can be used to verify some degree of regional consistency.

| | |
|---|---|
| *DQ 4-L* | *The person responsible must (a) identify and (b) investigate all anomalous data and outliers collected using validated continuous ambient air data reduced to hourly averages, or sub-hourly averages if applicable for parameter measured.* |
| *DQ 4-M* | *Justification for decisions regarding validity of anomalous data or outliers in DQ 4 L must be recorded by the person responsible in the data validation log in DQ 4 B.* |
| *DQ 4-N* | *The person responsible must (a) record decisions regarding the validity of anomalous data and outliers, and (b) describe the justification for each decision in the data validation log in DQ 4 B.* |

Any anomalous data or outliers identified as inconsistent with dependent or independent data, or not representative of the time or place monitored, should be considered valid unless there is compelling evidence to the contrary.

Suspect data should be investigated by going back and making sure that nothing was missed during primary validation. This would include checking supporting site information and ensuring that validation codes were

applied correctly. Further investigation of suspect data may determine that an analyzer malfunction or other issue affected data in an unanticipated way.

Data found to be invalid should be investigated according to DQ 4-F and flagged appropriately. Invalidated periods and investigation findings would be detailed in the validation log and monthly report.

Time series plots should be used to review data visually, since time series plots with multiple parameters displayed together can show relationships that are difficult to see with large amounts of tabular data. Some examples of dependent relationships between related parameters are listed below:

$O_3$ and NO are often anti-correlated. NO reacts with $O_3$, which can result in low daytime $O_3$ in urban areas, and higher $O_3$ downwind of urban areas.

$O_3$ is formed through photochemical process in the atmosphere, and concentrations often increase with higher UV and temperature measurements (e.g., diurnal highs during the middle of the day, and seasonal highs during the summer).

Pollutant events are often evident in multiple parameters (e.g., PM, $NO_x$, and hydrocarbon may exhibit similar behavior).

Pollutant levels might change abruptly if wind direction and wind speed change abruptly.

$PM_{10}$ particles are inclusive of $PM_{2.5}$, so $PM_{2.5}$ concentrations should not be greater than PM10 for collocated analyzers.

High $PM_{10}$ events are often associated with strong winds.

Temperature and relative humidity are generally inversely related.

Values of 0 for wind speed or wind direction for several consecutive hours when ambient temperature is below freezing and relative humidity is high (or precipitation recently occurred) may indicate a frozen sensor.

The above list is not comprehensive, and data contradictory to any of these examples may not be invalid, but may warrant additional investigation.

Independent data sets (e.g., site-to-site comparisons) are especially useful for meteorological data, as these parameters are often fairly consistent over large geographic areas. Data points originally identified as outliers could be justified as valid by citing similar spikes or dips during the same approximate time period at a nearby site.

## 4.5 Level 3 – Independent Assessment

Level 3 validation is a final cursory review of validated data by someone independent of both field operations and primary data validation. The intent of this level of review is not to repeat primary validation tasks, but rather to assure that data have undergone a final independent QA review and endorsement before data are submitted.

| |
|---|
| *DQ 4-O*   *The person responsible must conduct a final data review using an individual independent of both field operations and primary data validation activities prior to submission to the Regulator.* |

The independent reviewer should have some knowledge of pollutant and meteorological behavior and be familiar enough with the site to evaluate data based on expected and historical behavior.

This level of review should involve validated data reduced to hourly averages (or sub-hourly as appropriate) which are reviewed manually using time series plots.

Any periods of data identified as suspect can be communicated to the data validator for investigation and subsequent data validation modifications, or for additional validation justification prior to data submittal. Reports and data are certified when submitted as per Chapter 9.

## 4.6 Post-Final Validation Procedures – Annual Validation

Despite the best efforts of all data validators, errors and omissions may occur in the data validation process. If errors or omissions in the data are suspected or discovered after the initial submittal of data, the post-validation step serves to re evaluate the affected data.

Data reviews on an annual basis can highlight data issues or patterns which were not clear on a monthly basis.

> *DQ 4-P*    *The person responsible must review all validated data for the previous calendar year as an annual quality assurance check prior to submitting an annual report to the Regulator.*

This review should include a cursory inspection of annual charts, and basic statistics including comparisons to historical mean, maximum and minimum values.

Ambient air quality and meteorological monitoring data are used by the Regulator to report on the current state and trends of air quality and inform air quality management. The Regulator reviews data submitted to Alberta's Ambient Air Quality Data Warehouse annually to ensure good quality data are stored and distributed. This review does not replace the requirement(s) in DQ 4-P.

