Oil Sands Monitoring
Quality Assurance Guidance for Short Term Air Studies

Guidance Document

March 2014

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Alberta Environmental Monitoring, Evaluation and Reporting Agency
9th floor, 9888 Jasper Avenue, Edmonton, AB T5J 5C6
Phone: 780-229-7200 Toll Free: 1-844-3AEMERA Fax: 780-702-0169

aemera.org

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Prepared by

Michael C. McCarthy, PhD
Andrew P. Rutter, PhD
Hilary R. Hafner
Sonoma Technology, Inc.
1455 N. McDowell Blvd., Suite D
Petaluma, CA 94954-6503
Ph 707.665.9900 | F 707.665.9800
sonomatech.com

Prepared for

Alberta Environmental Monitoring, Evaluation and Reporting Agency
9th Floor, 9888 Jasper Avenue
Edmonton, Alberta, Canada T5J 5C6

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Any comments, questions, or suggestions regarding the content of this document may be directed to:

Standards & Technologies Group
Alberta Environmental Monitoring Evaluation and Reporting Agency

9th floor, 9888 Jasper Avenue
Edmonton, Alberta T5J 5C6

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Glossary

Term	Definition
AAAQOs	Alberta Ambient Air Quality Objectives
AEMERA	Alberta Environmental Monitoring, Evaluation, and Reporting Agency
BTEX	Benzene, toluene, ethylbenzene, and xylenes
Decision rule	An “if…then” statement used to determine whether action is needed
DOC	Demonstration of capability
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
FTIR	Fourier Transform Infrared Spectrometer
GC-MS	Gas chromatography-mass spectrometer
Implementation Plan	Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring
JOSM	Joint Oil Sands Monitoring
MDL	Method detection limit
MQO	Measurement quality objective
NELAP	National Environmental Laboratory Accreditation Program
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen (NO + NO_2)
OS-DMN	Oil Sands Data Management Network
PAH	Polycyclic aromatic hydrocarbon
PM_{10}	Particulate matter with a diameter of 10 micrometers or less
$PM_{2.5}$	Particulate matter with a diameter of 2.5 micrometers or less
QA	Quality assurance – systematic planning activities done to ensure quality
QAPP	Quality assurance project plan
QC	Quality control – the activities and techniques performed as part of the quality assurance system
SO_2	Sulfur dioxide
SOP	Standard operating procedure
TSP	Total suspended particulate
VOC	Volatile organic compound

1. Introduction

Alberta's Oil Sands cover a vast area, stretching across northern and central Alberta from the Peace River to the Saskatchewan border. The Athabasca Oil Sands cover the largest area, although Oil Sands are also located along the Peace River in northwestern Alberta and in the Cold Lake area along the Saskatchewan border. **Figure 1-1** shows the Oil Sands areas within Alberta.

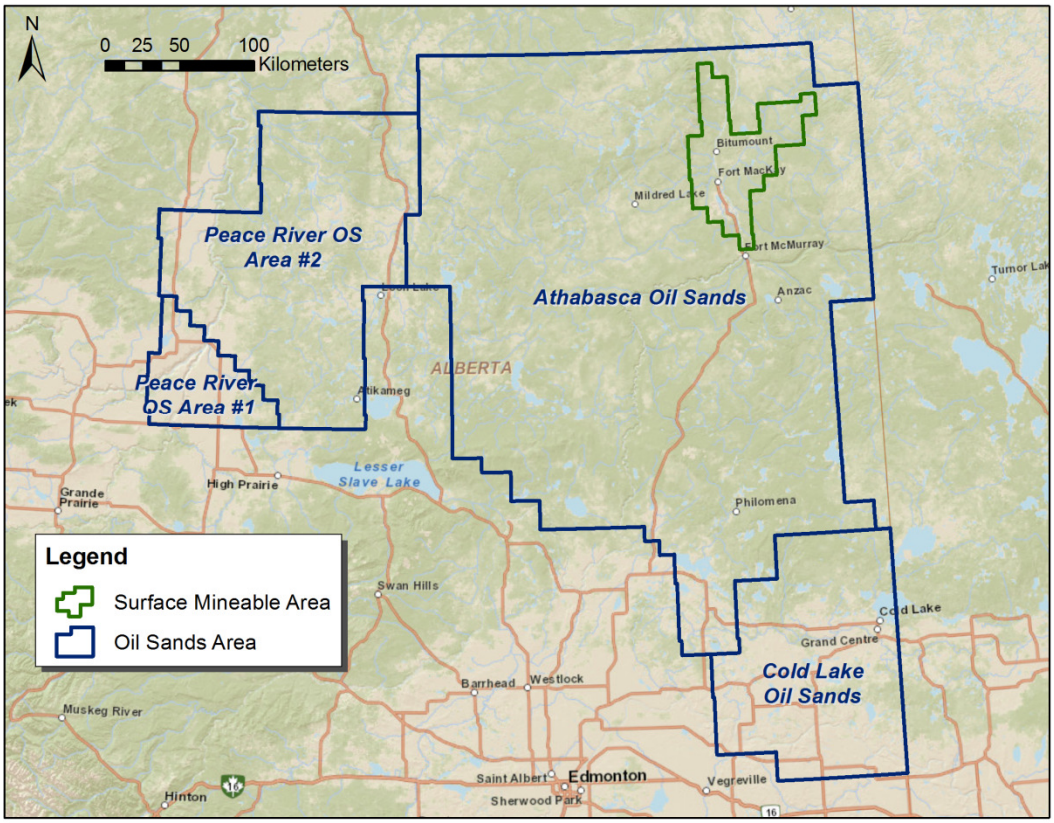

Figure 1-1. Boundaries of the four Oil Sands areas within Alberta.

The expansion of oil extraction in the Oil Sands has been accompanied by enhanced monitoring of air, water, terrestrial, and ecological impacts. While considerable monitoring is already taking place, a scientifically credible and transparent approach to environmental monitoring is needed. The Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring (referred to in this document as the "Implementation Plan") lists several objectives for environmental monitoring in the Oil Sands regions, including

- Support sound decision-making by governments as well as stakeholders
- Ensure transparency through accessible, comparable, and quality-assured data
- Enhance science-based monitoring for improved characterization of the state of the environment, and collect the information necessary to understand cumulative effects

- Improve analysis of existing monitoring data to develop a better understanding of historical baselines and changes
- Reflect the trans-boundary nature of potential environmental impacts and promote collaboration with the Governments of Saskatchewan and the Northwest Territories

Any organization conducting environmental monitoring under the Implementation Plan needs a quality management system to ensure that sample collection, analysis, and data management are of sufficient quality to be used in the integrated monitoring program. This document provides guidance and templates for investigators conducting short-term air monitoring projects in the Oil Sands regions so that their quality assurance documentation will be detailed enough for other concerned parties to evaluate the documentation, conduct their own analyses, and draw their own conclusions from the monitoring results.

1.1 Background on the Implementation Plan

The Implementation Plan outlines how the Governments of Alberta and Canada will work together as partners to implement a monitoring program of the environmental impacts of Oil Sands exploration. The monitoring program will be fully integrated into national and provincial monitoring systems and will provide reliable data on environmental conditions in the Oil Sands area. The scientific goals of the Implementation Plan are to understand the human and ecological impacts of Oil Sands exploration by using a combination of air, water, land, and biodiversity monitoring.

While this guidance document focuses on the quality management needed for short-term air monitoring projects, a comprehensive set of monitoring activities are taking place under the Implementation Plan to address concerns across multiple environmental disciplines. The following list summarizes the environmental areas of concern and associated activities:

- **Air Quality**. Air contaminants are emitted from Oil Sands developments, including surface and *in situ* extraction operations, industrial smokestacks, tailings ponds, transportation, and dust from mining operations, and are expected to pose a risk to human and ecosystem health. Routine long-term air quality monitoring efforts will be supported by short-term air monitoring studies.
- **Acid Deposition**. Sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) emitted by industrial activities into the atmosphere are transformed to sulfuric and nitric acid and are deposited onto the landscape and into lakes and rivers through wet and dry deposition. Deposition measurements and modeling are being conducted to assess ecosystem exposure.
- **Water Quality**. Water quality monitoring provides an integrated understanding of the impacts of the Oil Sands industry on the aquatic environment.
- **Aquatic Ecosystem Health**. Monitoring of indicator species will be used to assess the risk of adverse ecosystem health effects.

- **Wildlife Toxicology**. Indicator species of a variety of wildlife classes will be monitored to develop a broader understanding of the impacts of Oil Sands contaminants on terrestrial biodiversity and ecological integrity in the area.
- **Terrestrial Biodiversity and Habitat Disturbance**. Monitoring will improve the understanding of cumulative and individual effects of land disturbance by Oil Sands exploration on terrestrial biodiversity.

Air quality monitoring efforts in the Oil Sands region are already ongoing in a broad network of permanent sites. However, despite current monitoring efforts, significant questions remain regarding emissions, the chemical transformation of these emissions in the atmosphere, their long-range transport, and their effects on the ecosystem and human health. Short-term air monitoring studies conducted under the Implementation Plan are a complementary component to the routine air monitoring network. The goal of this document is to ensure that parties conducting short-term air monitoring under the Implementation Plan have quality management systems in place so that project results are comparable to those conducted in the broader monitoring program and adequate to answer the questions motivating the work.

1.2 Framework for Quality Management

A quality management framework describes your organization's quality system, which ensures that every aspect of a project conducted by your organization maintains acceptable standards of quality. Quality management frameworks consist of several components that often take the form of documents. Data quality objectives (DQOs), quality assurance project plans (QAPPs), standard operating procedures (SOPs), and data management are all elements of a Quality Management Framework.

Each short-term monitoring project conducted under the Implementation Plan will be required to produce several quality documents to ensure that projects produce data that will make the project, and the integrated monitoring program, successful. The DQO and QAPP serve as design and planning tools for researchers and clients to agree upon, as references for the researchers to use during a measurement study, and as documentation to accompany finalized data. In addition, the QAPP and SOPs detail how projects are conducted. The SOPs are the detailed, written instructions for routine sampling or analysis activities. Developing and following SOPs are integral to a successful quality system, as the SOP ensures that sample collection and analysis procedures are performed uniformly and in a reproducible way.

The terms "quality assurance" and "quality control" are often used interchangeably, despite having different technical definitions. "Quality assurance" describes the planned, systematic activities that are implemented so that data quality objectives will be met. "Quality control" is the set of observations, techniques, and activities performed to ensure data quality during the study. This document is primarily focused on the components of a quality assurance system.

Here we provide an overview of each of the major components of quality management that should be included in the planning and execution of monitoring conducted under the Implementation Plan. Detailed discussions and templates are included later in the document.

1.2.1 Data Quality Objectives

DQOs establish performance criteria for measurements so that the resulting data will be of sufficient quality and quantity to answer your motivating questions. In general, performance criteria are a set of specifications for a monitoring project to ensure that newly collected data are of sufficient quality and quantity to address the project's goals.

