

Reg 7 Harmonization

Recommendations Report

for the Colorado Energy and Carbon Management Commission
and the CDPHE Air Pollution Control Division

1 Summary of Recommendations

This report is a product of Ajax Analytics. The document and the recommendations herein do not necessarily represent the views of Colorado's Governor's Office, Office of State Planning and Budgeting, the Colorado Department of Natural Resources, the Colorado Department of Public Health and Environment or any other state agency.

This document provides recommendations for future Reg 7 data to be collected, a suggested format for Reg 7 Monitoring Plan and Monthly Monitoring Report submissions, and a process for collecting, reviewing and processing Reg 7 data for analysis.

These recommendations are designed to enhance a proposed process that automates a large portion of the operator report submission and review. This vision allows for an operator to define their monitoring program once, in a common YAML format that is both computer and human readable. The operator can upload this templated document to a Colorado Department of Public Health and Environment, Air Pollution Control Division (APCD) folder or web page where automated scripts can verify the document and immediately tell the operator whether the document is correct and complete. As the monitoring program changes and the operator adds more information like event investigation results or an operational activity timeline, this base template is simply updated and re-submitted. Because the data is submitted in a standardized format, data validation and consolidation becomes largely automated.

After initial setup, this process will be able to handle thousands of Reg 7 report submissions a month for the cost of 1-2 APCD resources plus the cost of maintaining a web portal and automation scripts. Changes to Reg 7 guidance or reporting requirements can be managed and implemented with controlled, versioned, template governance processes and little confusion during the guidance transitions.

Below is a summary of each of the data collection recommendations described in this document, along with the envisioned benefits that become possible if the recommendation is implemented:

Recommendation	Description	Benefit
Equipment	Standardize the list of on-pad equipment names that operators report in a taxonomy. Collect dates for when equipment is placed in service and removed. Collect geographic coordinates for where the equipment is placed.	When coupled with monitoring data, APCD will be able to identify correlations between the types of equipment onsite and increases in the monitoring measurements. This can guide investigation toward equipment that generates more or fewer emissions. Geographic coordinates, if coupled with high-resolution monitoring data, can help operators and APCD triangulate the most probable sources of specific emission plumes. It may be possible to track a plume's travel across different nearby monitoring programs.
Operational Activity	Standardize the list of operational activities that operators report in a taxonomy. Collect specific dates for when operational activities begin and end. Collect geographic coordinates for where the operational activity is occurring.	When coupled with monitoring data, APCD will be able to identify correlations between the type of operational activities and increases in monitoring measurements. This can help inform which operational activities generate larger or more frequent emissions. This information may inform the potential (or actual) cumulative impacts of multiple operational activities in an area during a specific time period.
Operator's Event Thresholds	Standardize the way event thresholds are defined and described. Create specific fields that describe the response priority, the time resolution, the threshold values, and the operator's planned response actions.	Standardization of the description of event thresholds will maintain freedom for operators to explore various event thresholds while also allowing APCD to directly compare the efficacy of various event thresholds. When coupled with monitoring data that at least meets the highest resolution time interval, APCD will have the monitoring data needed to verify, or audit, operator's event reporting and response actions for each threshold.
Monitoring Data: Reporting Intervals	Collect sensor system data at a consistent time resolution from all Reg 7 monitoring programs. Recommend matching the operator's lowest recording interval of 1-minute. If the goal of speciated measurements is to support plume source attribution during events, then trigger automated sampling during events and collect speciated measurements at higher resolution (instantaneous to 1-hour samples). If the goal of speciated measurements is to support	Consistent reporting intervals in submitted data simplify data processing. Running 1 billion records through a single script is safer, easier, and less expensive than developing and running 10 different validation scripts for 1 million records. Higher resolution data will increase APCD's capability of determining the efficacy of event threshold definitions. When high resolution TVOC (or Methane Indicator) data is coupled with high resolution wind data, APCD gains the ability to triangulate plumes that

	comparisons of Reg 7 data with health guideline values, then collect speciated measurements at sample windows that align with current health guideline exposure intervals.	may have originated off of the operator's targeted points, enhancing the ability to identify leaks from nearby non-targeted P&A wells, gathering lines, or pipelines.
Monitoring Data: Attributes	Standardize a number of attributes that are reported along with monitoring data, such as the layers of aggregation applied to the data, the start and end dates of the reporting interval, and the parameter and unit names.	Standardizing how Reg 7 data is submitted reduces the need to make assumptions about what the data represents during processing and analysis.
Technology Specification	Standardize a list of fields and allowable values that describe the technologies that are collecting, aggregating, and managing monitoring data.	Knowledge of the technologies involved in delivering monitoring data enables APCD to create automated validations that are specific to the nuances of each technology. Validations can be run to confirm that reported data is within a specific sensor's working range, or data can be tagged if a specific data management platform is known to adjust the reported data with an algorithm.
Monitoring Site Definition	Enforce the definition of a monitoring site record as the geographic coordinates of the site, the dates that the site was deployed, and the technologies that were deployed at the site. Organize these data in a specific way to minimize the size of the dataset while also minimizing the complexity of tracking relationships within the data.	Standardizing the definition of a monitoring site ensures that monitoring data is always connected to the specific location where the measurement was taken and connected to the specifications of the technology that collected the measurement.
Specific Data Formatting	Standardize geographic coordinates as decimal format to 5 decimal digits representing +/-3m accuracy (typical phone GPS accuracy). Standardize date formats to the RFC 3339 standard, recommending "YYYY-MM-DD HH:mm:ssZ"	This format of geographic coordinates is commonly used and most programming languages can readily process the coordinates. The coordinates are specific enough to accurately place objects without requiring specialized GPS measurement equipment. This common date/time standard limits the allowable possible formats for time and date data. Most programming languages can readily parse this format. The format remains human-readable. Inclusion of the time zone offset from GMT removes the need for APCD to make any assumptions about whether the data was submitted in UTC, MDT, or MST.

With the recommendations in this document, the APCD will:

- Assess the feasibility of implementing each recommendation.
- Determine whether the recommendation in this document should be modified to better serve the goals of Reg 7 or to better align with other data standards.

- Identify the appropriate path for receiving and incorporating internal and/or external stakeholder feedback on these recommendations.
- Design and execute an implementation plan for those improvements that are identified as beneficial to the goals and objectives of Reg 7.

2 Background

2.1 Overview

In early 2021, the State of Colorado implemented new air pollution control requirements for oil and gas operators. These requirements mandate air quality monitoring before, during, and after oil and gas pre-production operations. This particular requirement is part of a regulation called Regulation Number 7, or Reg 7.

The 2021 changes to Reg 7 are innovative because they allow operators to explore various monitoring technologies and approaches to reduce greenhouse gasses, air toxics, and ozone precursors. The flexibility in the rule appears to be intended to encourage the private market to identify the most effective and cost-efficient methods for air monitoring during oil and gas pre-production and early production activities while striving to reduce emissions from the oil and gas industry.

Under Reg 7, operators must submit an Air Monitoring Plan for approval before commencing pre-production operations. Once the plan is approved and monitoring begins, operators are required to submit a Monthly Monitoring Report, which includes summary data about their facilities, operations during the month, and their air monitoring efforts.

These plans and reports are submitted to the Colorado Department of Public Health and Environment's Air Pollution Control Division (CDPHE APCD), also known as the APCD.

 This document assumes familiarity with the Reg 7 Harmonization processes and data model outlined in the main report: Reg 7 Harmonization Core Questions Report.

2.2 Reg 7: An iterative learning process

Although the current Reg 7 rule language and guidance documents outline requirements for continuous air monitoring and the content to be provided in plans and reports, they do not specify the type of technology, time resolution, submission format, or specific data attributes to

be provided. Without specifications, oil and gas operators use different approaches and formats when structuring their reports and providing information.

The initial version of the regulation was intentionally flexible to allow for continuous monitoring to begin and for the industry and regulators to learn from the process. The goal was to identify effective monitoring practices and provide guidance for future improvements.

Continuous monitoring at this scale, especially in relation to oil and gas operations, is a relatively new field in air science. It heavily relies on technology that is less than 10 years old. Standards and best practices are still being developed by the monitoring technology market, academia, and research agencies.

The main objective of this project was to consolidate and analyze a subset of the reported Reg 7 data. The secondary objective was to use this consolidation and harmonization process to identify the standards, best practices, technologies, and data analysis methods that are most suitable for streamlining and improving Reg 7 continuous monitoring requirements, practices, and data.

At the beginning of the project, the project team was asked the following specific questions, which are addressed in this document:

- What additional information does the APCD need to standardize in order to appropriately analyze and interpret the data?
- What data can the APCD request from operators in the future to gain a better understanding of the information gathered through Reg 7 monitoring?
- What recommendations does the project team have for the format in which operators should submit this data in the future to facilitate data quality assurance and compilation?
- What recommendations does the project team have for maintaining this dataset as new reports are submitted by operators?
- What factors should the APCD consider when recommending monitoring equipment, including equipment selection, best practices for use, and data treatment and management?
- What recommendations does the project team have for the optimal utilization of this dataset, including appropriate and inappropriate uses of the data?

3 Recommendations

The project team was tasked with reviewing the report submissions to identify information that would be useful to include in every report.

Identifying data that is not currently present but would be helpful if the data were included can be a challenging task that requires creativity, experience, and subject matter expertise. Having a variety of data formats was beneficial in this regard as each operator provided information which they believed could be useful for Reg 7's primary objectives. Some operators provided more information than others, and the variety of content allowed the project team to gauge the type of data that could be provided. This allowed for the assessment of whether having a more complete dataset for a given data element would have added utility in the Reg 7 core questions analysis.

To provide the most value in this report, detail about every field format and allowable list of values that was uncovered during the Reg 7 Harmonization project is not included and is available within the Retool Reg 7 Data Entry App and the Dataiku Project Flows. This report focuses on the most critical opportunities for standardization, which were those data objects and elements that required the most effort to find, extract, and harmonize – and which provided the greatest challenges during analysis of the core questions. The following information elaborates on these elements that would be most beneficial to request or standardize in monthly Reg7 reports.

3.1.1 Equipment Types and Dates

Clear insight into the types of pre-production and production equipment in operation at the oil and gas facility will provide analysts with the ability to identify relationships between certain activities or equipment and elevated VOC observations. For example, with knowledge about when a drill rig was onsite and whether the drill rig was powered by line electricity or generators, the APCD could evaluate whether there is a significant relationship between electric drilling rigs and fewer elevated VOC observations.

In order to build information about the equipment attributes of a facility, the following five pieces of information are needed:

Equipment Type: The type of equipment in service. Ideally defined as a hierarchical set of fields.

Equipment Deployed: The date that the equipment was put into service.

Equipment Removed: The date that the equipment was removed from service.