# 5.0 References

Canadian Council of Ministers of the Environment (CCME). (2019). *Ambient Air Monitoring and Quality Assurance/Quality Control Guidelines.* Retrieved from Canadian Council of Ministers of the Environment (CCME) Web Site: https://ccme.ca/en/res/ambientairmonitoringandqa-qcguidelines_ensecure.pdf

# Appendix A Calculation of Analyzer Operational Time

Analyzer operational time is calculated according to Equations 1, 2 and 3 (section 4.1.3). It is a measure of analyzer operation, rather than a measure of resulting valid, quality assured data. The following are examples and guidance on what QA/QC activities are considered allowable operational time and what is considered downtime. Table A.1 provides different QA/QC scenarios and indicates which activities fall under the QA/QC allotment, which are considered downtime, and whether or not quality assured, reportable data is produced.

Overall:

- If it is planned work (scheduled and documented in the QAP), the work, and everything that surrounds that work, is considered routine QA/QC (part of analyzer operational time). The hours are absent from both the numerator and the denominator.
- If it is unplanned and reactionary work due to analyzer malfunction or failure, the time for the work and everything that surrounds that work is considered downtime and removed from the numerator.
- There is a distinction between "allowable downtime" for QA/QC and quality assured data periods. Time is allotted for required, routine QA/QC activities (daily zero/span, routine multi-point as found verification or calibration, planned preventative maintenance and analyzer replacement that is documented in the QAP), however data during these activities does not represent ambient conditions (it is not reportable, usable data). The operational time measure is not a measure of data availability or quality assured data, it is a measure of analyzer availability.

**Calculation Example 1:**

With 744 hours in the month, if 1 hour per day is used for zero/span tests (31 hours total) and 8 hours are used for planned, routine maintenance during a routine calibration (including conducting a multi-point as found verification, the maintenance work and the follow up calibration) and there were no other issues in the month, operational time would be calculated as:

$$t_a = t_m - t_q - t_d$$

$$= 744 - (31+8) - 0$$

$$= 705$$

Type equation here.

$$t = t_m - t_q$$

$$= 744 - (31+8)$$

$$= 705$$

Type equation here.

$$\text{Operational time} = \frac{t_a}{t} \times 100\%$$

$$= \frac{705}{705} \times 100\%$$

$$= 100\%$$

**Calculation Example 2:**

With 744 hours in the month, if 1 hour per day is used for zero/spans (31 hours total), 6 hours are used for the routine calibration, and 16 hours of downtime are incurred due to a pump failure (with resulting pump replacement and follow up calibration), operational time would be calculated as:

$$t_a = t_m - t_q - t_d$$

$$= 744 - (31+6) - 16$$

$= 691$

Type equation here.

$t = t_m - t_q$

$= 744 - (31+6)$

$= 707$

Type equation here.

Operational time $= \dfrac{t_a}{t} \times 100\%$

$= \dfrac{691}{707} \times 100\%$

$= 97.7\%$

All data must be properly flagged for maintenance activities (calibration, zero/span, reasons for offline) as valid or invalid data, as per the Ambient Air Quality Data Submitter's Guide.

Planned, preventative maintenance must be outlined in the QAP, including data handling during QA/QC activities.

This approach of providing an allotment of time for required QA/QC activities is very flexible. It allows the opportunity for 100% uptime while conducting the prescribed QA/QC required by the AMD.

**Table A.1** **Different scenarios for ambient analyzer operational time calculation**

| Activity/Data Treatment | Quality assured, reportable data?[1] | Downtime? | Falls under QA/QC allotment? | Subtract hours from just numerator or both?[2] | Note/Comments: |
|---|---|---|---|---|---|
| Routine multi-point as found verification or calibration | no | no | yes | numerator & denominator | Calibration flagged as such. |
| Daily zero/span (one per day or as captured in the QAP) | no | no | yes | numerator & denominator | Zero span flagged as such. |
| Pre-planned (in QAP), preventative maintenance, including multi-point as found verification, calibration and analyzer warmup and stabilization for planned analyzer maintenance or replacement | no | no | yes | numerator & denominator | Planned preventative maintenance would be flagged as such. |
| Repair or maintenance following analyzer failure or malfunction (not planned). Includes as-found verification (if possible), calibration and warmup/ stabilization following unplanned maintenance, repair or replacement. E.g., failed to meet AMD-specified zero-span, multi-point as found verification, or calibration acceptance criteria; power outage; pump failure. | no | yes | no | just numerator | Non-routine maintenance flagged as such. |
| Time taken to physically remove and install an analyzer | no | no (when planned replacement) yes (when replacement due to analyzer malfunction; unplanned) | yes (when planned) no (when due to analyzer malfunction; unplanned) | numerator & denominator (if planned) just numerator (if unplanned) | There is an equipment replacement flag for this instance. If the swap was planned it would be considered QA/QC and removed from both the numerator and the denominator, if unplanned it goes against operational time and is subtracted from numerator. |
| Additional non-routine zero/span, conducted in response to analyzer malfunction or failure | no | yes | no | just numerator | Indicates a malfunction in the zero/span system or the analyzer; flagged as non-routine maintenance. |

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[1] In all scenarios, data captured is not quality assured (not representative of ambient conditions), and therefore is not reportable, or is not available.

[2] There is no case where you subtract only from denominator, as the pre-planned/scheduled QA/QC time does not appear in the numerator or the denominator.

# Appendix B    Calculation of Average Wind Speed and Direction

When calculating the average wind speed and direction, whether from base averages to determine the 1-hour average wind speed and direction, or a longer term average from the 1-hour wind speed and direction, care must be taken to ensure this is a proper vector average.
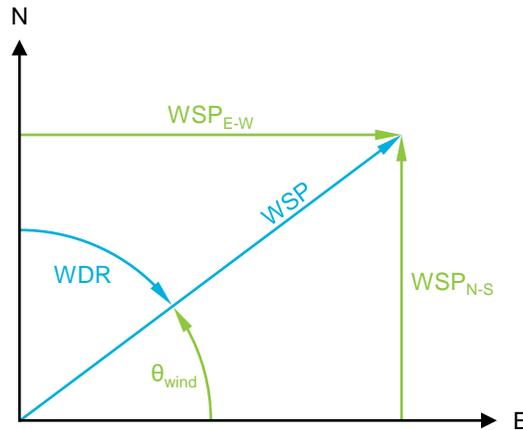


**Figure 2**          **Diagram of components of wind speed and direction measurements**

When recording wind data, the wind speed (WSP) is the absolute wind speed and does not itself contain direction information; the wind direction (WDR) has to be measured and recorded separately. In the meteorological convention, a WDR of 0° indicates due north, and this value increases clockwise. These two values together give the direction and speed of the wind.

If the WSP measurements over time are averaged together, this can give an overall indication of whether the winds were strong or light, however there is no indication of whether the wind was consistently from one direction or blew in different directions.

If the WDR measurements are averaged together, the result usually loses physical meaning. A relatively constant wind from the east may have an average WDR of about 90°, because WDR values will all be near 90°. A relatively constant wind from the north however will have values near 0° and also near 360°. Averaging these together could give a result of about 180°, which would indicate south – the opposite of the true wind direction.

To properly average wind data over time, the wind must be mathematically converted to separate north-south and east-west components. To do this, first the wind direction must be converted from the meteorological convention to the mathematical convention in which an angle of 0° corresponds to due-east and increases counter-clockwise, with equation 1.

$$\theta_{wind} = 90° - WDR$$                                                     Equation 1

where:

$\theta_{wind}$    = the mathematical angle of the wind

WDR    = the meteorological wind direction in degrees

The north-south and east-west wind speed components can then be found with equations 2 and 3:

$$WSP_{E\text{-}W} = WSP \times \cos(\theta_{wind})$$ 

Equation 2

$$WSP_{N\text{-}S} = WSP \times \sin(\theta_{wind})$$ 

Equation 3

    where:
    $WSP_{E\text{-}W}$ = the east-west component of wind speed
    $WSP_{N\text{-}S}$ = the north-south component of wind speed
    $WSP$    = the meteorological wind speed

Care must be taken to ensure the wind angle ($\theta_{wind}$) is in the correct units (radians or degrees) for the calculation – for example Excel requires the angle to be in radians; angles in degrees can be converted to radians with the RADIANS function.

These components ($WSP_{E\text{-}W}$ and $WSP_{N\text{-}S}$) can then be averaged to produce an average east-west and average north-south wind speed using a simple arithmetic average (i.e., sum of the individual measurements divided by the total number of measurements). The overall average wind speed is then calculated with equation 4:

$$\text{average WSP} = \sqrt{(\text{average WSP}_{E\text{-}W})^2 + (\text{average WSP}_{N\text{-}S})^2}$$ 

Equation 4

    where:
    average WSP    = the overall average wind speed
    average $WSP_{E\text{-}W}$ = the average of the east-west components of wind speed
    average $WSP_{N\text{-}S}$ = the average of the north-south components of wind speed

The average wind direction can be found using the average east-west and north-south wind speeds as in equation 5:

$$\text{average } \theta_{wind} = \tan^{-1}\left(\frac{\text{average WSP}_{N\text{-}S}}{\text{average WSP}_{E\text{-}W}}\right)$$ 

Equation 5

Once again, however, care must be taken to ensure both that the angle is in the correct quadrant as the inverse tangent or arctangent function will report results from -90 to 90 degrees, or $-\pi/2$ to $\pi/2$ radians because it typically cannot determine whether numerator, denominator, or both are negative. Excel, for example, has the ATAN2 function, however, which takes separate x and y inputs and will give the correct result if used as in equation 6:

$$\text{average } \theta_{wind} = \text{ATAN2}(\text{average WSP}_{E\text{-}W}, \ \text{average WSP}_{N\text{-}S})$$ 

Equation 6

In Excel, this result will be in radians but can be converted to degrees with the DEGREES function. The average $\theta_{wind}$ will have to be converted back to meteorological wind direction, using the same process as was used to convert meteorological wind direction to mathematical angle as shown in equation 7:

$$\text{average WDR} = 90° - \text{average } \theta_{wind}$$ 

Equation 7

Lastly, if the result is negative, it can be made positive by adding 360°.