The process for establishing data quality objectives consists of several iterative steps used to thoroughly and systematically plan a scientific study. The benefits of establishing data quality objectives are that measurement projects will have a higher degree of success and use fewer resources. Data will be of sufficient quality to address the stated objectives and will ensure they can be integrated into the wider monitoring program that is being conducted. The structured format of the DQO process also helps multidisciplinary teams communicate during the planning stages, and ensures that adequate documentation is generated to support the data once they are collected. All of these benefits ultimately result in more rapid peer review and acceptance. We describe DQOs in more detail in Section 2.

1.2.2 Quality Assurance Project Plans

The QAPP documents the key elements of quality assurance. The QAPP also acts as documentation of how the study was conducted so that a third party not involved in the study can independently assess the uses and limitations of your collected environmental data with confidence. The QAPP is essentially the *who, what, why, when, where,* and *how* document and serves the following functions:

- Defines the project organization and *who* is responsible for the different quality assurance tasks.
- Lists *what* are the
  - Project objectives;
  - DQOs;
  - Quality assurance procedures;
  - Quality control steps to be taken; and
  - Corrective actions that will be used.
- Explains *why* the project is occurring by defining the objectives and the decisions, recommendations, or estimations that will be made as a result of the project.
- Details *when* the various elements of quality assurance and control will occur throughout the project, as well as the timeframe of the project itself.
- Identifies *where* the data collection will take place and (if necessary) where the analysis will be performed. This component includes identifying the spatial extent and representativeness of the study domain.
- Explains *how* the data collection will be performed, including sampling collection methods, equipment, and analysis procedures. It also explains sample handling procedures and how data will be managed, formatted, and archived after collection.

1.2.3 Standard Operating Procedures

An SOP is a set of detailed, written instructions for your routine sampling or analysis activities. Developing and following SOPs is integral to a successful quality system, as the SOP ensures that sample collection and analysis procedures are performed uniformly and in a reproducible way, irrespective of who conducts the collection or analyses. The SOP typically describes the procedures to be followed in greater detail than a published method does, and provides detail specific to the research organization performing the study.

1.2.4 Data Management

The foundation of the integrated monitoring program is a strong commitment to transparency and accessibility. Information generated under the Implementation Plan will be submitted to the Oil Sands Data Management Network (OS-DMN), which is an integrated, publically accessible data management system. Quality documents and data will be uploaded to the OS-DMN in a timely, standardized, and coordinated manner to ensure transparency and accessibility. In addition, inclusion of sufficient metadata to ensure the usability of the data (e.g., data qualifiers, site information, quality codes) will be expected.

1.2.5 Risk Management

Research activities often involve risk in several areas, any one of which has the potential to cause your project difficulties or failures. However, project difficulties and failures can be mitigated or avoided altogether by careful planning. A good risk management plan identifies the possible areas of risk and discusses how these problems will be resolved through project planning. The idea behind risk management is to ensure the project has a high chance of success even if some aspects of the project do not go according to plan.

1.3 Overview of the Document

This guide is intended to help you to document your study design, effectively establish and communicate your DQOs, and efficiently write a QAPP that meets the expectations set forth in the Implementation Plan.

- Section 2 of this document describes DQOs and the process by which they are established and refined.
- Section 3 describes the components of a QAPP.
- Section 4 discusses SOPs.
- Section 5 identifies key components of risk management.
- Section 6 contains references.
- **Appendix A** is a sample QAPP for you to use as a concrete example when writing your QAPP.
- **Appendices B and C** are QAPP and SOP templates that are provided to make the writing process easier.

2. Data Quality Objectives

DQOs establish performance criteria for monitoring studies so that the resulting data will be of sufficient quality and quantity to answer the motivating questions. During the project planning phase, you establish DQOs that define whether enough data are collected in the right places, at the right times, and with the sufficient measurement performance characteristics (e.g., accuracy, precision, detection limits) to provide a statistically robust answer. DQOs specify the tolerable levels of uncertainty in the data collected in your study to be used in making policy decisions or recommending courses of action.

There are two purposes for DQOs in projects conducted under the Implementation Plan. The first is to ensure that the data collected will be of sufficient quality and quantity to address the objective being investigated. The second is to ensure that the data are of high enough quality to be compared with other measurements collected as part of the integrated Oil Sands monitoring program. While DQOs are established during the planning phase, they can be documented in the QAPP (see Section 3.3) and may not require separate documentation.

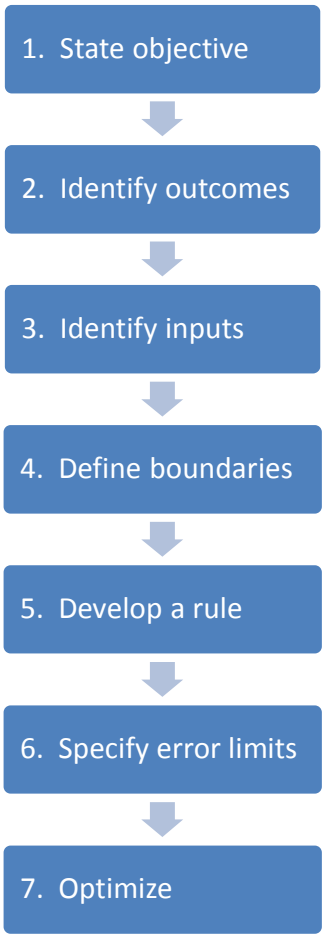

Figure 2-1. Steps in planning DQOs.

The DQO planning process scales with the size of the project. It may be sufficient for smaller research projects involving one research group to describe their DQOs using a few sentences or bullet points in the QAPP. Large multi-group monitoring campaigns may need a more detailed DQO process and a separate document that extensively describes the DQOs and how they were determined. Regardless of the size of the project, the DQO process consists of several steps, as shown in **Figure 2-1**. This section highlights the most important points from each of the steps to help you efficiently write DQOs for your project.

2.1 State the Objective

State concisely the specific objective to be solved or investigated, decision to be made, or hypothesis to be tested.

The statement of the objective ideally starts as a one-sentence description. This sentence can then be expanded as needed. The objective may also be illustrated with a figure.

For monitoring projects in the Oil Sands, examples of air quality questions include

- What contaminants are being emitted from Oil Sands mining and extraction activities, at what rates, and from which sources?

- What are the impacts of Oil Sands operations on human health and the surrounding ecology?
- What might be the future deterioration of human health through exposure to harmful volatile organic compounds (VOCs) as a result of anticipated Oil Sands development?

Taking the first bullet as an example, we can state that the objective is *"Identify the contaminants being emitted from Oil Sands mining and extraction activities, quantify the emission rates, and identify the emission sources."*

The description of an air quality question or objective can be elaborated using a conceptual model, which can be a simple diagram or a short paragraph giving the audience a broader view of the problem. The conceptual model may describe contaminant emission sources, their environmental transport and fate, and any important aspects of the local meteorology and topography. The conceptual model may also show knowledge gaps and where assumptions have to be made.

The following text is an example of an objective. Note that text formatted in this style (beige text box with a blue outline) denotes an example illustrating the concept; this style is used throughout the document to highlight such examples.

> Compare measurements of speciated VOCs in the Oil Sands to Alberta Ambient Air Quality Objectives (AAAQOs).

In writing the objective, consider

- Prior studies and information about the objective
- A justification of why new data are needed
- Project budget and schedule
- Constraints such as access permissions, weather, or personnel availability

Steps to Take

- Write a concise description of the objective
- Illustrate the objective using a conceptual model
- Discuss what data you will need and explain why these new measurements are needed

2.2 Identify Study Outcomes

Create a decision statement that can be answered at the end of the study, and list the outcomes that may result.

A decision statement is a question that comes from the objective. It can be answered "Yes" or "No," which then triggers a course of action. For monitoring projects in the Oil Sands, examples of decision statements might be

- Are VOC concentrations exceeding AAAQOs?
- Are critical loads of acidity exceeded in water bodies impacted by acid rain formed from SO_2 and NO_x?
- Is routine monitoring of a contaminant needed to assess its cumulative effects[1] on human and ecosystem health?

> Do speciated VOCs emitted from *in situ* extraction of bitumen exceed the 1-hr AAAQO?
>
> If yes, a decision on whether additional or enhanced monitoring at the site should be made.

In the decision statement, list possible outcomes of the study. These might include performing more monitoring, investigating mitigation strategies, or developing a management plan.

Steps to Take

- Write decision statements
- List possible outcomes

2.3 Identify Inputs

Describe the information needed to resolve the decision statement.

The inputs to a decision statement include the measurements and the action level that will be used to make the decision at the end of the study. You establish what needs to be measured, when, where, how often, and how accurately. You also determine the action level(s) the measurements will be compared against to make the decision. The main goal is to decide on the elements of the study design that will determine the expected uncertainty in the final decision. The study design should ensure that the uncertainties are small enough that the correct decision can be made when the final data set is compared against the action level. Information established in this section includes

- Parameters to be measured (contaminants, meteorology, etc.)
- Measurement technique and instrumentation to be used
- Number of samples to be collected
- Frequency and duration of sample collections or monitoring
- Number and locations of monitors
- Nature of the action level
- Rationale for the action level

[1] Cumulative effects are the combined effects of past, present and foreseeable human activities, over time, on the environment, economy and society in a particular place. See http://environment.alberta.ca/0890.html for more details.

We note that the action level may be quantitative or qualitative. In some cases, the action level may be a concentration limit or emission rate that is defined by a regulatory standard or objective. In other cases the action level may be a qualitative standard based on the judgment of the investigator. For example, leaks from an *in situ* extraction facility cannot be quantified using an infrared camera, but the images collected may show the decision maker that some of the leaks found are large enough to warrant repair.

> Measure benzene, toluene, ethylbenzene, and xylenes (BTEX) using a Fourier Transform Infrared Spectrometer (FTIR) for three winter months in the Cold Lake Region.
>
> Action Level: 1-hr AAAQOs for benzene, toluene, ethylbenzene, and xylenes.

Steps to Take

- List the measurement parameters (e.g., contaminants, meteorology, emissions activity)
- Select, or justify, the sampling and analysis methods for your study
- Identify action level(s)

2.4 Define Study Boundaries

Define the spatial and temporal domains of your study.

The study boundaries delineate the geographical area over which the study is conducted and establish the start and end dates. The geographic extent of the study is normally shown with a map; see the example in **Figure 2-2**. The map (or series of maps, if necessary) may contain locations of proposed and existing monitors, emissions sources, receptors of concern (e.g., population centers, lakes, rivers), current Oil Sands operations, and predominant wind patterns. The duration of the study can be communicated with a timeline, table, or schedule.

It is important to communicate the scale of inference, which is the spatial and temporal extent the measurements will represent. Stationary and mobile measurements will be used to draw conclusions on what is occurring throughout the study area. The scale of inference relates the extent to which you think it reasonable to extrapolate the stationary and mobile measurements to the parts of the study domain you could not measure.