Equipment Latitude/Longitude: The specific location of the equipment.

Facility Name (or ID): The facility where the equipment was placed in service.

We recommend that an equipment type taxonomy be created for operators to provide consistent nomenclature and sufficient detail. The 2-tiered equipment type taxonomy used for the Reg 7 Harmonization project, found in Appendix A, can serve as a starting point. We recommend at least a 2-tier taxonomy, though APCD may be able to get the most accurate and complete taxonomy by working with operators to create one that is not overly burdensome to use.

3.1.2 Operational Activity Types and Dates

Clear insight into the operational activities performed within an oil and gas operation will provide analysts the ability to identify statistically significant elevated VOC observations during certain operational activities and enable APCD to identify activities that may have the greatest opportunity for additional emission reductions. For example, more precise visibility into operational activity start and stop times can allow for a better association of which operational activities incur the most frequent elevated VOC observations

In order to better relate monitoring data to ongoing operational activities in the area around the monitoring site, the following 5 key attributes should be collected:

Operational Activity Type: The type of operational activity being performed. Ideally in a hierarchical set of fields.

Operational Activity Start: The start date of the operational activity. (Time also preferred, if possible)

Operational Activity End: The end date of the operational activity. (Time also preferred, if possible)

Operational Activity Latitude/Longitude: The specific geographic location (lat/long) of the operational activity.

Facility Name (or ID): The facility where the operational activity was performed.

The start and end dates for operational activities can be somewhat fluid within an operation, with occasional planned or unplanned gaps in operations. For example, drilling may occur, then pause for a day due to weather conditions, then begin again. While APCD may request specific activity records for each stop and start, it is likely less burdensome to the operator to provide some guidance on how long a stoppage must be in order to request this information. A planned break of weeks may require reporting an activity as started, then stopped, then

started again. An unplanned break of a day may not require an update of the operational activity stop and start dates.

Similarly, operational activities may overlap, sometimes referred to as Simultaneous Operations, or SimOps. Any evaluations of these start/stop times should allow for overlap while providing a complete look at the lifecycle of operations during this monitoring.

With a well-defined operational activity taxonomy and complete start/stop dates, APCD should be able to re-create the activities that occurred at the facility without any gaps or assumptions.

The specific location of the operational activities also requires some judgment as to the required specificity. In many cases, the central location of the facility where the activity is occurring could suffice as also being the location of the activity. Within very large, multi-pad operations, however, it could be useful to know that a drilling activity occurred 300' away from a later production operation, both of which may be 200' away from the reported center of the facility.

3.1.3 Standardized Geographic Coordinates

Providing geographic coordinate standards can be a complex and involved task, with many varieties of standards related to geographic and projection coordinate systems, the format of the data, and the measurement precision that is required.

We recommend simple standards that are easy to follow and are commonly used in many of the GPS tools that operators are likely to use when collecting this information (i.e.: cellular phones, Google Maps, etc.).

In the Reg 7 Harmonization project, all geographic coordinate data was converted to a simple decimal number field with a precision of 5 decimal places and forced trailing zeros. When placed in a field together, a comma-space separator between latitude and longitude was used.

Coordinates should be provided as a single text field with the following format (##.#####, - ###.#####). Ideally, latitude and longitude can be provided in separate fields, removing the risk of an invalid separator being used.

Operators should provide data with a measurement precision of +/- 3 meters (or 5 decimal places), which most cellular phones are more than capable of when given time to stabilize the coordinate measurement (and in some cases, requiring that a "precise location" setting be enabled).

We do not recommend that the GPS coordinates provided by the cellular modems within a small sensor system be used to provide coordinate information. In our experience, the

modems and GPS firmware used in small sensor systems are not often as fast nor as precise as those used in cell phones.

3.1.4 Standardized Event Threshold Definitions

One challenge in the Reg 7 Harmonization dataset was that the information about the event threshold definitions were provided in natural text, or paragraph, form. As part of the Reg 7 Harmonization process, the operator's natural text was classified into a set of standard classification fields and tags which could then be used for analysis.

In order to both allow for variability in the types of event thresholds while also providing some standardization, the following fields should be provided as part of an event threshold definition within a monitoring program:

Event Level: The magnitude/priority classification of the measured value serving as the threshold (e.g.: "high, medium, low priority" or "extra-small, small, medium, large, extra-large magnitude")

Reporting Resolution: The numeric time resolution, in minutes, of the data being monitored for event threshold exceedance (e.g.: "1")

Reporting Aggregation Method: The aggregation method being applied to get from the recorded interval to the reported interval (e.g.: time-block average, moving average)

Parameter: The parameter being monitored for the event threshold.

Units: The units of measurement for the parameter being monitored for the event threshold.

Comparison Operator: Defines whether the reported value needs to meet, exceed, or meet and exceed the threshold value. Recommend only ">=".

Threshold Value: The measured value that must be met or exceeded in order to prompt an event threshold exceedance.

Consecutive Readings: How many consecutive measurements above the threshold value must be observed in order to prompt an event threshold exceedance.

Actions: A standardized list of actions that are planned to be performed upon an exceedance of the event threshold (e.g.: internal notification, investigate, LDAR inspection, etc.)

Natural Language Description: A field that allows the operator to provide context or nuance that they deem important, but which is not captured in the standardized fields.

Another challenge with the operator's event threshold definitions is that often, the data resolution of the operator's event threshold was different than the resolution of the data in the monthly reports. This results in the inability to review the specific TVOC Indicator data that prompted an event and the inability to validate how many event threshold exceedances occurred. For example, many event thresholds were defined as something similar to "An alert level of 1 ppm (1-minute average) total VOCs." or "3 ppm TVOC for three consecutive [1-minute] readings", however, the reported data interval in these monitoring programs was provided at 15-minute or 1-hour resolution. Therefore, different event threshold data and monthly report data resolution remove the ability to review reports alone for compliance assurance by the APCD and would require requesting additional data from the operator.

We recommend that monthly reporting data have consistent reporting intervals and that monthly reporting data be at a reporting interval that allows for re-creation of all event threshold intervals. Collecting the lowest common denominator time resolution (e.g. 1 minute) may result in an increase in data and storage requirements for the APCD though still allows for operators to explore varying time resolutions and frequencies for event thresholds. APCD would retain the ability to aggregate the reported data into the event threshold intervals, though at the cost of additional processing to compute the aggregations.

3.1.5 Standardized Event Threshold Value Definitions

Event threshold definitions used by operators were widely varied. Every monitoring program based their event thresholds on TVOC Indicator measurements from a PID or MOx sensor.

Two factors should be carried into event threshold standards. First, many operators provided a multi-tiered approach to event identification, with lower priority tiers raising awareness to potential issues and higher priority thresholds prompting an immediate investigation into possible causes for the event. Secondly, operator-reported data was inconsistent, in some cases even within the same monitoring site, such as units changing from "ppb as isobutylene equivalent" to "ppm as isobutylene equivalent", or with calibration settings appearing to change the magnitude of sensor peaks. These types of issues create challenges in defining simple thresholds that can be applied to all operators, technologies, and monitoring sites.

We recommend continuing the multi-tiered approach to event threshold definitions. Most operators provided thresholds with some sort of tier, such as ones that result in "internal" or "external" communications. We recommend that these tiers be standardized and defined so that they can be used with consistent meaning across monitoring programs (e.g. low, medium, high, critical priority event thresholds) and with event response actions and reporting

requirements defined to be in-line with the potential magnitude of the event. This approach can allow operators to maintain visibility into smaller events that, individually, may not be worth investigating, but which may be worth investigating in total if there are periods or types of activities that are found to generate many smaller events.

Creating default TVOC Indicator threshold standards is more challenging. Defining standards for event threshold values is dependent on 1) standardizing time resolution of sample and recording intervals and 2) ensuring sensors are used in such a way that the output from the TVOC Indicator sensor is not scaled inappropriately (i.e. no hard zero settings, aggregation, or calibration curves that artificially mute large sensor outputs), and 3) ensuring that sensors are not used beyond the end of their effective life (sensors with muted response due to aging or dirty components).

The Reg 7 Harmonization analysis had the benefit of working with select sites that included a complete dataset. For example, the TVOC Indicator Index leveraged a centered 4-day window of data to normalize data across different monitoring sites, programs, and technologies. A standardized operator threshold will require a threshold value structure that works as data is received by the operator, and not all sensor systems or data management platforms are currently capable of applying real-time normalization algorithms against the incoming data stream.

One possible approach to event threshold guidance may be to require event threshold settings that are defined as surpassing a level above the background range for each sensor. For example, if a sensor's typical background range is 80 mV to 130 mV (range = 50 mV), event thresholds can be set at levels of 5x (or 10x, or 15x, etc..) over the top of the baseline range. In this example, an event threshold would be 380 mv [130 mV upper baseline + (50 mV range x 5)]. This approach accommodates the varying response between different sensors and, if thresholds are re-calculated occasionally, can adapt to an individual sensor's changing response. This approach also incentivizes operators to calibrate effectively, as a calibration zero point that is set well above the sensor's "clean air" baseline will reduce the baseline range and highlight the issue through additional event threshold exceedances.

Another possible approach to validating event threshold values in the future may be to assess each monitoring program against the expected percentage of TVOC Indicator outliers. An initial read on the TVOC Indicator distribution from the Reg 7 Harmonization dataset suggests that about 3.5% of the recorded data can be expected to be outlier events. As the TVOC Indicator data is reported with more consistency and better information about the results of investigations are provided, APCD will be able to judge what percentage of outliers are expected to be low/medium/high priority events and develop better guidance on where operators should be defining the threshold values in order to maximize the environmental return on investment for investigations.

3.1.6 Event and Event Response Reporting

One challenge in the Reg 7 Harmonization dataset was that the information that the operators provided in response to events were provided in natural text, or paragraph, form. As part of the Reg 7 Harmonization process, the operator's natural text was classified into a set of standard classification fields and tags which could then be used for analysis.

In order to be able to evaluate events against each other, the definition of a common structure should be implemented for event reporting. In the Reg 7 Harmonization project, we identified monitoring event classification fields to structure the analysis. The following fields should be provided as part of an event response information:

Event Threshold Exceeded: A reference to the highest event threshold that was exceeded during the event window.

Event Start: The date and time that the event began (i.e.: TVOC Indicator left background ranges).

Event End: The date and time that the event appeared to end (i.e.: TVOC Indicator returned to background ranges)

Classification: The true-positive or false-positive classification of the event. Guidance should be that every event is assumed to be a true-positive unless there is clear evidence of a false-positive due to a confirmed sensor issue or maintenance activity.

Response Actions: A list of actions (tags) that were performed as a result of the event identification.

Suspected Reasons: A list of suspected possibilities for the event. Note that this list may grow, shrink, or change through the course of an investigation. Including conjecture like this in a report could be seen as a risk for an operator, unless there is a culture of understanding and collaboration in the investigative process.