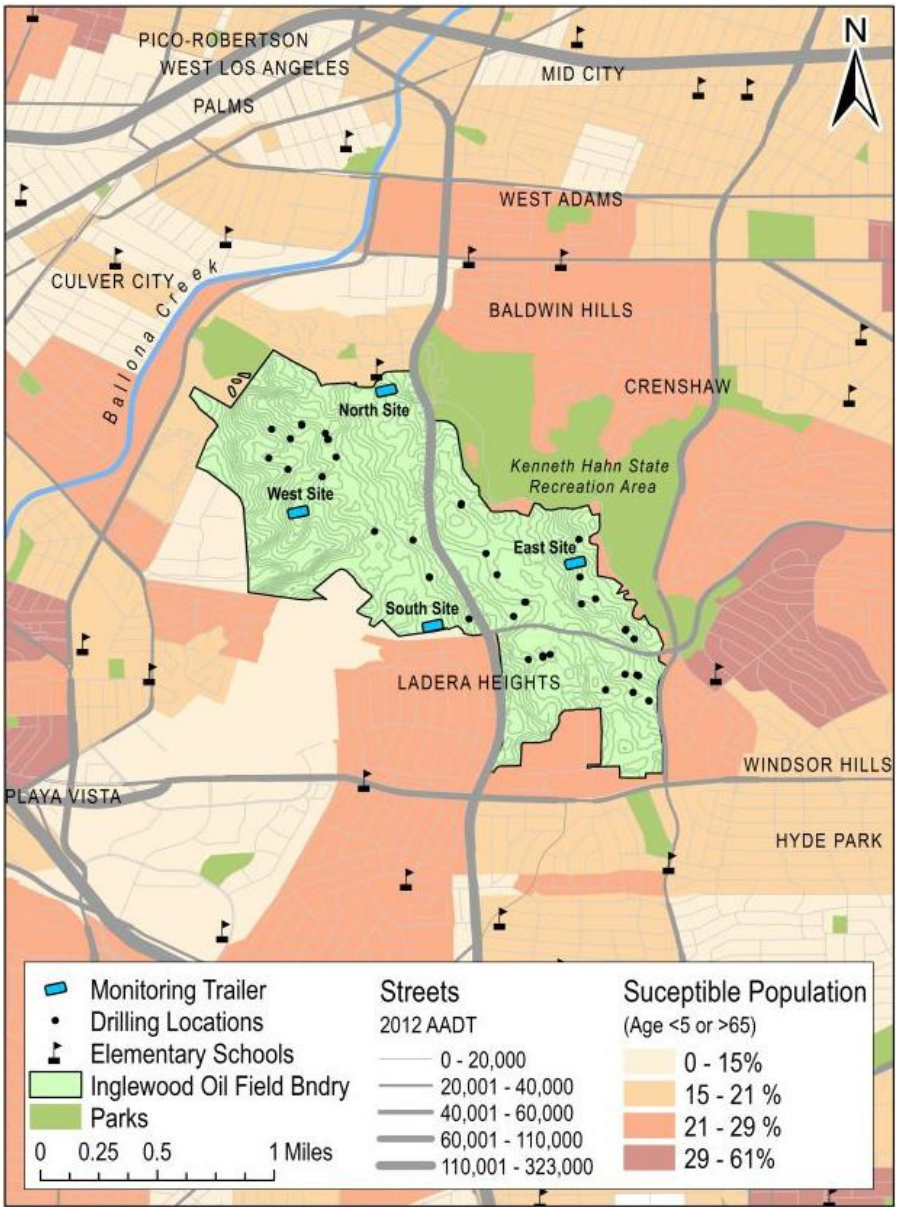

Figure 2-2. Example of a map showing the spatial extent of a short-term air monitoring campaign. Monitoring locations, emissions source locations (drill sites and roads), and sensitive receptors are shown. (AADT = Annual average daily traffic count.)

Steps to Take

- Define the geographical region and/or vertical extent of the atmosphere of the study
- Establish the start and end dates and schedule of the study

2.5 Develop a Rule

Develop a decision rule, which will be used to determine whether action is needed.

A decision rule is an "If … then …" logic statement as shown below or in this generalized example: "If measurements of parameter *A* are greater than (or less than) action level *X*, then action *Y* will be taken." Components of the decision rule are the statistical representation of parameter A, the action level above or below which actions are taken, and the actions themselves.

Statistical parameters that are often used to compare the measurements against an action level are the mean, median, or a percentile. Different statistical parameters have varying sensitivities to the distribution of the underlying measurements, number of samples, and resolution of the measurements.

The action is the planned consequence that will ensue if the action level is exceeded. These actions were listed in the study outcomes (see Section 2.2), and can be expanded upon here if necessary. Some decision rules may lead to a range of outcomes from which a decision maker can choose.

> If any 1-hr average BTEX concentrations are higher than 1-hr AAAQOs in more than one 1-hr sample a month, then recommend enhanced monitoring at the facility.

Steps to Take

- Write a decision rule
- Choose the statistical parameters you will use in your decision rule

2.6 Specify Error Limits

Specify the tolerable probability of an incorrect decision under the study design, and establish DQOs that will result in acceptable limits of uncertainty in the final data.

An incorrect decision is made when the measurement does not represent the true atmospheric value well enough in relation to the action level. For example, a measurement may be below the action level due to instrument bias, when in fact the true atmospheric value is above the action level. Another example would be a measurement made with a low enough precision that a particular exceedance of the action level is not statistically significant. In either scenario, the appropriate course of action may not be taken, which could have serious consequences if the true concentration poses a risk to human or ecological health. Conversely, an action level may be exceeded if measurements are not representative of typical conditions, which may lead to costly mitigation strategies that are not necessary.

The overriding goal of the DQO process is to design a study that leads to a correct decision. The likelihood that an incorrect decision will be made reflects a combination of how representative the data are, how accurate the measurements are, and how much data are available. Fewer decision errors are likely with large quantities of accurate data representing

the typical state of the atmosphere. DQOs can be set for study design components that control the uncertainty in the final data and thereby minimize the possibility of an incorrect decision. Some of the DQOs that follow were identified in Section 2.3, Identify Inputs, but are included here again for completeness:

- The measurement quality objectives (MQOs)
  - Precision
  - Bias
  - Drift
  - Resolution
  - Sensitivity
  - Method detection limit (MDL)
- The number of monitors and the locations required to capture a representative picture of what is occurring and to give a low enough total error. These components were identified in Section 2.3.
- The amount of useful data
  - Data quantity (i.e., number of samples/observations required for the study to achieve representative estimates)
  - Data completeness (e.g., 75% completeness required to calculate a 24-hr average)
  - Fraction of samples above MDL
  - Fraction of samples from a certain wind sector
  - Fraction of samples when emissions sources are operating normally
- The quality control (QC) procedures that will be used and the performance criteria for those procedures
  - Calibrations
  - Blanks
  - Comparability between instruments during collocation periods (e.g., slope, R^2)
- Tolerable levels of total uncertainty in the decision statement (i.e., 95% confidence or 80% confidence), and tolerable probability of incorrect decisions (e.g., 5%)

Qualitative DQOs can be more subjective, so short discussions explaining these may be needed. Examples of qualitative DQOs are the representativeness of the measurements and the comparability of data collection methods. For example, site representativeness could be based on guidance followed, and judgments made, concerning site selection and probe placement. Comparability discussions could summarize published intercomparison studies between research-grade and established commercial instruments.

For more information on this aspect of the DQO process, the U.S. Environmental Protection Agency (U.S. EPA) *Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4* (U.S. Environmental Protection Agency, 2006) is a good resource.

The instrument precision for an hourly value is determined to be ±10% at the 95% confidence level. Therefore, hourly concentrations less than 90% of the 1-hr AAAQO will be considered significantly lower than the AAAQO. Conversely, concentrations that are 110% of the 1-hr AAAQO will be considered significantly higher than the AAAQO. Finally, values within 10% of the AAAQO will be considered statistically indistinguishable from the AAAQO at the 95% confidence level.

Steps to Take

- Establish the likelihood of an incorrect decision with the study design and decide whether it is tolerable
- Consider whether your measurement technique has the performance characteristics necessary for the study
- Select DQOs
- Determine the number of samples needed to achieve final results of sufficient certainty

2.7 Optimize Resources and DQOs

Adjust the study design to balance the available resources to achieve the optimal data quality and quantity.

Optimizing resources and DQOs is usually necessary because the DQOs defined in the initial study design may be too expensive to implement, require longer sampling times, or require too many sampling resources (e.g., sites, canisters, personnel). Besides funding, other resources may be limited, such as options for measurement technologies, lack of ideal sampling conditions, and numbers of samples or sampling locations. In such instances, the study scope can be changed or the acceptable limits of error relaxed. Reformulating the DQOs to best utilize the available resources is often a necessary part of the DQO process.

The instrument operation is less reliable at temperatures below -10℃. Perform the study during three summer months to ensure higher rates of data capture during the study.

Steps to Take

- Modify the scope of the study to match available resources
- Select different measurement techniques
- Alter the DQOs to reflect the new study design

3. Quality Assurance Project Plans

A QAPP documents the key elements of quality assurance. The QAPP must be made available upon request to Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA) and other stakeholders.

This section provides guidance on what is normally included in each section of a QAPP (see **Figure 3-1**) so you can write a QAPP quickly and efficiently. Many of these sections will have been considered and documented as part of the proposal process, development of DQOs, and during the study design. In particular, Sections 3.1 to 3.4 (objectives, project description, DQOs and performance criteria, and monitoring locations) are established during the DQO process discussed in Section 2.

Note that some sections may not be applicable to every project (e.g., there may not be any laboratory analysis) and thus may not be needed in your QAPP. Each QAPP should only contain the sections necessary to document the activities that are relevant for your monitoring project.

Figure 3-1. Sections to include in a QAPP.

3.1 Objectives and Background

3.1.1 Objectives

Think of this section of the QAPP as equivalent to the abstract of a journal article. Use it to provide the synopsis of the project in a paragraph. Objectives will have been considered during the DQO process (as described in Section 2). We recommend using that text to fill in this section of the QAPP.

3.1.2 Background

Briefly discuss what is already known about the study objective and the greater context for the study. Think of this section as equivalent to the introduction section of a journal article. Explain the motivations for the monitoring study. Describe findings of previous investigations conducted in both the Oil Sands region and in other locations with similar operations that can provide insight. Provide references for the background information presented. Justify why new measurements are needed by explaining the knowledge gaps that your study will address.

3.2 Project Description

Describe the work to be performed in one to two paragraphs from both scientific and project management perspectives. Much of the information needed will be available from the proposal and the DQO planning process described in Section 2. State the project objectives, the parameters of concern, and the geographical area to be studied. Identify the emission sources and discuss their contributions to the contaminants of concern. Identify population centers and/or ecosystems within the study area. State the organizations that will be involved in the project and their respective roles and responsibilities. These topics will be discussed in more detail in the following subsections, so only a high level discussion is needed here.

3.2.1 Measurements and Samples

Identify the parameters that will be measured during the project and the methods used. Provide a table of this information. Explain how the measurements will be used to meet the project objectives. List and reference any standard methods that will be used and attach SOPs. Reference any regulatory measurement protocols that you may be following.

List the numbers of samples to be collected, the sampling frequencies, and the sampling durations as shown in the example in **Table 3-1**. Separate discrete and continuous sampling methods in this section.

For discrete sampling methods, provide a table of the number of samples for each parameter at each location, the sampling frequencies and durations, the sampling schedule including start and end dates, and the required data completeness. For continuous sampling methods, state the start and end dates, the sampling duration (e.g., 1-minute, 1-hr), and the

required data completeness. For semi-continuous methods (e.g., 1-hr samples collected every other hour), also state the sampling frequency.

Briefly explain how the sampling approach provides sufficient data to answer the question of interest. Demonstrate how the variability in parameters will be captured with the sample collection approach.

Table 3-1. Example of a table of sample counts, frequency, duration, and sampling period of parameters measured at two sites.

Location	Parameter	Number of Samples	Frequency	Duration	Start Date	End Date
Site 1	$PM_{2.5}$	30	1-in-3 days	24 hours	1/1/15	3/30/15
Site 2	$PM_{2.5}$	30	1-in-3 days	24 hours	1/1/15	3/30/15

3.2.2 Spatial and Temporal Extents

Describe the spatial and temporal extents of the project. The spatial extent is the geographic area covered by the study. The temporal extent is the time period over which measurements are made.

Describe the geographic area covered using a map like the example given in the DQO section (Figure 2-2). Show fixed monitoring locations and any proposed mobile monitoring paths or flight tracks. Show the locations of emission sources, population centers, and relevant ecosystems, such as lakes and forests. Describe key geographical features important to the study (e.g., is the study set in a river valley with limited ventilation during winter?). Incorporate the discussion of the scale of inference established in Section 2.4.

Describe the project's sample collection or monitoring schedule. Demonstrate how the project schedule will capture typical variability in concentrations.

3.2.3 Roles and Responsibilities

Describe the roles and responsibilities of key personnel involved in the project. Use the organizational chart (see example at **Figure 3-2**) in the QAPP template as a means of illustrating reporting relationships. List the key personnel involved in the project with their roles and responsibilities, affiliations, and titles. Discuss the tasks they will be performing. Provide the reasons for selecting the key personnel for their roles (i.e., their qualifications, specialized training, and experience). Identify their quality assurance (QA) and QC responsibilities. Provide contact information for the key personnel involved in the study.

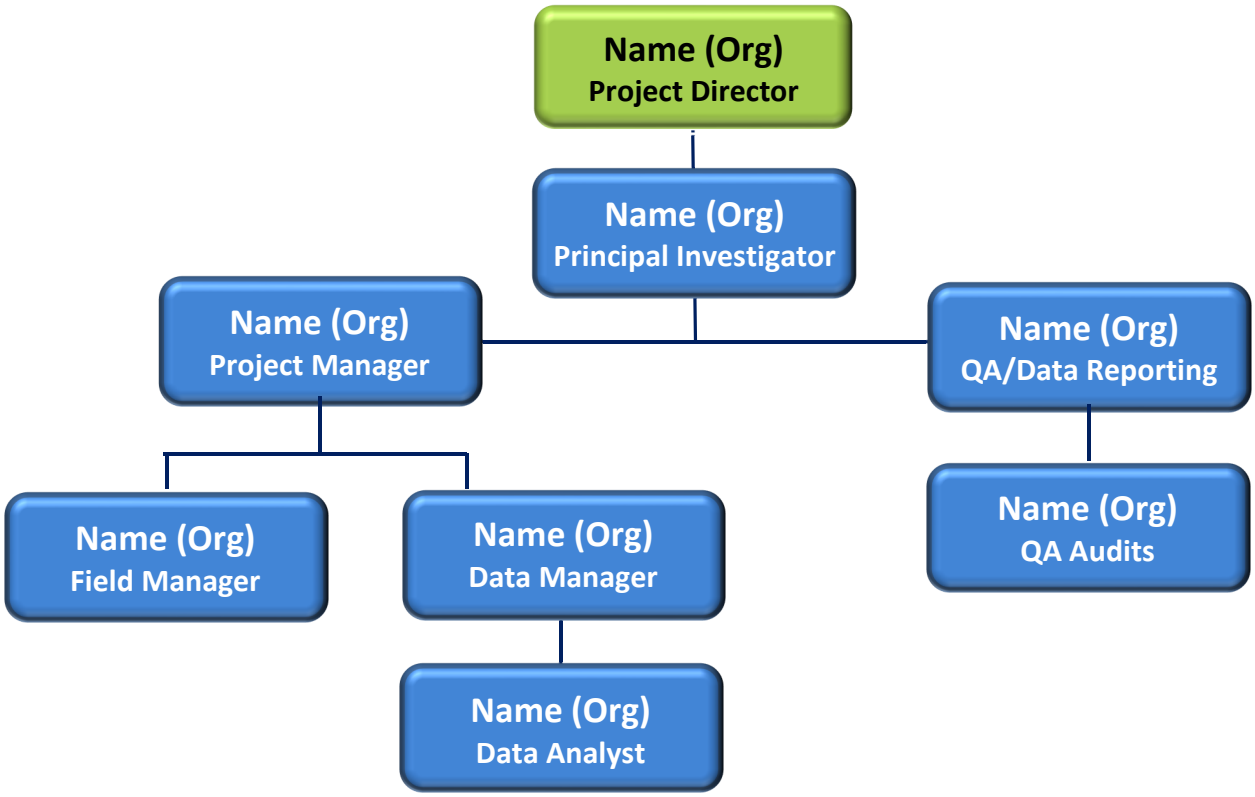

Figure 3-2. Example of an organization chart. This chart is editable.

3.2.4 Schedule and Milestones

Discuss the project schedule and milestones. Show how long each portion of the project will take, when various tasks will be started and completed, and when reports and data will be delivered. Show the project schedule using a table (see QAPP template for example), Gantt chart, or timeline. Include the durations of project tasks such as planning, instrument preparation, site preparation, installation, monitoring, and decommissioning of the site. Specify dates for major milestones. List any potential disruptions to the schedule and discuss plans for handling contingencies that could cause delays in completing milestones. **Table 3-2** is an example of a project schedule.

Table 3-2. Example of a project schedule.

Milestone	Date Completed
Project kickoff meeting	January 1, 2014
Beginning of monitoring	April 1, 2014
End of monitoring	September 20, 2014
Data delivery	November 30, 2014
Final report	January 15, 2015

3.3 Data Quality Objectives and Performance Criteria

Discuss the DQOs and performance criteria that have been selected for the project. The DQO section of a QAPP identifies and discusses the DQOs and performance criteria selected to ensure that data are of sufficient quality and quantity to meet project objectives. The DQOs were selected during the planning process described in Section 2. Give a short description for each DQO, including how it will be assessed and why it is important for ensuring sufficient quality in the final data. Provide references for each DQO if available. Present the DQOs in one or more tables such as the example given below. Provide the sources of the quality objectives (i.e., planning phase of study, regulatory publications, technical assistance documents, or other guidance materials). Examples of DQOs are provided in Section 2.6 and in **Table 3-3** on the following page.

3.4 Monitoring Locations

Describe the monitoring locations. Show the geographic location using a map. Provide GPS coordinates and street addresses if available. State the monitoring objectives of each location. Discuss how and why the monitoring locations were chosen. List the parameters measured at each location. If relevant, discuss the land use and topography surrounding the monitoring locations. Mention any scenarios that could bias the measurements. Identify any relevant siting guidance or requirements that have been followed and discuss any deviations from siting requirements.

Provide maps of potential flight paths or mobile monitoring paths.

Table 3-3. Example of a table listing some DQOs for a measurement study.

Parameter	Number of Monitoring Locations	Data Quantity	Data Completeness	Fraction of Samples Above MDL	Calibration Performance Criteria	Collocation Regression Slope and R-Squared
Volatile organic compounds (VOCs)	4	3 months of 1-hr measurements	75%	75%	±5% at each calibration point[1]	Slope = 1.0±0.2 R^2≥0.9
Oxides of nitrogen (NO_x)	1	3 months of 1-hr measurements	90%	95%	±10% at each calibration point	Slope = 1.0±0.1 R^2≥0.9
Ozone	1	3 months of 1-hr measurements	90%	95%	±10% at each calibration point	Slope = 1.0±0.1 R^2≥0.9

[1] The instrument response should be within 5% of the concentration being delivered to the instrument at each point on the calibration curve.

3.5 Sampling and Analysis Methods

The sampling and analysis methods section discusses how discrete samples will be collected, prepared, and analyzed. This section also describes how direct measurements will be made.

3.5.1 Sample Collection Methods

Describe sample collection methods used for collecting discrete samples that will be analyzed later (such as whole air samples collected in canisters). Direct measurement methods should be described in Section 5.6 of the QAPP. For sample collection methods, include details such as those in the following examples.

- The sampling equipment.
  - Sampling equipment and the collection method it uses.
  - Sample collection media used.
  - Operational ranges of samplers.
  - Height of the sensor or probe above the ground, or separation from surfaces such as the external walls of buildings.
  - Spacing between inlets.
  - Inlet and manifold materials and physical design geometry.
  - Suitability of equipment for the environmental conditions.
- The samples and sampling conditions.
  - Sample volumes.
  - Sample collection frequencies and durations.
  - Temperature and relative humidity the samples are held at after collection and during analysis.
  - Splitting and compositing schemes that will be used on discrete samples such as filters.
- The standard methods or customized procedures being used (attach SOPs).
- Known interferences.

3.5.2 Sample Preparation Methods

Describe how samples are prepared for analysis and discuss what measures are taken to ensure the integrity of the sample.

> Filters used to collect $PM_{2.5}$ for organic molecular marker measurements are pre-baked in an oven before use. They are touched only with solvent-cleaned metal tools and handled on solvent-cleaned surfaces. The samples collected on the filters are spiked with an isotopically labelled internal standard before extraction.

Reference any standard methods being used. Attach SOPs.

3.5.3 Sample Analysis Methods

Describe the sample analysis methods by discussing the analytical principle of the instruments being used. Provide technical specifications for equipment being used. Include details such as units, performance characteristics (MDLs, operational ranges, sensitivity, etc.), and other meta-information. Reference any standard methods being used. Attach SOPs.

3.5.4 Data Analysis Methods

Describe calculations and algorithms performed on raw data to convert instrument signal (e.g., voltage) or chemical analysis numbers (e.g., filter weight) to final data. List any software and programs used. Examples include data processing software for laboratory instruments, and custom programs written with statistical software. Reference any protocols or research articles followed.

3.5.5 Laboratory Accreditations

Provide information on any accreditations of the analyzing laboratory, such as those offered by the Standards Council of Canada or equivalent foreign bodies such as the National Environmental Laboratory Accreditation Program (NELAP).

3.5.6 Continuous (Direct) Measurement Methods

Describe any continuous or semi-continuous measurements. Identify the instruments that will be used and provide technical specifications and performance characteristics. Explain how the measurement method works. If applicable, describe the inlet materials, design, and operational characteristics (e.g., flow rate, particle size cut, filtration, conditioning of sample, concentration range). Describe data acquisition processes. Reference any standard methods being used. Attach SOPs.