Resolution: The operator's eventual resolution of the event (e.g.: "no resolution", "replaced leaking valve", etc.)

Commentary: Any commentary that the operator believes could be useful to know about the event, investigation, top suspected source, etc.

While a common set of standard fields will be useful for analysis and classification across many monitoring programs, there is also a question of whether each instance of an event threshold exceedance is an "event" or if some longer duration "episodes" are actually made up of multiple exceedance events.

For example, a large magnitude VOC plume episode can be expected to start with a low threshold exceedance, then a medium threshold exceedance, then perhaps a series of medium/large threshold exceedances, then slowly trail back to baseline with a series of low threshold exceedances. It is also likely that multiple monitoring sites register their own events as part of the episode. From a data model perspective, this could be modeled as an “Episode” that is related to a series of “Events”, or event threshold exceedances across multiple monitoring sites. This level of data capture and reporting can be challenging. As such, we recommend that Reg 7 guidance let operators define a single event record, as defined in the fields above, and register the event as an exceedance of the highest surpassed threshold. If the start and end dates of the event record are accurate, then the high resolution monitoring data can be explored for APCD analysts to reproduce the progression of the events and bundle them into episodes during analysis.

Another challenge that appeared to be partially addressed in the first year of Reg 7 monitoring and reporting relates to clarification of when operators needed to report on an event threshold exceedance. We understand and saw in the data that operators originally did not define lower event thresholds. This did not appear to be a common practice early in this regulatory program, which may have been out of concern for the reporting workload created, or perhaps based on a history of regulations being more focused on emergency-level events, rather than information-level and investigation-level events. We recommend finding a balance that encourages operators to note and investigate potential emission sources based on smaller anomalies in the monitoring data. It may be possible to guide operators toward providing simple documentation that events were observed and recognized while only requiring more detailed commentary on full investigations or exceedances of higher priority event thresholds.

3.1.7 Monitoring Data

Operator-reported monitoring data posed the biggest challenge to standardization in the Reg 7 Harmonization project. In total, the cleansing, standardization, quality check, and analysis processing for monitoring data required 196 interim datasets, 141 scripted data recipes, and 9 manual data mapping and classification tables.

The sub-sections below outline a series of recommendations that would remove the need for an estimated 80% of the data validation and standardization efforts performed in the Reg 7 Harmonization project.

Sample and Reporting Intervals

In determining our recommendation for monitoring data reporting intervals from sensor system data, we considered the following premises:

1. The core usefulness of TVOC Indicator data (the most prominent parameter used in Reg 7 monitoring), lies in the data's ability to identify outliers that may represent elevated VOC observations from the target facility.
2. There is a logarithmic loss in visibility as data is averaged, with most elevated observations becoming averaged into the baseline within aggregation intervals of a few hours.
3. Wind and meteorological measurements are provided largely in support of the TVOC Indicator data
4. Monitoring systems record data at 1-minute time resolution or less, and data is aggregated to longer time resolutions for comparison to higher priority event thresholds and monthly report submission to the APCD.
5. The biggest challenge in processing reported monitoring data in this project was not the volume of data, but the variety of data. Every different reporting interval required creation of a new portion of the data pipeline and different approaches to standardizing the monitoring data that was delivered.

Therefore, considering the above observations as premises for a recommendation:

If the goal of Reg 7 monitoring is to be able to identify potential leaks and emissions, then the project team recommends that reported data be collected at the highest-resolution time interval available (1-minute). Higher resolution data enables more specific tracking of plume transport and improves the ability to triangulate a potential source (both within the targeted facility and also from non-targeted sources, such as nearby P&A wells in the area). The APCD should consider whether the benefits of higher resolution data provide sufficient value to outweigh any additional data management and/or storage costs.

We recommend that wind and meteorological measurements be reported at the same resolution as monitoring data.

In any case, we recommend that all monitoring programs submit reported data with the same interval. If this is not possible, limit the number of allowable reporting intervals as much as possible.

We do not have a static recommendation for the sample intervals for speciated measurements.

If the goal of speciated measurements is to validate TVOC Indicator events and identify emission sources, then we recommend high-resolution speciated sampling that is automatically triggered by sensor systems during those moments when spikes in the TVOC Indicator trace occur. In this case, instantaneous to 1-hour sampling intervals will likely provide the information about the in-plume VOC composition that is required for source attribution.

If the goal of speciated measurement is to assess concentration levels in an area against the latest health guideline values, then we recommend aligning the sampling interval with the health guideline values of concern. This will be most useful if samples are collected during periods when elevated emission levels are expected (i.e.: when TVOC Indicator sensors can inform the frequency and magnitude of VOC concentrations in the area).

In any case, speciated measurement intervals and sensor system measurement intervals do not necessarily need to be aligned.

Reporting Interval Dates

We recommend that all monitoring data measurements are reported with both a reporting interval start and reporting interval end date and time, to seconds precision. This approach facilitates automated quality assurance scripts without requiring any assumptions about whether there are missing time periods or changing reporting intervals.

Aggregation Allowances

We recommend that a measurement value for a reporting interval only be populated if at least some percentage of the measurements sampled and recorded within the reporting interval are included.

For example, if a sensor system takes measurements at a 1-second sampling interval, and averages the sampled measurements into a 1-minute recorded data interval, there should be 60 1-second measurements being averaged into the recorded data. If there are regularly 20 or 30 measurements included in the 1-minute recorded average - even if the sensor system is averaging appropriately using the number of samples, rather than the number of elapsed seconds - these small gaps in the averaging will make any later time aggregations performed for reporting or analysis incorrect. At the scale of data that Reg 7 monitoring produces, this inaccuracy due to averaging incomplete averages can compound quickly.

We do not recommend requiring 100% completeness in order to generate a reporting interval aggregation, as this requirement may mean leaving some useful information inaccessible. At a 1-minute reporting interval, an 80% complete input data rate would likely be acceptable without creating an excessive average-of-averages issue. At a 15-minute reporting interval, which is itself calculated from a series of 1-minute recording intervals, the complete input data rate should be higher, perhaps at 90% or 95% complete input data rate in order to minimize the amount of inaccuracy introduced by averaging averages.

Parameters and Units

Data provided to the Reg 7 Harmonization project included a wide variety of parameter names and units. While it did appear that, over time, additional guidance was introduced to help standardize the parameters, the issue with units for each parameter persisted.

We recommend that all sensor system data be submitted with the same parameter and unit combinations. The units and parameters set as standards for the Reg 7 Harmonization project can serve as a starting point and are defined below:

Parameter	Units
temperature	F
atmospheric pressure	mbar
relative humidity	percent
wind speed	mph
wind direction	degrees
tvoc indicator	<multiple depending on technology>
methane indicator	ppm
pm 1.0	ug/m3
pm 2.5	ug/m3
pm 10	ug/m3

Parameter and unit standards are more challenging for speciated compounds as there are multiple accepted names for many compounds and laboratories that perform analysis do not always provide operators the same compound names or use the same naming conventions as are requested by the standard. Many times, lab results are provided in PDF format or with units in ppb or ug/m3, making it difficult to extract the speciated results into a common standard.

In the Reg 7 Harmonization project, a list of names for speciated compounds was selected, and all parameters were enhanced with the molar weight to facilitate conversion from ug/m3 into parts-per-billion. The list of speciated parameter and units combinations provided in Appendix C can serve as a starting point for APCD standard requirements.

Metric Naming

One issue discovered during the Reg 7 Harmonization project was maintaining visibility into the reporting, recording, and sampling intervals along with the parameter and units for each measurement value.

While duplicative to some extent, we recommend requiring that every measurement value provided also include a “metric” definition that follows a naming convention to describe the value being presented in detail. The naming convention that we recommend is as follows:

*(reporting interval and aggregation method(recording interval and aggregation method(sample window **per** sample interval parameter units)))*

For example: (1h avg(1m avg(1s relative humidity percent)))

This simple, code-parseable metric name tells us that the value presented under this metric is based on 1-second samples that were averaged into 1-minute recording intervals, and averaged again into 1-hour reporting intervals. An analyst now has visibility into the potential for an average-of-averages inaccuracy, as well as knowledge that this was a nearly-continuous measurement that has been aggregated into a longer interval. They also know that, if requested, they may be able to get access to the 1-minute recorded data.

This naming convention can be consolidated in situations where any of the intervals simply pass the value through. For example, most speciated measurements will have an aligned reporting, recording, and sampling interval, therefore a 1-hour canister sample metric such as (1h avg(1h avg(1h benzene ppb))) could be simplified to (1h benzene ppb).

In another example, a measurement from a gas chromatography system that samples for 40-minutes and analyzes the sample for 20 minutes, then reports data as a 1-hour sample interval may have a metric such as (1h avg(40m per 1h avg benzene ppb)), which maintains clarity in the 20-minute difference between the sampling interval and the presented reporting interval.

We decided on this metric naming convention based on our own experience with the issue, and our approach was guided by a paper titled “Naming Convention from Climate and Observation Data” published by the Norwegian Meteorological Institute (linked below) where they have defined standards to solve for these same concerns.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjAmqy9mKiCAxWCm2oFHfcRAzcQFnoECBIQAQ&url=https%3A%2F%2Fwww.met.no%2Fpublikasjoner%2Fmet-report%2Fmet-report-2017%2F_%2Fattachment%2Fdownload%2Faf238036-3b9a-465b-a0ea-c994bf4df734%3Afd46e83c4e312dd8493160f77e8d5df0823cf07e%2FMETreport-bora-naming-convention_unsigned.pdf&usg=AOvVaw0GQuqC1UfbchxVPhqUTS5i&opi=89978449achment › download

3.1.8 Technology Specification

One significant challenge that the Reg 7 Harmonization project faced was identifying and standardizing technology attributes and specifications that could be tied to the reported measurement values. Technology recommendations are in two parts: A) recommended information to collect regarding the technologies that are recording measurement values, and B) recommendations regarding the definition of a monitoring site where deployed technologies are part of the definition of the monitoring site.

A. Recommended Information to Capture about Technologies

While several iterations of technology definitions were considered in the Reg 7 Harmonization project, the final technology stack and technology data model that was included in the master dataset remains imperfect, but is as close as we could come to what we believe will provide useful attributes for data segmentation and analysis. The concept here is that any measurement value provided should have a relationship with each of the technologies that had a role in delivering the measurement from the time of sampling through to the reported value.

For example, a wind direction measurement is measured by a wind sensor, processed and aggregated within a sensor system, sent to a data management platform. Each of these technologies has a role in transforming, processing, and/or aggregating the physical measurement (a voltage reading of some kind) into a reported wind direction degrees from north that an analyst is using. Having basic information about each of these technologies can be important when determining how to best use the measurement value.

As a result of these learnings, we recommend that the following technology attributes within a monitoring plan be collected. This recommended data collection structure is presented as a partial technology stack example in YAML format, as the vertical nature of this data model can be challenging to grasp when presented as a list of fields. Exploring this data in the Retool: Ajax Reg 7 Master Data Application also makes the recommended data structure more clear.

```
technology_stack:
  name: '15m Airwatch System w/ Davis Instruments 6410 on Airwatch Plat
  technologies:
    - name: 'Data Management Platform'
      model: 'Airwatch Platform'
      parameters: ''
      type: 'data management platform'
      communication_method: ''
      power_source: ''
      solar_panel: ''
      battery: ''
      sampling_method: ''
      algorithmic_data_adjustment: 'N'
      recording_interval: ''
      recording_aggregation_method: ''
      reporting_interval: '15m'
      reporting_aggregation_method: 'pass-through'
      measurement_range: ''
      minimum_detect_limit: ''
      sensitivity_resolution: ''
```

```

sample_window: ''
sample_interval: ''
starting_threshold: ''
accuracy: ''
compass_orientation_method: ''
sampling_location: ''
planned_number_of_analytes: ''
planned_laboratory: ''
reference_method: ''
- name: 'Sensor System'
  model: 'WSP Airwatch System'
  parameters: ''
  type: 'low-cost sensor system'
  communication_method: 'Cellular'
  power_source: 'solar + battery'
  solar_panel: ''
  battery: ''
  sampling_method: 'passive [assumed]'
  algorithmic_data_adjustment: 'Y'
  recording_interval: '15m'
  recording_aggregation_method: 'pass-through'
  reporting_interval: ''
  reporting_aggregation_method: ''
  measurement_range: ''
  minimum_detect_limit: ''
  sensitivity_resolution: ''
  sample_window: ''
  sample_interval: ''
  starting_threshold: ''
  accuracy: ''
  compass_orientation_method: ''
  sampling_location: ''
  planned_number_of_analytes: ''
  planned_laboratory: ''
  reference_method: ''
- name: 'VOC Sensor'
  model: 'Sensiron SGPC3 [assumed]'
  parameters: 'tvoc indicator'
  type: 'metal oxide'
  communication_method: ''
  power_source: ''
  solar_panel: ''
  battery: ''
  sampling_method: ''
  algorithmic_data_adjustment: ''
  recording_interval: ''
  recording_aggregation_method: ''
  reporting_interval: ''
  reporting_aggregation_method: ''
  measurement_range: '0-60000 ppb TVOC as ethanol equivalent'
  minimum_detect_limit: '1 ppb TVOC as ethanol equivalent'
  sensitivity_resolution: '+/-15% TVOC as ethanol equivalent'
  sample_window: '<1s [assumed]'
  sample_interval: '15m'
  starting_threshold: ''
  accuracy: ''
  compass_orientation_method: ''
  sampling_location: ''
  planned_number_of_analytes: ''
  planned_laboratory: ''
  reference_method: ''

```

B. Recommended Application of Technology Specifications to Monitoring Site Definition

The most unambiguous approach to recording technology attributes associated with each measurement would be to “tag” every measurement value with all relevant information about the technologies that contributed to the measurement value. However, this de-normalized data structure would create an immense dataset size. Alternatively, a data structure at 3rd normal form would accomplish this goal, but introduces attributes within many-to-many relationships – which we are trying to avoid for simplicity in the data model.

The recommended approach maintains an efficient dataset structure while still providing for the ability to relate every measurement with the technologies that played a role in delivering the measurement value. For this, we recommend associating a monitoring site with all of the technologies that are deployed at the monitoring site. Specific technologies can be linked by parameter name to the measurement values. In this way, for example, we can record the accuracy specification for wind speed sensor at a monitoring site once and then be able to find the accuracy specification for every wind speed measurement recorded at that monitoring site.

This approach does require that the technologies deployed at a monitoring site become part of the definition for a monitoring site. This means that a monitoring site (that is, the definition of a monitoring site record) is a combination of:

- 1) the site’s location,
- 2) the technologies that are deployed at that location, and
- 3) the start and end times that the monitoring site existed at this location with this technology configuration.

Under this approach, if an operator changes any attribute of a site’s technology stack (for example, adds a wind sensor to the monitoring site), then the operator should be providing an end date for the monitoring site record with a technology stack that does not have a wind sensor and creating a new monitoring site record with the technology stack that does include a wind sensor (along with the start date for the new site configuration). Even though the name and coordinates may not change, a new record should be created (though for clarity, we do recommend changing monitoring site name as well).

Similarly, if an operator moves a monitoring site from one geographic position (indicated by lat/long) to another, even temporarily, the operator should be providing an end date for the site at the old position and creating a new monitoring site record for the new position.

This approach to addressing technology attributes as a key component of a monitoring site definition was influenced by a presentation by Dr. Jonathan Callahan called “Universal Data Structures for Air Quality Data” presented at the UC Davis Air Sensors International Conference in 2022 [<https://asic.aqrc.ucdavis.edu/sites/g/files/dgvnsk3466/files/inline-files/Jonathan%20Callahan%20-%20Universal%20Data%20Structures%20%20for%20Air%20Quality%20Data.pdf>].

3.1.9 Date Formatting

Date formatting presented some challenges in the Reg 7 Harmonization monitoring report data. In general, dates and times were presented with a variety of formats - even within the same monitoring report - creating challenges in parsing and standardizing datetime data.

We recommend standardizing date time data based on RFC 3339 definitions, as this standard provides the most constrained set of allowable date time formats. We do not recommend standardizing on ISO 8601, as this standard allows for a large number of date time formats that can become difficult to maintain in processing and validation scripts and which can be difficult for humans to read. For a visualization of allowable formats, see this helpful visualization of the standards: <https://ijmacd.github.io/rfc3339-iso8601/>

We recommend that guidance documentation refer to RFC 3339 as a standard, but encourage all date and date time data to align with the following format:

YYYY-MM-DD HH:mm:ssZ

For example: 2023-05-01 22:02:00-06

- Year should be provided with four digits.
- Month should be provided as two digits.
- Day should be provided as two digits.
- Hours should be provided in 24-hour format with two digits.
- Minutes should be provided with two digits.
- Seconds should be provided with two digits.
- Time zone offset should be provided as the UTC offset in hours and minutes.
- Dashes separate year, month, and days
- A space separates the date and time ('T' optional)
- The UTC offset should immediately follow the time without a space.

This recommended date time format incorporates any of the operator's daylight savings time decisions and removes the need to make assumptions regarding time zone of the data or the application of daylight savings time.

4 Recommended Submission Format

We identified the following base requirements for a recommended format for monitoring plan and monthly report submission. The report format should be:

- Able to be created and managed by humans if needed (be human readable)
- Readily accessible by computer scripts and/or code for automated data processing and quality assurance checks
- Readily re-factor into an API-based submission in the future
- Able to manage and convey a hierarchy of 1:M relationships between data objects
- Minimize tracking or synchronizing cross-object identifiers or relationships
- Enable (and/or enforce) standardized lists of values and tags
- Easily adapt to additional fields or requirements
- Enable automated capture and traceability of updates or changes across monthly reports

We recommend that all monitoring plans and reports be submitted in the same YAML formatted document, coupled with a CSV file for submission of monitoring data. While YAML is not a common data format in the environmental monitoring industry, it is an extremely common data file format in the software industry. The basics of a YAML document are simple to learn, and Reg 7 monitoring program and monthly report definitions are not likely to require more structure than a basic YAML document can provide.

With a common YAML document structure, both monitoring plans and monthly reports can utilize the same document. This would allow APCD to readily provide an automated report submission tool that provides operators immediate feedback on missing data, poor structure, or lacking adherence to regulatory guidance within seconds of submission, rather than investing in back-and-forth email validation.

Internally within the APCD, by using a common file management tool such as GIT, every change to a monitoring plan, and subsequent updates to the plan structure via a monitoring report can be tracked and reviewed quickly, with a readily available view into specific line-by-line changes to the YAML document over time.

Utilizing the same document structure for monitoring plans and monthly reports allows for operators to provide the information that they know during the planning stage, and then simply add more information and/or update the existing plan document when delivering a monthly report. As a program changes, existing data can be updated and new data can be added. Through a tool such as GIT, APCD will maintain a complete history of changes to the document over time, while always knowing which document is the current “main” document describing a monitoring program.

Appendix D to this document contains an example (partial) YAML formatted monitoring plan/report for a program with multiple facilities, operational activities equipment, etc.

Appendix E to this document contains a sample CSV monitoring data file designed to accompany the YAML file in a monthly report submission.

This format recommendation was inspired by the use of YAML templates by Amazon Web Services (AWS), the most popular cloud infrastructure company in the world. AWS utilizes YAML as one of the primary methods for humans to define hierarchical definitions for cloud infrastructure that AWS servers can then read and process. The basics of a YAML document can be learned here within a few minutes: <https://learnxinyminutes.com/docs/yaml/>

5 Recommended Submission Process

5.1 Process Overview

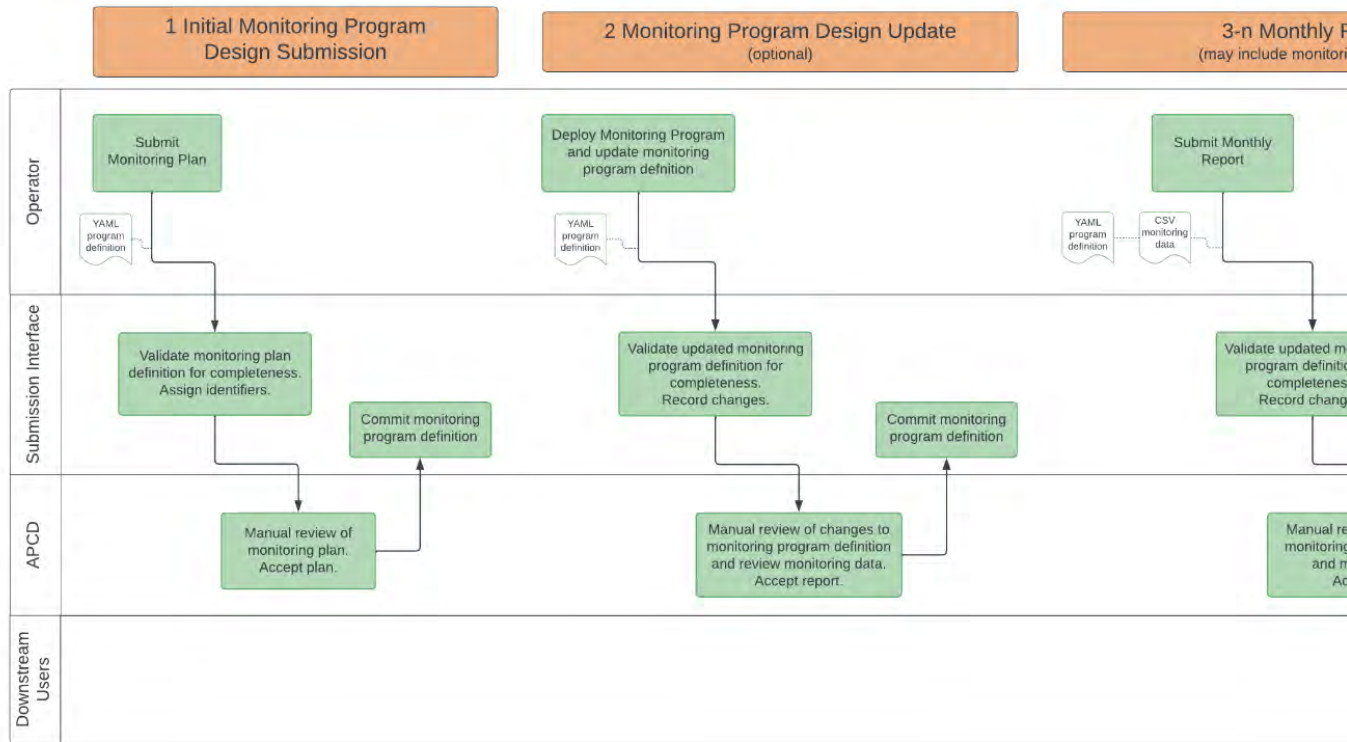
The current, Excel-based, monitoring plan and monthly report format is not scalable. Keeping up with the projected volume of incoming plans and reports would likely require at least 3 to 6 full time resources at an estimated cost of \$300,000 to \$700,000 per year (likely more), plus infrastructure costs.

With the volume of monitoring plans and monthly reports currently submitted, scaling to a process that allows operators to submit reports in a more self-service method, then automating the file management and initial quality check process would allow APCD to process high volumes of monitoring plans and reports with 1 to 2 resources and with higher quality output.

The recommended process outlined below may serve as a starting point for APCD process design efforts. In this vision:

- A. Operators authenticate to a website or online file store and upload a Reg 7 Monitoring Document YAML file as their initial monitoring plan.
- B. Automated APCD processing reviews the plan with a validation script, immediately notifying the operator whether the plan was accepted for APCD review or whether the plan is missing required elements or information is outside of an expected value (e.g. wind direction greater than 360 degrees).

- C. Upon the automated review of the monitoring plan passing, the monitoring plan is placed into a file system managed by GIT version control, upon which an APCD resource reviews the plan and either informs the operator of additional requirements and revisions, or updates the document to accept the plan.
- D. Once an operator starts monitoring and is ready to submit their first monthly monitoring report, the operator updates their plan document with corrected information and actual deployment information and submits the monitoring program document and a CSV with the monitoring data through the APCD website or online file store.
- E. Automated APCD processing reviews the monthly report files with a validation script, immediately notifying the operator whether the monthly report was accepted for APCD review or whether the plan is missing required elements.
- F. Upon the automated review of the monthly report passing, the monthly report files are placed into the file system managed by GIT version control, where an APCD resource reviews the updates to the plan and either informs the operator of additional requirements and revisions, or updates the document to accept the plan.
- G. The latest accepted monitoring program definition documents and related CSV files with monitoring data are committed within a single, controlled location for access (or pushed transfer) into other downstream systems (such as public share systems, APCD data consolidation databases, or Colorado Air Enterprise Databases)



5.2 Implementation

Implementing a process similar to this recommendation will require the following steps be executed:

- 1) Define the monitoring program definition YAML file structure. Create the final version 1 template.
- 2) Define the list of values for controlled-entry fields (operational activity taxonomy, equipment taxonomy, county list, type fields, event actions, etc.)
- 3) Create the infrastructure for the submission interface. Folder structure and naming conventions, GIT interfaces, validation rules and scripts, etc.
- 4) Draft user documentation for the YAML monitoring program definition, including definitions, examples, and constraints for the values entered in each field.
- 5) Define the processes for submission, the specific procedures for review and acceptance of program definitions and monitoring data files, the communication flows for when plans or reports are rejected for various reasons, etc.

We recommend that APCD test all templates and processes with existing monitoring programs, requesting the additional data from operators as necessary. APCD could also choose to execute a pilot test with one newer program in order to find the opportunities to

improve the template and processes within the concept, then also use the pilot to test documentation, infrastructure, and automated validation scripts.

5.3 Process Governance and Ownership

This recommended process is very much a draft vision. In creating a process that can scale efficiently, there are many decisions that will need to be made. APCD now has significant experience in the variety of edge cases that may come up and some of the nuances that exist between different types of programs. This experience will help to ensure that these definitions hit the necessary marks. However, change is inevitable. As the APCD, and operators, learn more, there will be changes to allowable lists of values for fields, the creation of additional fields for data collection, and the removal of fields that are deemed unnecessary.

To plan for the inevitable need for change, we recommend defining governance principles, defining ownership and defining processes for how these templates and processes can change over time. We recommend that:

- APCD version the YAML template. This will allow for smooth transitions from one version of the template to another. For example, the header of the YAML template should include a version tag like this:

```
---
APCD_template_version: 1
APCD_template_released: 2024-02-13
```

- APCD design a process for operators and stakeholders to request changes to the template and/or field constraints and set up a regular cadence for reviewing and implementing change requests.
 - For example: if an operator is using a new type of equipment that doesn't exist in the equipment taxonomy, an APCD governance owner should have a process for vetting, deciding, and updating the equipment taxonomy quickly, but while ensuring that documentation is updated and that stakeholders have had a chance to chime in on the validity of the request.
-

Appendix A: Example Equipment Taxonomy

Following is the equipment type taxonomy used for the Reg 7 Harmonization project. Each level of this taxonomy includes additional detail to identify the piece of equipment. It is recommended that equipment be identified on the most detailed level possible.

Equipment Type Level 1	Equipment Type Level 2
Cement Silo	
Compressor	
Compressor	Air Compressor
Compressor	Gas Lift Compressor
Compressor	Wellhead Compressor
Cooler	
Drill Rig	
Electric Motor	
Electrical Rack	
Engine	
Engine	Compressor Engine
Engine	Generator
Flowline	
Mechanical Refrigeration Unit	
Meter Equipment	
Meter Equipment	Gas Meter
Meter Equipment	Liquid Meter
Mud Treatment	
Mud Treatment	Centrifuge
Mud Treatment	Gasbuster & Shaker
Mud Treatment	Mud Pump
Mud Treatment	Mud Tank

Oil Polisher	
Pipe Rack	
Pump	
Pump	Chemical Pump
Pump	Recycle Pump
Routine Or Predictable Emissions	
Sand Storage	
Separator	
Separator	2-Phase Separator
Separator	3-Phase Separator
Separator	Bulk Separator
Separator	Flowback Test Separator
Separator	Gas Scrubber
Separator	Sand Trap
Separator	Vapor Recovery Tower
Tank	
Tank Truck Loadout	
Tank Truck Loadout	Hydrocarbon Truck Loadout
Tank Truck Loadout	Water Truck Loadout
Tank	Chemical Tank
Tank	Drillout Tanks
Tank	Freshwater Tank
Tank	Fuel Tank
Tank	Gun Barrel Tank
Tank	Hydrocarbon Tank
Tank	Hydrocarbon Tank
Tank	Hydrocarbon Tank
Tank	Produced Water Tank
Tank	Pumpdown Tanks
Tank	Rig Water Tank

Tank	Three Sided Tank
Unspecified Equipment	Completions
Unspecified Equipment	Drilling
Unspecified Equipment	Flowback
Unspecified Equipment	Production
Vapor Control System	
Vapor Control System	Emissions Control Device
Vapor Control System	Flare Line
Vapor Control System	Knockout Drum
Vapor Recovery Unit	
Wellhead	
Wellhead	Pumpjack

Appendix B: Example Operational Activity Taxonomy

Following is the operational activity type taxonomy used for the Reg 7 Harmonization project. This taxonomy is based on operator-reports and is suspected to be incomplete. Each level of this taxonomy includes additional detail to identify the specific activity being performed. It is recommended that activities be identified on the most detailed level possible.

Operational Activity Level 1	Operational Activity Level 2	Operational Activity Level 3	Operational Activity Level 4
Abandonment			
Abandonment	Shut In and Abandoned		
Abandonment	Well Capping		
Abandonment	Well Shutdown		
Pre-Operations			
Pre-Operations	Production of Existing Wells		
Pre-Production			

Pre-Production	Construction		
Pre-Production	Construction	Earthwork	
Pre-Production	Construction	Equipment Installation	
Pre-Production	Construction	Soundwall Installation	
Pre-Production	Construction	Soundwall Removal	
Pre-Production	Drilling		
Pre-Production	Drilling	Hydrocarbon Layer Drilling	
Pre-Production	Drilling	Non-Hydrocarbon Layer Drilling	
Pre-Production	Drilling	Non-Hydrocarbon Layer Drilling	Surface Casing
Pre-Production	Drilling	Non-Hydrocarbon Layer Drilling	Spudding
Pre-Production	Drilling	Rig mob/de-mob	
Pre-Production	Flowback		
Pre-Production	Flowback	Sand Trap Emptying	
Idle			
Pre-Production	Well Completions		
Pre-Production	Well Completions	Tubing	
Pre-Production	Well Completions	Drill Out/Mill Out	
Pre-Production	Well Completions	Hydraulic Fracturing	
Pre-Production	Well Completions	Setting Wellheads	
Production			
Production	Production Maintenance		
Production	Production Maintenance	Flowline Maintenance	
Production	Production Maintenance	Separator Cleaning	
Production	Production Maintenance	Well Liquids Unloading	
Production	Production Maintenance	Wellbore Cleaning	
Production	Production Maintenance	Wellbore Swabbing	
Production	Production Maintenance	Workover Rig	
Production	Shut In		

Appendix C: Speciated Parameter Standards

Following are the speciated parameter names and units that were used in the Reg 7 Harmonization project. It is recommended to create a standardization list and also include various aliases for each parameter to aid name transformation.

Parameter	Units	Molar Mass (for conversion)
benzene	ppb	78.11
ethylbenzene	ppb	106.16
m+p-xylene	ppb	106.16
o-xylene	ppb	106.16
toluene	ppb	92.14
1,1,1-trichloroethane	ppb	133.4
1,4-bromofluorobenzene	ppb	175
1,1,2,2-tetrachloroethane	ppb	167.8
1,1,2-trichlorotrifluoroethane	ppb	187.37
1,1-dichloroethane	ppb	98.96
1,1-dichloroethene	ppb	96.94
1,2,4-trichlorobenzene	ppb	181.4
1,2,4-trimethylbenzene	ppb	120.19
1,2-dibromoethane	ppb	187.86
1,2-dichlorobenzene	ppb	147
1,2-dichloroethane	ppb	98.96
1,2-dichloropropane	ppb	112.98
1,2-dichlorotetrafluoroethane	ppb	170.92
1,3,5-trimethylbenzene	ppb	120.19
1,3-butadiene	ppb	54.09

1,3-dichlorobenzene	ppb	147
1,4-dichlorobenzene	ppb	147
1,4-dioxane	ppb	88.11
2,2,4-trimethylpentane	ppb	114.23
2-butanone	ppb	72.11
2-chlorotoluene	ppb	126.58
2-hexanone	ppb	100.16
2-propanol	ppb	60.1
3-chloro-1-propene	ppb	76.52
4-ethyltoluene	ppb	120.19
4-methyl-2-pentanone	ppb	100.16
acetone	ppb	58.08
bromodichloromethane	ppb	163.83
bromoform	ppb	252.73
bromomethane	ppb	94.94
carbon disulfide	ppb	76.15
chlorobenzene	ppb	112.55
chlorodibromomethane	ppb	208.28
chloroethane	ppb	64.51
chloroform	ppb	119.37
chloromethane	ppb	50.49
chloromethylbenzene	ppb	126.58
cis-1,2-dichloroethene	ppb	96.94
cis-1,3-dichloropropene	ppb	126.97
cyclohexane	ppb	84.16
dichlorodifluoromethane	ppb	120.91
dichloromethane	ppb	84.93
ethanol	ppb	46.07
gasoline, natural	ppb	72
hexachlorobutadiene	ppb	260.8

isopropylbenzene	ppb	120.19
methyl methacrylate	ppb	100.12
methyl tert-butyl ether	ppb	88.15
naphthalene	ppb	128.17
n-heptane	ppb	100.2
n-hexane	ppb	86.18
propylene	ppb	42.08
styrene	ppb	104.15
tetrachloromethane	ppb	153.8
tetrahydrofuran	ppb	72.11
trans-1,2-dichloroethene	ppb	96.94
trans-1,3-dichloropropene	ppb	110.97
trichloroethylene	ppb	131.38
trichlorofluoromethane	ppb	137.36
vinyl acetate	ppb	86.09
vinyl bromide	ppb	106.95
vinyl chloride	ppb	62.5
1,2,3-trimethylbenzene	ppb	120.19
1-butene	ppb	56.11
1-pentene	ppb	70.13
2,3,4-trimethylpentane	ppb	114.23
2,3-dimethylpentane	ppb	100.2
2,4-dimethylpentane	ppb	100.2
2-ethyltoluene	ppb	120.19
2-methylheptane	ppb	114.23
2-methylhexane	ppb	100.2
2-methylpentane	ppb	86.18
3-ethyltoluene	ppb	120.19
3-methylheptane	ppb	114.23
3-methylhexane	ppb	100.2

3-methylpentane	ppb	86.18
butane	ppb	58.12
cyclopentane	ppb	70.13
ethane	ppb	30.07
ethene	ppb	28.05
isobutane	ppb	58.12
isopentane	ppb	72.15
isoprene	ppb	68.12
methanol	ppb	32.042
methylcyclohexane	ppb	98.19
methylcyclopentane	ppb	84.16
n-butane	ppb	58.12
n-decane	ppb	142.28
n-nonane	ppb	128.25
n-octane	ppb	114.23
n-pentane	ppb	72.15
n-propylbenzene	ppb	120.19
n-undecane	ppb	156.31
propane	ppb	44.1
xylene	ppb	106.16

Appendix D: Example YAML Document Format

Below is a partial monitoring program entered into a sample YAML template. Not all instances of each object definition are included.

```
---
```

```
APCD template_version: 1
```

APCD_template_released: 2024-02-13

This section of the document records information about the owner of the monitoring plans
and reports

document_submission:

operator: Civitas
submitted_by: First LastName
submitter_email: xxxx@xxxxx.com
submission_date: 2021-04-14 13:42:00-06
accepted: 2021-04-25 12:15:00-06
accepted_by: APCDFirst APCDLastName

This section of the document records updates and submission history for this monitoring
program definition

document_updates:

- purpose: Monitoring Plan Initial Submission April 2021
revision_date: 2021-04-23 09:14:00-06
revision_accepted: 2021-04-25 12:15:00-06
- purpose: Monitoring Plan Revision 1 April 2021
revision_date: 2021-04-23 09:14:00-06
revision_accepted: 2021-04-25 12:15:00-06
- purpose: Monthly Report Submission June 2021
revision_date: 2021-06-30 14:43:00-06
revision_accepted: 2021-07-02 15:53:00-06
- purpose: Monthly Report Submission July 2021
revision_date: 2021-07-31 14:43:00-06
revision_accepted: 2021-08-05 13:01:00-06

This section of the document captures the current definition of the monitoring program

monitoring_program:

uuid: 468bbba9-0a9e-4c81-ac35-22465c8bf57c
name: Civitas North Stampede 2021
aliases:

- Bison North Stampede 2021
- Civitas North Stampede 2022

planned_start: 2021-06-01 00:00:00+06

planned_end: 2022-04-11 23:59:59+07

operator:

uuid: 7ea9bbd8-692d-4115-90da-c25d3a5ada40
name: Civitas North, LLC

aliases:

- Civitas North
- Civitas

facilities:

- facility_name: Stampede 8-60
uuid: 46c49151-f6cb-4e9d-85ea-94ee5b51f993
latitude: 40.697745
longitude: -104.096942
address: 123 County Road 45 Springfield, CO 80524
county: Weld County
land_legal_description: SE SW S12 T1N R65W
airs_id: 123-9DDD

```

aliases:
  - Stampede FED 8-60 Pad
equipment:
  - uuid: 848bbba9-0a9e-4c81-ac35-22465c8bb59a
    equipment_type_l1: Vapor Control System
    equipment_type_l2: Emissions Control Device
    quantity: 1
    latitude: 40.697743
    longitude: -104.096939
    airs_id: 123-9D1B
    original_name: ECD
wells:
  - uuid: d5218215-57fb-4733-9a62-f3979fc3bc98
    well_name: Well 1
    api_number: 05-123-47188
    latitude: 40.697339
    longitude: -104.096629
  - uuid: 848bbba9-0a9e-4c81-ac35-22465c8bb59a
    well_name: Well 2
    api_number: 05-123-47181
    latitude: 40.697753
    longitude: -104.096491
operational_activities:
  - uuid: 1b374253-6a27-424a-957b-873ae78f7eb1
    activity_type_l1: Pre-Production
    activity_type_l2: Well Completions
    activity_type_l3: Hydraulic Fracturing
    activity_type_l4: Pretend Level 4
    start: 2021-11-01 00:00:00+00
    end: 2021-11-11 23:59:59+00
    original_name: Hydraulic Fracturing / Well Completion
  - uuid: d5218215-57fb-4733-9a62-f3979fc3bc98
    activity_type_l1: Production
    start: 2021-12-01 00:00:00+00
    end: 2021-12-31 23:59:59+00
    original_name: Early Production
- facility_name: Stampede Pretend Production 8-60
  uuid: 46c49151-f6cb-4e9d-85ea-94ee5b51f985
  latitude: 40.697765
  longitude: -104.096962
  address: 126 County Road 45 Springfield, CO 80524
  county: Weld County
  land_legal_description: SE SW S12 T1N R65W
  airs_id: 123-9DDD
  aliases:
    - Stampede FED 8-60 Pad
  equipment:
    - uuid: 848bbba9-0a9e-4c81-ac35-22465c8bb59a
      equipment_type_l1: Tank
      equipment_type_l2: Produced Water Tank
      quantity: 2
      latitude: 40.697743

```

```

    longitude: -104.096939
    airs_id: 123-9D1B
    original_name: Crude oil Tanks
  - uuid: 848bbba9-0a9e-4c81-ac35-22465c8bb59a
    equipment_type_l1: Tank
    equipment_type_l2: Hydrocarbon Tank
    equipment_type_l3: Production Tank
    quantity: 6
    latitude: 40.697743
    longitude: -104.096939
    airs_id: 123-9D1B
    original_name: Crude oil Tanks
service_provider:
  uuid: 46c49151-f6cb-4e9d-85ea-94ee5b51f985
  name: WSP
  aliases:
    - LT Environmental
stakeholders:
  - uuid: 5760dad-1ca1-4e7c-9a28-e307577f593c
    first_name: Jason
    last_name: Maxey
    job_title: ""
    organization: Weld County
    email: aaaaaaa@weldgov.com
    address: ""
    phone_1: (970) 400-###-###
    phone_2: ""
    type: Local Government Contact
  - uuid: 082f652c-1c44-4ccb-9fe8-1e3c23825783
    first_name: First
    last_name: Last
    job_title: EHS Manager
    organization: ""
    email: xxxxxx@xxxx.com
    address: ""
    phone_1: "(720) ###-####"
    phone_2: ""
    type: Operator Contact
monitoring_event_thresholds:
  - name: "Civitas North,LLC Low Priority Threshold: 1, 1-minute TVOC Indicator avg
    >= 1"
    uuid: e7f2eeba-b0fb-4caf-8844-f2aba0775678
    defined_by: Civitas North, LLC
    event_level: Low
    metric: 1m avg of 1s TVOC Indicator ppm as isobutylene equivalent
    parameter: TVOC Indicator
    reporting_aggregation_method: none [recorded data]
    comparison_operator: ">="
    threshold_value: "1"
    reporting_resolution_minutes: "1"
    consecutive_readings: "1"
    actions:

```

- Internal Notification

original_trigger_description: A single TVOC reading of 1 ppm is met or exceeded
original_action_description: If a single TVOC reading of 1 ppm is met or exceeded, an automated email notification will be sent to the operator and contractor.

- name: "Civitas North, LLC High Priority Threshold: 1, 1-minute TVOC Indicator avg >= 1 ppm"
uuid: 596f789c-5510-4873-a366-09c72c84cf06
defined_by: Civitas North, LLC
event_level: High
metric: 1m avg of 1s TVOC Indicator ppm as isobutylene equivalent
parameter: TVOC Indicator
reporting_aggregation_method: none [recorded data]
comparison_operator: ">="

threshold_value: "5"
reporting_resolution_minutes: "1"
consecutive_readings: "1"

actions:

- Internal Notification
- Investigate
- Evaluate
- Corrective Maintenance
- LDAR Inspection

original_trigger_description: A TVOC reading is detected at or above the determined threshold level of 5 ppm
original_action_description: If a single TVOC reading of 5 ppm is met or exceeded, an automated email notification will be sent to the operator and contractor. After the email notification, possible data investigations include a site inspection, review of drilling logs and other site activity, an LDAR inspection, and maintenance on the monitoring system to ensure proper functionality. An initial notification will be sent by Bison to APCD and local agencies within 48 hours of a reading exceeding the 5 ppm threshold. Laboratory results will be presented in monthly reports to APCD and local agencies.

monitoring_sites:

- name: West
uuid: 0609474a-0340-4141-a7c6-6cc90f1f38f0
data_start: 2021-05-21 09:14:44+06
data_end: 2022-02-13 04:43:21+07
latitude: "40.697362"
longitude: "-104.098757"
aliases:
 - Site 4

potential_sources:

- name: Stampede 8-60
type: Facility
latitude: "40.697747"
longitude: "-104.096942"
distance_from_monitoring_site: 528
azimuth_from_monitoring_site: 74.4
cardinal_direction_from_monitoring_site: NE
- name: Well 1 @ Stampede 8-60

```
type: Well
geopoint: POINT (-104.096995 40.697746)
distance_from_monitoring_site: "528"
azimuth_from_monitoring_site: "74.0"
cardinal_direction_from_monitoring_site: NE
technology_stack:
  uuid: 5442d004-40dc-4c27-9f97-f2a1b6974058
  name: 15m Airwatch System on Airwatch Platform + Davis Instruments 6410 + 24h
    canister at Eurofins
technologies:
  - name: Sensor System
    model: WSP Airwatch System
    parameters: ""
    type: low-cost sensor system
    communication_method: Cellular
    power_source: solar + battery
    solar_panel: ""
    battery: ""
    sampling_method: passive [assumed]
    algorithmic_data_adjustment: Y
    recording_interval: 15m
    recording_aggregation_method: pass-through
    reporting_interval: ""
    reporting_aggregation_method: ""
    measurement_range: ""
    minimum_detect_limit: ""
    sensitivity_resolution: ""
    sample_window: ""
    sample_interval: ""
    starting_threshold: ""
    accuracy: ""
    compass_orientation_method: ""
    sampling_location: ""
    planned_number_of_analytes: ""
    planned_laboratory: ""
    reference_method: ""
  - name: Data Management Platform
    model: Airwatch Platform
    parameters: ""
    type: data management platform
    communication_method: ""
    power_source: ""
    solar_panel: ""
    battery: ""
    sampling_method: ""
    algorithmic_data_adjustment: N
    recording_interval: ""
    recording_aggregation_method: ""
    reporting_interval: 15m
    reporting_aggregation_method: pass-through
    measurement_range: ""
    minimum_detect_limit: ""
```

```

sensitivity_resolution: ""
sample_window: ""
sample_interval: ""
starting_threshold: ""
accuracy: ""
compass_orientation_method: ""
sampling_location: ""
planned_number_of_analytes: ""
planned_laboratory: ""
reference_method: ""
- name: VOC Sensor
  model: Sensiron SGPC3 [assumed]
  parameters: tvoc indicator
  type: metal oxide
  communication_method: ""
  power_source: ""
  solar_panel: ""
  battery: ""
  sampling_method: ""
  algorithmic_data_adjustment: ""
  recording_interval: ""
  recording_aggregation_method: ""
  reporting_interval: ""
  reporting_aggregation_method: ""
  measurement_range: 0-60000 ppb TVOC as ethanol equivalent
  minimum_detect_limit: 1 ppb TVOC as ethanol equivalent
  sensitivity_resolution: +/-15% TVOC as ethanol equivalent
  sample_window: <1s [assumed]
  sample_interval: 15m
  starting_threshold: ""
  accuracy: ""
  compass_orientation_method: ""
  sampling_location: ""
  planned_number_of_analytes: ""
  planned_laboratory: ""
  reference_method: ""
- name: Wind Sensor
  model: Davis Instruments 6410
  parameters: wind speed
  type: cup and vane
  communication_method: ""
  power_source: ""
  solar_panel: ""
  battery: ""
  sampling_method: ""
  algorithmic_data_adjustment: ""
  recording_interval: ""
  recording_aggregation_method: ""
  reporting_interval: ""
  reporting_aggregation_method: ""
  measurement_range: 1-200 mph
  minimum_detect_limit: ""

```

```

    sensitivity_resolution: 1 mph
    sample_window: 1s [assumed]
    sample_interval: 15m
    starting_threshold: 0.5 mph [assumed]
    accuracy: +/-2 mph to +/-5%
    compass_orientation_method: ""
    sampling_location: ""
    planned_number_of_analytes: ""
    planned_laboratory: ""
    reference_method: ""
monitoring_maintenance:
- uuid: ebe1e705-aa44-45cc-a0e9-f1054ec719cd
  maintenance_type_l1: Calibration
  maintenance_type_l2: Bump Testing
  downtime_reason_l1: null
  downtime_reason_l2: null
  start: 2022-02-08 00:00:00+07
  end: 2022-02-08 11:59:59+07
  on_technology_stack: 15m Airwatch System on Airwatch Platform + Davis
    Instruments 6410 + 24h canister at Eurofins
  original_description: Bump testing was conducted on February 8, 2022 at the
    Stampede Pad location. Per the monitoring plan SOP, each monitor
    onsite was bump tested twice with a known concentration of
    isobutylene and the sensor reponse was measured against an
    acceptable range.
- uuid: 19ba0a87-fb51-4754-bf9e-7ea7fbc5072e
  maintenance_type_l1: Calibration
  maintenance_type_l2: Bump Testing
  downtime_reason_l1: null
  downtime_reason_l2: null
  start: 2022-01-14 00:00:00+07
  end: 2022-01-14 11:59:59+07
  on_technology_stack: 15m Airwatch System on Airwatch Platform + Davis
    Instruments 6410 + 24h canister at Eurofins
  original_description: Bump testing was conducted on January 14, 2022 at the
    Stampede Pad location. Per the monitoring plan SOP, each monitor
    onsite was bump tested twice with a known concentration of
    isobutylene and the sensor reponse was measured against an
    acceptable range.
monitoring_events:
- uuid: a4a953c5-5d86-4a68-88f8-b05576480116
  name: 1 ppm Threshold Exceedance at Stampede on 5/18/22 9:00 am
  start: 2022-05-18 09:00:00+06
  end: null
  classification: True Positive [possible real-world emissions event trigger]
  source: Operator Reported
  response_actions: No action needed
  suspected_reasons: Unknown
  resolution: No Resolution/Unknown Resolution
  original_commentary: Site 1 and Site 3 had readings above the internal
    notification level of 1 ppm at the times listed. Based on site
    activity and duration of elevated readings no company response was

```

required. See "Event Level Exceedances" tab at end of sheet.

- uuid: 22b6d84b-acfe-4bbd-8742-b851e41d8334
name: 1 ppm Threshold Exceedance at Stampede on 5/18/22 9:00 am
start: 2022-05-19 11:15:00+06
end: null
classification: True Positive [possible real-world emissions event trigger]
source: Operator Reported
response_actions: No action needed
suspected_reasons: Unknown
resolution: No Resolution/Unknown Resolution
original_commentary: Site 1 and Site 3 had readings above the internal notification level of 1 ppm at the times listed. Based on site activity and duration of elevated readings no company response was required. See "Event Level Exceedances" tab at end of sheet.

monitoring_data:

- monthly_report_date: 2022-04-30 12:00:00+06
file_name: Civitas North Stampede 2021_Monitoring Data_2022.04
- monthly_report_date: 2022-05-31 12:00:00+06
file_name: Civitas North Stampede 2021_Monitoring Data_2022.05

Appendix E: Example Monitoring Data Table (CSV)

Recommended Monthly Report: Monitoring Data file comma separated value format, presented as a table:

	parameter	units	reporting_start	reporting_end	measurement_val
g(1s relative humidity percent)))	relative humidity	percent	2022-04-30 12:00:00-06	2022-05-01 12:14:59-06	17.608
g(1s relative humidity percent)))	relative humidity	percent	2022-05-01 12:15:00-06	2022-05-02 12:29:59-06	18.335
g(1s relative humidity percent)))	relative humidity	percent	2022-05-02 12:30:00-06	2022-05-03 12:44:59-06	17.827
g(1s relative humidity percent)))	relative humidity	percent	2022-05-03 12:45:00-06	2022-05-04 12:59:59-06	17.131
g(1s relative humidity percent)))	relative humidity	percent	2022-05-04 13:00:00-06	2022-05-05 13:14:59-06	19.249
g(1s relative humidity percent)))	relative humidity	percent	2022-05-05 13:15:00-06	2022-05-06 13:29:59-06	21.987
g(1s relative humidity percent)))	relative humidity	percent	2022-05-06 13:30:00-06	2022-05-07 13:44:59-06	18.326
g(1s relative humidity percent)))	relative humidity	percent	2022-05-07 13:45:00-06	2022-05-08 13:59:59-06	19.293
g(1s relative humidity percent)))	relative humidity	percent	2022-05-08 14:00:00-06	2022-05-09 14:14:59-06	16.642
g(1s relative humidity percent)))	relative humidity	percent	2022-05-09 14:15:00-06	2022-05-10 14:29:59-06	17.233
g(1s relative humidity percent)))	relative humidity	percent	2022-05-10 14:30:00-06	2022-05-11 14:44:59-06	16.863
g(1s relative humidity percent)))	relative humidity	percent	2022-05-11 14:45:00-06	2022-05-12 14:59:59-06	15.77

g(1s relative humidity percent)))	relative humidity	percent	2022-05-12 15:00:00-06	2022-05-13 15:14:59-06	15.839
g(1s relative humidity percent)))	relative humidity	percent	2022-05-13 15:15:00-06	2022-05-14 15:29:59-06	16.162
g(1s relative humidity percent)))	relative humidity	percent	2022-05-14 15:30:00-06	2022-05-15 15:44:59-06	15.596
g(1s relative humidity percent)))	relative humidity	percent	2022-05-15 15:45:00-06	2022-05-16 15:59:59-06	18.55
g(1s relative humidity percent)))	relative humidity	percent	2022-05-16 16:00:00-06	2022-05-17 16:14:59-06	13.748
g(1s relative humidity percent)))	relative humidity	percent	2022-05-17 16:15:00-06	2022-05-18 16:29:59-06	15.85
g(1s relative humidity percent)))	relative humidity	percent	2022-05-18 16:30:00-06	2022-05-19 16:44:59-06	13.542
g(1s relative humidity percent)))	relative humidity	percent	2022-05-19 16:45:00-06	2022-05-20 16:59:59-06	14.306
g(1s relative humidity percent)))	relative humidity	percent	2022-05-20 17:00:00-06	2022-05-21 17:14:59-06	15.252
g(1s relative humidity percent)))	relative humidity	percent	2022-05-21 17:15:00-06	2022-05-22 17:29:59-06	12.805
g(1s relative humidity percent)))	relative humidity	percent	2022-05-22 17:30:00-06	2022-05-23 17:44:59-06	12.106
g(1s relative humidity percent)))	relative humidity	percent	2022-05-23 17:45:00-06	2022-05-24 17:59:59-06	11.825
g(1s relative humidity percent)))	relative humidity	percent	2022-05-24 18:00:00-06	2022-05-25 18:14:59-06	11.472
g(1s relative humidity percent)))	relative humidity	percent	2022-05-25 18:15:00-06	2022-05-26 18:29:59-06	15.612
g(1s relative humidity percent)))	relative humidity	percent	2022-05-26 18:30:00-06	2022-05-27 18:44:59-06	11.805
g(1s temperature F)))	temperature	F	2022-04-30 12:00:00-06	2022-05-01 12:14:59-06	75.326
g(1s temperature F)))	temperature	F	2022-05-01 12:15:00-06	2022-05-02 12:29:59-06	76.226
g(1s temperature F)))	temperature	F	2022-05-02 12:30:00-06	2022-05-03 12:44:59-06	76.298
g(1s temperature F)))	temperature	F	2022-05-03 12:45:00-06	2022-05-04 12:59:59-06	75.794
g(1s temperature F)))	temperature	F	2022-05-04 13:00:00-06	2022-05-05 13:14:59-06	75.74
g(1s temperature F)))	temperature	F	2022-05-05 13:15:00-06	2022-05-06 13:29:59-06	75.092
g(1s temperature F)))	temperature	F	2022-05-06 13:30:00-06	2022-05-07 13:44:59-06	76.334
g(1s temperature F)))	temperature	F	2022-05-07 13:45:00-06	2022-05-08 13:59:59-06	75.92
g(1s temperature F)))	temperature	F	2022-05-08 14:00:00-06	2022-05-09 14:14:59-06	76.496
g(1s temperature F)))	temperature	F	2022-05-09 14:15:00-06	2022-05-10 14:29:59-06	77
g(1s temperature F)))	temperature	F	2022-05-10 14:30:00-06	2022-05-11 14:44:59-06	75.884
g(1s temperature F)))	temperature	F	2022-05-11 14:45:00-06	2022-05-12 14:59:59-06	76.658
g(1s temperature F)))	temperature	F	2022-05-12 15:00:00-06	2022-05-13 15:14:59-06	78.692
g(1s temperature F)))	temperature	F	2022-05-13 15:15:00-06	2022-05-14 15:29:59-06	79.142
g(1s temperature F)))	temperature	F	2022-05-14 15:30:00-06	2022-05-15 15:44:59-06	78.908
g(1s temperature F)))	temperature	F	2022-05-15 15:45:00-06	2022-05-16 15:59:59-06	78.98
g(1s temperature F)))	temperature	F	2022-05-16 16:00:00-06	2022-05-17 16:14:59-06	81.338
g(1s temperature F)))	temperature	F	2022-05-17 16:15:00-06	2022-05-18 16:29:59-06	82.346
g(1s temperature F)))	temperature	F	2022-05-18 16:30:00-06	2022-05-19 16:44:59-06	82.778
g(1s temperature F)))	temperature	F	2022-05-19 16:45:00-06	2022-05-20 16:59:59-06	80.762
g(1s temperature F)))	temperature	F	2022-05-20 17:00:00-06	2022-05-21 17:14:59-06	79.862
g(1s temperature F)))	temperature	F	2022-05-21 17:15:00-06	2022-05-22 17:29:59-06	85.622

g(1s temperature F))	temperature	F	2022-05-22 17:30:00-06	2022-05-23 17:44:59-06	84.74
g(1s temperature F))	temperature	F	2022-05-23 17:45:00-06	2022-05-24 17:59:59-06	83.768
g(1s temperature F))	temperature	F	2022-05-24 18:00:00-06	2022-05-25 18:14:59-06	84.452
g(1s temperature F))	temperature	F	2022-05-25 18:15:00-06	2022-05-26 18:29:59-06	86.468
g(1s temperature F))	temperature	F	2022-05-26 18:30:00-06	2022-05-27 18:44:59-06	82.922
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-04-30 12:00:00-06	2022-05-01 12:14:59-06	
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-01 12:15:00-06	2022-05-02 12:29:59-06	
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-02 12:30:00-06	2022-05-03 12:44:59-06	14
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-03 12:45:00-06	2022-05-04 12:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-04 13:00:00-06	2022-05-05 13:14:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-05 13:15:00-06	2022-05-06 13:29:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-06 13:30:00-06	2022-05-07 13:44:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-07 13:45:00-06	2022-05-08 13:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-08 14:00:00-06	2022-05-09 14:14:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-09 14:15:00-06	2022-05-10 14:29:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-10 14:30:00-06	2022-05-11 14:44:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-11 14:45:00-06	2022-05-12 14:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-12 15:00:00-06	2022-05-13 15:14:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-13 15:15:00-06	2022-05-14 15:29:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-14 15:30:00-06	2022-05-15 15:44:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-15 15:45:00-06	2022-05-16 15:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-16 16:00:00-06	2022-05-17 16:14:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-17 16:15:00-06	2022-05-18 16:29:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-18 16:30:00-06	2022-05-19 16:44:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-19 16:45:00-06	2022-05-20 16:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-20 17:00:00-06	2022-05-21 17:14:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-21 17:15:00-06	2022-05-22 17:29:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-22 17:30:00-06	2022-05-23 17:44:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-23 17:45:00-06	2022-05-24 17:59:59-06	0
g(1s tvoc indicator ppb as ethanol equivalent)))	tvoc indicator	ppb as ethanol equivalent	2022-05-24 18:00:00-06	2022-05-25 18:14:59-06	0

Recommended Monthly Report: Monitoring Data file comma separated value format,
presented as CSV text:

```
monitoring_program_name,monitoring_site_name,metric,parameter,units,reporting_start,reporting_end,measurement_value,missing_reason,commentary
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,4/30/22 12:00,5/1/22 12:14,17.608,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/1/22 12:15,5/2/22 12:29,18.335,,
```

Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/2/22 12:30,5/3/22 12:44,17.827,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/3/22 12:45,5/4/22 12:59,17.131,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/4/22 13:00,5/5/22 13:14,19.249,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/5/22 13:15,5/6/22 13:29,21.987,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/6/22 13:30,5/7/22 13:44,18.326,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/7/22 13:45,5/8/22 13:59,19.293,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/8/22 14:00,5/9/22 14:14,16.642,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/9/22 14:15,5/10/22 14:29,17.233,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/10/22 14:30,5/11/22 14:44,16.863,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/11/22 14:45,5/12/22 14:59,15.77,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/12/22 15:00,5/13/22 15:14,15.839,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/13/22 15:15,5/14/22 15:29,16.162,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/14/22 15:30,5/15/22 15:44,15.596,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/15/22 15:45,5/16/22 15:59,18.55,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/16/22 16:00,5/17/22 16:14,13.748,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/17/22 16:15,5/18/22 16:29,15.85,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/18/22 16:30,5/19/22 16:44,13.542,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/19/22 16:45,5/20/22 16:59,14.306,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/20/22 17:00,5/21/22 17:14,15.252,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/21/22 17:15,5/22/22 17:29,12.805,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/22/22 17:30,5/23/22 17:44,12.106,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/23/22 17:45,5/24/22 17:59,11.825,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/24/22 18:00,5/25/22 18:14,11.472,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/25/22 18:15,5/26/22 18:29,15.612,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s relative humidity percent))),relative humidity,percent,5/26/22 18:30,5/27/22 18:44,11.805,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,4/30/22 12:00,5/1/22 12:14,75.326,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/1/22 12:15,5/2/22 12:29,76.226,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/2/22 12:30,5/3/22 12:44,76.298,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/3/22 12:45,5/4/22 12:59,75.794,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/4/22 13:00,5/5/22 13:14,75.74,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/5/22 13:15,5/6/22 13:29,75.092,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/6/22 13:30,5/7/22 13:44,76.334,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/7/22 13:45,5/8/22 13:59,75.92,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/8/22 14:00,5/9/22 14:14,76.496,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/9/22 14:15,5/10/22 14:29,77,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/10/22 14:30,5/11/22 14:44,75.884,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/11/22 14:45,5/12/22 14:59,76.658,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/12/22 15:00,5/13/22 15:14,78.692,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/13/22 15:15,5/14/22 15:29,79.142,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/14/22 15:30,5/15/22 15:44,78.908,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/15/22 15:45,5/16/22 15:59,78.98,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/16/22 16:00,5/17/22 16:14,81.338,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/17/22 16:15,5/18/22 16:29,82.346,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/18/22 16:30,5/19/22 16:44,82.778,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/19/22 16:45,5/20/22 16:59,80.762,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/20/22 17:00,5/21/22 17:14,79.862,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/21/22 17:15,5/22/22 17:29,85.622,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/22/22 17:30,5/23/22 17:44,84.74,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/23/22 17:45,5/24/22 17:59,83.768,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/24/22 18:00,5/25/22 18:14,84.452,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/25/22 18:15,5/26/22 18:29,86.468,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s temperature F))),temperature,F,5/26/22 18:30,5/27/22 18:44,82.922,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,4/30/22 12:00,5/1/22 12:14,,calibration,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/1/22 12:15,5/2/22 12:29,,calibration,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/2/22 12:30,5/3/22 12:44,14,,Post-calibration event. Confirmed sensor issue.

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/3/22 12:45,5/4/22 12:59,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/4/22 13:00,5/5/22 13:14,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/5/22 13:15,5/6/22 13:29,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/6/22 13:30,5/7/22 13:44,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/7/22 13:45,5/8/22 13:59,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/8/22 14:00,5/9/22 14:14,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/9/22 14:15,5/10/22 14:29,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/10/22 14:30,5/11/22 14:44,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/11/22 14:45,5/12/22 14:59,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/12/22 15:00,5/13/22 15:14,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/13/22 15:15,5/14/22 15:29,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/14/22 15:30,5/15/22 15:44,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/15/22 15:45,5/16/22 15:59,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/16/22 16:00,5/17/22 16:14,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/17/22 16:15,5/18/22 16:29,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/18/22 16:30,5/19/22 16:44,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/19/22 16:45,5/20/22 16:59,0,,

Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/20/22 17:00,5/21/22 17:14,0,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/21/22 17:15,5/22/22 17:29,0,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/22/22 17:30,5/23/22 17:44,0,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/23/22 17:45,5/24/22 17:59,0,,
Civitas North Stampede 2021,West,(15m avg(1m avg(1s tvoc indicator ppb as ethanol equivalent))),tvoc indicator,ppb as ethanol equivalent,5/24/22 18:00,5/25/22 18:14,0,,