3.6 Sample Handling Procedures

The sample handling procedures section discusses the measures taken to ensure that sample integrity is maintained. Mistakes can cause samples to become invalid and unusable. Describe the sample handling throughout the sample life cycle, from generation to archival.

3.6.1 Handling

Discuss handling procedures needed to minimize sample contamination, modification, or damage. Handling techniques that minimize contamination include the use of powder-free gloves, triple-acid-washed tweezers, solvent-cleaned foil surfaces, prebaked storage containers, etc. Describe sample containers and any special preparation necessary. Specify how quickly samples should be removed from a sampler after the sampling period. Give temperatures at which samples should be shipped from the sampling location back to the laboratory. Specify

holding times once the sample is at the laboratory. Discuss methods and any special considerations for sample transportation.

3.6.2 Storage

Describe the location where the samples are stored, their physical state, and any special considerations such as temperature, light, or storage under an inert gas. Describe storage containers, and whether any special preparation is required (e.g., acid washing, solvent cleaning). Describe how the sample containers are sealed. State whether the samples have to be stored in a certain state (e.g., acid-digested or homogenized). Demonstrate that the method of storage will not compromise the integrity of the samples. This can be accomplished by explaining the requirements for sampling integrity (e.g., ultra cleanliness) and identifying how the methods meet the requirement (e.g., solvent-washed metal containers double-sealed in plastic bags). Identify samples that have a limited shelf life and establish requirements for analysis before the samples expire.

3.6.3 Tracking

Describe how samples are tracked from the moment of collection to the time they are archived. If a chain of custody is used, describe the method (e.g., paper document or part of a digital data record). Identify the individuals responsible for tracking the samples during each stage of the sample's life cycle.

3.6.4 Archival

Discuss where the samples are archived, their physical state, and the environmental conditions. Discuss when and how long they are archived. Specify the expected shelf life of samples in the archive and demonstrate that the archive will not compromise the sample integrity.

3.7 Quality Section

Describe the QC procedures and activities that will be conducted during the project.

3.7.1 Quality Control Activities

Describe the QC activities. State and reference any quality requirements you are trying to meet. State how often you will apply quality procedures. Identify sources and traceability of standards.

Examples of QC procedures applicable to both discrete and continuous (direct) measurement methods are

- **Acceptance testing of instrumentation and equipment integration**. Identifies whether equipment is fit for service before it is used. Normally, performance tests are done when new equipment is received, after it is repaired, and when it is installed at a monitoring site.

- **Instrument performance checks**. Ensures instruments will produce accurate data. These checks are used for instruments making direct measurements in the field and instruments used in analytical laboratories. Examples include calibrations, blanks, zero checks, drift checks, noise checks, leak and flow checks, span and precision checks, and comparisons of collocated instruments.
- **Certification of standards (such as gas bottles) and reference equipment (e.g., flow meters)**. Ensures that equipment calibrations are traceable to a common standard.
- **Equipment maintenance**. Ensures the quality of the data by maintaining optimal performance.

Examples of QC procedures applicable to discrete measurement methods are

- **Sampling, preparation, and analysis method checks**. Ensures the overall sampling and analysis method will produce accurate data. These are used for discrete samples that are collected onsite and analyzed later. Examples include sample splits[2] in the field, blanks, spikes, and internal standards. Preparation and analysis methods can be checked by processing standard solutions and standard reference materials as if they were samples.
- **Inspection and acceptance of supplies and consumables**. Identifies imperfections and contamination that could affect sample integrity.

Examples of QC procedures applicable to continuous (direct) methods may include

- **Routine Level 0 checks of the data through web connection**. Identifies problems with direct measurements quickly so that data losses are minimal. Also allows anomalous data to be removed quickly.
- **Visual inspection of equipment**. Identifies problems with installations, or problems that have developed with the equipment since the last visit.
- **Diagnostic checks of the instrument test functions**. Identifies equipment problems.

3.7.2 Acceptance Criteria

Quantify acceptance criteria for each QC activity using a table (see **Table 3-4** for examples). The table should include a brief description of the procedures, the criteria, and the frequency with which the procedure should be performed. Some acceptance criteria need additional clarification. For example, the acceptance criteria for the calibration of an ozone instrument may be that each calibration point must agree within a certain percentage of the audit concentration. This difference may be 2% of the highest audit concentration. Clarifying text beyond the table will be useful.

[2] Sample splits divide a sample so that replicate analyses can be made by the same laboratory or by different laboratories.

Table 3-4. Example of an acceptance criteria table for three parameters.

Parameter	Type	Accuracy Criteria	Frequency
Oxides of nitrogen	Dynamic dilution of calibration gas with gas phase titration	±15% at each calibration point	Within 60 days of startup and at three-month intervals.
Ozone	Dynamic dilution of calibration gas with gas phase titration	±15% at each calibration point	Within 60 days of startup and at three-month intervals.
$PM_{2.5}$	Flow rate verification with certified flow meter	±5% of certified flow meter	Within 60 days of startup and at three-month intervals.

3.7.3 Quality Assurance

Perform internal and external audits to ensure that instrumentation is operating within recommended parameters. Audits are performed by either a member of the organization (internal) or a member of another organization (external).

3.7.4 Corrective Actions

Corrective actions resolve and prevent recurrences of problems that can arise during a project, such as issues related to data quality and timeliness of deliverables. Describe in this section actions to be taken to identify, report, and correct problems. Also describe what actions will be taken to prevent them from recurring. Corrective actions identify the root cause of a problem, verify that the problem is solved, and document the cause and the solution.

> Contamination was discovered in several VOC sampling canisters. The contamination was traced back to solvent contamination. The solvent provider was changed.

Discuss the process by which problems are reported when they are identified using the QC procedures in Section 3.7. Identify to whom problems are reported. If possible, list the individuals responsible for deciding upon, implementing, and supervising corrective actions for the various aspects of the project, such as monitoring, data management, data analysis, schedule, logistics, and QA. Describe the processes for evaluating the effectiveness of the corrective actions.

3.8 Data Validation and Usability

Data validation activities ensure that only data of acceptable quality are reported. Describe the data validation activities that will be performed. Identify the person responsible for each aspect of the data validation.

3.8.1 Validation Records

Describe how all data validation activities are documented. Demonstrate how an independent observer will be able to determine how raw data were transformed into the final data, and identify the individuals who make changes and add null and qualifier codes.

Data Validation Codes

List and define the null and qualifier codes used. Null codes tell the user the data are invalid and the cause for invalidation. Qualifier codes alert the data user to suspected biases and interferences in the data. Describe how codes are attached to the data record, and the process for tracking when they were added and by whom.

Data Validation Logs

Describe the data validation logs used to keep a record of validation activities. Discuss what information the logs contain, how they are modified, how modifications are tracked, the format of the logs, how and where they are stored, and how they are reported.

Data Completeness Criteria

State the completeness criteria for each parameter (if applicable) and over what period completeness is calculated. Show how the data are recorded as unusable if the criteria are not met.

3.8.2 Validation Levels

Level 0 – Preliminary Verification

Describe the validation of raw data. Describe the manual and automatic QC checks used to screen and flag the raw data. Explain methods for investigating suspect data. Describe the corrective actions taken when anomalous or erroneous data are found. State criteria used for accepting, rejecting, or qualifying data.

Level 1 – Primary Validation

Describe the validation of Level 0 data. Justify why any commonly performed validation procedures are not being conducted. Examples of procedures include

- Review qualifier and null codes from the preliminary verification.

- Review supporting information, such as diagnostic data, site logs, and calibration and audit records.
- Treat over-range and outlier values.
- Adjust baselines and below-zero values.
- Preserve derived parameter relationships; e.g., the sum of NO and NO_2 should equal NO_x.
- Use project-specific calculations or algorithms.

There may be several levels of performance criteria to use for data validation, such as critical or operational criteria.[3] Failure to meet critical criteria results in invalid data. An example of a critical check is a span and precision check that does not meet specified performance criteria. Similarly, if operational criteria are not met, the data may be invalidated, although review of other available information may be pertinent before deciding whether to invalidate the data. An example of an operational criteria is the shelter temperature dropping below the lower temperature criterion by 5℃. However, if the precision and span data meet critical criteria, the data may still be considered valid in this situation.

Level 2 – Final Validation

Describe the validation of Level 1 data. Discuss methods to compare measurements at a given site, or between data measured in the same region at different sites. Measurements of regional contaminants such as ozone made at neighboring monitoring locations could be compared to check that measurements agree within expectations. Discuss methods for comparing historical data (e.g., time-series analysis).

Comparisons of $PM_{2.5}$ and PM_{10} measurements made at the same site should show that the $PM_{2.5}$ concentration is less than or equal to the PM_{10} concentration.

Level 3 – Independent Data Review

Describe the independent review used to validate Level 2 data. Clarify whether the reviews will be conducted internally or externally. Clearly demonstrate that the person performing the Level 3 data review is independent of field operations and/or Level 1 and 2 data validation.

[3] For EPA's official definition see section 3.3 of the Quality Assurance Handbook for Air Pollutions Measurement Systems (Volume II) (U.S. Environmental Protection Agency, 2013). The handbook is available online at http://www.epa.gov/ttnamti1/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf.

Post-Final Validation

Describe the process used to identify, invalidate, or correct data that are found to be erroneous after initial submission.

3.8.3 Usability

Demonstrate that your data meet the project objectives. Show that your data are well documented. Explain why the data format you have chosen is easy to understand and use.

3.9 Data and Records Management

The data and records management processes maintain the integrity of data and records throughout the project. Explain how you will manage and store documentation, records, data, and metadata from their generation through the archival process. Discuss methods for managing data versions, which involve tracking and undoing any transformation, validation, or adjustments that may be made. Describe hardware and software to be used. We strongly recommend that investigators consult with AEMERA to determine which data formats to use for submission.

3.9.1 Data Management

Discuss the equipment and process by which data will be acquired and stored. For example, describe the data acquisition system and the method used to retrieve the data from the monitoring location. State whether the data will be polled[4] or pushed.[5] Describe the server used to host the database. Describe the database and data management software used to store and process the data. State whether the database is custom built or commercially available. Discuss QA procedures applied to the database and data management software. Describe backup strategies and state the storage time for data. Give an overview of the data management process using a flow chart (see **Figure 3-3** for an example). Provide an overview of data management activities using a table (see **Table 3-5** for an example).

[4] Data polling: A program running on a computer at the storage location contacts the data acquisition system at the monitoring location and requests a data transfer. Polling is done on a schedule, such as once per hour.
[5] Data pushing: A program running on a computer at the monitoring location sends the data to the storage location on a schedule.

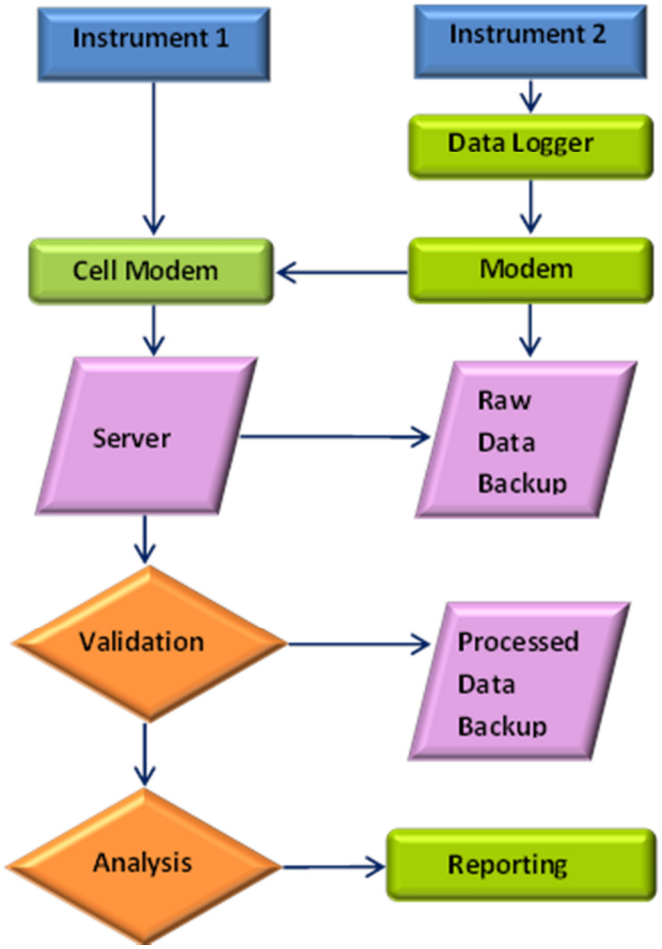

Figure 3-1. Example of a data management flow chart.

3.9.2 Records

List what records will be created and what they will contain. Identify the formats of each type of record (paper, digital, etc.). State where and for how long the records will be stored (e.g., at the monitoring location, at the offices of the monitoring organization, or on third-party servers). Identify the individuals responsible for creating and taking custody of the records. This can be communicated using a table, as shown in the example in Table 3-5.

Table 1-1. Example of a table describing data and record management.

Data or Record Type	Description	Storage Location and Format	Responsib Party
Raw monitoring data	Raw data	Database	Project Manager
QA/QC data, site logs, calibrations, audits	Data precision and accuracy; site activities; calibration values; audit reports	Database, digital document files, hardcopies (Site Logs only)	Field technician
Metadata	Site/instrument setup, calibration information for certified standards, dates of calibrations and audits, etc.	Database, digital document files as applicable	Field technician
Project study validated data	Level 2 validated monthly data sets	Database, digital document files	Project Manager

3.10 Assessment and Oversight

3.10.1 Assessments

Describe the internal and external assessments that will be used to make sure the data being produced will be comparable with other measurements of the same parameters in the Oil Sands. Discuss

- Audit procedures (both internal and external) of the measurement equipment and technical systems.
- Frequency of instrument calibrations and audits.
- Laboratory accreditations (e.g., proficiency testing).
- Internal or external peer-review of data.

3.10.2 Oversight

Describe the internal and oversight structures used to supervise progress and to review the quality of data. Internal and external oversight structures should be described. Use the organizational chart provided in Section 2 of the QAPP template to illustrate these structures. Identify key individuals and provide their title, role, and contact information.

List and describe reports that will be sent to internal management and to AEMERA discussing project progress and summarizing findings. Identify recipient(s) of progress reports and data summaries.

3.11 Reporting and Timeliness

The formats and schedules of deliverables should meet the needs of AEMERA and other stakeholders. Deliverables should be submitted to AEMERA and any other funding agencies on the schedule set out in the contract. Deliverables may include

- Work plans
- Quality assurance documents
- Risk management documents
- Site visit reports
- Audit reports
- Preliminary and final data
- Progress reports
- Interim and final reports
- Presentations
- Manuscripts
- Posters

Data should be released according to the schedule agreed upon . AEMERA expects to receive a copy of the final data at the end of the contract period for their use. Other funding agencies may have similar expectations. Use this section to outline when data will be reported within the contracted period and that data and results will be delivered to stakeholders in a usable format.

Specify reporting timelines for deliverables, as shown in the example in **Table 3-6**. Identify the timeline for submission of preliminary data (if required) and final validated data to the AEMERA data archive. Discuss critical path items and the dates when they must be completed for deliverables to be reported and submitted on schedule.

List the formats of deliverables. Specify the formats of written data summaries (e.g., technical memoranda, executive summaries, full reports). Consult with AEMERA to ensure data formats meet AEMERA guidelines.

Table 1-2. Example of a deliverables schedule.

Deliverable	Format	Due Date
Work Plan	PDF file	February 1, 2014
QAPP	PDF file	April 1, 2014
Audit Reports	PDF file	June 1, 2014, and November 1, 2014
Raw Data	CSV file	November 1, 2014
Finalized Level 2 Data	CSV file	January 15, 2014
Final Report	PDF file	January 15, 2014

4. Standard Operating Procedures

An SOP is a detailed set of instructions that documents how your organization performs routine activities, such as sampling, monitoring, and analysis. SOPs are integral to a successful quality system because, when everyone involved follows them, sampling, monitoring, and analysis procedures can be uniformly and reproducibly performed. When SOPs are followed, the quality of data should be consistent regardless of who has generated, processed, and managed the data.

SOPs are clear and simple. They are written concisely in a step-by-step, easy-to-read format, using the active voice and the present verb tense. The SOP is illustrated with flow charts, diagrams, and photographs wherever appropriate. SOPs are typically referenced in the QAPP and attached as appendices to the QAPP.

SOPs are needed even when established methods are being used (e.g., a standard analytical method, a method described in a peer-reviewed journal article, instructions from a user manual). The SOP may describe the procedures to be followed in greater detail than the established method does. These additional details clarify unclear instructions in the established method, or they provide information on how your organization performs the procedure.

A short-term air monitoring project may have as few or as many SOPs as are necessary to document the procedures used. The SOPs may describe activities related to any aspect of the project, although in this guide we focus on describing SOPs for sampling and analysis activities. Such activities may include

- Cleaning sampling equipment
- Preparing sampling media
- Operating sampling equipment
- Preparing samples for analysis
- Operating laboratory-based instruments that are used to make measurements on discrete samples
- Operating field-based instruments that make direct measurements
- Project-specific data handling
- Project-specific data management

Please note that our suggested SOP organization (and template) is in a different order than that recommended by the U.S. EPA; it may not be necessary to reformat existing SOPs to follow the organizational structure in this guidance document as long as the SOP includes all relevant sections.

4.1 SOP Sections

4.1.1 Scope and Applicability

The scope and applicability section establishes the proper use of the method described by the SOP. This section should be one to two paragraphs. First, explain the purpose of the method; then discuss the applicability of the method by identifying the conditions under which it is designed to be used.

Key details might include

- Target parameters, contaminants, or analytes (e.g., benzene, wind speed)
- Measurement principle (e.g., gas chromatography for analyte separation and flame-ionization detection for analysis)
- Type of equipment used (e.g., Synspec GC955 model 800)
- Key performance characteristics (e.g., analyte detection limits of ~100 ppt at 1-hr resolution)

The applicability of the method should describe the representative conditions under which the SOP is appropriate. The SOP should specifically identify any expected conditions that may occur during the short-term air monitoring project under which the method is not applicable. Key details might include

- Operating temperature ranges (e.g., 10℃ to 40℃)
- Minimum and/or maximum sampling duration
- Humidity ranges
- Interferents (i.e., other pollutants that may be misidentified as the target species)

> This method measures ppb concentrations of benzene and toluene in ambient air sampled over a two-week period using passive samplers. The method performs optimally at temperatures between 10℃ and 40℃, and at relative humidities between 20% and 80%.

4.1.2 Method Summary

The method summary concisely describes the main steps of the procedure. The section should be about one paragraph. Start with an overview sentence and then describe the main components. Cite any standard methods or journal articles on which the method is based. Note any significant deviations from the methods that were followed.

Passive SKC Tenax GR sorbent diffusive samplers are used to sample benzene and toluene. Samplers are deployed on 3 m poles and covered to protect them from precipitation. Weekly integrated samples are collected for one year. The collected volatile organic compounds (VOCs) are thermally desorbed and analyzed using gas chromatography-mass spectrometry (GC-MS) as described in U.S. EPA method TO-17.

4.1.3 Equipment, Materials, Chemicals, and Facilities

The equipment, materials, chemicals, and facilities section describes what is needed to perform the method and gives preparation instructions where needed. Give enough information to make sure that all the items and facilities described are being used correctly. Give specifications (or citations) where appropriate. Examples of what might be discussed for each topic in this section are

- **Equipment**. Hardware used for sampling, handling, processing, and analysis procedures, such as samplers, monitors, laboratory-based analyzers, clean hoods, clean rooms, fume hoods, glassware, and tools.
- **Materials**. Consumables used for sampling, handling, processing, and analysis procedures, such as gloves, bags, sample storage containers, materials used for clean surfaces, pipettes, and applicators.
- **Chemicals**. Solvents, reagents, and standards used. Specify the purity of the chemical required. If the chemical is a traceable standard, give the identification number (e.g., NIST-211d is a toluene standard). Give step-by-step preparation instructions.
- **Facilities**. Specialized rooms, laboratories, immovable equipment, or vehicles that are needed to perform the method successfully. Examples might include a class 100 clean room for handling samples that must not be contaminated with dust, an ultra-clean laboratory for analysis of trace-metals, or a mobile laboratory equipped with operational instruments while the vehicle is in motion.

Describe the assembly or setup of sampling and analytical equipment used. These instructions should include diagrams and photos and be separated into multiple steps. Give instructions for cleaning and testing procedures for relevant components of the equipment. Provide detailed instructions for making chemicals that are not purchased.

For facilities, it may be helpful to the operator to describe important aspects of the room's operation. Give operating conditions and performance criteria. Discuss maintenance procedures for key components of the facility, such as how and when to replace filters in a clean room air handling system. Give directions on how to avoid contaminating or damaging the facility.

4.1.4 Health and Safety Warnings

Health and safety warnings provide the operator with sufficient information for safely conducting the method. They also contain the procedures to follow during emergency situations. Provide health and safety warnings about any part of the SOP that could cause injury or death. The warning will usually contain information about the hazard, the activity that the hazard makes dangerous, and how to protect against injury. If the SOP is long, consider reiterating health and safety warnings in the relevant sections. Much of the information needed for this section may be contained in Materials Safety Data Sheets, and in safety documents written by your organization, such as a Chemical Hygiene Plan.

The warnings should provide sufficient information to characterize the hazard so that operators can avoid injury. Hazards to discuss in this section may include

- Corrosive, flammable, toxic, or carcinogenic chemicals
- Radiation
- Light that can cause blindness
- Electricity
- Objects, fluids, or gases that are hot or cold enough to cause burns
- Sharp objects
- Pressurized vessels that may explode
- Unguarded mechanisms

Summarize the health or safety concern that the hazard presents and append more detailed information if available (e.g., Material Safety Data Sheets). Discuss clean-up procedures for spills and leaks and describe appropriate disposal procedures. Identify any equipment that will become contaminated with a hazardous material and discuss how it should be handled, cleaned, or disposed of safely. Describe the disposal of hazardous materials and contaminated equipment in this section, and provide more detailed instructions in the waste management section next.

In addition to characterizing the hazard, the warning should identify specific activities that are made dangerous by the hazard and describe what precautions the operator should take to avoid injury. Discuss techniques, personal protective equipment, and laboratory management practices that will prevent injury. For example, describe how to handle strong acids, give specifications for gloves to use with solvents, give specifications of eye protection to use with ultraviolet light sources, and state the class of fume hood needed for handling volatile compounds.

In this section, identify to whom to report accidents and spills to in your organization. Provide contact information for the emergency services that will respond to an accident.

> ***4.1 Chemical Hazards***
>
> *…The following analytes covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: vinyl chloride and trichloroethylene. Primary standards of these toxic compounds are prepared from commercially prepared gas reference standards that are available in various gas cylinder sizes. These standards must be prepared in a fume hood…*
>
> *…The procedure described in this SOP involves the use of cryogenic liquids for cooling the Entech concentrator. Region 9 SOP 770, Handling Cryogenic Materials, provides guidelines for the safe handling of these materials…*
>
> —Excerpt from a U.S. EPA Region 9 SOP for EPA method TO-15.

4.1.5 Procedure

The procedure provides step-by-step instructions for every part of the method in plain English illustrated by diagrams, pictures, and/or flowcharts. Anyone with the required training and experience should be able to accurately perform the method from beginning to end with these instructions. Provide enough guidance so that the operator knows how to collect representative samples, perform accurate analyses, and operate equipment properly. Also, give enough information so that the operator can identify when the method is not working as intended. Provide explicit instructions on how to avoid making common mistakes.

The length of the procedure depends upon the complexity of the method. Simple procedures may only be a few lines. More complex procedures may be several pages long and be separated into subsections. Concisely present the instructions as numbered steps. Avoid writing paragraphs as these are more difficult to follow while working.

A procedure describing a sampling and analysis method may contain the following subsections:

- Sample media preparation
- Sampling equipment cleaning, assembly, and preparation
- Sample collection
- Sample shipping and storage
- Sample preparation
- Analytical equipment cleaning, assembly, and preparation
- Sample analysis

A procedure describing the operation of sampling or analysis equipment might contain only some of these subsections. For example, a procedure might only contain instructions on cleaning, assembly, preparatory tests, and operation.

Provide the operator with enough detail to perform the procedure properly without having to consult other sources of information. Give weights, flow rates, temperatures, volumes, sampling frequencies, and durations of activities. Include photographs and diagrams wherever possible, as they are a more effective means of communication than descriptive text. Any routine QC procedures described in Section 4.1.6 should also appear (by name only) in the appropriate steps.

4.1.6 Quality Control Procedures

QC procedures assure the data will be of sufficient quality and quantity to meet the project objectives. The procedures you describe in this section are specific to the method described by the SOP. Some of what is needed for this section may also be in the QAPP (see Section 3.7) although the text may need to be tailored to the method being described.

In this section, list and describe each QC procedure to be used. Give step-by-step instructions explaining how to perform each procedure. These instructions should list the equipment, materials, and chemicals needed. Provide the performance criteria for each of the QC procedures. These can be given in the description or as a summary table. Also specify the frequency of the QC procedures. For example, if the method analyzes samples in batches, provide a typical batch sequence showing where the QC checks are performed. If the SOP describes QC checks performed on a continuous air monitoring device, give the schedule of the checks (e.g., daily at 2 a.m., once weekly, twice per year). Describe calculations that are performed with the QC check measurements to determine if the method is within control limits, or is producing data of acceptable accuracy and precision. Examples of QC procedures typically discussed in this section are listed in detail in Section 3.7 of this guidance document. Additional examples of QC procedures are shown below in **Table 4-1** and the text box that follows the table**.**

Table 4-1. Example of performance criteria for QC used in the analysis of discrete samples.

Type	Criteria	Frequency
Replicates	±10%	Every 10 samples
Field Blank	<0.1 µg m^{-3}	1 for every 5 samples
Matrix Spikes	±20% of the expected value	Every 20 samples
Laboratory Quality Control Sample	±20% of the expected value	At the start of every batch

Standard Reference Material (SRM) – A traceable standard material with known analyte concentrations (e.g., NIST 1648a, which is urban particulate matter with certified concentrations of trace metals). The SRM is used to verify the extraction procedure.

A blank filter containing SRM NIST 1648a is prepared and is processed like a sample. At least one SRM is analyzed with each batch. The analyte recoveries must be between 85 – 115% of the certified concentrations. If the SRM fails to meet criteria after one reanalysis, associated samples must be given a qualifier code.

—Example developed from an SOP for acid digestion and inductively coupled plasma-mass spectrometry analysis of ambient particulate matter collected on filters.

4.1.7 Data and Records Management

Data and records management maintain the integrity of information generated throughout the project. Give detailed instructions of what data and records to create; how to create them; what information they should contain; how, when, and by whom they should be modified; where they should be stored; and when the project data should be submitted to the AEMERA database. Provide examples of checklists, handling forms, and sample outputs that will be used or generated during the SOP. The Alberta Monitoring Directive provides instruction on reporting data.[6]

Data generated during an air monitoring project include measurements made in the field or the laboratory and any associated metadata. Provide examples of files in which these parameters will be saved. Annotate and describe key metadata, such as the units, site locations, codes, and qualifiers; see **Table 4-2** for an example.

In many cases, calculations are performed on the raw data produced by analytical instruments. Give instructions on how to perform such calculations, explicitly defining equations to be used. If applicable, give the values or ranges of values that would are expected from the calculations.

Records generated during an air monitoring project can include handwritten or digital documentation that accompany the data and contain important metadata. For discrete sampling programs, records are normally created and filled out during the sample preparation and collection stages. For continuous sampling programs, records are generated during instrument performance assessments and during data validation activities.

[6] http://environment.gov.ab.ca/info/library/8339.pdf.

Examples include

- Field log sheets
- Chain of custody forms (see **Figure 4-1**)
- Audit reports
- Data validation records

List and describe the records that need to be created and maintained for the procedure. State when and by whom they should be created and updated. Provide examples of the forms and files that will be used as records.

Table 4-2. Example of a table listing measurement units for submission to OS-DMN.

Contaminant	Units of Measurement
Particulate matter (TSP, PM_{10} and $PM_{2.5}$) and its constituents	$\mu g/m^3$
VOCs[1]	ppb
PAHs[2]	ng/m^3

[1]Volatile organic compounds
[2]Polycyclic aromatic hydrocarbons

Discuss where data and records will be stored, for how long, and who has access to them. State who has permission to modify the records. Document any backup procedures used to ensure data security and version control.

4.1.8 Interferences

The interferences section identifies things that may hinder, obstruct, or impede the ability of the method to measure the target analytes properly. Interferences may include

- Compounds that have overlapping peaks or spectra with the compound of interest
- Contamination artifacts
- Memory effects[7]
- Instrument noise

Discuss how potential interferences affect the measurements and explain why (if known). Identify which analytes are most affected by the interferences. Discuss the specific effect the interference has on the measurements. For example, explain whether the interferences cause the measurements to be biased low or high, and if they decrease the precision of the measurement. Give instructions on how to avoid and resolve interferences.

[7] Contamination or passivation of a reusable sample collection device that carries over from one use to the next.

CHAIN OF CUSTODY FORM

Sheet ____ of ____

Investigator *(name, address, ph & fax nos.)* Contact person:					**Sample matrix**						**Sample preservation**					**Analysis**								
Site																								
Laboratory *(name, address, ph & fax nos.)* Contact person:																								
Courier *(name, address, ph & fax nos.)* Contact person:																								
Sample ID	**Laboratory ID**	**Container**	**Sampling**																					
			Date	Time																				
Investigator: I attest that the proper field sampling procedures were used during the collection of these samples.									**Sampler name:** *(print & signature)*											*(Date)*					
Relinquished by: *(print & signature)*			Date	Time					Received by: *(print & signature)*							Date				Time				
Relinquished by: *(print & signature)*			Date	Time					Received by: *(print & signature)*							Date				Time				
Relinquished by: *(print & signature)*			Date	Time					Received by: *(print & signature)*							Date				Time				

Figure 4-1. An example of a chain of custody form used by the New South Wales Environmental Protection Authority, Australia (http://www.epa.nsw.gov.au/mao/servicestation.htm#appendix a. chain of custody form).

> *The majority of contamination artifacts [the interferences in this example] in the GC analysis arise from impurities in the carrier gas, organic compounds out-gassing from the components upstream of the GC, and solvent vapors in the laboratory. The analytical system must be demonstrated to be clean using humidified zero air blanks. Avoid non-chromatographic grade stainless steel tubing, non-Teflon thread sealants, or flow controllers with Buna-N rubber components."*
>
> —Example developed from EPA Method TO-15 for measuring VOCs in air samples.

4.1.9 Qualifications and Specialized Training

The qualifications and specialized training section ensures that the method is performed by personnel with the appropriate skills and experience. List the necessary degree qualifications, required internal or external training courses, and certificates that staff must hold. Document any prior experience necessary to perform the method. Identify what documentation is required and who should receive and store the documentation. **Table 4-3** shows an example.

Table 4-3. Example of qualifications, training, and certifications required to perform SOP 123 for VOC analyses by U.S. EPA Method TO-15. Example developed in part from the Wisconsin State Laboratory of Hygiene Quality Assurance manual.

Qualification, Training, or Certification	Documentation
Undergraduate-level course in analytical chemistry	Official transcript
Initial laboratory safety training course	Signed form
Yearly laboratory safety seminar	Signed form
Method training form	Signed form
Demonstration of Capability (DOC) certification	Signed certificate
Certification for current technical methods	Signed certificate

4.1.10 Waste Management

The waste management section describes procedures for disposing of waste generated during the procedure. The section should give all the information the operator needs to dispose of the waste safely in compliance with relevant Federal, provincial, and local regulations. Much of the information needed for this section may be contained in safety documents written by your organization, such as a Chemical Hygiene Plan. Give step-by-step instructions if necessary. Hazardous waste disposal may be discussed in the health and safety warnings section, but it is

recommended that you give detailed step-by-step instructions of how to perform the disposal in this section. Provide contact information for Environmental Health and Safety staff at your organization so that any questions can be quickly resolved.

For further information on waste management, consult the Workplace Hazard Management Information System[8] and Alberta ESRD's Hazardous Waste Management rules and regulations.[9]

4.1.11 Glossary

The glossary provides definitions of acronyms and specialized terms. Include any terms that may be unclear to people who are unfamiliar with the method. Describe each acronym or specialized term in plain language. The descriptions should be concise, though a more involved definition may require a paragraph.

4.1.12 References

The references identify the source material and communications that were used to develop the SOP. References would include standard methods, journal articles, conference papers, text books, internal presentations, and personal communications. The personal communications could be advice or guidance from experts in the procedure or the method it describes. The communication could be written or verbal. Unpublished materials and communications should be documented in the SOP, or in an attachment.

[8] http://www.hc-sc.gc.ca/ewh-semt/occup-travail/whmis-simdut/index-eng.php.
[9] http://environment.alberta.ca/02643.html.

5. Risk Management

Research activities often involve risk, which could develop into a problem causing a project to be unsuccessful. Projects may fail because of insufficient data quality or quantity, inconclusive results, late deliverables, cost overruns, or injuries to personnel. This section provides a brief overview of possible risks that may cause failures for air monitoring projects in the Oil Sands region. The goal of the section is to help you think about potential problems that could arise during your project and ways to mitigate them.

We have identified and described ways to mitigate risk in six areas of an air monitoring project that should be considered during the project planning phase as shown in **Figure 5-1**. These include

1. Project management plan
2. Study design
3. Equipment
4. Project location
5. Quality assurance procedures
6. Safety

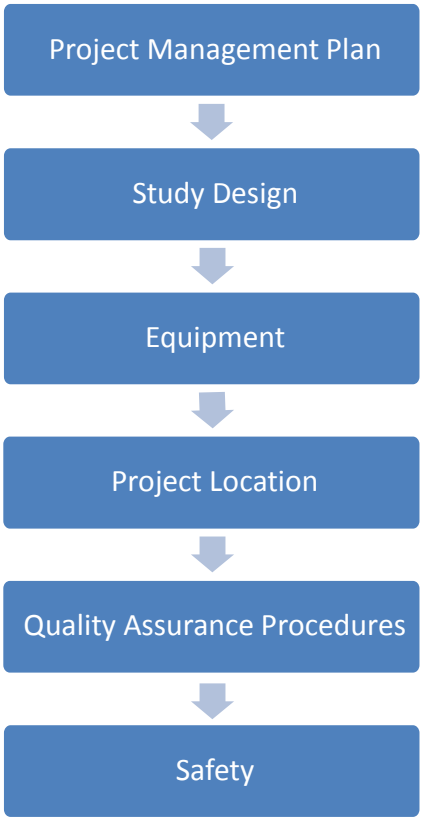

Figure 5-1. Risk management components.

You will most likely be required to describe your risk management plans when proposing air monitoring projects in the Oil Sands region. However, you should check with the project lead at AEMERA to determine if your project requires the risk management plan to be described in a stand-alone document that is written after your project has been funded.

5.1 Project Management Plan

Successful field studies are well managed to ensure the sampling and analysis efforts proceed as intended, deliverables are on time, and costs are kept in budget. Every project has four common areas that can experience problems: schedule, logistics, budget, and staffing. For each of these, consider the following:

- **Schedule**. Plan for constraints in the schedule due to weather, staff availability, and equipment availability.
- **Logistics**. Allow time for equipment to pass through customs, or for equipment to be shipped to the project staging area.
- **Budget**. Allow for various unexpected contingencies such as failed sampling days or equipment failure. Plan for inflation and potential fluctuations in currency exchange rates (if necessary).

- **Staffing**. Establish redundancy across staff to accommodate illness, family emergencies, etc. Allow staff enough downtime for sleep and rest during field projects to avoid introducing critical errors and to lower the risk of injury. Establish well in advance that all personnel have the correct paperwork and permissions to work in Canada.

5.2 Study Design

The field study design is important for project success because the design determines whether sufficient data will be collected to provide conclusive results. A study can be designed to minimize the risk of data impairment and loss. Consider

- **Study schedule**
  - Understand the historical climatology for the measurement location so that the study can be timed appropriately.
  - Schedule studies early in the optimal window so that weather changes at the end of the window will not curtail the study.
  - Identify a study window that is longer than the study itself so that the start of data collection can be delayed, and the end of data collection can be extended if more measurements are needed.
- **Sampling**
  - Collect more samples earlier in the study if you are studying episodic air pollution events. For example, sample on modest air pollution episode days of interest at the start of the study, and then focus on the days on which more severe air pollution occurs toward the end of the study. This approach ensures that usable data sets are collected early on, because equipment failures or a lack of anticipated air pollution events could prevent usable data from being collected later in the study.
  - Collect more discrete samples earlier in the study if you are establishing a longer-term monitoring campaign. This approach ensures you will identify quality control problems earlier in the study, giving time for corrective actions.
  - Include extra sample days in case failures of key equipment occur, or weather conditions are not conducive to making measurements. These extra days may apply to both mobile and stationary monitoring. Assume that a certain percentage of data will not be usable. The probability of unusable data increases as the number of measured parameters, instruments, and research groups increases.
  - Create a menu of sampling plans from which to select for mobile or flight sampling campaigns. For example, have several predetermined routes or flight tracks to choose from on the day of a mobile monitoring effort, and then select the appropriate one for the forecast weather conditions, emissions patterns, or other criteria.
- **Testing**
  - Prior to study deployment, perform test runs with a “beginning-to-end” approach where data are collected, processed, and analyzed through to their final form. With this approach, you can evaluate all aspects of data collection and analysis, and fix problems ahead of time. This testing could be done before the equipment leaves the laboratory, or during a study period after it is installed at the monitoring location.

  - Install instruments a few days before the official data collection begins to allow time to work out any problems.

- **Flexibility**
  - Consider alternate plans for all aspects of the study. For example, identify backup sampling locations, and wherever possible, have redundancy across staff.
  - Recognize which aspects of the study design are out of your control, and design flexibility into the plan. For example, a particular emissions source may be down for maintenance for several weeks at the start of your campaign. In this case, ensure that the study window is sufficiently long to account for the types of downtime that may occur.

5.3 Equipment

Proper site selection and equipment operation are vital to reduce the risk associated with collecting insufficient data, which can cause study failure. The choice of monitoring locations, and keeping instruments operational, are important to the success of field study. A secure monitoring location minimizes the risks of costly relocations, equipment damage and theft, and injuries to personnel. Equipment that is kept in good working order helps minimize the risk of data impairment and loss. Consider

- **Select secure, safe, and accessible monitoring locations**.
  - Avoid monitoring locations in insecure or high-crime areas to reduce risk to site operators. Equipment may be damaged or stolen.
  - Avoid locations with site hazards. Sites should be sufficiently far from safety hazards (e.g., the shoulders of busy roads, near construction equipment or earth movers).
  - Avoid monitoring locations on private land for which access may not be renewed or where access may only be at the landlord's discretion.

- **Keep inventories of spare equipment and parts to minimize instrument downtime**.
  - Have sufficient supplies of parts with short life expectancies, that are hard to get, or that have significant lead times to replace.
  - State contingencies for failures of rare or expensive parts on custom-built research instruments.

- **Consider keeping spare instruments available so you can replace broken equipment promptly**. The broken equipment can then be repaired without a lengthy interruption to monitoring, and either reinstalled at the site or used as a spare.

5.4 Project Location

Appropriate preparation specific to the region where the field study will be conducted is important for the success of the project. Some examples of things to consider for key characteristics of the Oil Sands region include

- **Low temperatures**. Some instruments need to be placed in a heated shelter and their inlets may also need heating to avoid icing or condensation. Measurements may be lost if the shelter heaters are not powerful enough during an exceptionally cold period.

- **Precipitation**. If you are using satellite communications, you may need to install heaters or covers to avoid losing the connection due to icing or snow cover of the dish. During heavy rain, monitoring locations may become flooded if not sited appropriately.
- **Remoteness**. Consider supply lines for consumables, repairs, and spare parts; sample shipment; and emergency extraction of injured or sick personnel. Costs for travel and lodging may be higher than expected, particularly if hotel accommodations are limited. Site access may require off-road vehicles.
- **Availability of points of contact**. You may rely upon a liaison to gain access to a site. Ensure that backup contacts are available in case the primary liaison is unavailable (e.g., due to travel or illness).
- **Extreme weather**. Weather conditions—such as rain, lightning, snow, poor visibility, high winds, or extreme cold—will impact some field operations.
- **Wildlife**. There is an abundance of wildlife in many parts of the Oil Sands. Large animals can be a hazard for personnel and equipment. Smaller animals and insects can damage equipment or be a nuisance during field operations.

5.5 Quality Assurance Procedures

QA procedures are used to identify and rectify problems with the sampling and analysis activities so that data of sufficient quality and quantity are collected. Consider

- Plan sufficient budget and resources for QA samples and testing. Allocating at least 10% of budget, staff, and resources to QA is a good approach.
- Conduct external independent audits of instruments.
- Compare unproven research grade instruments against a reference method.
- Collect duplicate measurements at stationary sites for a representative fraction of the samples (e.g., 10%).
- Collect duplicate measurements along mobile sampling routes or flight tracks for a representative fraction of the routes/tracks. This can be done by collocating multiple sampling platforms along the same segment of the route at the start and end of a measurement session.
- Repeat mobile sampling routes or flight tracks on multiple days. This allows you to see how a region of interest changes during the study period.
- Look at data as soon after they are collected as possible to ensure that problems are identified and resolved quickly.

5.6 Safety

The health and safety of all personnel is an important component of any field study. Important considerations in field studies are having appropriate safety equipment, understanding safety rules, appropriate operation of vehicles, following safety procedures,

severe weather events, electrical hazards, and other hazards. A brief description of some field study safety procedures are listed here.

- **Safety equipment** – These could include safety glasses, hard hats, safety shoes or boots, work gloves, ear protection, reflective vests, and fire-retardant clothing.
- **Safety rules** – Examples include
  - Reading danger warning on labels
  - Cleaning up oil, grease, or water spills
  - Lifting heavy loads should be done with the legs and not with the back, or by using dollies or other mechanical equipment
  - Know correct use of power and hand tools prior to use.
  - Consider all wires “live” until checked out.
  - Properly ground electrical equipment.
  - Report any injuries immediately to a supervisor.
- **Vehicle operation** – Field studies may require operation of vehicles. Only authorized personnel should be allowed to drive the vehicles. Vehicles should never be operated under conditions of physical or mental impairment whether due to illness, medication, or intoxication.
- **Safety procedures** – Field studies may be conducted on private or public property. Personnel should familiarize themselves with specific safety requirements of those sites. Personnel should also be trained in safety procedures for any equipment they are operating. Attempt to perform work during hours when others are available to help in case of an emergency or work as part of a buddy system.
- **Severe weather events** – Weather conditions will impact some field operations, such as rain, lightning, snow, poor visibility, high winds, or extreme cold. The overriding concern is the health of personnel; equipment protection is secondary. Avoid outdoor activity during lightning storms, hail storms, heavy rain, or any weather condition that represents unreasonable hazard. Relocate equipment, cover it, and strap it down tightly. Follow all safety instructions from civil authorities and field and project managers.
- **Electrical hazards** – Completely power down equipment before conducting any work on the equipment. Don’t wear jewelry while working with electrical equipment. Avoid repairing power supplies or other high voltage devices in the field. Label all equipment and devices that may cause harm or death upon electrical activation.

6. References

U.S. Environmental Protection Agency (2006) Guidance on systematic planning using the data quality objectives process (EPA QA/G-4). Prepared by the U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, EPA/240/B-06/001, February. Available at http://www.epa.gov/quality1/qs-docs/g4-final.pdf.

U.S. Environmental Protection Agency (2013) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-13-003, May. Available at http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf.