Alberta Biodiversity Monitoring Institute

Quality Management Plan

Version 2.0

ABMI ALBERTA BIODIVERSITY MONITORING INSTITUTE

Approvals

Version Number # 2.0

Approved by:	Executive Director	2022-02-02 Date
Approved by:	Program Manager	2022-02-02 Date
Approved by:	Corrina Copp Information Coordinator	2022-02-02 Date

Revision History Log

Version #	Revision Date	Author	Changes
1.0	2016-04	Katherine Maxcy	Drafted
1.1	2016-08	Katherine Maxcy	Incorporated revisions after internal review.
1.2	2018-04	Corrina Copp	Incorporated revisions after internal review.
2.0	2022-01	Corrina Copp	Incorporated revisions after internal review. Significant changes made, please see Centre QMPs for detailed changes.

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List of Abbreviations

ABMI	Alberta Biodiversity Monitoring Institute
AC	Application Centre
ACIMS	Alberta Conservation Management Information System
ALPHA	Advanced Landcover Prediction and Habitat Assessment
ALPHA-S	Advanced Landcover Prediction and Habitat Assessment-Satellite
ARU	Autonomous Recording Unit
EO	Executive Office
FWMIS	Fish and Wildlife Management Information System
GC	Geospatial Centre
GIS	Geographic Information System
GPS	Global Positioning System
HF	Human Footprint
HFI	Human Footprint Inventory
HFMG	Human Footprint Mapping Group
IC	Information Centre
MC	Monitoring Centre
PC	Processing Centre
QA	Quality Assurance
QC	Quality Control
QMP	Quality Management Plan
SC	Science Centre
SOP	Standard Operating Procedure
SSW	Site Summary Workbench
TWB	Taxonomic Workbench

CHAPTER 1: DOCUMENT DESCRIPTION AND ORGANIZATION

1 Background

The Alberta Biodiversity Monitoring Institute (ABMI) collects data on a range of attributes (e.g., species, habitats, ecosystems, land use) that are used as indicators of environmental health in Alberta. This is a valuable source of data for the province, and as such, it is important to ensure the data is of known quality (Ferretti 2009, 2011, Houston and Hiederer 2009, Sólymos et al. 2015). When setting quality objectives for data it is important to understand its intended use (EPA 2001, Chapman 2005, GLNPO 2008, Ferretti 2009, 2011, Martín and Ballard 2010, Gasparini et al. 2011, Sólymos et al. 2015). A structured quality management plan (QMP) improves confidence that data is being effectively handled and, therefore, increases its use by stakeholders (Chapman 2005, Houston and Hiederer 2009, Sólymos et al. 2015).

A QMP is an organization's description of the processes that govern quality assurance activities (Lawrence 1999, GLNPO 2008). It contains the necessary elements to plan, implement, document, assess, and improve a quality management system (EPA 2001, Ferretti 2009). The QMP may be viewed as an "umbrella" document under which all quality assurance (QA) and quality control (QC) products and activities are contained (EPA 2001). The basic goal of the QMP is to provide a means to document and verify the quality of information being produced and provide guidance to program personnel to meet quality objectives (Shampine 1993). A QMP is a critical feature of a biodiversity monitoring program to ensure the program can meet stated quality objectives (Shampine 1993, EPA 2001, Sólymos et al. 2015). This QMP outlines the ABMI quality management system.

1.1 Objective

The objective of this QMP is to describe the ABMI quality management system as it relates to all data collection and processing activities, data analysis, and the production of associated data products. It describes how each ABMI business unit (Centre) will plan, implement, document, assess, and improve its quality system to produce and curate high-quality well documented biodiversity information.

1.2 QMP Report Organization

There are six Centres within the ABMI (see Chapter 2 for a complete description of each Centre). Because each Centre is responsible for different aspects of the data management cycle, each Centre has created their own QMP which is included as a chapter in this overarching document. Each Centre QMP follows the same format (EPA 2001, GLNPO 2008), and includes the following elements:

- Element 1.0 Quality Management Policy, Goals, and Objectives: defines Centre quality management policies, goals, and objectives;
- Element 2.0 Quality System Components: describes the main components of the quality management system and the activities and tools used to implement this system;
- Element 3.0 Quality Training System: describes the quality training system implemented by each Centre to ensure quality management objectives are being met;
- Element 4.0 Contractor Requirements: discusses the process for procuring services and Contractor requirements for meeting quality objectives;
- Element 5.0 Documents and Records: provides information on the document control system including: document preparation; document reviews, approvals, and revisions; document control; document storage and archival system;
- Element 6.0 Information Management: discusses the processes for managing information, including a description of computer hardware and software administration;
- Element 7.0 Systematic Quality Assurance Planning: discusses the process for systematically planning and implementing the quality management system;
- Element 8.0 Quality Implementation of Work Processes: discusses how each Centre implements its quality work processes;
- Element 9.0 Quality Assessment and Response System: describes the application of assessment tools that are used to evaluate the effectiveness of each Centre's quality management system and to improve its performance;
- Element 10.0 Commitment to Quality Improvement: summarizes each Centre's ongoing activities towards continued improvement of data collection, analysis, and management activities as well as biodiversity information products.

Not all 10 elements are applicable within each Centre's data quality management activities. If an element does not apply for a Centre, then it is left out of their respective QMP.

1.3 Maintenance of this Document

This is the ABMI's second revised iteration of the QMP. As such, this QMP is a working document that will undergo changes as the ABMI quality management system evolves and grows with the addition of new information, and revision of existing procedures as part of the ABMI's continuous improvement efforts.

The Information Coordinator (Information Centre) will be responsible for updating and/or coordinating reviews of the QMP. The QMP document control system is as follows:

- The Information Coordinator will be responsible for coordinating reviews of the ABMI QMP, and collating the Centre QMPs into the final QMP document.

- One person from each Centre who is a current member of the ABMI's Data Management Committee will be accountable for review and update of their respective Centre's QMP.
- During the first three years of the QMP implementation, the QMP will be reviewed annually to test, revise and update the quality management system within each Centre, and to ensure all components of the quality management process have been included.
- After this development period, the document will be reviewed every two years to ensure QA procedures are up-to-date.
- Edits made to the document will be classified as minor or major by the Information Coordinator. Minor edits encompass small changes to this plan, while major edits encompass significant changes to specific document sections, the addition/omission of a specific section, change in responsibilities, or reorganization of existing functions.
- Document changes will be noted in the tracking sheet at the beginning of this document. Minor edits will require the number after the decimal to be changed. All major edits require the number preceding the decimal place to be changed. The individual making the edit is required to put their name, the date of the edit, and make a comment as to where changes were made.
- The most current version of this document will be kept on ClickUp. All older versions will be archived in ClickUp within the same directory in the archive folder. A hard copy of the document will also be available from the Information Coordinator.
- The ABMI QMP will be made publicly available on the ABMI website.

1.4 Report Overview

This report is divided into nine chapters (and appendices) including:

- Chapter 1: Document Description and Organization
- Chapter 2: The ABMI Program
- Chapter 3: Monitoring Centre QMP
- Chapter 4: Processing Centre QMP
- Chapter 5: Information Centre QMP
- Chapter 6: Science Centre QMP
- Chapter 7: Geospatial Centre QMP
- Chapter 8: Application Centre QMP
- Chapter 9: WildTrax QMP
- Appendices

1.5 References

Chapman, A. D. 2005. Principles of data quality. Report available at: www2.gbif.org/DataQuality.pdf.

EPA. 2001. EPA requirements for Quality Management Plans. Report available at: www.epa.gov/quality/qs-docs/r2-final.pdf.

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CHAPTER 2: THE ABMI PROGRAM

2 ABMI Description

The ABMI is a not-for-profit, science organization that conducts biodiversity monitoring in the province of Alberta. The ABMI's mission is to track changes in Alberta's wildlife and their habitats from border to border, and provide ongoing, relevant information on Alberta's living resources to support natural resource and land-use decision making in the province.

The ABMI manages and implements a science-based program that monitors and reports on biodiversity status and trends throughout Alberta. As one component of our status and trend monitoring, the ABMI employs a systematic grid of 1,656 site locations, spaced 20 km apart, to collect biodiversity data on terrestrial and wetland sites. In addition, the ABMI Geospatial Centre (GC) monitors the state of Alberta's human footprint using fine-resolution aerial photography and satellite imagery.

Data collection and analysis are significant components of the ABMI program. The Science Centre (SC) leads the development and improvement of data collection protocols. The ABMI's Monitoring Centre (MC) leads the implementation of these protocols in the field while the Processing Centre (PC) leads the implementation of laboratory-based protocols. The ABMI's Information Centre (IC) ensures data is stored and accessible to stakeholders. Together the SC and IC are responsible for aspects of data evaluation and reporting. In addition, the Application Centre (AC) uses the ABMI data to support a wide range of environmental planning and management needs. Projects such as the implementation of regional monitoring priorities, climate change adaptation and reclamation consultations, and the assessment of ecosystem services underscore the importance of the ABMI program.

2.1 Operational Management

To execute its mission, the ABMI relies on leadership provided by its Board of Directors and a Science Advisory Committee. The Board of Directors has authority and responsibility over the business of the Institute. As the governing body, the Board helps to direct the strategic management and corporate performance at the ABMI. In addition, the Science Advisory Committee provides external, third-party review and recommendations on strategic science decisions as they relate to the operating principles endorsed by the Institute's members.

The ABMI has an Executive Office and six Centres (Figure 2.1.1).

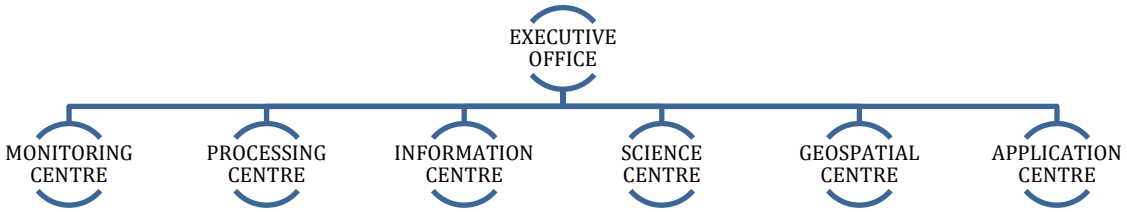

Figure 2.1.1. Organizational structure of the ABMI.

Each Centre in the ABMI is accountable for implementing QAQC activities consistent with their mandate:

- Executive Office (EO) → holds ultimate operational accountability.
- Monitoring Centre (MC) → is responsible for collecting biodiversity-related field data for the ABMI program. This involves ensuring data is collected consistently and reflects the conditions in the field, communicating all aspects of the data collection activities to other units, delivering data components to the correct destinations, and providing "first pass" quality control.
- Processing Centre (PC) → manages the curatorial and taxonomic expertise for the specimens and samples collected in the field. The PC plays an important role in the information flow within the Institute, being responsible for the processing and identification of all specimens collected in the field, and generating the ABMI's species-level data.
- Information Centre (IC) → is responsible for providing data management and infrastructure support for the data and information generated by the ABMI. This includes the execution of quality control procedures on all aspects of the data cycle to ensure standards described in this document are met for all ABMI data products and services. Also, part of the IC business portfolio is the management of the website and the development of new communication strategies to deliver information to users.
- Science Centre (SC) → analyzes and produces information from the data collected in the field that allows users to interpret patterns and trends in the changing environment in Alberta. The SC is vital to maintaining scientific excellence in the data and information generated by the ABMI, and plays an important role in managing quality control of the field activities.
- Geospatial Centre (GC) → generates all the remote sensing and geospatial data and information to support the ABMI's user needs. This is a multifaceted responsibility that includes developing and testing new remotely sensed methodologies, developing new data products, and performing quality assurance on the information and products being delivered to the public.

- Application Centre (AC) → leverages the data generated by the ABMI and undertakes projects that help demonstrate the value of the program and the benefit to Albertans. In applying the data and information of the ABMI, the AC brings value to the ABMI's mission.

2.2 The Data

As a source of biodiversity knowledge for the province of Alberta, the data produced by the ABMI must meet high quality standards to maximize usage and support environmental decisions (Ferretti 2009, 2011, Houston and Hiederer 2009, Sólymos et al. 2015). Without good data, the ability of government, industry, academics, and the people of Alberta to understand the implications of environmental change to the province would be severely impaired.

The credibility of the ABMI in fulfilling its key role in monitoring Alberta's biodiversity rests on its core operating principles of being:

- Independent, as it operates at arm's length from government and industry;
- Scientifically Credible, with the program being validated through peer review and by the Science Advisory Committee;
- Relevant and Accessible, developing products that will meet stakeholder's needs; and
- Transparent, with open governance and operations to promote engagement and accountability.

2.3 Data Products Explained

The ABMI delivers data on the status of the biodiversity of Alberta. To do so, the Institute collects a variety of types of data, and generates unique products, all of which are part of the Institute's portfolio.

The ABMI's data products fall into four categories: collected data, processed data, platforms/tools, and derived products, with a variety of products classified under each category (Table 2.3.1). Quality management of each product is defined and delivered based on guidelines created by the responsible Centre.

Table 2.3.1. All ABMI products divided into the 4 categories, collected data, processed data, platforms/tools and derived products.

Collected Data	Processed Data	Platforms/Tools	Derived Data
Field Monitoring Data	Human Footprint Maps	WildTrax	Species-Habitat Relationship
Site Photos	Landcover Inventory Maps	Wildlift	Species Distributions
Audio Files (i.e., Autonomous Recording Unit & Riverforks)	Species Identifications	cure4insect	Intactness Maps & Coefficients

Rare Animal Surveys	Climate Change Vulnerability Index	wildRtrax	Biodiversity Status Reports
Rare Plant Surveys	Ecosystem Services		Data & Analytics Portal (Biodiversity Browser, Data Download, Mapping Portal)
Remote Camera Images	ALPHA: Predictive Landcover Products		The Status of Land Cover and Biodiversity Reports
Well-site Reclamation	Wall-to-wall Vegetation Layer		Landowner Data Packages
	Wetland Inventory		Factsheets
	Harvest Area Spectral Regeneration		

Collected data refers to all data that are collected by the ABMI from the field and that receive no further manipulation (Sólymos et al. 2015) for a description of the data collection process). Processed data refers to all the data generated by the organization based on the collected or external data sources. Platforms/tools refer to publicly accessible tools that have been built by the ABMI and partners to facilitate data management, interpretation and processing. Derived products refer to all the products produced by the ABMI through the interpretation and analysis of the collected or processed data.

For a summary and description of the ABMI data management cycle see Sólymos et al. (2015).

2.4 Dimensions, Definitions, and Deliveries

The ABMI QMP uses quality assurance dimensions and definitions derived by the Statistics Canada's Quality Assurance Framework (Table 2.4.1; (Statistics Canada 2002, 2017). The dimensions have been modified to fit within the ABMI's data quality management system.

Table 2.4.1. Definitions and ABMI deliverables organized according to the six data quality dimensions defined in the Statistics Canada's Quality Assurance Framework (Statistics Canada 2002).

Dimensions	Definitions	ABMI Deliverables
Accuracy	The degree to which data correctly describes the observed or predicted phenomena they were designed to measure.	• Continuous training of new and existing staff on quality assurance practices • Automated quality assurance systems • Standard Operating Procedures • Internal and external audits
Interpretability	Availability of supplementary information and metadata necessary to interpret and utilize data appropriately.	• Metadata templates and automated real-time updates • Metadata policy • Online documentation and instructions
Coherence	The degree to which the data can be brought together with other data, products, or information within the broader analytical framework and over time.	• Quality control practices including user-based updates and yearly activity evaluations • Standard Operating Procedures • Data entry templates and online portals • Data Management Committee and data longevity and archival process
Timeliness	The delay between the reference point of collection data and information and the date data become available for public use.	• Data release schedules • Data delivery agreement
Accessibility	The ease with which data can be accessed as it pertains to the ease of getting the data as well as the suitability of the form with which the data is accessed.	• Database infrastructure and online delivery vehicle • Multi-format delivery
Relevance	The degree to which data meets the needs of the users. It is concerned with whether the available information sheds light on the issues of most importance to users.	• Selection of biodiversity and land cover variables measured • Sampling design and implementation data collection protocols • Project design framework • Product updates and relevance evaluation • Long-term monitoring data value

2.5 References

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CHAPTER 3: MONITORING CENTRE QMP

Approvals

Approved by: _____ _____

Monitoring Centre Director Date

Monitoring Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	MC QMP Created
2016-10-05	Chris O'Sullivan	MC QMP updated following internal review
2017-11-23	Chris O'Sullivan	MC QMP updated following internal review. Minor changes made.
2021-11-02	David Evans, Amanda Schmidt	Minor changes including updated references, documentation, data management tools and software, and hardware.

3 Monitoring Centre Background

The ABMI Monitoring Centre (MC) is the business unit that collects biodiversity-related field data for the ABMI program. This complex process involves a breadth of activities including ensuring data is collected with integrity and reflects the true conditions in the field, communicating all aspects of the data collection activities to other units in full disclosure, delivering data components to the correct destinations, and providing "first pass" quality control by maintaining a feedback loop with other units on the efficacy or inadequacy of the field protocols.

As the primary handlers of field data, the MC is responsible for collecting data with accuracy, error checking the data, and delivering this data in a timely manner to other Centres for further management processing. This quality management plan (QMP) outlines the MC's quality management system as it relates to data collection activities.

3.1 Element 1: Quality Management Policy, Goals, and Objectives

3.1.1 Quality Assurance Policy

The ABMI MC is responsible for the collection of a broad range of environmental data used as indicators of environmental health in the province of Alberta. As the foundation of the program, the MC's quality assurance policy ensures that all data generated is of known quality and adequate for its intended use, its quality assurance (QA) procedures are well documented, and that the data is verifiable. The MC quality management system establishes acceptable performance criteria concerning the collection and documentation of data. This includes

ensuring adequate quality management steps and procedures are used throughout the entire data collection process, from protocol development and refinement through data transfer to the Information Centre (IC). The MC Director, Team Lead and Field Coordinators are responsible for the annual review of the MC QA and quality control (QC) processes and documentation to ensure they accurately reflect MC actions prior to, during and post field data collection.

3.1.2 *Monitoring Centre Organizational Structure*

Figure 3.1.1 represents the organizational structure of the MC and identifies responsibilities associated with each job title.

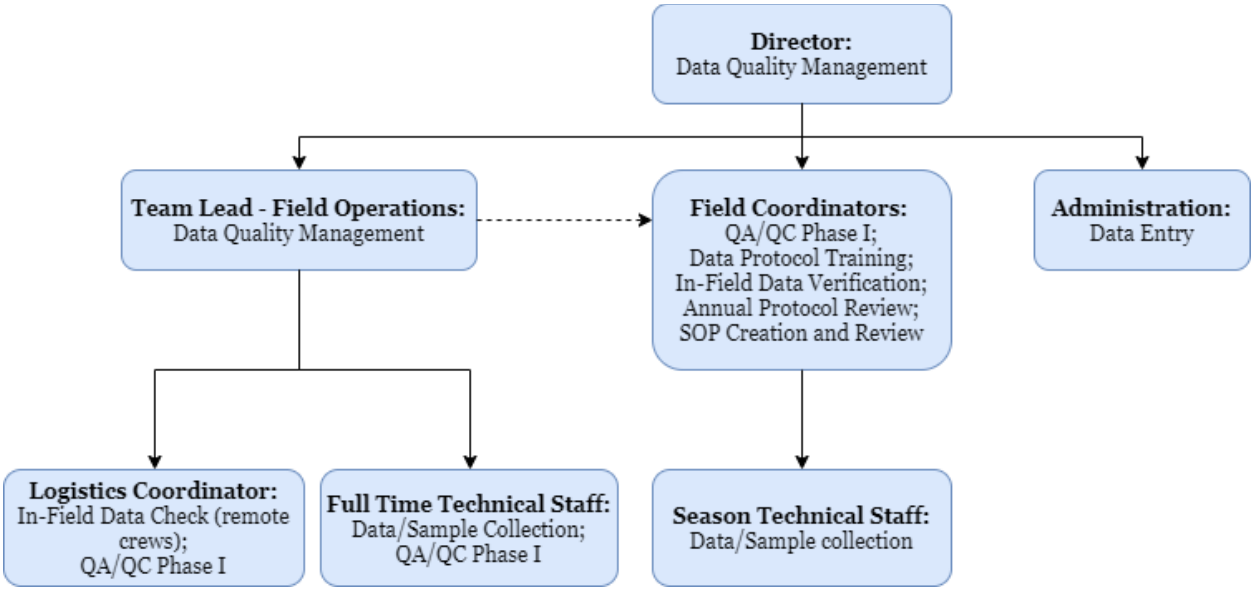

Figure 3.1.1. Organization chart representing roles within the Monitoring Centre. Dotted line indicates a spot check, by the Team Lead, of data reviewed by the field coordinators.

3.1.3 *Staff Roles, Responsibilities, and Authorities*

MC staff roles, responsibilities, and authorities as they pertain to QAQC procedures are summarized in Table 3.1.1.

Table 3.1.1. Staff roles, responsibilities, and authorities for the MC.

Responsibility	Data Task	Technical Activities	Authority
Director	Data Quality Management	Facilitate the development of data QAQC processes. Ensure these processes are implemented and monitor how the system is performing. Promote the concept of continuous improvement.	MC sign off on all processes and procedures.
Team Lead - Field Operations	Data Quality Management	Assist in facilitating development and improvement of data QAQC processes.	Delegated by the Director.
	Data Quality	Ensure QAQC process implementation and monitoring.	As delegated by the Director.
	Monitoring	Monitor QAQC processes and direct changes through data and field checks on field staff.	As required by the Director.
Field Coordinators	Field Site Selection	Off-grid sites, wetland sites and alternative terrestrial and aquatic field sites must be selected using satellite imagery/GIS, based on predefined criteria.	Off-grid site selection confirmed by Science Centre (SC) to ensure sites meet site selection criteria.
	QAQC Phase I	Verification and assurance of compiled raw field data.	Carry out data QAQC activities and confirm completion with Information Coordinator.
	Data Protocol Training	Summer technologists and winter contract staff are trained to collect data according to standardized protocols.	Provide instruction and feedback to technologists.
	In-Field Data Verification	Accompany crews to field sites in order to review collection methods and correct mistakes.	Provide instruction and feedback to technologists.
	Annual Protocol Review	Review field data collection protocols to make any necessary additions or revisions.	Complete draft revisions and submit to SC for final approval.
	Standard Operating Procedure (SOP)	Create, review and revise data SOPs on an as needed basis i.e., protocol changes or additions.	Submit to MC Director for final approval.

	Creation and Review		
Logistics Coordinator	Hardware Care and Maintenance	Coordinate and manage the maintenance and calibration of field equipment for data collection.	
	In-field Data Verification	(see above)	
	Data Protocol Training	(see above)	
	QAQC Phase I	(see above)	
Full-time Technical Staff	In-field Data Verification	(see above)	
	Data Protocol Training	(see above)	
	QAQC Phase I	(see above)	
	In-field Data Verification	(see above)	
Seasonal Technical Staff	Data and Sample Collection	Data and samples are collected from the field and submitted to Field Coordinators.	Confirm completion with Field Coordinators.

3.1.4 *Technical Activities*

The MC's primary role is to collect, validate and deliver ABMI biodiversity field data. Cyclical operation, data collection, validation and delivery are planned and implemented on an annual basis following set timelines for each phase. The various activities in this process, described in Table 3.1.1, are governed by standardized protocols and procedures aimed at managing quality control and ensuring a high level of consistency and accuracy in ABMI field data from year to year. Figure 3.1.2 provides a basic overview of the MC annual data cycle and activities involved in planning, collection, and release of biodiversity field data by the MC.

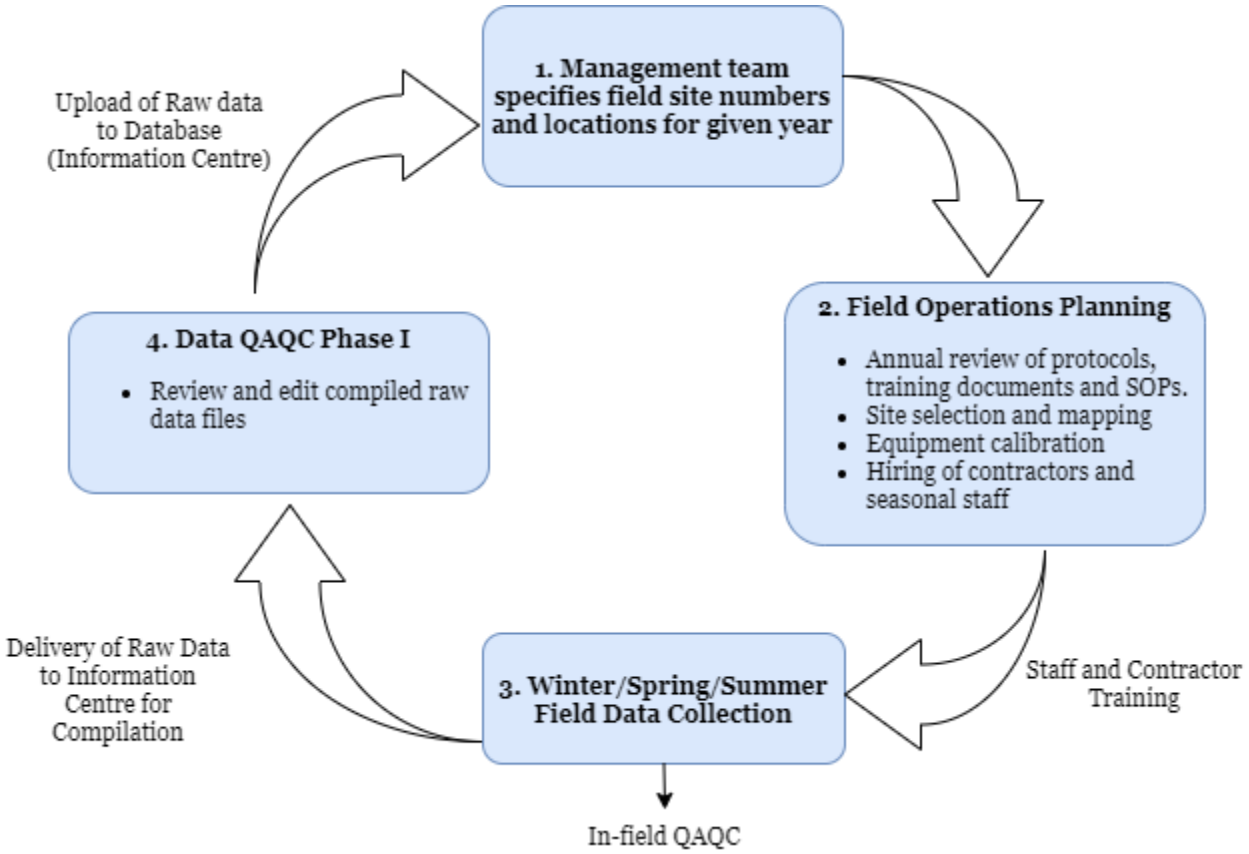

Figure 3.1.2. Overview of data cycle for planning, collection, and release of ABMI biodiversity field data.

3.1.5 *Quality System Implementation*

MC Management will ensure that all applicable elements of the quality system are understood and implemented by:

- Ensuring the quality management system is reviewed and updated by all applicable staff, annually;
- Conducting periodic in season quality checks to ensure compliance of applicable elements. For example, the Team Lead will conduct spot checks on data collected to ensure that the data review being conducted by Field Coordinators follows the MC QMP throughout the field season. The Team Lead will check for accuracy, consistency, and ensure that the data meets the quality guidelines set;
- Compiling a summary for the IC highlighting areas of concern where data quality and management processes may be improved;
- Providing an overview of the quality management system as part of the onboarding process for new employees.

3.2 Element 2: Quality System Components

The ABMI MC's management of data quality is governed by a variety of documents and resources that comprise the MC's quality management system. These provide clear and consistent guidance over the various activities and processes involved in collection and delivery of high-quality data. A broad overview of the system components is provided in Table 3.2.1.

Table 3.2.1. Quality system components completed by the MC.

Component	Status
Centre QMP	Quality Management Plan for the ABMI MC.
Quality Planning	Ongoing. Planning occurs at various levels across ABMI Centres, by the Management Team and Data Management Committee, is also carried out in regular internal meetings, and during operational planning by MC staff.
Field Data Collection Protocols	Reviewed on an annual basis each fall, with changes made as needed to improve data collection or when new protocols are introduced.
Data Verification SOP	Updated whenever necessary to maintain concurrence with data collection protocols.
Data Management Tools and Software	Updated whenever necessary to maintain concurrence with data collection protocols, and to meet data collection and management needs.
Field Staff Training Program	Ongoing with respect to full-time staff. Internal training program materials for seasonal staff and contractors are reviewed and updated annually to maintain concurrence and improve delivery.

3.2.1 *Monitoring Centre Quality Management Plan (QMP)*

The QMP is a key document within the ABMI's overall quality management system and describes the means by which the MC's quality policy is applied. This provides an overview of the documents and activities involved in managing and ensuring the delivery of high-quality field data. This includes systematic planning and review processes, as well as the personnel responsible for carrying out data related activities.

3.2.2 *Annual Reviews and Planning*

Various documents and tools are subject to annual review with the aim of continually improving the quality of ABMI biodiversity field data collection. These include but are not limited to:

- Data collection protocols;
- Data verification SOPs;
- Equipment and data collection tools;
- Protocol training modules, materials, and resources;
- Data management software and tools (i.e., ABMI tablet program).

MC management is responsible for monitoring program performance and evaluating the adequacy and completeness of the data quality activities, typically with significant input from MC staff as well as other ABMI Centres, specifically the IC and SC. Staff suggesting changes or that have expertise in an area typically draft suggested revisions. Final draft revisions are submitted to management for approval before implementation.

3.2.3 *Centre Specific Documentation*

All collection of ABMI biodiversity field data conducted by the MC is standardized using field protocols which describe the materials and methods used to collect each type of data, from ecosites, and breeding bird recordings to soil cores. Separate sets of field protocols have been developed for Terrestrial and Wetland data collection, and for deployment and retrieval of Autonomous Recording Units (ARUs) and camera traps. Additional protocols are also in place for samples collected in the field that must be analyzed in the laboratory to get data, such as soil core and tree core processing. See Table 3.2.2 for a complete list of field and laboratory protocol documents utilized by the ABMI MC.

Table 3.2.2. Field and lab data collection protocols.

Protocol Document	Version	Centre Responsible	Last update	Notes
Terrestrial Field Protocols (ABMI 2019b)	2019-04-10	MC	2019	Individual protocols include: Ecosites; Soil Cores; Trees and Snags; Tree Cores; Vascular Plants; Moss and Lichen Collection; Downed Woody Material; Site Photos; Canopy Cover
Wetland Field Protocols (ABMI 2019c)	2019-07-02	MC	2019	Individual protocols include: Water Chemistry; Aquatic Invertebrate Survey; Shoreline Characteristics; Bathymetry; Vascular Plant Survey; Zone Delineation; Shrub 2D, Site Photos
Camera and ARU Deployment and Retrieval Protocol (ABMI 2018)	2018-12-21	MC	2018	Details standardized methods for deployment of camera-trap and autonomous recording units and collection of related data
Soil Core Processing (ABMI 2014)	10-30-2014	MC	2014	Protocol describing laboratory testing of soil pH and carbon
Tree Core Processing (ABMI 2018a)	12-01-2018	MC	2018	Protocol describing processing of tree cores for dendrochronology data

3.2.4 *Data Verification and Validation*

Data verification and quality assurance is a central component of both training and review of field data collection protocols. The MC implements several quality assurance procedures that support collection of high-quality field data. These procedures are described in the "Field" and "In-Season" Data Verification SOPs listed in Table 3.2.3.

Following both classroom and practical instruction, field technicians must demonstrate their ability to follow protocols and collect high quality field data during a "Mock field day" which

follows each training period. The mock field day provides an opportunity for technicians to collect a complete site's worth of data at a practice field site while under supervision of qualified instructors. This allows instructors to observe and correct any errors that technicians may be making and ensures protocols are being followed accurately before technicians begin collecting real data in the field.

A second quality check occurs when technicians begin collecting data in the field (ABMI 2018d). During this check, Field Coordinators accompany technicians to sampling sites to observe and verify that protocols are being followed correctly. To ensure consistency in how the audit is carried out by different Field Coordinators, a standard checklist has been developed which describes observations and questions when assessing technicians as they implement the field protocols (both terrestrial and wetland) (ABMI 2018c).

Once site level data and samples have been collected, technicians submit these to Field Coordinators for a final review before data is submitted to the IC for compilation (ABMI 2019). This review occurs either during or at the end of each field shift. The check allows Field Coordinators to identify and correct errors or inconsistencies in technicians' data and provide constructive feedback to technicians to avoid similar mistakes in the future.

3.2.5 *Standard Operating Procedures*

The MC uses a series of SOPs that govern work on data verification and validation. These SOPs are instructions which Field Coordinators and Full-Time Technical Staff follow to systematically verify that ABMI biodiversity data is being collected in the same way, and that these data are verified in a consistent, and complete manner. This ensures the data is accurate and errors in the datasets are minimized.

Table 3.2.3. List of SOPs governing field data management.

Data SOP	SOP Number	Centre Responsible	Date
Post-Season Data Verification for Terrestrial and Wetland Protocols (ABMI 2019a)	ABMI-MC-SOP-001	MC	2019
In-Season Data Verification for Terrestrial and Wetland Protocols (ABMI 2019)	ABMI-MC-SOP-002	MC	2019
Field Verification for Terrestrial and Wetland Protocols (ABMI 2018d)	ABMI-MC-SOP-003	MC	2018
Naming Process for Core Sites and Off Grid Sites (ABMI 2018e)	ABMI-MC-SOP-004	MC	2018
Wetland Site Selection Procedure (ABMI 2010)		MC	2010
Creating Access Maps (ABMI 2018b)		MC	2018

3.2.6 *Training Program*

Given the many different types of field data collected as part of the ABMI's biodiversity monitoring program, a substantial level of training is required for field and technical staff, which also includes training of external contractors. To standardize training and instruction, individual training modules have been developed for each type of data collected (e.g., tree coring, vascular plant surveys). These modules generally include a combination of classroom and field exercises. The training modules are reviewed annually and updated (if necessary) depending on changes to established field protocols.

Training is supplemented with additional resources that assist in accurate collection of data, including maps, guidebooks, cheat-sheets, and other materials.

Additional training specific to job requirements is provided to field technologists on an as-needed basis (See Appendix 1.0 for a complete list of safety-related training). While not necessarily related to data management, this training provides technical staff with the appropriate skills and knowledge to carry out data collection activities in a safe and effective manner. Full-time staff such as Field Coordinators and full time Technical Staff are provided with training on an ongoing, as-needed basis.

3.2.7 *Data Management Tools and Software*

In addition to collection protocols, data quality management is supported by a number of software tools and applications. Refer to Section 3.6.2 for further details.

3.2.8 *Element 3: Quality Training System*

A combination of full-time and short-term contract staff are involved in collecting ABMI data. When hiring new or returning staff the requirements listed in Table 3.2.4 are the primary technical qualifications considered.

Table 3.2.4. General qualifications and training requirements.

Type of Qualification	Minimum requirement	Before or After Hiring
Post-Secondary Education	1 year of post-secondary education.	Before
Field Experience	Preferably a paid position for 2 summers, but equivalent experience accepted.	Before
Safety Training	All SOP and training courses relevant to the type of protocols being conducted and the region staff will be working in. See Appendix 1.0 for safety training requirements.	After
Protocol Training	All protocol training relevant to the type of work being conducted and region staff will be working in.	After
Plant Identification	Minimum 80% on test administered at interview (required for Plant Technicians only).	Before
Driver's License	A Class 5 License or equivalent	Before

After staff are hired, the MC has established a process for instructing staff on ABMI protocols, and the minimum requirements technicians must pass before collecting data; protocol training requirements are listed and described in Table 3.2.5.

Table 3.2.5. Protocol training requirements.

Protocol	Elements	Responsibility	Updated	QAQC Checks
Wetland Reconnaissance	In classroom presentation and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentation. • One full site's worth of mock data collection is submitted to a supervisor for review and feedback.
Terrestrial Establishment	In classroom presentations, field practice, and mock field exercise.	All Field Coordinators	Annually	• Standardized presentations. • Cheat Sheets. • Establishment of a minimum of ¼ of a site evaluated by full-time staff and assessed for accuracy.
Terrestrial Spring Protocols	In classroom presentations, field practice, and mock field exercise.	All Field Coordinators	Annually	• Standardized presentations. • Group field exercises to calibrate technicians' visual estimates and ecosite classifications. All estimates should be within one category of the group average or +/- 20%. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback. • A minimum of 2 days of Moss/Lichen training consisting of both field and class-room training. • Moss/Lichen data from a minimum of ¼ of a mock site must be submitted to a Moss/Lichen expert for review and feedback.
Terrestrial Summer Protocols – Plant	In classroom presentations, field practice, and mock field exercise.	Terrestrial Field Coordinators	Annually	• Standardized presentations. • A minimum of 2 days of Vascular Plant training consisting of both field and class-room training. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback.
Terrestrial Summer Protocols – Non-Plant	In classroom presentations, field practice, and mock field exercise.	Terrestrial Field Coordinators	Annually	• Standardized presentations. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback.

Wetland Summer Protocols – Plant	In classroom presentations, worksheets, scenarios, field practice, and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentations. • A minimum of 2 days of Vascular Plant training consisting of both field and class-room training. • Group field exercises to calibrate technicians' visual estimates, zone classifications and ecosite classifications. All estimates should be within one category of the group average or +/- 20%. • A minimum of one common transect must be completed by all plant technicians. All technicians should miss/collect additional species within 25% of each other and a vegetation expert. • A minimum of ¼ of a wetland site's worth of mock site data, preferably with at least one transect in each zone present at the wetland must be submitted to a supervisor for review and feedback.
Wetland Summer Protocols – Non-Plant	In classroom presentations, worksheets, scenarios, field practice, and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentations. • Group practice visual estimates to calibrate all staff's data collection. All estimates should be within one category of the group average or +/- 20%. • A minimum of 5 practice depth points • A minimum of 1/3 of a wetland site's worth of mock site data, preferably with at least some data for each protocol must be submitted to a supervisor for review and feedback.

3.3 Element 4: Contractor Requirements

Procurement for the MC can range from general supplies to highly technical data collection equipment, to contracts for winter equipment deployment, and sample processing and analysis. All procurement of items and/or services by the MC is done under Contract number C2017000788 between the ABMI and InnoTech Alberta. All procurement of items/services follows the Directives and Policies outlined by InnoTech Alberta (Table 3.3.1).

Table 3.3.1. Directives and policies related to procurement of items/services for InnoTech Alberta, and followed by the MC.

Document	Version	Responsible Authority	Effective Date
Procurement Standard	FM-STD1_IA	InnoTech Alberta	November 1, 2016
Capital and Attractive Asset	TM-STD4-PCR1_IA	InnoTech Alberta	November 1, 2016
Procurement Procedure	FM-STD1-PCR1_IA	InnoTech Alberta	November 1, 2016
Shipping and Receiving Procedure	FM-STD1-PCR2_IA	InnoTech Alberta	November 1, 2016
Financial Delegation of Authority	CG-STD1_IA	InnoTech Alberta	July 23, 2019
Contracts Procedure	InnoTech Alberta is still reworking this document	InnoTech Alberta	

While the MC does procure items/services through Alberta Innovates, the MC also has separate and detailed documents pertaining to specific services that are contracted.

3.4 Element 5: Documents and Records

The MC maintains three types of documents that need to be reviewed, updated, and approved on a regular basis. These documents include: standard operating procedures (SOPs), lab protocols, and field protocols. The management of these documents will be discussed in turn.

3.4.1 *Standard Operating Procedures*

- *Review:* data-related SOPs are reviewed on an annual basis. After QAQC of each year's data, the SOPs listed in Table 3.2.3 are updated by MC staff, resolving issues identified in the data management cycle that impact data quality.
- *Approval:* Field Coordinators (MC) and the Information Coordinator (IC) finalize resolutions for data inconsistencies. The MC edits the SOPs and makes the final approval.
- *Maintenance:*
    - All drafts are documented on the monitoring project drive on the InnoTech Alberta network.
    - The Field Coordinators are responsible for SOP updates and revisions.
    - All versions are documented within the SOP.

3.4.2 *Lab Protocols*

Lab protocols are the responsibility of the MC, IC, and the Processing Centre (PC). Each lab protocol remains in a draft format until it is complete. Staff members will know when a

protocol is finished being revised when it is changed to a final version. Versions and the person responsible for protocol edits are tracked on Microsoft Teams. The review process is as follows:

- *Review:* as needed when relevant changes occur to the field protocols which would alter how lab samples are collected.
- *Approval:* Field Coordinators (MC), the PC, and the IC are responsible for updates and approvals to the lab protocols.
- *Maintenance:*
    - All drafts are saved at Microsoft Teams and on the public ABMI website.
    - MC Field Coordinators are responsible for updates to the lab protocols as required.
    - All versions are managed on Microsoft Teams to track edits and who was responsible for the edits.

3.4.3 Field Protocols

Field protocols are the responsibility of the SC and the MC. Field protocols remain in a draft format until they are complete. Staff members will know when a protocol is finished being revised when it is changed to a final version. Versions and the person responsible for protocol edits are tracked on Microsoft Teams. The review process is as follows:

- ***Review:*** after each field season, the protocols are reviewed for inconsistencies, redundant data collection, opportunities for improved efficiency and effectiveness of data collection.
- ***Revision:*** the MC suggests changes to the protocols based on success and failures during the implementation of data collection in the field. These suggestions are tracked in the protocol document in Microsoft Word and are shared with the SC through *Microsoft Teams*. The protocol stays in a draft format until the SC has approved the final updates. The MC updates the protocols and will change the document to a final version. All versions are tracked. Protocols are updated annually.
- ***Approval:*** the SC provides feedback on protocol updates. The SC is responsible for reviewing any changes proposed by the MC and will complete the final approval of these documents.
- *Maintenance:*
    - Complete protocol drafts and final versions are kept on Microsoft Teams and are made available to the MC and the SC. Final versions are linked to ClickUp.
    - An abridged copy of the protocols is maintained by the SC and is made publicly available at abmi.ca in the Publications section.
    - A hard copy and an electronic copy are made available to the technical staff hired to complete data collection. These copies are dated and expire at the end of each season. The old copies are then recycled and removed from hardware (Tablets).
- ***Preparation:*** new protocols are written as new processes are introduced.

- *Confidentiality:*
  - All staff members who handle confidential data (e.g., site location coordinates, access information) are required to sign a Confidentiality Agreement.
  - Site locations and sensitive information are saved on a confidential network and server with strict access requirements.
  - All data are uploaded onto an FTP server and are handled by the Database Programmer within the IC.
  - Equipment used for data collection is handled by the MC and is cleared once the data is archived at the MC according to the MC Data Management Plan and saved on the secure network.

3.5 Element 6: Information Management

3.5.1 *MC Hardware Description and Maintenance*

The MC uses several types of hardware to collect data (Table 3.5.1). A description of hardware testing, verification, and management is summarized below.

Table 3.5.1.Hardware used by the MC to complete field data collection.

Hardware	Requires software management	SOP	Centre Responsible
Quanta Hydrolab	N	Manufacturer User Manual and Checklist; Hydrolab Maintenance Spreadsheet	MC
YSI Pro Plus Meter	N	Manufacturer User Manual; Hydrolab Maintenance Spreadsheet	MC
Camera Trap: Reconyx® PC900 and HP2X	Y	Deployment and Retrieval Protocol; Manufacturer Instructions	MC
ARUs (SM3 and SM4 Units)	Y	Wildlife Acoustics, Song Meter SM3 Bioacoustics Recorder User Guide. Wildlife Acoustics, Inc. Wildlife Acoustics, Song Meter SM4 Bioacoustics Recorder User Guide. Wildlife Acoustics, Inc.	MC
Panasonic Toughbook Tablets (U1, M1, and G1 Units)	Y	N/A	MC | IC
Digital Camera	N	Manufacturer User Manual	MC
Trimble GPS Unit	Y	Manufacturer User Manual	MC
Vertex Hypsometer	Y	Manufacturer User Manual	MC
Garmin GPS Unit	Y	Manufacturer User Manual	MC

3.5.1.1 Hydrolabs and Pro Plus Meters

To monitor water quality at ABMI wetland sites, the ABMI uses the Quanta Hydrolab and YSI Pro Plus Meter. The MC uses the following quality assurance procedures to ensure each unit is functioning properly:

- Testing and verification of each unit is performed by MC Field Coordinators following the procedure designed by ABMI staff, Campbell Scientific and Hoskin Scientific; procedures are outlined in Hydrolab and Pro Plus Meter operating manuals (available online).
- Maintenance procedures are performed by Field Coordinators in accordance with the operating manuals; all maintenance procedures are recorded in the Hydrolab Maintenance Spreadsheet.
- Pre-season, and in-season calibration of the units are performed by Field Coordinators and Full-Time Technical Staff following the procedure designed by the MC and maintenance guidelines in user manuals.
- All units are tested in field by Technical Staff for usability, durability, and functionality.

These additional procedures are followed to ensure water quality readings are as accurate as possible:

- SOPs for units are outlined in ABMI's Wetland Field Data Collection Protocols (ABMI 2019c), and training is provided by ABMI Field Coordinators;
- Expected readings and ranges are provided by the ABMI SC Wetland Ecologist in accordance with historical data. Readings falling outside of these ranges are confirmed with alternative measures (reference standards, pH strips);
- Prior to field use, Hydrolabs and Pro Plus Meters are tested and compared to each other to ensure accuracy and consistency;
- In-field quality checks are performed by MC Field Coordinators;
- Post-season data quality management is performed by MC Field Coordinators.

3.5.1.2 Camera Traps

To monitor wildlife (mainly mammals) at ABMI sites, the ABMI uses camera traps to detect species that are present at each site. Camera trap setting parameters are developed by the SC. The MC programs the cameras pre-deployment or in the field using the *Remote Camera Trap Settings* outlined in the Autonomous Recording Unit (ARU) and Remote Camera Trap Protocols (ABMI 2018). Any changes are verified by the SC prior to deployment in the field. During camera retrieval, the MC documents any physical damage or mechanical issues with the units. These units are examined in detail after the field season by the MC, field tested, and, if necessary, sent to Reconyx® for repair or exchange. The MC is responsible for keeping an updated inventory of cameras, which includes ordering and maintaining records of any repairs.

3.5.1.3 Autonomous Recording Units

To monitor vocalizing species at ABMI sites, such as songbirds, owls, and amphibians, the ABMI uses ARUs at each terrestrial site. Prior to deployment, ARUs are programmed using a PGM file and the SM3 and SM4 configuration utility (Table 3.5.2). The program file contains all the information for audio settings, file type, gain and schedule except for date, time and field prefix which are checked and set by the MC manually. Specific settings are outlined in the ARU and Remote Camera Trap Protocols (ABMI 2018). Any scheduling changes are verified by the SC prior to deployment in the field. During ARU retrieval, the MC inspects, and documents details about externally damaged units. During the recording proofing stage, ARU audio files are checked for discrepancies between microphones and microphones that did not work during recording. The MC is responsible for identifying units with physical or mechanical damage and either sending them to be fixed or re-calibrating the microphones using ABMI Extech calibrators.

3.5.1.4 Panasonic Tablet

Panasonic tablets are used in the field so data can be entered directly into the computer during data collection. Each field protocol has associated data sheets preprogrammed into the tablet to maximize data entry efficiency. The MC uses the following quality assurance procedures to ensure tablets are functioning properly:

- The MC staff are responsible for ensuring each tablet is loaded with the most recent updates from the IC;
- The MC works with the IC to test data entry sheets, and make modifications as needed, prior to the start of the field season;
- Technical staff are responsible for maintaining tablets in the field;
- General software updates are performed on the hardware on an as needed basis;
- New models of tablets are tested in field by the MC on a small scale before implementing newer models on a large scale. This ensures hardware performance still meets the demands of field data collection.

3.5.1.5 Trimble

Trimble GPS units (5T and XT) are used in the field to locate sites with a high degree of accuracy (<1.0m accuracy) in locations. The Trimble GPS units are used at sites where we are unable to leave permanent markers and there is no overhead cover, such as on private land, pastures, in the high alpine and on rocky outcroppings. Waypoints can be provided to the Trimble unit as well as recorded in and exported from the unit. Trimble waypoints are verified in the field by measuring distances using a compass and tape to ensure the waypoints are correct and accurate.

- Technical staff are responsible for maintaining Trimble Units in the field;
- General software updates are performed on the hardware on an as needed basis.

3.5.1.6 Vertex Hypsometer

Vertex Hypsometers (Vertex III and IV, and Transponder T3) are used to measure tree height in the field. Prior to the field season service@haglofinc.com is contacted to inquire about any updates to firmware. These updates are implemented if deemed necessary by the Team Lead – Field Operations.

- Technical staff are responsible for maintaining Vertex Hypsometers in the field;
- General software updates are performed on the hardware on an as needed basis.

3.5.1.7 Garmin GPS

Garmin GPSMAP 78 Units are used daily to navigate to sites in the field using given waypoints, mark locations associated with data, and to mark locations to enable return to a permanent marker or deployed sensor. These GPS units generally achieve a GPS accuracy of about ±3 m. The MC staff check for updates annually and software is updated as needed through Garmin Express which can be downloaded from Garmin's website.

3.5.2 *MC Software Description and Maintenance*

The MC uses several pieces of software during data collection (Table 3.5.2). A description of software testing, verification, and management is summarized below.

Table 3.5.2. Software used by the MC to complete field data collection and ensure its accuracy.

Software name	Version	SOP	Function/Use	Centre Responsible
Bulk Rename Utility	2.7.1.3	NONE	Mass file naming program.	MC
Automated Recording Unit Firmware	SM3: SYS1-35A.SM3 SM4: SYS2-22A.SM4	https://wildlifeacoustics.com/download/firmware-updates	Ensures the units are working properly.	MC
ARU Program	SM3: SM3ConfiguratorInstaller-1.3.1.exe SM4: SM4ConfiguratorInstaller-2.2.0.exe	https://wildlifeacoustics.com/download/firmware-updates	SC uses the program to delineate when protocols are being collected.	SC | IC | MC | BU
ABMI Tablet	N/A	N/A	Field data collection on Panasonic Tablets.	IC | MC
Site Summary Workbench	N/A	NA	Tracks field data collections.	IC | MC

GPS Pathfinder Office	N/A	N/A	Trimble data storage and management. Data upload download interface – refer to owner's manual.	MC
Terrasync	N/A	N/A	Trimble software loaded on handheld units used to obtain sub-meter waypoint accuracy.	MC
Garmin Express	N/A	N/A	Used to help manage Garmin GPS devices.	MC
ArcGIS	N/A	In development	Site selection and mapping; field planning; management of site coordinate data.	InnoTech Alberta | MC
OziExplorer	N/A	N/A	GPS coordinate data collection and management.	MC

3.5.2.1 Bulk Rename Utility

The Bulk Rename Utility is used to rename multiple files and/or folders based upon flexible criteria. This software is used by the MC to simultaneously rename multiple files or folders according to the standard practices described in field, lab or other protocols (i.e., naming of images captured by camera traps). This ensures consistency among file and document naming and is an important tool for good data organization and management of digital information. Bulk Rename Utility is available for download from http://www.bulkrenameutility.co.uk with version updates on the website as well. The version used by the IC is updated whenever use or compatibility with other programs necessitates.

3.5.2.2 Autonomous Recording Unit Firmware and Program

ARUs are used to record breeding bird (and other species) vocalizations in order to collect data on species presence and abundance. ARU Firmware refers to permanent software that supplies the units' function. The ARU Program is software that is used to set the recording schedule. Pre-field season the SC creates the ARU recording schedule. It is then written to file using the SM Configurator software listed in Table 3.5.2 creating the scheduling program and sent to the MC. It is the responsibility of the MC to ensure all ARUs are updated with the latest Firmware, downloaded from https://wildlifeacoustics.com/download/firmware-updates. It is the responsibility of the MC to ensure the updated scheduling program provided by the bioacoustics unit is loaded onto each unit prior to field deployment.

3.5.2.3 ABMI Tablet Program

The ABMI IC has built and maintains a custom-built software program loaded onto tablet computers which are designed for collecting the ABMI field data. This data collection software replaces paper data sheets, and it incorporates various tools and features which support the collection of consistent, complete and accurate field data. It also expedites the process for compiling and submitting raw field data for verification and quality assurance.

In cooperation with the MC, the data collection software is reviewed and updated on an annual basis to incorporate changes to improve function and maintain concurrency with protocols and project needs. Any software changes are tested prior to field deployments to ensure program function and data integrity are maintained. The program runs on Windows 7 and Windows 10 operating systems. Hardware used is a Panasonic Toughbook™ tablet computer (U1, M1, and G1 models).

3.5.2.4 Site Summary Workbench

Site Summary Workbench is a web-based application created and managed by the IC, used for tracking completion of data and specimen collection at the field site level. It functions as an important tool in communicating site-level information about data and specimen collection between ABMI Centres.

The MC is responsible for updating all protocols following each site visit by the MC with the date of collection, collection status, data collection method, comments, access type, and site condition. The MC is responsible for all sites visited.

3.5.2.5 GPS Pathfinder Office (Trimble)

GPS Pathfinder Office is a licensed software provided by Trimble and used in the office by MC Field Coordinators. It is used for viewing data collected, creating data, data storage, upload/download of field data. All software updates are provided by Trimble and are updated regularly.

3.5.2.6 Terrasync

Terrasync is licensed software provided by Trimble and is designed to collect high quality positional GIS data efficiently in the field. A Trimble unit with Terrasync software is used when permanent markers cannot be used to mark the location of an ABMI site, in order to ensure high quality positional GIS data is collected for subsequent years of data collection. Refer to Trimble Getting Started Guide Terrasync Software and MC training materials.

3.5.2.7 Garmin Express

- Licensed software is used by the MC to help manage Garmin GPS devices.
- Garmin Express, and accompanying updates, are available for download at http://software.garmin.com/en-US/express.html

3.5.2.8 ArcGIS

GIS software is used in various respects for field planning and data management, including site selection, access, habitat, and wetland zone classification, as well as mapping and management of wetland bathymetric transects. (ABMI 2010, 2015, 2018b)

The MC is responsible for the testing and maintenance of the software.

3.5.2.9 OziExplorer

OziExplorer is licensed software used by the MC for management of GPS waypoints given to Technical Staff and received from staff from the field. GPS points are edited, uploaded (from GPS units to laptops), downloaded (to GPS units), and viewed using this program. OziExplorer can be downloaded from http://www.oziexplorer.com/au/.

3.5.3 *Project Management*

3.5.3.1 Trello

Trello is a web-based project and work-flow management tool used by the ABMI MC, IC and PC to communicate, track and record data verification activities involved in Data QAQC Phase I and Phase II (ABMI 2019). Trello is available at the following hyperlink https://trello.com/en.

3.5.3.2 Microsoft Teams

Microsoft Teams is a Project Management tool used to manage communication, create and hold virtual meetings/training sessions and facilitate the successful organization of field activities across bases and teams. Microsoft Teams can be used to facilitate virtual training sessions, meetings with staff for data check in, to provide announcements, to share maps/waypoints/field site records, and schedules.

3.5.3.3 ClickUp

ClickUp is a Project Management tool used to manage individual tasks, subtasks related to projects and grant deliverables. Tasks are assigned to MC staff by the MC Director or project manager as required.

3.5.3.4 FileZilla File Transfer Platform (FTP)

FileZilla file transfer platform is used to transfer sensitive documents such as site waypoints, maps and data between MC staff, summer field staff and staff from other Centres.

3.6 Element 7: Systematic Quality Assurance Planning

3.6.1 *Planning and Prioritization*

Data operations are planned and prioritized in accordance with seasonal timelines for field data collection, verification, and delivery, as well as in balance with other operational activities carried out by the MC. Examples of this include site visits and protocol verification while technical staff are in the field, as well as data QAQC activities that occur once collection has been completed. An overview of the data collection cycle is provided in Figure 3.1.2.

Collection of biodiversity field data is carried out on an annual seasonal cycle (e.g., camera trap and ARU deployment in winter, moss and lichen surveys in the spring, vascular plant surveys in summer), with verification and quality management processes occurring at multiple stages

throughout. Systems used to ensure effective planning and prioritization of data collection activities include:

- Periodic team meetings throughout the year between the MC Director and MC staff that allow for strategic planning of data operations, field preparations, and follow-up processes;
- Regular meetings among terrestrial and wetland Field and Logistics Coordinators along with the Team Lead to prioritize and plan specific activities. The Team Lead facilitates delegation of priorities which involve full-time Technical Staff;

Both types of meetings are used to generate "action items", wherein staff are assigned to carry out specific tasks prior to planned deadlines, as well as identify needs and objectives for developing or revising quality-related documentation.

Specific planning items related to data collection and quality are:

- Annual revision of protocols, SOPs, and training modules;
- Annual updates to ABMI tablet program;
- Regular updates to the ABMI site summary workbench before, during and after data collection;
- Site selection, mapping and access (see ABMI 2010, 2015, 2018b, Table 3.2.3);
- Hiring and training of qualified personnel for contract and seasonal data collection work;
- Data verification and QAQC processes that occur before, during, and after various stages in the data collection and release cycle (Figure 3.1.2).

3.6.2 *Resource Allocation*

Scheduling of data activities, including field data collection, are determined based on a variety of factors which include budget, stakeholder involvement, and pre-existing capacity and resources. These factors determine the number of field sites and associated data that the MC can deliver on an annual basis.

- The MC's annual budget is allocated by ABMI's Executive Management Team and managed internally by the MC Director. On a project basis, budget planning is supported by the Team Lead - Field Operations, as well as the Logistics Coordinator who manages the MC's field equipment inventory.
- Allocation of resources is based on funding priorities, as well as efficiencies and projected costs associated with deliverables. Delivery of data from sites accessible only by helicopter for example, requires proportionally more resources than data delivered for sites accessible by foot and road.
- Personnel requirements and individual involvement are determined based on tasks and associated deliverables (i.e., hiring of seasonal technicians). Wherever advantageous, involvement of staff may be decided based on relevant experience or expertise with the specific task or deliverable at hand.

Specifications for measuring and verifying data quality are described in data verification SOPs (Table 3.2.1, Table 3.2.3). Timelines associated with these activities are based around the annual planning cycle described in Figure 3.1.2.

Updates to QAQC activities are made as needed, such as when protocols are updated, or when problem areas are identified. Updates are generally made by Field Coordinators in consultation with the Information Coordinator and SC specialists. Changes are subject to final approval by the MC Director.

3.7 Element 8: Quality Implementation of Work Processes

At every step in the data cycle (Figure 3.1.2) there are several work processes (e.g., field protocols, SOPs) that provide the instructions for completing each step. In addition, the MC uses several mechanisms (e.g., in field QA/QC, data checks) to ensure work processes are being implemented correctly and have been completed as required.

3.7.1 *Site Summary Workbench*

- Ensure all selected sites for the applicable field season are uploaded prior to data collection.
- Ensure sites and associated protocols are updated frequently throughout data collection to inform the IC and PC of data collection completion, issues, and discrepancies.

3.7.2 *Pre-season Checklist*

- Ensure all equipment is functioning, tested for accuracy, and is fully calibrated.
- Confirm with the Northern GIS Coordinator site names for on and off-grid sites.
- Confirm with Team Lead site names for all other sites (e.g., OSM).
- Confirm field sites with the IC Access Team, create a tentative data collection schedule.
- Ensure all protocols are up-to-date for data collection, confirm with the SC.
- Ensure enough technical staff are hired for the field season.

3.7.3 *Field Data Collection Verification*

Quality assurance processes are in place during field data collection to ensure technicians collect the full complement of ABMI data, and that the data have been verified, checked for completeness, errors, and inconsistencies so that mistakes can be rectified. These processes are documented in an SOP (ABMI 2018d), and include the following:

- Field Coordinators complete data checks with their technical staff correcting for data errors when detected (e.g., recorded percent cover of trees is inconsistent with selected ecosite classification).
- The Team Lead checks for accuracy and completeness of data collected submitted by the Field Coordinators during QAQC data checks.

- All data that is collected is assigned initials so there is a record of who completed the work and it is known who to direct questions to.
- At the end of each data collection shift, Field Coordinators submit data to the Database Programmer to compile.
- Site Summary workbench is completed by the Field Coordinators at least every three days during shift, as well as at the end of each shift. Site Summary Workbench documents whether a site was completed and contains important information pertaining to site specific data collections. It is checked by the PC, the Team Lead from the MC, SC, and IC.

3.7.4 *Field Data QAQC Procedure Implementation*

Following completion of field data collection at the end of each season, the raw field data from all sites are compiled by the IC Database Programmer. These files are reviewed in detail by Field Coordinators as part of the ABMI's data quality and assurance process to ensure the data is complete, consistent, and free of substantive errors (ABMI 2016). QAQC of field data occurs in two phases.

In Phase I, QC procedures are implemented by MC Field Coordinators in the following way:

- All raw data files are uploaded onto ClickUp by the Information Coordinator;
- One Coordinator is designated to each protocol (example: Vascular plant protocol) to QAQC the data. A different Coordinator is assigned to each of the most complicated protocols to QAQC those data sets again. QC procedures are implemented using a checklist to identify and correct errors/omissions in the data for each protocol. Once the checklist is completed a list of corrections are made on ClickUp to track changes to the data;
- Errors are evaluated on a case-by-case basis. Whenever possible, data are corrected using a variety of resources including other existing data for the site, observer field comments, and site photos. In cases where irreparable errors are found, value records are assigned as DNC (Did Not Collect) with the exception of Moss and Lichen where irreparable errors may be left as observers may not observe the same microhabitats in each sample plot.

Following the first phase of post-season data verification, data are uploaded by the IC Database Programmer into the Development Website —a pre-cursory platform of the ABMI's online data portal.

In Phase II, QC procedures entail data verification implemented by the IC in order to ensure no errors were generated through the upload process, as well as to verify that data is consistent with metadata and protocol descriptions supplied in the download package.

3.7.5 *Contractor Training - Deployment of Cameras and ARUs*

The MC uses the following work processes as part of QAQC procedures associated with cameras and ARUs:

- All contractors hired to deploy remote cameras and ARUs are required to complete ABMI designed field training modules before going into the field.
- Field Coordinators develop training modules which are edited for accuracy and completeness by other Field Coordinators. Work completed on the training modules is documented and tracked.
- Field exercises are conducted with the contractors to ensure accuracy of data collection.
- After the first field visit, Field Coordinators check the data for errors, inconsistencies, completeness, and overall quality. Issues are discussed and clarifications are made to prevent future errors.
- The MC is responsible for contractor data during QAQC Phase I and the IC is responsible during QAQC Phase II.

3.7.6 *Off-grid Site Selection*

The SC often supplements data collection at ABMI sites with data collected at off-grid sites. These sites are chosen to complement the ABMI's systematic grid, to improve sampling coverage along the gradient of human footprint levels. This improves estimation of relationships between biodiversity and human land use, in addition to allowing the ABMI to address specific short-term questions. Therefore, these sites are selected based on predefined criteria established by the SC. The following is a description of the work processes implemented by the MC to ensure off-grid site selection meets the established criteria:

- The SC is responsible for outlining the off-grid site criteria;
- The MC selects sites that fit the outlined criteria and saves these in ArcGIS.
- The Northern GIS Coordinator from the GC is responsible for providing permanent off-grid site names to the MC (ABMI 2018e).

3.7.7 *GIS Data Management*

GIS data is critical to ensure all ABMI sites (including terrestrial and wetland sites) can be revisited during Rotation 2 of the data collection cycle. Therefore, all information required in order to revisit each site is compiled, organized, checked for completeness, and archived by the MC for future use. Site coordinates (e.g., permanent marker locations) are also sent to the GC for management.

3.7.8 *Sample Management*

During data collection, the MC must collect several samples that need processing in a laboratory before data can be recorded. Implementation of work processes associated with managing samples collected are described in lab processing manuals (Table 3.7.1). Note that samples may be collected by the MC, but may be processed by another Centre.

Table 3.7.1. List of field samples collected by the MC, and the title of sample management protocols for each sample type. Tree cores are processed and stored within the MC, all additional samples are sent to the PC for processing and storage. All protocols are available at: http://www.abmi.ca/home/publications.

Sample Type	Sample Management Protocols	Updates Managed By:	Samples Processed By:
Soil Cores	30102014_Soil Lab Processing	MC | PC | SC	PC
Tree Cores	30102014_Tree Core Processing	MC	MC
Water sampling	Processing Water Samples	MC | IC | RAM	PC
Vascular Plants	Processing Vascular Plants	MC | PC | SC	PC
Moss and Lichen	Lichen Processing, Taxonomy and Conservation Bryophyte Processing, Taxonomy and Conservation	MC | PC | SC	PC
Aquatic Invertebrate	Quality Assurance Procedures for Aquatic Invertebrate Sorting, Identification, and Data Validation	MC | PC | SC	PC
Mites	Processing Mites	MC | PC | SC	PC

3.8 Element 9: Quality Assessment and Response System

Technical assessments are evaluation processes focused on specific technical practices and procedures, such as data checking. The purpose is to measure the performance or effectiveness of technical systems and their elements (with respect to documented specifications and objectives). The MC uses several assessment tools to evaluate the performance of data management processes, identify potential quality issues, and outline corrective actions, including:

- All MC Protocols and SOPs are reviewed and updated annually to ensure the quality management system is adequate and functioning as expected and required based on the previous season's data collection. Reviews and updates are completed by MC Field Coordinators with input and recommendations from the SC and the Information Coordinator.
- Modifications to Field Data Collection Protocols are made by Field Coordinators with final approval of all changes by the MC Director and the SC.
- Software and Firmware of all technical equipment are updated as released by the manufacturer.
- Tablet updates are implemented as required, and significant updates are made annually based on the previous field season.
- All process and document changes are maintained and managed through "versions" that are kept on a permanent record.

- Field Coordinators document all quality issues that arise during the field season and initiate immediate action to issue, if possible. If it cannot be immediately remediated, Field Coordinators will document the issue and provide a solution in the off season and incorporate the solution into the appropriate QAQC document or notify the IC.
- The Team Lead will ensure that all protocols and procedures are consistent throughout the field season by conducting on site field visits and spot checks.
- The MC Director facilitates and finalizes all changes and updates to documents, procedures, and SOPs before submitting to the IC and SC if required.

3.9 Element 10: Commitment to Quality Improvement

With oversight and facilitation by the MC Director and Team Lead, Field Coordinators and full time Technical Staff are committed to improving the quality of ABMI data that is collected in the field. Quality improvement activities to identify and ameliorate adverse conditions to quality include:

- Ensuring that all Protocols, Procedures, Equipment, and SOPs are updated (if required) at minimum annually and if possible, in the field (Element 5 – Documents and Records).
- Documenting changes to Quality Documents through "versions" in a permanent record (Microsoft Teams).
- With oversight by the MC Director and Team Lead, preventing quality breakdown by having consistent simultaneous training at all training locations (Table 3.2.5).
- Identifying areas for improvement through data quality control and assurance activities (field sites visits, post-collection data review).
- Identifying necessary updates to the ABMI tablet program in order to maintain concurrence with protocols and improve quality functions (e.g., program restrictions and data entry menus, taxonomic changes to species lists). Coordinate implementation and testing of changes with the ABMI Database Programmer (IC).
- Involving ABMI staff from other Centres to provide specific expertise where of benefit to quality (i.e., moss and lichen collection, plant taxonomy).
- Two Field Coordinators, one terrestrial and one wetland, represent the MC at ABMI Data Management Committee meetings. Here they discuss data management, quality issues, and improvement options, with representatives from other Centres, as well as receive and relay updates from other Centres.

Conditions that may negatively impact data quality are managed through:

- Prevention by using standardized procedures that govern data collection, and verification and review;
- Systematic checks at multiple stages of the data management process to identify present concerns (e.g., data collection procedures during site visits, annual reviews).

Corrective and preventative actions are implemented on a case-by-case basis depending on the type of condition (i.e., individual vs systemic error).

Staff at all levels are encouraged to participate in the quality improvement process in accordance with the Monitoring Centre's Quality Assurance Policy outlined in Section 3.1.

3.10 MC QMP References

ABMI. (2010) *Wetland Site Selection Procedure*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2014) *Processing Mineral Soil Samples*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at abmi.ca.

ABMI. (2015) *Selecting Camera and ARU Points*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018) *Camera and ARU Deployment and Retrieval Process*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018a) *Tree Core Processing Protocols.* Field Protocol, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018b) *Creating Access Maps*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018c) *Field Data Quality Assessment and Control*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018d) *Field Verification for Terrestrial and Wetland Protocols*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2018e) *Naming Process for Core Sites and Off Grid Sites*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2019) *In-Season Data Verification for Terrestrial and Wetland Protocols*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2019a) *Post-Season Data Verification for Terrestrial and Wetland Protocols*. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. (2019b) Terrestrial Field Data Collection Protocols *(Abridged)*. Field Protocol, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at abmi.ca.

ABMI. (2019c) *Wetland Field Data Collection Protocols (Abridged)*. Field Protocol, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at abmi.ca.

MC Data Management Plan

CHAPTER 4: PROCESSING CENTRE QMP

Approvals

Approved by: _____ _____

Processing Centre Director Date

Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	PC QMP Created
2016-10-05	Michelle Mark	PC QMP Updated following internal review.
2017-11-08	Michelle Mark	PC QMP Updated following internal review. Minor revision made.
2021-10-04	Michelle Mark, Rob Hinchliffe, Tyler Cobb	Minor changes including updated references, designations, documentation, and data management tools and software, and added content to auditing processes.

4 Processing Centre Description

The Processing Centre (PC) at the University of Alberta (UofA) is responsible for processing and identifying samples of vascular plants, bryophytes, lichen, armoured mites, and aquatic invertebrates collected by the Monitoring Centre (MC) each year from ABMI terrestrial and aquatic field sites. Creating the highest quality data possible involves quality control strategies for: field collection training, collection methods, transport procedures, metadata management, sample preparation, sorting, and lastly, advanced classification and curation of specimens for long-term storage. This QMP outlines the PC's quality management system to curate high quality specimen data.

4.1 Element 1: Quality Management Policy, Goals, and Objectives

4.1.1 *Quality Assurance Policy*

The PC is committed to the identification of ABMI specimens to the highest degree of accuracy possible. If the expert is not >95% confident in the species ID, the specimen will be identified to the highest taxonomic level possible with this degree of confidence. Experts are required to use the most up-to-date scientific resources and naming standards (ABMI 2016, 2017d). A high level of taxonomic expertise is continuously maintained throughout the PC to ensure this policy is met.

4.1.2 *Organizational Structure:*

The organization of the PC is outlined in Figure 4.1.1.

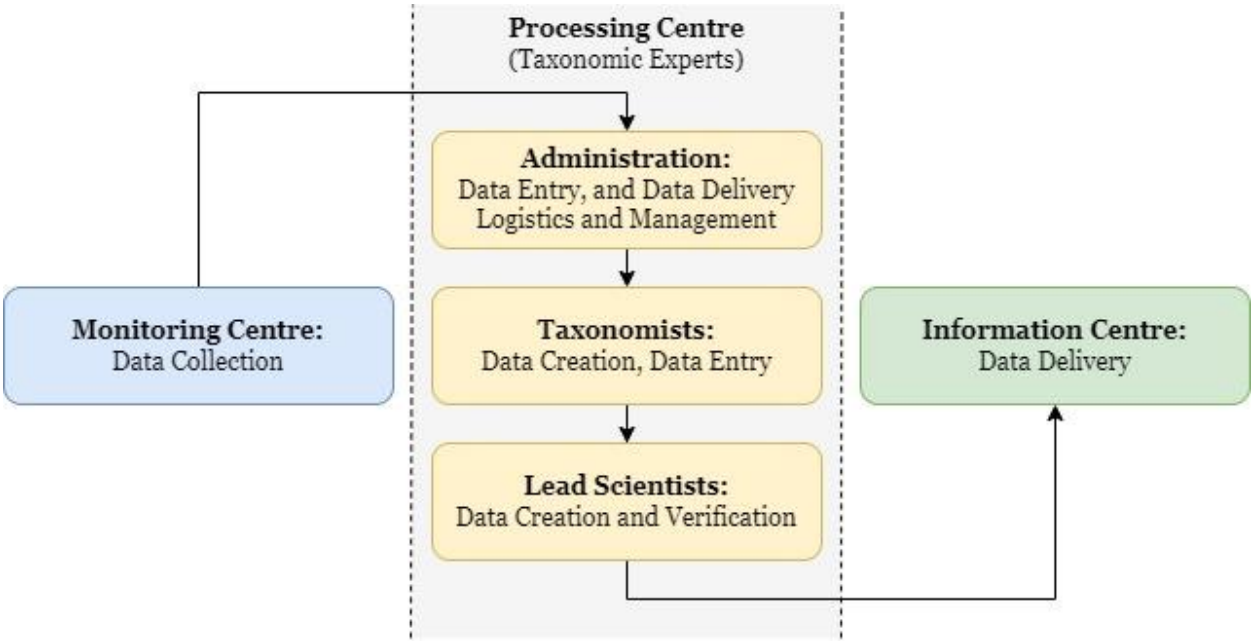

Figure 4.1.1. PC organizational chart. Flow from specimen receipt through to data creation and delivery.

There are three levels of designation within the PC:

- Administration → The administrative roles provide logistical support and event coordination, managing data only as it arrives from the Monitoring Centre (MC) and just prior to being delivered to the Information Centre (IC) as outlined in Table 4.1.1
- Lead Scientist → Persons in this role have earned their designations as experts through academic achievements, and experience in their taxonomic specialty. Ongoing participation and active contribution to the overall advancement within their given field is considered essential.
- Taxonomist → Has at minimum, two years Post-Secondary Science education and biological field experience. Taxon-specific technical skills are then developed under the direct guidance and supervision of their supervising Lead Scientist.

Table 4.1.1. Summary of data task, technical activities and the quality system tools used to support quality management in the PC.

Data Task	Responsible Party	Technical Activities	Quality System Tools Used
Field Tech *Training* and Field QAQC	Taxonomic Teams | MC Field Coordinators	Visits by Lichen, Bryophyte, and Vascular Plant teams to field training centres to ensure correct collection methods and uniform search protocols. • Train field crews to identify species in the field; • Train field crews to collect and store voucher quality specimens; and • Field visitation after first collection round to reinforce training or aid in difficult areas by Taxonomist Experts.	Field Training manual (ABMI 2019)
Field QAQC for Vascular Plant ID	Vascular Plant Lead Scientist	Teaches Family+ level ID skills and introduces ID resources to be used in field to go beyond Family. • Oversees training for collection, pressing and labeling; • Trains for difficult groups and rare plant sampling protocols; • Vascular Plant Lead Scientist develops field voucher list; and • Field visitation after first collection round to reinforce training, aid in difficult areas, and provide additional support, when necessary, by Taxonomic Experts.	Field Training manual (ABMI 2019); Protocols for Processing Vascular Plants (ABMI 2017c); Specimen Verification Summary (ABMI 2016)
Sample Receipt	PC Director, Taxonomic Teams	Initial upload of all data from field. QAQC of samples to ensure field data and sample information match.	Protocols for Processing (ABMI 2016, 2017c, 2017d, 2018a, 2018b, 2021)
Data Portal Upload	System Analyst	Field data uploaded into the Data Portal for all Plant, Lichen, Bryophyte, and Aquatic samples received.	
Rough Sort	Lead Scientists, Taxonomists, and Some Field Technicians	• Field crews identify common species of Moss and Lichen, each data entry is seconded by a qualified Taxonomic Experts. • Aquatic Invertebrates are separated from sample and sorted to Family or Order. All	Protocols for processing (ABMI 2017d, 2018b, 2021)

		of these groupings and residuals are double-checked by a trained Taxonomist. • Oribatid Mites are sorted, identified and slide mounted for further verification by the Lead Taxonomist.	
Advanced Identification	Lead Scientists and Taxonomists	Data is created as specimens are identified to the lowest taxonomic rank possible via: • Microscope analysis • Advanced imaging (SEM) • Chemical and/or molecular analysis if required • Reference collection • Internal verification	Protocols for processing (ABMI 2016, 2017c, 2017d, 2018a, 2018b, 2021)
Data Submission	Lead Scientists, IC System Analyst	Taxonomic Experts compile and execute final data checking processes as outlined in protocols. IC verifies new ABMI species records and ensures it is incorporated into Taxonomic Workbench.	Protocols for processing (ABMI 2016, 2017c, 2017d, 2018a, 2018b, 2021)
Specimen Storage & Accessioning	Lead Scientists and Taxonomists	Generation of unique numbers for specimens selected for final accessioning into a permanent collection.	Protocols for storage (ABMI 2016, 2017c, 2017d, 2018a, 2018b, 2021)
Data Amendments	Lead Scientists	• Corrections are uploaded annually or on an as-needed basis. • Newly described species incorporated as published.	Data Portal, Taxonomic Workbench
Taxonomic Updates	Lead Scientists	• Nomenclature changes and revisions to be done as and when they occur, with updates applied to existing databases	Taxonomic Workbench updated a minimum of 1 per annum (ABMI 2012, 2017a)

4.1.3 *Technical activities:*

The PC's primary role is to process and identify collected specimens, and to update and maintain the ABMI taxonomic database according to accepted Standard Operator Procedures (SOPs; ABMI 2012, 2017a). The annual cycle of data begins each year with field crew training, processing specimens, specimen identification and data entry, data validation and data delivery. Updates to taxonomic databases, corrections (if required) and curation of voucher specimens occur on an ongoing basis. The various activities in this process (described in Table 4.1.1) are governed by standardized protocols and procedures aimed at managing quality control, ensuring a high level of consistency in terms of managing samples and identifying

specimens from year to year. Figure 4.1.2 provides a basic overview of the PC annual data cycle and activities involved in planning, training, both before and during the season, identification, and release of species data by the PC.

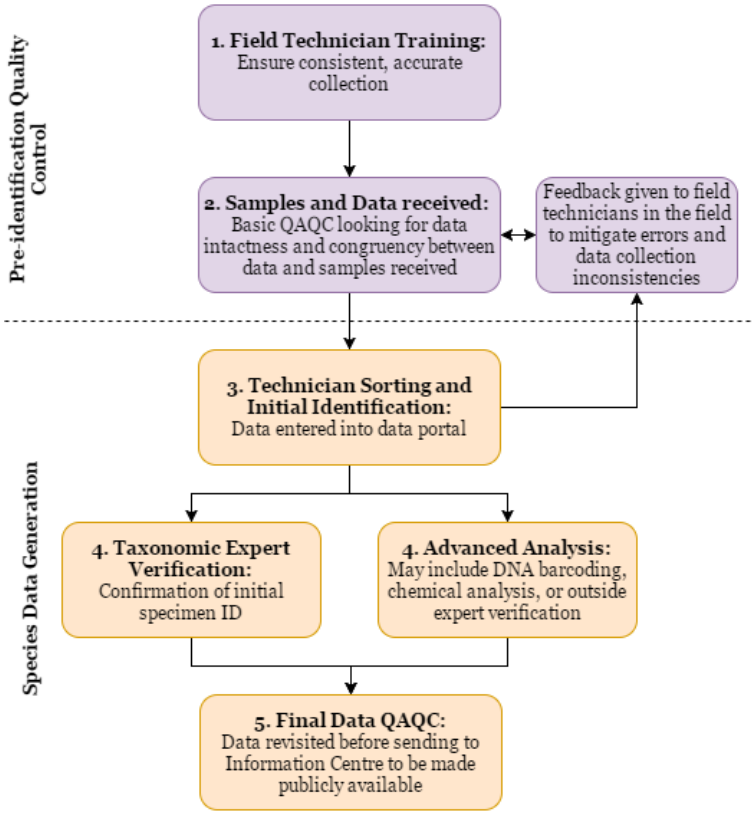

Figure 4.1.2. Specimen and sample data flow from pre-collection through generation to public delivery. Purple boxes denote pre-identification quality control measures. Orange boxes denote species data generation processes.

4.1.4 Quality System Implementation

The PC Director will ensure that all applicable elements of the quality system are understood and implemented by:

- conducting annual quality management system reviews and updates by all applicable staff;
- ensuring that each Lead Scientist conducts a predetermined number of quality checks during specimen processing to ensure accuracy and consistency throughout the identification process;
- ensuring that Lead Scientists maintain accuracy, consistency, and quality of all specimen identifications;

- using audits to assess curation and database accuracy and ease of curated specimen retrieval;
- compiling a summary of quality management activities during specimen processing highlighting areas of concern where data quality and management processes may be improved;
- ensuring the quality management system is part of staff training for new employees; and
- making all necessary resources available for the taxonomic teams to adequately perform their duties in a timely manner. This includes, but is not limited to: standard operational procedure training, access to reference collections, laboratory space, high quality diagnostic tools, as well as computer and advanced procedural training.

4.2 Element 2: Quality System Components

The management of data quality in the PC is governed by a variety of documents and resources that comprise the PC's quality management system. These provide clear and consistent guidance over the various activities and processes involved in collection, processing, identification, and delivery of high-quality data. PC quality system components include:

- SOPs and Lab Protocols;
- ongoing training and specialization via both internal and external education;
- access to the most advanced taxonomic tools available, such as Scanning Electron Microscopy (SEM) imaging as well as chemical and molecular techniques such as chromatography and DNA barcoding to ensure the most accurate and highest quality identification possible;
- annual reviews and planning with an aim for continuous improvement in specimen processing and identification, and data entry and data management; and
- supporting high quality growth and curation of specimen collections following Provincial standards for curation.

4.2.1 *Standard Operating Procedures and Lab Protocols*

The PC uses a series of SOPs and Lab Protocols to achieve overall data quality goals and objectives, promoting consistency in the quality and integrity of specimen processing and identification procedures, along with the data generated (Table 4.2.1). The development and implementation of SOPs and Lab Protocols at all stages of the sample collection, processing, identification, and data entry is one of the key mechanisms to ensure the implementation of the QMP.

Lead Scientists are responsible for overseeing the maintenance and implementation of Lab Protocols and SOPs associated with their particular taxa. The Lab Protocols and SOPs are written and maintained by ABMI Lead Scientists; however, these documents may be developed collaboratively, particularly for procedures with complex workflows. All Lab

Protocols and SOPs are reviewed and approved by the PC Director. External reviews are conducted where necessary at the discretion of the Lead Scientists and/or the PC Director. See Table 4.2.1 for a list of SOPs and Lab Protocols currently maintained by the PC.

Table 4.2.1. List of Lab Protocols and SOPs developed for the data management cycle.

Lab Protocol/SOP Title	SOP Number	Date Created/Modified
SOP Template	ABMI-IC-SOP-001	2012
Processing Bryophytes	ABMI-PC-SOP-001	2018
Quality Assurance Procedures for Aquatic Invertebrate Sorting, Identification, and Data Verification	ABMI-PC-SOP-002	2017
Processing Mites	ABMI-PC-SOP-003	2021
Processing Lichens	ABMI-PC-SOP-005	2018
Processing Vascular Plants	ABMI-PC-SOP-006	2017
Processing Organic Soil	ABMI-PC-SOP-010	2014
Processing Mineral Soil	ABMI-PC-SOP-010	2014
Processing Water Samples	ABMI-PC-SOP-017	2015

4.2.2 *Ongoing Training and Specialization*

The success of the quality management system depends on commitment by the employees to implement the system on a daily basis. Given that a substantial level of training is required by PC staff in order to process and identify collected specimens, the PC includes the following components as part of its training program, including:

- annual training seminars run by Lead Scientists to ensure technicians are adequately trained to process and identify specimens. Training is supplemented through the provision of additional resources that assist in accurate specimen identification and data entry, such as: taxonomic keys, guidebooks, and reference collections;
- regular testing of the year-round technical staff to determine the knowledge and competence for identification, individual training needs, and next steps in their taxonomic skill development;
- resources for additional training as necessary (e.g., courses, seminars, and conferences); and
- certification, training records, and performance review records kept current and maintained by PC Director.

4.2.3 *Annual Reviews and Planning*

There is an annual performance evaluation, in which all employees meet with the PC Director to review and assess the previous year's performance. This process serves not only to highlight competencies, but also areas of improvement where corrective measures may be required.

Informal reviews are conducted within each Taxonomic team at the conclusion of each field season to identify any areas of concern that may have arisen.

4.3 Element 3: Quality Training System

The PC ensures all staff are adequately trained to perform their assigned duties. This includes ensuring that candidates meet educational requirements (i.e., graduate degrees, certifications, diplomas, etc.). Lead Scientists must have demonstrated productivity and experience in their field (years of experience working with taxon, peer-reviewed publications, technical reports, etc.). Staff are provided with the resources and other relevant material required to perform their duties. The PC Director ensures resources are available for staff members to participate in local and international conferences and workshops to stay current with taxonomic changes.

A combination of full-time and short-term contract personnel may be used to process and identify specimens under the guidance of the Lead Scientists. For both returning staff or when hiring new staff, the criteria outlined in Table 4.3.1 are the primary technical qualifications that are considered during the hiring process.

Table 4.3.1. General qualifications and training requirements for taxonomists.

Type of Qualification	Minimum Requirement	Before or After Hiring
Post-Secondary Education	2 Years in a scientific discipline	Before
Field Experience	Preferably a paid position for 2 summers, but equivalent experience accepted.	Before
Computer Competency	General computer literacy required; further training provided for specialty programs (such as Photoshop).	Before
Lab Training	All lab training relevant to the taxonomic identification.	After
Collection Skills	All field training will be provided by Core Taxonomic crew to ensure correct collection techniques are applied.	After

The following section outlines the process used to train staff on PC protocols and the minimum testing requirements technicians must pass before processing and identifying specimens.

4.3.1 *Taxonomic Identification Training Requirements*

4.3.1.1 Oribatid Mites

Training to identify Oribatid (armoured) mites is as follows:

- New staff are given classroom instruction and begin to work with practice samples for the first month, or until such a time as they can correctly identify 95% or more of the mite specimens accurately to morphospecies. Once this has occurred, the trainee identifies mite specimens collected at ABMI sites; 100% of specimens identified are

verified by the Lead Scientist until ≥95% accuracy of identification has been achieved at two ABMI sites.
- The Lead Scientist then verifies 25% of all morphospecies identifications by each lab staff for two out of five randomly selected ABMI sites during the second week to ensure that ≥ 95% of specimens are sorted to correct morphospecies.
- In subsequent weeks, a qualified sorting supervisor verifies 25% of all morphospecies identifications by each lab staff for one out of five randomly selected ABMI sites to ensure that ≥ 95% of specimens are sorted to correct morphospecies.
- For quality assurance, all advanced slide mounted IDs are completed by the Lead Scientist (ABMI 2021).

4.3.1.2 Bryophytes and Lichen

For Bryophytes and Lichen, Lead Scientists and Taxonomists provide specialized training to all summer lab technicians. They also supervise all sorting and data entry activities to ensure ≥95% accuracy to the desired taxonomic level. A progressive learning approach including direct handling of reference specimens and use of a dissecting microscope are key elements to the training process. Each summer technician is required to pass a qualifying exam to demonstrate their skill at:

- correctly identifying 25 common Alberta bryophytes and lichen species or major groups; and
- sorting/identifying specimens with ≥95% accuracy from the bulk field-collected samples.

For each summer technician, identification and sorting of their first ABMI site is carefully supervised and, once complete, all sorted specimens, residuals and data entry is verified by the Lead Scientists and technicians. Any errors or omissions are corrected at the time of inspection. Once ≥95% accuracy is achieved, the remaining the sites are sorted with partial verification (limited to voucher taxa and data entry for each site). Random QA/QC inspections are then conducted throughout the sorting process by the Bryophytes and Lichen Lead Scientists and Technicians (ABMI 2018a, 2018b).

4.3.1.3 Aquatic Invertebrates

The Aquatic Invertebrate Taxonomist and Aquatic Invertebrate Technicians train and supervise all summer lab technicians. To be classified as an Aquatic Invertebrate Technician, the person must have:

- more than 1 years' experience identifying taxa found in Alberta; and
- successfully completed an exam by identifying representative specimens with at least 95% accuracy from the samples that are sorted for the ABMI.

Summer lab technician training take place during the first two days of the lab session and includes: lab safety, chemical handling, basic lab procedures, specimen sorting and handling, specimen identification, and data entry (ABMI 2017d).

Basic identification training is provided for summer lab technicians at the beginning of the lab session but the learn as you go approach is a key element to the training process. Because of this, lab QAQC is integrated into the lab sorting process as an ongoing operation. Both systematic and random QAQC inspections are conducted throughout the sorting of each site and again once the site has been completed (ABMI 2017d). Any errors or omissions are corrected at the time of inspection (ABMI 2017e).

4.3.1.4 Vascular Plants

One Vascular Plant Taxonomic Specialist is employed to identify plant specimens. Verification of identifications are completed by external experts as described in the Specimen Verification Summary document (ABMI 2017c). The Vascular Plant Lead Scientist receives support from the Rare Plants Committee to aid in the challenges that arise regarding rare species analysis, identification, and nomenclature changes (ABMI 2017c).

4.4 Element 4: Contractor Requirements

Procurement of services for the PC is generally related to identifying specimens. Contracts may be awarded through an open bidding process, or may be directly awarded when advanced identification services are required. In all instances, the PC Director ensures contractors have the required expertise, particularly when advanced identification services are required (ABMI 2016).

4.5 Element 5: Documents and Records

The PC Director maintains SOPs and Lab Protocols as the primary QAQC documents; management of these documents is described below.

4.5.1 Standard Operating Procedures

There is a SOP (other lab protocol) for each taxonomic group that details the lab protocols and procedures regarding QAQC for that particular group (ABMI 2017c, 2017e, 2018a, 2018b, 2021). Each SOP is reviewed and updated as required by each Lead Scientist to accommodate any program or procedural alterations. Protocols are approved by the PC Director.

4.5.2 Laboratory Protocols

There are laboratory procedures for each taxonomic group that outlines in detail how lab data is processed (e.g., soil, water, tree cores). Current drafts of the most up-to-date laboratory procedures are available on the ABMI website (abmi.ca). Protocols are approved by the PC Director.

4.6 Element 6: Information Management

4.6.1 PC Software and Maintenance

The PC uses software applications to assist with data management, processing, and review. Software is described in the following.

4.6.1.1 Online Data Portal

The PC is moving towards an online data portal for its data storage and specimen processing requirements. This data portal, tailored for each taxonomic group, is used to enter data directly into a database during the identification process. The online data portal replaces paper data sheets, and it incorporates various tools and features which support data entry and minimize errors that could potentially be made during the data entry process (e.g., eliminating spelling errors, flagging rare and uncommon species for verification). In cooperation with the IC, the online data portal is reviewed and updated on a semi-annual basis to incorporate changes to improve functionality with protocols and project needs.

4.6.1.2 Taxonomic Workbench

Taxonomic naming alterations are reviewed and edited annually via the Taxonomic Workbench (ABMI 2012, 2017a). The Taxonomic Workbench (TWB) is a database created in Oracle which is used to track and update taxonomic information associated with species data collected using ABMI protocols. Each year, the TWB is updated with new taxa added, and all the taxonomic information is reviewed by Lead Scientists.

4.6.1.3 Site Summary Workbench

The Site Summary Workbench is a web-based application used for tracking completion of data and specimen collection at the field site level. It functions as an important tool in communicating site-level information about data and specimen collection between ABMI Centres.

4.6.1.4 ABMI Tablet Program

The ABMI IC maintains a custom-built software program loaded onto tablet computers which are designed for collecting the ABMI field data. Panasonic tablets are used in the field so data can be entered directly into the computer during data collection. Each field protocol has associated data sheets preprogrammed into the tablet to maximize data entry efficiency. The MC uses the following quality assurance procedures to ensure tablets are functioning properly:

- The Field Coordinators are responsible for ensuring each tablet is loaded with the most recent updates from the IC;
- The MC works with the IC and PC to test data entry sheets, and make modifications as needed, prior to the start of the field season;
- Technical staff are responsible for maintaining tablets in the field;
- General software updates are performed on the hardware on an as needed basis;

- New models of tablets are tested in field by the MC on a small scale before implementing newer models on a large scale. This ensures hardware performance still meets the demands of field data collection.

4.6.2 *Project Management*

The Processing Centre's individual taxonomic groups have different temporal workflows and small teams ranging from 1-3 persons. The overarching project management tool used by the Processing Centre is:

4.6.2.1 ClickUp

ClickUp is a Project Management tool used to manage individual tasks, subtasks related to projects and grant deliverables. Tasks are assigned to PC staff by the PC Director or project manager as required.

4.7 Element 7: Systematic Quality Assurance Planning

The primary mechanisms used by the PC to support systematic quality assurance planning include the following.

4.7.1 *Monthly Planning Meetings*

It is impossible to know with certainty how many specimens will be received in any given sampling season. This inherent variability requires open lines of communication amongst taxonomic teams so that continuous adjustments can be made to increase efficiencies, and determine the needs of the PC on any given year. The effectiveness of the systems in place is assessed and maintained primarily by each Taxonomic Head, who is responsible for giving an approximated data delivery date for dissemination and analysis to the public. This may mean designing a new data portal, or hiring more personnel as the sample sizes dictate.

Monthly meetings provide updates and progress reports which allow the PC to address any logistical problems as issues arise. With all members of staff and the PC Director present, issues and/or concerns and potential solutions are discussed, with action items and timelines assigned to the appropriate member of staff. In addition, the PC Director meets weekly with each Lead Scientist to ensure a nimble response and resolution to emerging issues. The resolution progress is then followed up on or coordinated by the PC Director as required. The frequency of these sessions allows for quick response to any current or foreseeable obstacles so that they may be addressed in a timely manner.

4.7.2 *Working Plan*

Individual work plans are created and reviewed for each member of staff in an annual employee performance evaluation conducted by the PC Director. Staff performance and workplans are examined carefully to determine potential support required and training opportunities to improve upon for the upcoming year.

4.7.3 *Quality Assurance Documents*

The required annual review and updates of quality assurance documents such as this QMP and approved SOPs (managed by the PC Director) ensures there is continuous planning and quality improvement associated with all aspects of the data management cycle managed by the PC.

4.8 Element 8: Quality Implementation of Work Processes

At every step in the data cycle managed by the PC, there are several work processes (e.g., lab protocols, SOPs) that provide the instructions for completing each step. In addition, the PC uses several mechanisms (e.g., regular meetings, training) to ensure work processes are being implemented correctly and have been completed as required.

4.8.1 *Standard Operating Procedures*

The main system of implementation for PC QA management activities is through the development and execution of SOPs, and the development and maintenance of taxonomic keys. SOPs detail the operational tasks associated with identifying specimens in each taxonomic group. Table 4.2.1 provides a current list of SOPs that have been developed as part of the PC's sample processing, specimen identification, and data management activities. Please note some SOPs are at early stages of development. The PC Director ensures that all staff have access to SOPs.

4.8.2 *Laboratory Protocols*

Laboratory protocols outline step-by-step instructions on how lab data is processed for each taxonomic group. These protocols are key to ensuring standard and consistent work processes to achieve high data quality standards. The PC Director ensures that all staff have access to lab protocols.

4.8.3 *Training*

As discussed in Section 4.5, the Lead Scientists make certain that all PC personnel are trained in QA procedures, understand their specific roles and responsibilities, and that the QC activities as described in the SOPs are adhered to. The active engagement of staff in the QA planning process raises the awareness and understanding of the quality management system at the earliest stages of planning.

4.8.4 *Communication*

The Processing Centre has regular monthly meetings to connect and discuss current activities and challenges. Each taxonomic group conducts a pre-season and post season QA/QC review annually. Communications between Centres is facilitated via the ABMI Intranet, as a central secured location for all publications, protocols, schedules, and shared documents.

4.9 Element 9: Quality Assessment and Response System

To evaluate the performance of the PC's quality management system, the PC uses the following assessment tools: taxonomic identification audits, data quality audits, and performance evaluations.

4.9.1 *Taxonomic Identification Audits*

The ABMI Taxonomy Team at the UofA strives to assign the most accurate scientific name to each collected specimen. Ascribing a taxonomic name to a specimen with confidence is not always a rapid and straightforward exercise—proper identification often requires multiple lines of evidence. All taxonomic groups undergo periodic audits to ensure specimens are being correctly identified. There are two levels of identification audits:

- Internal audits: Internal audits are performed on a regular basis at all steps of the sorting and identification process to ensure a minimum level of accuracy.
    - Rough sort → a 95% identification rate is the goal during the rough sort—a process meant to separate individual species from each other in a sample, and identify common species.
    - Identification → approximately 1/5 of randomly selected samples identified by full-time technical staff are audited by the Taxonomic Lead for each group; accuracy of ≥ 95% is expected for identification; for aquatic invertebrates 1/10 random specimens not identified to species are reviewed by the Taxonomic Lead.
    - Specimens are regularly cross-checked by at least one other individual. These checks can be random, or targeted when experts lack confidence in certain identifications.
- External audits: for specific taxonomic groups, regular consultation with external experts is ongoing and may include sending samples as loans to other institutions for verification.
    - Outside expert opinion → For specimens that are difficult to identify, team members discuss the specimen and attempt to reach a consensus. If a consensus cannot be reached, the specimen is identified only to the highest taxonomic level of consensus.
    - Digital images of the specimen are usually insufficient for conveying detailed, fine features. Particularly challenging specimens may be sent to outside experts for verification and to support ongoing skill development. In some cases, verification may be obtained by analysis of DNA.

4.9.2 *Performance Reviews*

Staff performance reviews are managed by the PC Director and conducted on an annual basis. The process aims to ensure support for ongoing growth of taxonomic skills, professional development as well as improved team-level efficiency, productivity and morale. The PC

Director also participates in a 360-review with all PC staff and other members of the ABMI management group.

4.9.3 *Quality Improvement*

One of the underlying philosophies of the ABMI PC's quality management system (like all other Centre's in the ABMI) is that of continuous improvement. Many of the activities described in this QMP are included, in part, to facilitate continued improvement of sample processing and specimen identification in the PC. For example, annual workplans, annual staff training, and taxonomic identification audits all serve as mechanisms to identify areas that need improvement and provide opportunities to make those improvements.

4.10 Element 10: Commitment to Quality Improvement

The PC is fully committed to a process of continual improvement to sample processing and specimen identification as part of our sample management system, to produce and curate high-quality, well-documented taxonomic data that is trusted by all users. With oversight and facilitation by the PC Director and Lead Scientists, Taxonomic Teams will identify and improve adverse conditions to quality, and future quality by:

- ensuring that all protocols, procedures, equipment, and SOPs are updated annually, or as required;
- with oversight by the PC Director, prevent quality breakdown by having quality and consistent training at all levels of specimen handling, processing, and identification;
- identifying areas for improvement through data QAQC activities like data verification, post-collection data review, and taxonomic audits;
- identifying necessary updates to the ABMI tablet program, Site Summary Workbench, and the Data Portal program in order to maintain concurrence with protocols and improve quality functions (e.g., program restrictions and data entry menus, nomenclature or other changes to species lists);
- Working with the ABMI Database Programmer (IC) to facilitate the implementation and testing of changes to the data entry portal program;
- Developing built-in mechanisms for consistency, such as preloaded species names to negate spelling errors, or automatic flagging of cryptic or rare species identification for further verification;
- Collaboration and cross-training with ABMI staff from other Centres where their expertise is of benefit to the quality of the data collected and/or provided; and
- Centre integrated Data Management, Communications, and Science Committee participation in ABMI-wide committees to address and collectively solve any cross-Centre problems or concerns.

4.11 PC References

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CHAPTER 5: INFORMATION CENTRE QMP

Approvals

Approved by: _____ _____

Information Centre Director Date

Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	IC QMP created
2016-10-05	Katherine Maxcy, Corrina Copp	IC QMP updated following internal review.
2017-11-23	Katherine Maxcy, Corrina Copp	IC QMP updated following internal review. Minor revisions made.
2021-12-10	Corrina Copp, Katherine Maxcy, Joan Fang	Minor changes made. Updated organizational structure, references, staff roles, and documentation.

5 Information Centre Description

The ABMI is committed to the collection, generation, and distribution of high-quality biodiversity information for the province of Alberta. The ABMI Information Centre (IC) is the curator of all ABMI data and data products, and as such, is responsible for providing data management and infrastructure support for all the data and data information products generated by the ABMI. The IC Quality Management Plan (QMP) describes the quality management system employed by the IC to ensure the execution of quality control procedures at all steps in the data management cycle. The following is a description of the IC quality management system.

5.1 Element 1: Quality Management Policy, Goals, and Objectives

The goal of the IC QMP is to provide an overview of the IC's guiding principles and practices which ensure the creation of high-quality data and data products. The quality management policy of the IC is four-fold (following EPA 2002):

- Accuracy: all ABMI data collected is verified to be as accurate as possible;
- Objectivity: all ABMI biodiversity data and information is presented appropriately, and in an understandable, clear, and unbiased manner;

- Utility: the IC provides quality data for intended use;[1] and
- Integrity: all ABMI biodiversity data and information is protected from unauthorized access to ensure the information is not corrupted or falsified.

To meet these policy objectives, the IC has established the following quality management objectives (FREP Quality Assurance Working Group 2005, GLNPO 2008):

- Resources:[2] IC management will ensure there are adequate resources allocated to data quality management. Resources which are essential to maintain and improve the quality of biodiversity information include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources;
- Ongoing activity: data quality management is embedded in daily IC activities (e.g., training, Standard Operating Procedures [SOPs]), creating an expectation of quality and excellence;
- Systematic planning: through goal setting, action, and corrective activities, quality management activities will be systematically incorporated into all IC activities;
- Quality system documentation: all quality management activities will have documentation to ensure users are able to evaluate the data relative to their own needs (Shampine 1993). This includes a QMP and data management plan, approved by the IC Director, which describes how the IC will meet its quality objectives; and
- Data Management Group: a dedicated data management group within the IC meets monthly to discuss data management issues and identify ways to improve the data management process to ensure proper data organization, management, and delivery.

5.1.1 *Organizational Structure*

Figure 5.1.1 represents the IC organizational structure. The roles and responsibilities associated with each job title can be found in Table 5.1.1.

[1] Data quality is a critical aspect to an environmental monitoring program. However, data quality can only be determined by the context in which the data is used (Ferretti 2009, 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martín and Ballard 2010).

[2] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

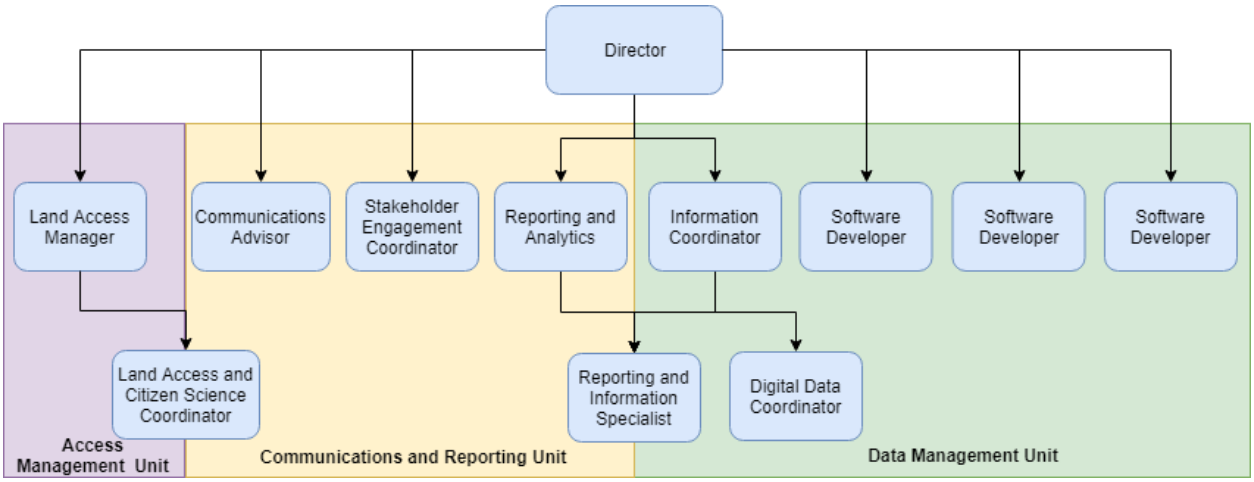

Figure 5.1.1. Organization chart representing roles within the IC.

5.1.2 Staff Roles, Responsibilities, and Authorities

The Information Coordinator, and Software Developers are the four staff members primarily responsible for the IC quality management system. A complete description of IC staff roles, responsibilities, and authorities as they pertain to data management are listed in Table 5.1.1.

Table 5.1.1. The IC staff roles, responsibilities, and authorities.

Responsibility	Data task	Technical Activities	Authority
Director	Personnel I Access Management	Submit requests to add/remove staff access to ABMI servers and secure data.	Confirms appropriate staff access
	QMP and SOP Review and Approval	Review and approve IC QMP and all IC SOPs.	Approves final QMP and SOPs.
Information Coordinator	Manage QAQC Phase I	Check data tables for duplicates, empty cells, missing sites, etc.	Confirms completion of QAQC Phase 1
	Manage QAQC Phase II	Double-check data tables for duplicates, empty cells, and verify tables contain data from all sites expected; metadata is checked and verified.	Confirms completion of QAQC Phase II
	Data Receiving, Cleaning & Loading	Load all data to a temporary holding system. Manage error resolution, and data verification.	Confirms all data modifications and QAQC activities are recorded. Ensures the SOP is followed
	Updating Metadata	Manage updates to ABMI written methods for each written protocol. Manage	Confirms metadata is up-to-date. Confirms metadata corresponds to datasets. Ensures the SOP is followed.

		updates to the metadata workbench.	
	Data Contamination & Error Resolution	Perform preliminary error review on data. Update raw data tables using data modification tools. Develop and maintain an error tracking table. Perform or manage problem analyses and resolution.	Confirms the completion of error review. Confirms the documentation of error resolution. Ensures the SOP is followed.
	Data Storage & Backup	Backup and archive all active files. Manage the archiving of all static files. Oversee development of a recovery system testing plan.	Confirms static files are archived. Ensures the SOP is followed.
	Data Security	Oversee risk assessment to electronic information.	Ensures workstation is protected. Ensures the SOP is followed.
	Website Synchronization	Update and upload metadata files.	Confirms uploaded metadata is accurate. Ensures the SOP is followed.
	Taxonomic Workbench	Manage the implementation of guild structure. Coordinate the review of species by Taxonomists for verification.	Confirms the workbench is updated by Taxonomist annually. Confirms the review of assigned groups and species by experts.
	Species of Concern Data Screening	Initiate the screening process. Update list of potential elements of management concern. Manage the screening of species/data.	Confirms the completion of the screening process. Verifies these species are removed from the public file. Ensures the SOP is followed.
	Personnel Access Management	Grant/decline access to non ABMI staff.	Ensures the SOP is followed.
	Bird Recording and Site Receiving	Obtain data from data authorities. Manage data verification process. Manage error resolution process.	Confirms all data is successfully loaded to servers. Ensures a permanent record of all QAQC activities is archived. Ensures the SOP is followed.
	Coordinate Camera Trap Image Processing	Coordinate and manage the image tagging process.	Ensures the SOP is followed.
	Public Release of Photos	Manage the review and release process for site and camera trap images internally and externally.	Ensures the SOP is followed.

Software Developer I	Data Receiving, Cleaning & Loading	Load data to Oracle database. Assess data for errors.	Informs Information Coordinator about errors.
	Data Contamination & Error Resolution	Run algorithms on data tables. Develop and update a data modification tool.	Provide outputs to the Information Coordinator.
	Data Storage & Backup	Manage servers. Backup and archive all active files. Manage database, web and GIS servers. Manage and test data recovery of local servers.	Confirms active files are backed up. Confirms servers are working properly. Ensures the SOP is followed.
	Data Security	Administer access control over local, database, web and GIS servers.	Ensures the SOP is followed.
	Personal Access Management	Manage user accounts, grant/revoke access to ABMI resources.	Ensures the SOP is followed.
Software Developer II	Website Synchronization	Update taxonomic information and Biodiversity Browser on ABMI website. Create and copy commonly requested data files to the web server.	Verifies Biodiversity Browser is up-to-date. Ensures the SOP is followed.
	Metadata Updating	Maintain metadata workbench.	Ensures the SOP is followed.
	Data Security	Administer access control over local, database, web and GIS servers.	Ensures the SOP is followed.
	Taxonomic Workbench	Update taxonomic information as required.	Ensures the SOP is followed.
	Species of Concern Data Screening	Manage the screening of species/data.	Confirms the completion of the screening process. Ensures the SOP is followed.
Software Developer III	WildTrax Development	Support WildTrax front-end development.	Ensures the SOP is followed.
Software Developer IV	WildTrax Development	Support WildTrax full stack development	Ensures the SOP is followed.
Land Access Manager	Land Access Data	Manage site access and landholder data, including personal information, permissions granted/denied, correspondence, and site location.	Confirms records are complete and up to date each season and imported to the master file.
	Landholder Data Reporting	Manage the creation and distribution of site data packages, including access to	Confirms the distribution of data packages.

		camera images and ARU recordings.	
	Submitting to Fish and Wildlife Management Information System (FWMIS) and Alberta Conservation Management Information System (ACMIS)	Ensure species to be submitted to FWMIS follow the decision tree for species of concern.	Approves if records can be submitted to FWMIS/ACIMS.
	Species of Concern Data Screening	Apply the decision tree to species of concern list.	Decides if the records are to be released or not.
Land Access and Citizen Science Coordinator	Posting to Social Media	Manages social media posts for NatureLynx.	Ensures the SOP is followed.
Digital Data Coordinator	Coordinate and Manage Bioacoustic Unit (BU) and BAM data	Coordinate BAM and BU data management.	Ensures the SOP is followed.
Communications Advisor	Print/Web Communications	Produce original content or coordinate with others to produce content for the ABMI blog, stakeholders, or other communications needs.	Ensures public-facing content is appropriate and on-brand.
	Editorial Oversight	Review and refine print or web content intended for public release.	Ensures the ABMI Communication Strategy is followed.
	Production and Review Support	Coordinate or support the production of reports, graphics, or other content, either internally or with the support of external vendors, as needed.	Ensures the ABMI Communication Strategy is followed
	Communications Support	Support internal communications, social media, or other outreach activities as needed.	Ensures the SOP is followed.
Stakeholder Engagement Coordinator	Stakeholder Engagement Plan	Develop and coordinate the ABMI stakeholder engagement plan	Updates and releases the ABMI stakeholder engagement plan.
	Stakeholder Feedback Database	Develop and manage database for collecting and responding to stakeholder feedback.	Ensures the stakeholder engagement plan is followed.
	Stakeholder Engagement Materials	Work with ABMI's Communications Advisor and other ABMI Centres to develop up-to-date stakeholder	Ensures the stakeholder engagement plan is followed

		engagement materials that reflect new innovations and functionality in ABMI's products and services.	
	Knowledge Exchange Forum	Coordinate and plan ABMI's external Knowledge Exchange Forum.	Ensures the stakeholder engagement plan is followed.
	Internal Forum	Organizes and coordinates internal forums to enhance awareness and understanding of ABMI products and services within ABMI staff to support their activities as ABMI ambassadors.	Ensures the stakeholder engagement plan is followed.
	Posting to Social Media	Manage social media posts for the ABMI.	Ensures the SOP, and ABMI Communication Strategy are followed.
	Public Release of ABMI Photos	Manage the review and release process for site and camera trap images externally.	Ensures the SOP is followed.
	Municipality Engagement	Contact and organize opportunities to engage with rural and urban municipalities.	Ensures the stakeholder engagement plan is followed.
	Communications Working Group	Organize/chair monthly CWG meetings. Send monthly CWG newsletter (minus summer months).	
	Internal TranSEKT Group	Organize/chair quarterly meetings for the Internal TranSEKT group (Stakeholder Engagement and Knowledge Translation).	
Reporting & Analytics	Biodiversity Browser Species Profile Annual Update	Coordinate updates to the model results for species profiles in the Biodiversity Browser including: habitat associations, sector effects, & predicted relative abundance.	Confirms habitat and human footprint categories are updated in graphs. Ensures graphs in Biodiversity Browser match the graphs on the Science Centre (SC) development site. Coordinates updates to interpretation of all results in species profiles with write-ups.
	Update Species Data for Data Download	Coordinate updates to species-level datasets for public release.	Ensures all data files from SC have been converted to public data formats.

			Ensures metadata for public data have been updated. Verifies public files have been added to the ABMI website and links to files are active.
	Update Biodiversity Spatial Data for Data Download	Coordinate updates to GIS Biodiversity Data.	Ensures GIS data for biodiversity mapping products are added to ABMI's public FTP site and made available for download.
	ABMI Mapping Portal Updates	Coordinate the addition of new maps to ABMI Mapping Portal.	Coordinates transfer of spatial data to MP database. Ensures metadata is complete. Confirms map is displaying properly in MP.
	Status Reporting Data Summaries	Coordinate analysis and summary of human footprint and species results for reporting (online and print).	Ensures human footprint data is in the correct format for graphing. Ensures HF trend data is standardized. For species summaries, ensures SOP for processing results is followed.
All Staff	Data Storage & Backup	Backup workstations to server.	Confirms that backups are made weekly to their personal file on the server.
	Public Release of ABMI Photos	Review all archived photos.	Ensures photos satisfy criteria specified in the SOP. Consults Information Coordinator or Land Access Manager.
	Data Security	Manage security at personal workstation.	Verifies the installation of data security software. Ensures workstation is protected.
	Data Management	Participate in monthly meetings to discuss and identify potential data management issues and concerns. Action items are identified for resolution.	Ensures completion of assigned action items. Identifies issues for discussion.

5.1.3 *Technical Activities and Tasks*

The IC performs several tasks that relate to the handling of ABMI data. These tasks include, but are not limited to:

- Data receiving, cleaning, verification, and loading: ensures data integrity, correctness, and completeness by conducting routine and consistent checks. This activity is crucial to maintaining data quality in environmental monitoring programs;
- Updating metadata: ensures that the supplementary data which defines and describes the characteristics of all ABMI datasets are maintained and updated on a regular basis. This activity promotes the usability and longevity of data sets;
- Data contamination and error resolution: assessing datasets for range errors, outliers, and logic errors. Ensures data quality is maintained;
- Data screening: ensures that potentially sensitive information is not publicly released;
- Data storage, back-up, and archiving: regular backups and archiving is essential to maintaining data integrity, and ensures the long-term protection and accessibility of ABMI data;
- Data security: ensures that systems, processes, and procedures are protected from unintended activity or threats.
- Data processing: systematic quality control process undertaken to ensure raw data collected in the field is complete, consistent and of high quality prior to public release and use for statistical analyses.
- Data reporting: the release of quality-controlled data for public use and consumption. Includes the release of analyzed data sets in the form of online and hardcopy reports.

These umbrella activities are broken down into more specific tasks which are overseen by one to multiple IC staff (see Table 5.1.1 for specific tasks associated with each role).

5.1.4 *Quality System Implementation*

Implementation of the quality system will ensure staff are aware and familiar with their role and responsibility as it pertains to specific activities and tasks. Staff will then be able to regularly evaluate the implemented quality system to ensure efficient methods are utilized.

5.2 Element 2: Quality System Components

The IC must implement a quality management system which ensures the ABMI biodiversity information meets quality management policies and objectives (See Element 1: Quality Management Policy, Goals, and Objectives). The IC uses the following quality management practices and tools to implement its quality system, including (EPA 2001, GLNPO 2008):

- Quality Management Plan (QMP)
- Quality objectives and systematic planning
- Quality system documentation
- SOPs
- Training
- Quality Management Monthly Reporting
- Data Management Group (IC only)
- Data Management Committee (ABMI wide)

- Quality System Audits and Technical System Audits
- Annual review and quarterly work planning
- Hardware and software with built-in checks and verification rules
- Internal and external audits of QA systems

Each will be discussed in turn.

5.2.1 *Quality Management Plan*

The IC QMP is a description of the processes that govern the QA program within the IC, including QA-related policies and objectives, and the management and technical activities required to meet these policies and objectives. The QMP further serves to communicate the overall quality system to IC staff and collaborators; staff are encouraged to refer to the QMP on an ongoing basis to reinforce the QA program. The IC QMP is approved by the IC Director and Information Coordinator.

5.2.2 *Systematic Planning and Quality Objectives*

A systematic planning process is used to assess IC QA needs at each step of the data management process from the data receiving phase to the public delivery phase. This logical structure facilitates the planning of all data management activities in an iterative process of guidance, design, and feedback, ensuring quality objectives are met as efficiently as possible (EPA 2002).

As part of the planning process, the Information Coordinator chairs the ABMI Data Management Committee. The goal of the committee is to ensure proper data organization, management, and delivery. In order to accomplish this, the committee is tasked with identifying and understanding the ABMI's data management needs, developing strategies to improve data management shortcomings within the ABMI, and implementing new policies and processes relating to any data services provided by the Institute.

Execution and implementation of work plans, strategies, or processes developed by the Data Management Committee will remain the responsibility of individual business units. Ultimately, it falls on the ABMI Executive Team to decide whether or not to follow the committee's recommendations. The complete terms of reference for the Data Management Committee are included in Appendix 2.0.

5.2.2.1 Data Quality Objectives

The ABMI collects data throughout Alberta on a range of attributes (e.g., species, habitats, ecosystems, land use) that are used as indicators of environmental health. The large range of data collected allows the ABMI to track changes in Alberta's wildlife and their habitats from border to border, and provide ongoing, relevant, scientifically credible information on Alberta's living resources for Alberta's land-use decision makers. The raw data and data products to support land-use decision makers are maintained, in part, by the IC, whose intended objectives for data quality include:

- Accessibility: The ABMI collects abiotic and biotic data using numerous field and remote sensing protocols. After undergoing quality control by the ABMI the data is made available internally and then publicly without further modification. Raw data is publicly accessible at the scale of individual points.
- Accuracy and Consistency: To ensure data can be aggregated and compared, metadata is provided with all data that outlines the expected form and content (ABMI). Allowable ranges and values are outlined, including aspects such as missing values which are represented by VNA or DNC, which differ from values such as NONE or SNI.
- Spatial Scale: The ABMI uses a large-scale, systematic sampling design to collect unbiased data on a variety of biodiversity indicators and human land-use practices. This sampling design was implemented to draw inference about the provincial and regional state of these indicators. In general, the ABMI considers a "region" as a continuous or discontinuous area encompassing 50 or more sampling points. The ABMI is not optimally designed to provide results at the scale of individual points or very small regions (e.g., less than 50 points) (Herbers 2008).
- Completeness: Quality control steps are implemented to ensure data is complete (i.e., all sites surveyed in a given year are present, there are no blanks in the data set, etc.)
- Timeliness: The ABMI makes every effort to release information products in a timely manner while adhering to rigorous quality control. In general, ABMI information products are expected to become publicly accessible within 9 months of collection or production. The ABMI's information products become available to all stakeholders and the public at the same time.
- Integrity: The ABMI program is validated through peer review and by an international panel of experts. The ABMI is also validated through the implementation of its own internal quality standards.
- Reliability and Validity: Stable and consistent results, the goal of the ABMI is to measure the status and trend in biodiversity. A limitation to trend is that it takes time to measure how well a test measures what it is purported to measure. In ABMI's case, site revisits are needed, which began in 2015. Based on the 10-year Science Review, revisits are intended to occur approximately every 10- to 15- years (Schieck and Illerbrun 2019). In the interim, intactness and species relative abundance values are outlined in data products and reports to give insight on how species are responding to a changing landscape human footprint.
- Relevance: We ensure that our data products address the needs of our Stakeholders. The ABMI's information has significant application to the following regional and provincial management areas:
    - Strategic land-use planning,
    - Cumulative impact assessment and management,
    - Performance monitoring (effectiveness monitoring and stewardship reporting),
    - Status reporting, and
    - Adaptive management.

5.2.3 *Quality System Documentation*

The IC is required to have written and approved quality system documentation (e.g., QMP, SOPs) which provide details of the QA program. At a minimum, all QA documentation must be reviewed and approved by the Information Coordinator, with final approval by the IC Director. Approvals by domain experts and/or external reviewers are encouraged, and in many instances, also necessary. All QA documentation is filed with the Information Coordinator, who is also responsible for version control and archiving documents. Relevant documents related to quality system documentation include:

- ABMI User Guide to Preparing Standard Operating Procedures (ABMI 2013)
- ABMI Public Document Archive Policy and Procedure (ABMI 2016b);
- ABMI Information Backup and Storage (ABMI 2019b);
- ABMI Web Content Management (ABMI 2019c); and
- ABMI Document Version Control (ABMI 2019d).

5.2.4 *Standard Operating Procedures*

The IC uses a series of SOPs to achieve overall data quality goals and objectives, promoting consistency in the quality and integrity of ABMI data and associated products. The development and implementation of SOPs at all stages of the data cycle is one of the key mechanisms to ensure the implementation of the QMP. These SOPs are not only critical to ensuring that data processing activities are performed correctly and consistently, but also provide the basis for staff training programs (GLNPO 2008). The series of SOPs produced and maintained by the IC provide a systematic approach to verify and document that ABMI biodiversity data is consistent, complete, of known acceptable quality, and provides the IC with the following benefits (EPA 2002):

- Consistency in performance, particularly with respect to data verification and validation tasks;
- Improved data credibility and defensibility;
- Reduced errors;
- Improved efficiency throughout the data management system; and
- QA documentation.

The Information Coordinator is responsible for overseeing the development and implementation of IC SOPs. SOPs are written by the Information Coordinator and/or domain experts. SOPs may be developed collaboratively, particularly for procedures with complex workflows. All SOPs are reviewed and approved by the Information Coordinator, with final approval by the IC Director. External reviews are conducted where necessary at the discretion of the Information Coordinator and/or IC Director. See Table 5.2.1 for a list of SOPs currently maintained by the IC.

Table 5.2.1. List of SOPs developed for data management cycle.

SOP Title	SOP Number	Date
Guidance for preparing SOPs	ABMI-IC-SOP-001	2017
Updating Metadata	ABMI-IC-SOP-003	2012
Data contamination and error resolution	ABMI-IC-SOP-004	2011
Data storage, back-up and archiving	ABMI-IC-SOP-005	2019
Data security	ABMI-IC-SOP-006	2011
Website synchronization	ABMI-IC-SOP-007	2011
Updating the taxonomic workbench	ABMI-IC-SOP-008	2016
Species of special concern	ABMI-IC-SOP-009	2018
Data modification and auditing	ABMI-IC-SOP-010	2012
Personnel access management	ABMI-IC-SOP-011	2013
Bird recording and site photo receiving	ABMI-IC-SOP-012	2013
Tablet data receiving and cleaning	ABMI-IC-SOP-013	2019
Camera trap image processing	ABMI-IC-SOP-014	2018
Public Release of ABMI photos	ABMI-IC-SOP-015	2016
ABMI mandatory vascular plant specimen collection list	ABMI-IC-SOP-017	2017
Data sharing	ABMI-IC-SOP-019	2020
Field data QAQC	ABMI-IC-SOP-022	2020
Submitting FWMIS and ACMIS	ABMI-IC-SOP-023	2020
Site Location Management	ABMI-IC-SOP-024	2020
Posting to Social Media	ABMI-IC-SOP-025	2019
ABMI Web Content: ABMI Websites & E-Newsletters	ABMI-IC-SOP-026	2019
WildTrax Development (In development)	ABMI-IC-SOP-027	2020
Hosting ABMI Webinars	ABMI-IC-SOP-028	2021
Species Summaries for Reporting (in development)	ABMI-IC-SOP-xxx	2019
Biodiversity Browser - Annual Species Modelling Results Update (in development)	ABMI-IC-SOP-xxx	2018

See Appendix 3.0 for a copy of the foundational document—*Guidance for Preparing Standard Operating Procedures* (ABMI 2013)—used by the ABMI to implement quality control procedures as part of the data management cycle.

5.2.5 *Training (in development)*

Through its policies, guidelines and internal communications, ABMI has made it clear that everyone has a role to play in assuring the quality of the data. The success of the quality management system depends on commitment by the employees who are required to implement the program on a daily basis. To facilitate staff awareness of the quality management system, a quality awareness training program is implemented by the IC. Components of this training program include (but are not limited to):

- Mentorship and shadowing for new employees within the organization;
- General training seminar providing an overview of the IC QA program including: QA policies and objectives, description of roles and responsibilities, and a description of the QA documentation (e.g., QMP, SOPs) and where these documents can be accessed;
- Detailed training seminars pertaining to specific data management activities for domain experts;
- Record of QA training by IC staff;
- Testing to determine the knowledge and competence of domain experts on their use of appropriate QAQC procedures and to determine individual training needs; and
- Resources made available for additional quality training (e.g., course, seminars, conferences).

See Section 5.3 for further details on quality system training.

5.2.6 *Quality Management Monthly Reporting (in development)*

A brief status report is completed each month by the Information Coordinator which provides an update on the status of quality management activities. The report is presented to the IC Data Management Group for discussion at monthly meetings. This is an important management tool in the planning and implementation phases of the QA program to:

- prioritize QA activities; provide an update on the status and progress of action items;
- identify new tasks and priorities;
- identify problems/issues with specific QC tasks/processes; and
- adjust work plans and workloads.

At later stages, as the quality system cycle matures, this monthly reporting system will provide a means to assess QA activities and apply corrective action, as necessary, to ensure continued improvement in QA activities (GLNPO 2008).

5.2.7 *Quality System Audits and Technical System*

QA management system reviews (or quality system audits) are performed internally to evaluate the effectiveness of a quality management program (EPA 2001, GLNPO 2008). Internal audits are a priority for IC staff during the planning and implementation phases of the quality management program. Internal audits of data management workflows (e.g., data

receiving, data verification, data modification) are conducted by the Information Coordinator to ensure:

- adherence to the QMP;
- the existence of procedures to develop quality objectives and acceptance criteria;
- the existence of procedures to develop and approve quality assurance documentation;
- the existence of procedures to develop and approve SOPs;
- procedures, criteria, and schedules for designing and performing audits;
- the existence of a tracking system for ensuring corrective changes to the data are adequately reported;
- sufficient management support; and
- adequacy of allocated resources to achieve QA goals and objectives including appropriate level of financial and capacity devoted to the implementation of the quality system.

For example, the IC conducts regular audits on ABMI historical data to ensure data quality standards are maintained, and any changes to the field protocols over time are corrected and standardized. In addition, the Information Coordinator contracts taxonomy experts to audit the taxonomic library of ABMI at the end of the field season when new species are added.

5.2.8 *Annual Review and Work Planning*

An annual review of the quality management system is conducted by the Information Coordinator. The Information Coordinator prepares a briefing document for the Information Director (and other IC staff) providing (at a minimum) (GLNPO 2008):

- status and update of all QA activities;
- status and update on quality system documentation (e.g., QMP and SOPs i.e., have they been reviewed and updated for the year);
- results of all technical system audits and/or reviews;
- outstanding issues; and
- QA workplan for the upcoming year.

Following a review of the briefing report by IC staff, the Information Coordinator will coordinate and host an annual QA meeting. This will be an opportunity to review the workplan and ensure expectations around QA for the upcoming year are clearly outlined and understood. In the systematic planning framework of “plan, implement, assess, and correct”, this annual review will ensure the continued application of the quality system cycle. In addition, part of the mandate of the ABMI Data Management Committee which meets at a minimum of three times throughout the year, is to ensure data management systems are being implemented, quality control issues are addressed on an ongoing basis, and coordination of QAQC among Centres is maintained.

5.3 Element 3: Quality Training System

With an underlying philosophy of quality improvement, the success of the IC quality management system depends on commitment by the personnel who are required to implement the program daily. It is the IC policy to provide appropriate quality training to ensure all staff involved in the data management process use the quality management system and understand their roles and responsibilities with respect to quality management. The following describes the ABMI IC's quality management training system.

5.3.1 *Personnel Qualifications*

IC staff are hired based on their ability and qualifications to perform data quality-related tasks as identified in their job description. Education and experience constitute the primary means of qualification. Additional on-the-job training is also provided as needed at the discretion of the IC Director. Full records are maintained for all training undertaken by employees.

Towards assurance that all staff members are qualified and meet the required job specifications, the ABMI IC must follow and adhere to the University of Alberta staff hiring Rules and Regulations. Personnel qualifications are established by the Position Classification Plan, which describes the job specifications and the education and/or experience necessary to fill that position. The qualifications of all job applicants are reviewed by the IC Director and at least two other IC staff members to ensure applicants meet the minimum job requirements. The IC Director and at least two IC staff interview prescreened applicants and assess their qualifications as it relates to the posted job description. It is the responsibility of the IC Director to ensure staff members who need specialized training receive it.

5.3.2 *Information Coordinator Training*

The Information Coordinator will participate in training courses and presentations (including online training courses and webinars) on quality management topics that pertain to (data) quality management and assessment. Relevant conferences and meetings on the development and implementation of quality systems may be used for further training. In addition, the Information Coordinator will commit to an ongoing program of self-directed study to remain up-to-date on quality assurance topics.

5.3.3 *IC Personnel Quality Training System*

The IC Director is responsible for ensuring personnel are qualified to perform their jobs, including those aspects related to the quality management system. Further, it is the Information Coordinator who ensures all IC personnel are trained in QA procedures, and that the QC activities as described in IC SOPs are adhered to. Therefore, the Information Coordinator will develop and coordinate a quality assurance training program for IC staff. The basic intent of training is to describe, explain the importance of, and outline the roles and responsibilities of the IC quality management system. In order for responsibilities to be effectively understood, adequate training is essential.

The quality management training program includes (but is not limited to) (GLNPO 2008):

- training with respect to the QMP;
- training with respect to specific SOPs that pertain to staff job descriptions;
- performance evaluations pertaining to QA activities;
- assessment of training needs to maintain QA competencies; and
- completion of QA self-certification forms on an annual basis.

The Information Coordinator will develop and maintain a library of quality management documentation which is available to all IC staff for reference. To maintain a proactive approach to quality assurance, the Information Coordinator will actively engage employees on an ongoing basis in the development of quality management activities.

The Information Coordinator will keep a record of quality assurance training for each employee, and a summary of quality system training activities (e.g., list of training seminars/courses/conferences attended) will be included in the annual report.

Whenever the IC QMP undergoes major revision, training will take place within 6 months of its approval to ensure all IC staff are fully updated on changes to the quality system. Similarly, after SOP revision and approval, IC staff responsible for tasks within the SOP will receive necessary training to implement the SOP.

Note: quality training systems have not been completely implemented (e.g., QA self-certification forms)

5.3.4 User Guides

The IC has developed several tools and workbenches to assist with data QC. These tools and workbenches were designed based on user needs and desired functionalities. For example, the data entry portal used by the Processing Centre (PC) Taxonomists was designed to accommodate the needs of each taxonomic group. To ensure these tools are used correctly, User Guides are developed to lead new and current users through the system and workflow processes (Table 5.3.1).

Table 5.3.1. List of User Guides developed for data software training.

User Guide Title	User Guide Number	Date
Template	ABMI-IC-UG-000	2011
Taxonomic Workbench	ABMI-IC-UG-001	2017
Metadata Workbench	ABMI-IC-UG-002	2016
Camera Trap Image Processing Website	ABMI-IC-UG-003	2018 (archived)
Site Summary Workbench	ABMI-IC-UG-004	In development
Data Entry Portal	ABMI-IC-UG-005	In development
Guild Workbench	ABMI-IC-UG-006	In development
Tablet	ABMI-IC-UG-007	In development

5.4 Element 4: Contractor Requirements

Contractors hired under the IC will be required to read the QMP and participate in a brief QAQC seminar outlining the standard operating procedures and user guides associated with their specific work. Seminar length will depend on the services the contractor is providing which will determine the QA procedures they must adhere to.

5.5 Element 5: Documents and Records

The Information Coordinator is responsible for establishing and maintaining procedures for the timely preparation, review, approval, use, control, and revision of IC documents associated with the quality management system (GLNPO 2008). In addition, QA documentation must be appropriately archived so that information is readily retrievable for review and inspection (DWR 1998, GLNPO 2008). This section will outline the IC procedures for managing QA documents and records.

5.5.1 *Document Preparation*

The ABMI IC Director, Information Coordinator, or domain experts (e.g., Software Developers) will identify the need for a particular QA document. The Information Coordinator will identify who will prepare a particular QA document. A team approach may be used for multi-tasked processes where the experiences of several individuals are required.

5.5.2 *QA Documentation Reviews, Approvals, and Revisions*

The Information Coordinator manages quality assurance document reviews, approvals, and revisions. All QA documents must be reviewed and accepted (at a minimum) by the Information Coordinator, with final approval by the IC Director. The need for additional reviews (either internal or external) will be assessed on a case-by-case basis. For example, in addition to review and approval by the Information Coordinator and IC Director, all SOPs must be reviewed and accepted by the domain experts who perform the work and use the process. Signature approval indicates that a QA document has been both reviewed and approved by management.

SOP's will be systematically reviewed every year to ensure that procedures remain current and appropriate. The review date will be added to each SOP that has been reviewed. If an SOP describes a process that is no longer followed, the SOP will be withdrawn from the active file and archived.

5.5.3 *Document Control*

The Information Coordinator implements a documentation control system for QA documents, which includes two main responsibilities: keeping an inventory of all IC QA documents, and assignment of a QA documentation number to all QA documents and records. Documents and records maintained by the Information Coordinator include (DWR 1998, EPA 2001, GLNPO 2008):

- Quality Management Plan;
- IC Standard Operating Procedures;
- Records of employee training;
- Annual reports and workplans;
- Results of performance and system audits/reviews; and
- Documentation of QAQC issues and corrective actions taken.

All QA documentation is maintained and versioned on Google Drive. Working drafts are maintained on the Google Drive while final QA documentation, signed off by the Information Coordinator, Domain Expert and IC Director, are posted to the ABMI-wide ClickUp site and are subsequently updated on the ABMI website Quality Management Page.

5.5.4 *Document Storage and Archival System (In development)*

The system of storing QA documents, including current versions, old versions, and documents no longer in use, is managed by the Information Coordinator. The system ensures only the most recent version of each document is used. It also must outline where, and how, old versions are archived to prevent their continued use, while still ensuring the documents are available for auditing purposes or for historical review. An electronic storage and retrieval system is recommended over a hard-copy document format. Electronic access must be limited to a read-only format, thereby protecting against unauthorized changes made to the document. See GLNPO 2008, Daley 2005, NPS 2008 for systems related to data and documents.

The ABMI has also developed policy guidelines related to access and use of ABMI's public document archive. ABMI produces valuable grey literature, including: core reports on the status of biodiversity, reports from research projects, and technical documents such as standards and protocols as well as science development reports. ABMI also publishes peer-reviewed literature. These publications are at the centre of ABMI's business, demonstrating the value of our monitoring system and applied research projects to our diverse stakeholders. They represent a significant investment. To ensure the continued access and preservation of these valuable documents, the ABMI maintains a document archive system. The following documents provide instructions about how to manage and archive biodiversity-related information products:

- ABMI Public Document Archive Policy and Procedure (ABMI 2016b);
- Information Backup and Storage (ABMI 2019b);
- ABMI Web Content Management (ABMI 2019c); and
- ABMI Document Version Control (ABMI 2019d).

5.6 Element 6: Information Management

5.6.1 *Information Management System*

Information management includes all activities associated with planning, budgeting, organizing, directing, and controlling information (GLNPO 2008). As indicated by its title, the main function of the IC is to manage information. The primary goal of the IC is to develop and implement an efficient means of collating, storing, managing, searching, and disseminating quality biodiversity information in a variety of different forms (e.g., raw data, compiled data, and processed data, graphs, maps, reports). The IC responsibilities include (Daley 2005, NPS (National Park Service) 2008):

- defining the IC information management policy;
- defining and implementing data quality standards and processes;
- developing and maintaining information management systems (e.g., networks, hardware, software);
- providing database administration, management, and technical support;
- supporting specialized processing requirements (geographical information systems [GIS], remote sensing, etc.);
- developing and supporting specialized reporting requirements and requests; and
- serving as the main contact point for data/information dissemination;

The foundation for providing these services is a reliable and secure network of current computer technology including hardware (e.g., computers, servers, hardware necessary for networking), software (e.g., applications, database systems, computer programs), and web applications (NPS 2008) as described below.

5.6.2 *Infrastructure Description*

Because the ABMI collects and curates large amounts of data, specialized software and hardware architecture are required to support data management and user interaction (Sólymos et al. 2015). The system needs practical, logical, and cost-effective methods to organize, link, and store a diverse range of data sets—from raw field data, to audio files, to GIS layers, to the results of predictive modeling—in a systematic framework. Below is a basic summary of the ABMI infrastructure used to support the data management cycle.

5.6.2.1 Servers

The ABMI currently possesses servers that support the organization's activities. These servers can be broken into four primary functional types:

Work File Server:

- organizational and employee server, where any staff can store working files. These servers are regularly maintained and backed-up in accordance to the ABMI back-up procedure (ABMI 2019b); and

- local server, github, bitbucket.

Data File Server:

- repository of static data files. Files stored here do not typically change often and need a consistent location, such as in the case of GIS base layers, imagery, or final reports. These servers are designed for large storage capacities; and
- Cirrus, AWS, local server.

Database Server

- uses Oracle, PostgreSQL, MySQL, and other database software. Write access is under strict control to the Software Developers. Databases on this server are for long-term data storage and require quality database design, documentation, and administration. In some cases, where there is user input, files can change quickly, thus a well-designed back-up system is required; and
- Linode.

Website Server

- provides the "front-end" to accessing the data and products generated by the organization. This server is closely tied to the data file and database server; and
- AWS, Linode, local servers, Azure.

5.6.2.2 Oracle Database

Oracle database is the database management system (DBMS) application used by the IC to store and analyze data. It defines, creates, queries, updates, and manages data.

The ABMI Oracle database contains species and habitat raw and compiled data and their metadata, ABMI website contents, site metadata, taxonomic data, species guild, PC identification data, Geospatial data, etc. Oracle databases extract, transform and load external data into database tables, such as tablet data and WildTrax data. Oracle also helps analyze ABMI Data.

5.6.2.3 PostgreSQL Database

PostgreSQL database is the DBMS application used by the IC to store and analyze remote camera and acoustic data in WildTrax. It defines, creates, queries, updates and manages these data.

The WildTrax PostgreSQL database contains species tag information and their associated metadata such as organization, visit, location, task, and image or sound file information. PostgreSQL databases extract, transform, and load external data into database tables such as historical tagging data. PostgreSQL also facilitates data validation and constraints, and reporting in WildTrax.

5.6.2.4 Tablet Software

The ABMI uses specialized handheld computers (Panasonic Toughbook U1 Ultra) with customized databases to collect data in the field, allowing automated data quality control procedures to be implemented during data input. These computers bypass the step of manually recording field data on data sheets, allowing field crews to enter data directly into computer databases. Data tablets run standard Windows 7 OS, the field collection software uses .NET WinForms technology to create data entry interfaces, and SQLite databases to store data collected in the field. Data verification rules are built into the database to ensure that data are consistent and only include allowable codes. Each protocol is checked for accuracy and completeness by field supervisors from the Monitoring Centre (MC) and data backups are created.

Tablet software is updated annually. Updating the software removes any bugs present in the system from the previous field season. It is the responsibility of the Field Coordinators to notify the Software Developer when glitches are detected in the software by the field technicians. This also includes updates to any procedures or protocols that may have been altered since the last field season, such as the addition/removal of a collection field. Prior to the use of the tablets by field technicians, the updated software is tested by the Software Developer and MC Field Coordinators.

The plant collection/voucher list is an example of a file that needs to be updated in the tablet. This list is developed and updated by the Information Coordinator and Plant Taxonomist at the PC on an annual basis (ABMI 2016c).

5.6.2.5 Taxonomic Workbench

The ABMI's Taxonomic Workbench (TWB) is a database created in Oracle which is used to track and update taxonomic information associated with species data collected using ABMI protocols. The TWB contains sections for the following taxonomic groups: birds, mammals, plants, moss, lichen, and invertebrates. Each year the TWB is reviewed by Lead Scientists and is updated to include new taxa.

The TWB is an online software tool to manage taxonomic species names. It allows ABMI to audit and track the changing history of each species. The TWB initially loaded taxonomic data imported from the Integrated Taxonomic Information System. ABMI's Lead Scientists approve, modify, or reject taxonomic names and their hierarchy structures. The results (new species names) will then be applied to ABMI raw data, so every year ABMI data always use the latest taxonomic names.

The IC coordinates the species name audit annually or biannually. The Software Developer will first reset all species status as "Need to be Reviewed" in the TWB. The Information Coordinator will then contact the Lead Scientists and ask them to do the review online. All changes made will be approved by the Software Developer who ensures basic rules are followed, such as no special characters used in scientific names.

In addition, taxonomy is constantly changing. To ensure the ABMI TWB is up-to-date, and tracks name changes through time Lead Scientists can use the TWB whenever they need to make taxonomic name changes. Name changes are carried forward throughout the backend databases to ensure all data is up-to-date.

5.6.2.6 Site Summary Workbench

The ABMI's Site Summary Workbench (SSW) is a database created in Oracle which is used to track and update field site surveys and data collected. The workbench contains sections for adding field technician names and field sites, recording field site information, and for tracking shipped samples to the PC, such as soil, water and aquatic invertebrates.

Each year, the Information Coordinator updates SSW to include the field sites selected for the upcoming data collection year based on the field site record. All field sites added at this time are indicated as incomplete for spring, summer and winter protocols. Throughout the field season, Field Coordinators are responsible for updating their crew's field sites, including detailed comments where necessary. This includes indicating if field collected samples have been shipped to the PC. If there are changes to the initial site list, it is the responsibility of the Field Coordinators to inform the Information Coordinator.

At the end of the field season, the SSW field site list with associated status of all spring, summer, and winter protocols is downloaded and used as the Master List for field data QC. Prior to use, the list is verified by the MC to ensure all sites are present.

5.6.2.7 Data Entry Portal

The data entry portal is an online software tool used by ABMI PC staff and technicians to enter and verify lab identification results. Every year, the PC coordinates the compilation of a list of lab technician names to be registered in the SSW. Once users have been registered, they will be able to enter data using the portal.

To upload information into the data portal such as sites, the Software Developer will either use the tablet data or shipping document provided from the MC. An initial check of site names will be completed, and then site names and field status will be loaded into the backend databases. At this time, PC staff and technicians will be able to enter data into the data entry portal and verify them. After all the data is entered, the Software Developer will load data into the raw data section.

5.6.2.8 Metadata Workbench

The ABMI's Metadata Workbench (MWB) is a database created in Oracle used to manage, track and update metadata associated with data collected using ABMI protocols. The Workbench contains sections for all terrestrial and aquatic protocols. Each year, the MWB is updated to accommodate implementation or retraction of procedures and specific data fields within current protocols.

Updates to the metadata are determined during field data QC. MC Field Coordinators inform the Information Coordinator of any changes to the field protocols and subsequent metadata fields and values. Updates are made prior to public data release.

5.6.2.9 Guild Workbench (in development)

The guild workbench is a component of the data entry portal. This tool is an online software tool used to enter supplemental species information that is identified by the SC, IC, or Application Centre (AC). This information can be used for subsequent analysis by the SC, or within other tools such as the Mapping Portal.

To upload information into the guild workbench, the Software Developer will request an excel from the IC, SC or AC to bulk upload. After the data are uploaded, the user can make manual changes and entries. After all the data is entered and verified, the Software Developer will load data into the database.

5.6.3 *Managing File Archives*

- Camera trap photos are uploaded and stored on external hard drives and on an Amazon Cloud Server. This process is managed by the Information Coordinator, WildTrax Coordinator and Reporting & Information Specialist.
- MC Field Coordinators transfer collected field photos to the IC over a secure FTP server. The Information Coordinator is then responsible for migrating these photos to the secure Data Server. All files are logged to verify and determine missing or corrupt files.
- Public photos are archived on an ABMI server within the ABMI Photo Library folder. The Access Coordinator manages these images (ABMI 2016a).
- ARU files are uploaded and stored on external hard drives and on the BU Cirrus cloud server. MP3 files extracted and spectrograms created (jpgs) for analysis in WildTrax are stored on Amazon S3 Cloud Storage. This process is managed by the WildTrax Coordinator (ABMI 2021).
- Field collected data is transferred by the MC Field Coordinators to the IC over a secure FTP. The Information & Reporting Specialist is responsible for migrating these files to the secure Data Server, while the Information Coordinator is responsible for amalgamating the files, and posting them to Trello for Data QC to begin by the MC (ABMI 2019a).

5.6.4 *Project Management*

The IC uses various tools to support project management, and the corresponding workflows, deliverables and tasks. The following project management tools are used by the IC:

5.6.4.1 Trello

Trello is a web-based project and work-flow management tool used by the MC, IC and PC to communicate, track and record data verification activities involved in data QAQC Phase I and

Phase II (ABMI 2019a) and WildTrax Development. Trello is available at the following hyperlink https://trello.com/en.

5.6.4.2 ClickUp

ClickUp is a Project Management tool used to manage individual tasks, subtasks related to projects and grant deliverables. Tasks are assigned to IC staff by the IC Director or project manager as required. ClickUp is available at the following hyperlink https://clickup.com.

5.7 Element 7: Systematic Quality Assurance Planning

The primary mechanisms used by the IC to support systematic quality assurance planning include:

- IC Work Planning: the IC Director, in consultation with IC staff and other ABMI directors, develops a work plan and budget for the IC. This work plan includes identifying priorities for the quality management system and the allocation of appropriate resources (staff and budget) to complete work plan deliverables.
- Annual Individual Work Planning: all IC staff are required to submit annual work plans and budgets associated with those work plans to the IC Director. QAQC activities are highlighted as part of work planning. The IC Director discusses the work plans with all staff members, identifies priorities, and approves the final individual work plans.
- Data Management Group: the Data Management Group meets every month to discuss IC activities around data management. These regular meetings allow for the coordination, prioritization, and planning of data-related activities managed by the IC. In addition, quality management issues can be discussed and solutions proposed as part of the quality improvement process.
- Quality Assurance Documents: the required annual review and updates of quality assurance documents such as QMPs and approved SOPs (managed by the Information Coordinator) ensure there is continuous planning and quality improvement associated with all aspects of the data management cycle.
- Project Management Systems: the IC uses the program Trello to plan the QAQC data workflow and track the process identifying who is responsible for what tasks, ensure tasks are completed, and to track changes and discrepancies in ABMI data.

5.8 Element 8: Quality Implementation of Work Processes

The implementation of a quality management system is as important as planning the QA system (GLNPO 2008). Details of the processes for implementing the IC's quality management system are discussed in the following sections.

5.8.1 Standard Operating Procedures

The main system of implementation for QA management activities is through the development and execution of SOPs. SOPs detail the operational tasks associated with each

step in the data management process. Table 5.2.1 provides a current list of SOPs that have been developed as part of the ABMI'S IC data management process, and more are in development.

The Information Coordinator ensures that all staff have access to relevant planning documents, such as SOPs. As discussed in Section 5.3, the Information Coordinator makes certain all IC personnel are trained in QA procedures, understand their specific roles and responsibilities, and that the QC activities as described in the SOPs are adhered to. The active engagement of staff in the QA planning process raises the awareness and understanding of the quality management system at the earliest stages of planning.

5.8.2 *Data Management Group*

The IC Data Management Group meets monthly to provide status updates on the data management cycle, and to respond to any issues that materialize during management activities. Action items are identified, and agenda items are added to the next meeting agenda to ensure any issues have been dealt with.

5.8.3 *Staff Training*

As discussed in Section 5.3, all staff within the IC are provided with appropriate training to ensure all staff involved in the data management process understand their roles and responsibilities with respect to the quality management system and implement the system as outlined in quality management documents (e.g., SOPs).

5.8.4 *Dispute Resolution*

Disagreements may occur during the implementation of quality management activities. Involved IC staff will attempt to resolve conflict through discussion and negotiation first. If a resolution cannot be reached among the involved parties, the IC Director will decide the final outcome.

5.9 Element 9: Quality Assessment and Response System

An assessment is defined as a "formal evaluation of performance relative to predetermined standards" (GLNPO 2008). Quality assessments must be conducted periodically to evaluate the effectiveness of a quality system in meeting its goals, and to implement corrective actions where necessary to improve performance (DWR 1998, GLNPO 2008). There are a number of assessment tools that may be used to evaluate the effectiveness of the IC's quality system and to improve performance such as (DWR 1998, GLNPO 2008): quality system audits and technical system audits; data quality audits; peer reviews; performance evaluations. The following is a description of the IC's quality assessment and response system.

5.9.1 *Quality System Audits and Technical System Audits (in development)*

Quality system audits (QSAs), or management system reviews, are on-site evaluations to determine if the IC is implementing an effective quality management program (GLNPO 2008).

QSAs may be performed internally and managed by the Information Coordinator, or they may be performed by parties external to the IC. QSAs will be developed to evaluate adherence to the quality management system, effectiveness of the system, and the availability of resources (i.e., personnel, time, budget) to meet quality objectives (GLNPO 2008). The IC QSA may include reviews of the following:

- adherence to the ABMI IC quality management plan;
- procedures for developing quality objectives and other acceptance criteria;
- procedures for developing and approving quality system documentation;
- the existence and quality of QA documentation and its conformance with the requirements of the QMP;
- procedures for developing and approving SOPs;
- procedures, criteria, and schedules for designing and conducting audits;
- tracking systems for ensuring that the quality management program is functional and operating and that corrective actions disclosed by audits have been taken;
- responsibilities and authorities of the IC Director, Information Coordinator, and IC staff for carrying out the quality system;
- the level of financial resources and personnel devoted to the implementation of the quality system.

5.9.2 *Performance Reviews*

Staff performance reviews are conducted on an annual basis.

5.9.3 *Quality Improvement*

One of the underlying philosophies of the IC's quality management system is that of continuous improvement. Many of the activities described in this QMP are included, in part, to facilitate continued improvement of data management in the IC. For example, monthly reporting, annual workplans, quality system training, and quality system audits all serve as mechanisms to identify areas that need improvement and provide opportunities to implement corrective measures. In particular, the transition of manually recording data to inputting data directly into tablets is one key mechanism implemented by the ABMI to reduce steps in the data management cycle and to reduce error.

5.10 Element 10: Commitment to Quality Improvement

The IC is fully committed to a process of continual improvement of our data management activities to produce and curate high-quality, well documented biodiversity information that is trusted by all users.

5.11 IC QMP References

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CHAPTER 6: SCIENCE CENTRE QMP

Approvals

Approved by: _____ _____

Science Centre Co-Director Date

Science Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	SC QMP created
2016-10-05	Katherine Maxcy, Corrina Copp	SC QMP updated following internal review.
2017-07-10	Katherine Maxcy, Ermias Azeria, Corrina Copp	SC QMP updated following internal review. Minor revisions made.
2020-03-30	Jenet Dooley, Ermias Azeria, Shannon White	Minor changes made. Updated organizational structure, references, documentation. Added data verification and validation section.

6 Science Centre Description

The ABMI Science Centre (SC) summarizes and synthesizes data collected by ABMI using science-based tools to support effective management of natural resources in Alberta. The primary responsibilities of the SC include the following:

- Developing and testing methods to ensure that consistent high-quality information is collected;
- Developing analyses and summary methods that produce clear and understandable measures of status and trend for biodiversity;
- Producing outputs that facilitate sustainable biodiversity planning and management in Alberta;
- Positioning the ABMI so that its scientific merit is respected throughout the scientific community;
- Managing delivery of all aspects of the SC.

This QMP outlines the SC's quality management system as it related to analysis and interpretation of ABMI data.

6.1 Element 1: Quality Management Policy, Goals, and Objectives

The goal of the SC Quality Management Plan (QMP) is to provide an overview of the Centre's guiding principles and practices in ensuring the development and dissemination of science-based information and decision support tools. The objective is to ensure that all information generated by the SC is scientifically credible, and the products are relevant and accessible to intended users.

6.1.1 *Quality Assurance Policy*

To fulfill this mandate, the quality assurance policy of the SC follows the ABMI's overarching criteria for all information and products which include:

- Objectivity: all information and tools generated by the SC are science-based, repeatable and transparent;
- Utility: the SC generates quality information relevant for effective decision making[3]; and
- Integrity: the SC maintains and assures the accuracy of its products over its production cycle (raw data acquisition, processing, and analysis) and provides supporting information (manuals, metadata, and presentations) to prevent unintentional changes and use of the information.

To meet these policy objectives, the SC has established the following quality management objectives (FREP Quality Assurance Working Group 2005, GLNPO 2008):

- Resources[4] – SC management will ensure there are adequate resources allocated to quality management. Resources which are essential to maintain and improve the quality of biodiversity information include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources;
- Ongoing activity - Quality management will be embedded in daily SC activities (e.g., Standard Operating Procedures [SOPs], internal review) creating an expectation of quality and excellence;
- Systematic planning – Through goal setting, action, and corrective activities, quality management activities will be systematically incorporated into all SC activities;

[3] Data quality is a critical aspect to an environmental monitoring program. However, data quality can only be determined by the context in which the data is used (Ferretti 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martín and Ballard 2010).
[4] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

- Quality system documentation – All quality management activities will have documentation to ensure users can evaluate the data relative to their own needs (Shampine 1993). This includes a QMP, approved by the Science Director, which describes how the SC will meet its quality objectives.

6.1.2 Organizational structure

All members of the SC are involved with data quality assurance and control (Figure 6.1.1). The specific tasks assigned to each member vary by project, taxon, and through time. In addition, all the researchers are engaged in the QAQC processes that pertain to Centre-wide data activities and information products, and to between Centre activities (e.g., providing feedback through communications with Geospatial Centre [GC], Processing Centre [PC] and Information Centre [IC]). The SC also engages with a variety of research collaborators and stakeholders who use SC information for their specific area of interest.

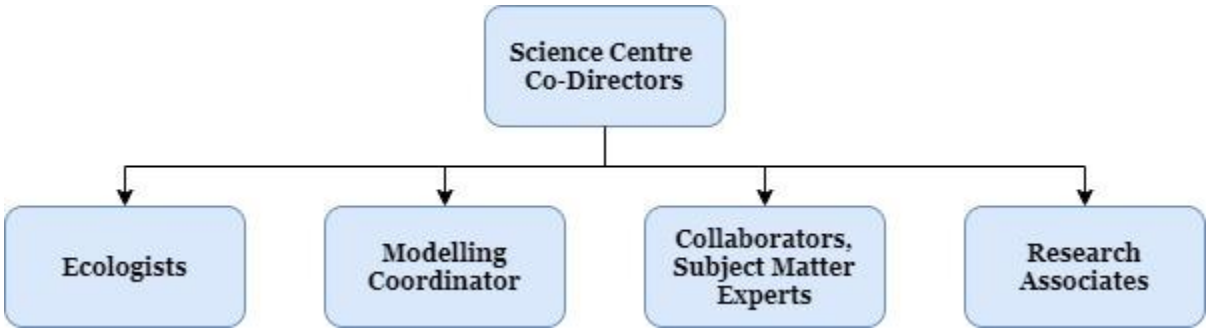

Figure 6.1.1. Organizational structure of the ABMI SC. All positions identified within the figure are involved with data quality.

6.1.3 Staff Roles, Responsibilities, Authorities, and Technical Activities

All technical activities undertaken by the SC are described in Table 6.1.1.

Table 6.1.1. Data tasks, staff responsibilities, technical activities, and quality tools used by the ABMI SC.

Data Task	Responsibility	Technical Activities	Quality System Tools Used	Notes
Evaluate change in human footprint (HF) over time	Multiple Ecologists	HF information for the 3 × 7s is compared among years	R-statistical package	

Summarize vegetation and HF into broad categories to support modelling and analyses	GIS Expert and Statistical Ecologist	Human footprint and vegetation are summarized at a variety of spatial scales around field sites, and for 1 km pixels throughout Alberta	ArcGIS and R-statistical package Unit tests[1] are used to test R package mefa4 regularly through continuous integration[2] procedures	Data sets are archived on the ABMI FTP server
Check ABMI species and habitat data for inconsistencies and summarize the data for modelling.	Multiple Ecologists	Data tables downloaded from the Oracle database are queried for inconsistency of species records	R-statistical package/Excel/Oracle	Identified issues are noted to respective Taxonomist at PC and corrections are implemented in the database accordingly
Model species distribution and habitat associations based on species, vegetation, and HF data. Predict species relative abundance throughout Alberta under reference and current conditions, differences between reference and current, and derive uncertainty in the predictions and generate excel and raster maps for dissemination. Combine information among species, habitats, and landscapes to create products that managers can use.	Multiple Ecologists	R-scripts are created to do the modelling and outputs for each species checked for any errors; Statistical tests of model performance are conducted to assess model calibration, reliability and discrimination	R-statistical package Cure4insect (Custom Reporting for Intactness and Sector Effects)	Scripts and compiled data are archived on the FTP server

Species Model Audit	Multiple ecologists; Experts on each taxonomic group	Model outputs including species-habitat association coefficients and prediction maps are assessed for their ecological sensibility by subject matter experts.	R-statistical package Excel	Experts send compiled information on the level of confidence of the model output of selected species. Results for species with erroneous patterns due to data deficiency or other limitations are noted and model outputs are not shared.

[1]Unit tests are meant to test the basic functionalities of software—if the software does not pass the test cases, source code is modified and tested again to ensure results are as error-free as possible. For more information see: (Sólymos 2009)

[2]Continuous integration is the practice of frequently integrating new code or changed code into the source code repository allowing programmers to immediately detect and correct small errors when the errors are easier to resolve.

6.2 Element 2: Quality System Components

The SC management of data quality is governed by a variety of documents and resources that provide clear and consistent guidance over the various activities and processes involved in the data analysis process; these components are described below.

- Quality Management Plan (QMP)
- SOPs
- Data and model documentation
- Data management tools and software
- Data verification and validation
- Unit test and integration of data
- Quality planning
- Professional development
- Contracts and grants with research collaborators

6.2.1 *Quality Management Plan*

The SC QMP describes the general processes that govern data management in the SC, including the policies and objectives and the technical and management activities required to

meet them. SC staff use the QMP on an ongoing basis to confirm that processes are being followed.

6.2.2 *Standard Operating Procedures*

The SC creates and maintains SOPs for data products created by SC staff (Table 6.2.1). Each SOP is updated as necessary when new data versions are released. Each SOP is reviewed and approved by the SC Co-Directors prior to release.

Table 6.2.1. List of SOPs and metadata produced by the ABMI SC.

Name	Brief Description	Last Updated
Alberta Backfilled Wall-to-Wall Vegetation Layer (Version6) Metadata (ABMI 2017)	This document provides metadata related to the Backfilled Wall-to-Wall Vegetation Layer created by ABMI. This GIS polygon layer includes information on six main landscape characteristics: 1. Vegetation Types, 2. Percentage of Pine, 3. Wetland Types and Moisture Regime, 4. Year of Origin (age), and 5. Soil Types.	June 02, 2017
Manual for Species Modeling and Intactness (ABMI 2015c), Version 2015-11-27	This document details the statistical methods used to produce models of the relationship of species and habitat elements to natural vegetation types, human footprint and climate and geographical gradients, and to derive current and reference conditions. In addition, the document outlines the index that the ABMI has developed to assess the intactness (or deviation from reference condition) for species, groups of species and habitat features. The methods presented here are continuously in revision, and updated versions of this document are released periodically.	April 14, 2016
ABMI Species Website Manual (ABMI 2017), Version 2017-03-23	This manual serves as background material for individual species results available from the ABMI. The document describes the content, methods, and limitations/caveats associated with species results.	March 23, 2017
Wetland – Spatial Data – GIS Processing for Wetland Habitat and Human Footprint (ABMI 2016)	This SOP describes the GIS processing for summarizing wetland habitat and HF data associated with the wetland spatial data. At each step, the location of the data, the responsible personnel, the task to be performed, and the process for error resolution are described.	May 12, 2016
Effective Mesh Size Layers Version 1.0 – Metadata (ABMI 2015a)	This document provides metadata for the Effective Mesh Size layers (Version 1.0) that were derived from the 2012 Wall-to-Wall Human Footprint Layer.	January 20, 2016
Wall-to-Wall Natural Cover Layers and Human Footprint Edge Buffer Layers (ABMI 2015b), Version 1.0 - Metadata	This document provides metadata related to the 2015 Edge Buffer Layer (Version 1.0) that ABMI created using the 2012 Wall-to-Wall Human Footprint Layer.	December 16, 2015
**Winter Snow Tracking – Spatial Data – GIS Processing* (ABMI 2014)	This SOP describes the GIS processing for summarizing HF data associated with the spatial mammal tracking data. At each step, the location of the data, the responsible personnel, the task to be performed, and the process for error resolution are described.	May 5, 2014
* Archived document		

6.2.3 *Data and Model Documentation*

Researchers in the SC publish technical reports or peer-reviewed publications that document data collection methods and modelling procedures (Table 6.2.2). The SC Researchers maintain interim documentation of active data or models in progress, including but not limited to model code and data processing and analysis code (e.g., R). The SC Researchers also use Git, which is a version control software, in conjunction with Github, which is a platform that hosts repositories of code and associated files. Code related to SC analyses and modeling is maintained on public repositories on Github, all within the ABbiodiversity organizational page[5] for easy accessibility and transparency. The major recurring analyses done by the SC (e.g., yearly reporting) are preserved and documented via Git, and the code base is accessible to multiple staff members.

Table 6.2.2. List of technical reports

Document Types	Reference
Field protocols	Terrestrial and wetland see protocols listed under Monitoring Centre QMP, Table 3.2.2.
Technical reports	Alberta Backfilled Wall-to-Wall Vegetation Layer (Version 6) Metadata.
	Manual for Species Modeling and Intactness (20029), Version 2016-04-14.
	Wetland – Spatial Data – GIS Processing for Wetland Habitat and Human Footprint.
	Winter Snow Tracking – Spatial Data – GIS Processing.
	Effective Mesh Size Layers Version 1.0 – Metadata.
	Wall-to-Wall Natural Cover Layers and Human Footprint Edge Buffer Layers Version 1.0 – Metadata.
	Sólymos, P. 2016. QPAD version 3 documentation. Technical Report, Boreal Avian Modelling Project, Edmonton, AB, Canada. pp 21.
	Sólymos, P., Mahon, C. L., Fontaine, T., and Bayne, E. M. (2015). Predictive models for estimating the cumulative effects of human development on migratory landbirds in the oil sands areas of Alberta. Technical report, Joint Oil Sands Monitoring: Cause-Effects Assessment of Oil Sands Activity on Migratory Landbirds, Edmonton, AB. pp. 38. Sólymos, P., J. D. Toms, S. M. Matsuoka, S. G. Cumming, N. K. S. Barker, W. E. Thogmartin, D. Stralberg, A. D. Crosby, F. V. Dénes, S. Haché, C. L. Mahon, F. K. A. Schmiegelow, and E. M. Bayne. (2020) Lessons learned from comparing spatially explicit models and the Partners in Flight approach to estimate population sizes of boreal birds in Alberta, Canada. Condor, 122(2): 1-22.
	Sólymos, P., Mahon, C. L., and Bayne, E. M. (2014). Development of predictive models for migratory landbirds and estimation of cumulative effects of human development in the oil sands areas of Alberta. Technical report, Joint Oil Sands Monitoring: Cause-Effects Assessment of Oil Sands Activity on Migratory Landbirds, Edmonton, AB. pp. 829.
R Packages	Cure4insect: R-package for Custom Reporting for Intactness and Sector Effects. The Cure4insect package is a decision support tool that enables custom reporting for probabilities of occurrence, intactness, and sector effects based on pre-processed or user defined landscapes. https://github.com/ABbiodiversity/cure4insect.

[5] Available here: https://abbiodiversity.github.io/

6.2.4 *Data Verification and Validation*

Data verification and quality assurance is a central component to the SC activities. Prior to analyses the SC implements several quality assurance procedures on the field and remote sensing data submitted by the GC, MC, PC, and IC. The data sets are inspected for taxonomic inconsistencies, outliers, and data entry errors. Potential inconsistencies, and errors, are flagged by the SC prior to analyses and they are discussed with the appropriate Centre. When the inconsistencies and errors are verified and solved, they are rectified and the data sets are updated by the appropriate Centre.

6.2.5 *Unit Tests/Continuous Integration*

The SC quality programming best practices includes the use of unit-testing to test functions in the statistical programming language R. In addition, R codes developed are continuously integrated into a repository (1.2.3 Data and Model Documentation). Continuous Integration is a development practice that requires developers to integrate code into a shared repository several times a day. Each check-in is then verified by an automated build, allowing teams to detect problems early.

6.2.6 *Professional Development*

The SC staff requires ongoing personal and professional development to ensure that it remains up to date in its field of expertise. Professional development is achieved by attending workshops and conferences and by working in collaboration with other staff and external researchers. In addition, the SC staff have ongoing access to peer-reviewed papers through the University of Alberta system. The SC staff present the outcomes of their work to other staff and external experts and researchers during bi-weekly and quarterly meetings. During these meetings, ideas are exchanged, analyses are validated, and results are reviewed and discussed.

6.2.7 *Contracts and Grants with Research Collaborators*

The SC enters into contracts and grants with research collaborators from other institutions. Expectations for deliverables for these collaborations are defined in the contracts. Deliverables are assessed against the contract specifications.

Relevant documents include the following:

- ABMI Agreement Template
- Contract for Services with Individuals or Small Businesses Template
- ABMI Grant Template

6.3 Element 3: Quality Training System

The SC ensures all staff are adequately trained to perform their assigned duties. This includes ensuring that candidates meet educational requirements (graduate degrees, certifications, diplomas, etc.), have demonstrated productivity and experience in the subject matter (peer-

reviewed publications, technical reports, etc.), and by checking professional recommendations. Staff are provided with the resources and other relevant material required to perform their duties. The SC Co-Directors ensure resources are available for staff members to participate in local and international conferences and workshops.

6.4 Element 4: Contractor Requirements

The SC procures data and services from a range of providers and collaborators. In all instances, the SC ensures the data and services are of a known and acceptable quality, and metadata are included. The SC follows the standard ABMI contracting procedures and contract templates; the "Description of Services" in each contract specifies the list of deliverables and the expected data quality.

6.5 Element 5: Documents and Records

The SC maintains technical documents, Standard Operating Procedures (SOP), and field protocols as the primary QAQC documents; management of these documents is described below.

6.5.1 *Document Preparation*

The ABMI SC Co-Directors or staff will identify the need for a particular SOP document. The SC Co-Directors will identify who will prepare a particular document; this is typically carried out by the SC staff that performs the specific activity.

6.5.2 *Documentation Reviews, Approvals, and Revisions*

Each SOP is updated as necessary when new data versions are released. Each SOP is reviewed by all the SC team and the final version is approved by the SC Co-Directors prior to release.

6.5.3 *Document/Record Control*

The SC Centre implements a documentation control system for SOP documents, which includes two main responsibilities: keeping an inventory of all SC SOP documents and assignment of a version number to all SOPs (see Table 6.2 and 6.3). The SC Data Management Committee (DMC) member is in charge of keeping the documents and records organized. A back up of the current SOP documents is also kept on the SC "S drive".

6.5.4 *Document Storage and Archival System*

The system of storing QAQC documents and model outputs, including current versions, old versions, and documents no longer in use, is managed by the SC DMC member. Documents are stored on the SC's Microsoft SharePoint. The system ensures only the most recent version of each record or SOP document is used. It also ensures old versions are archived properly and are accessible for historical review.

6.6 Element 6: Information Management

The SC uses data management tools and software to manipulate datasets, conduct analyses, and store the products of their analyses. Such tools and software include Oracle Database, ArcGIS, and R. The SC regularly updates the tools and software it uses to the most recent versions available.

6.6.1 *Computer Hardware and Software*

The SC relies on a range of software and computer languages for a variety of tasks:

- Databases: MS Access, Oracle, SQL, PostgreSQL
- Statistical Analysis: R Software for Statistical Computing, MS Excel, python
- Geographic Information Systems: ArcMap, Google Earth, QGIS
- Cloud Computing: Westgrid resources
- Version Control: Git with remote hosting on GitHub or Bitbucket

All SC researchers maintain up-to-date software installations. Because the analysis carried out by multiple ecologists are similar and must be coordinated among the researchers, all members are required to ensure the installation and updating of all the necessary packages as well as ensuring the scripts are in good order. Moreover, the SC ensures that high-performance computing hardware and data storage systems are available to the researchers to carry the data-intensive and high-level statistical computing tasks.

6.6.2 *Infrastructure Description*

6.6.2.1 Species Website (http://sc-dev.abmi.ca)

This website provides the outcomes of the SC analyses and resulting data products. More specifically, it provides information on spatial distribution, habitat associations, response to human footprint, and predicted relative abundance distribution for all species and groups of species assessed by the ABMI. The website provides information on Alberta's landscape condition and the geospatial information used in analyses. In addition, the links to relevant manuals, protocols, and metadata are provided on this website (Table 6.2). The SC updates the species website annually using the most current data available.

6.7 Element 7: Systematic Quality Assurance Planning

The SC activities are planned to meet ABMI's overall objectives of tracking changes in Alberta's wildlife and their habitats, and providing independent, ongoing, relevant, scientifically credible, and transparent information on Alberta's living resources. To fulfill the ABMI's mission the SC uses the following tools and/or activities to support quality management planning:

- Science Advisory Committee: provides high-level feedback to the ABMI Board about biodiversity monitoring and analyses;

- Operations and Management Teams: provide direction and feedback to the SC Co-Directors about monitoring and analyses methods, and how to position these to meet stakeholder needs;
- MC, PC, GC and IC: provide feedback to the SC about data collection protocols, information integration protocols, SOPs, and help to resolve issues as they arise;
- SC Team: holds bi-weekly teleconference calls and multiple face-to-face meetings each year to discuss and implement improvements to data collection, analyses, and reporting;
- Annual Work Plan for the SC: at the beginning of the fiscal year, a work plan is developed by the SC Co-Directors (in consultation with the ABMI Management Team) describing activities for the year;
- Annual Work Plans for each SC staff member, in consultation with the SC Co-Directors, creates an annual work plan to complete their portion of the identified SC tasks.

6.8 Element 8: Quality Implementation of Work Processes

The SC Co-Directors ensure that all applicable elements of the quality system are understood and implemented by:

- Creating and maintaining SOPs, or process documents, for regularly executed tasks;
- Developing metadata for data products created by the SC;
- Scheduling regular meetings to discuss data quality issues; and
- Participating in formal and informal peer-review of data products.

The SC staff are all responsible for ensuring that work is performed according to project work plans, that appropriate protocols are in use or being prepared as required for each project, and that staff are fulfilling their obligations under the executed contract or terms of employment. Annual work plans for each staff state their role in data quality management, including how much time they will allocate to work plans to ensure all project objectives, including data quality management tasks, have sufficient resources to be completed.

6.9 Element 9: Quality Assessment and Response System

The SC Co-Directors conduct regular reviews of the information products and tools generated by the Centre to ensure their quality and relevance for the intended users. All SC staff are involved in the technical review of interim and final products to ensure quality and adequacy of these. Moreover, the SC solicits reviews from other ABMI Centres and subject matter experts as required. The SC holds quarterly meetings where it shares its products and ongoing activities with staff from other Centres and collaborators for feedback. Expert reviews and recommendations are documented and, when required, corrective measures are implemented.

The main mechanisms of review of biodiversity information created by the SC, include:

- Internal review (i.e., within-SC);
- ABMI review (IC when report writing);
- External review;
- Peer review of scientific articles;
- Peer review of conference presentations;
- Review by Scientific Advisory Committee; and
- Species model audit by subject matter experts

6.10 Element 10: Commitment to Quality Improvement

All SC staff are required to participate in the quality assessment processes identified above through:

- Continual (internal) review of methods and SOPs;
- Updating previous analyses when new data and methods are available;
- Updating data sets to correct identified problems and to use new data or methods; and
- Incorporating feedback from peer-review and Advisory Committee.

SC staff members are all responsible for ensuring quality management and improvement of the data, methods used, and the analyses produced. One-on-one discussions and group meetings with SC staff and other Centres are frequently held to discuss problems as they occur. The appropriate corrective actions, and actions to prevent reoccurrence, are discussed and implemented. The SC staff that identified the issue is responsible to track corrective actions to closure.

6.11 SC QMP References

ABMI. 2014. Winter Snow Tracking – Spatial Data – GIS Processing. Standard Operating Procedure, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. 2015a. Effective Mesh Size Layers, Version 1.0 - Metadata. Metadata, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI. 2015b. Wall-to-Wall Natural Polygon Layers and Human Footprint Edge Buffer Layers, Version 1.0 - Metadata. Metadata, Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at abmi.ca.

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CHAPTER 7: GEOSPATIAL CENTRE QMP

Approvals

Approved by: _____ _____

Geospatial Centre Director Date

Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	GC QMP Created
2016-10-05	Katherine Maxcy, Cris Gray, Branko Hricko, Corrina Copp	GC QMP updated following internal review.
2017-07-14	Katherine Maxcy, Cris Gray, Branko Hricko, Corrina Copp	GC QMP updated following internal review. Minor revisions made.
2021-10-07	Cris Gray, Evan DeLancey, Jahan Kariyeva	Major changes made. Three program areas have been removed including the 3x7 Air Photo Interpretation program, Base Feature Updates, and Enhanced lakes due to discontinuation. Minor changes include updating references, organizational structure, and documentation.

7 Geospatial Centre Description

The ABMI Geospatial Centre (GC) develops and implements methods to monitor changes in habitat and human footprint. The Centre staff use aerial photography and satellite imagery coupled with machine learning and cloud computing to update or create GIS data and geospatial information products. The Centre currently produces and maintains three scale types of Geospatial products:

- Medium to coarse scale: wall-to-wall (W2W) and regional scale GIS layers describing Landcover (LC)/Vegetation (VEG) and Human Footprint (HF) throughout Alberta. Existing LC/VEG layers include W2W 2000 and 2010 VEG layers based on Landsat TM data; the composite Current Vegetation and Backfilled layers, which are used internally by the SC and updated as needed; layers produced by the ALPHA system, which uses machine learning to predict landcover status and dynamics across the province over time. Existing W2W HF layers include W2W 2007, 2010, 2012 HF layers, HFI 2010, HFI 2014, HFI 2015, HFI 2016, HFI 2017, HFI 2018; this product is updated annually starting from HFI 2014. Existing regional scale products include updated linear Base Features

for the Oil Sands Region and enhanced Human Footprint Inventory for the Oil Sands Region for 2018 and 2019 conditions.
- Sample-based scale: GIS inventory describing VEG and HF features for a grid of 3x7 km sample plots that cover approximately 5% of the province. These products are used by the Science Centre (SC) and Information Centre (IC) to report on the annual trend in habitat and human footprint change.
- Site-specific scale: GIS inventory describing HF in buffers around ABMI field sites. This information is used by the SC to determine how species sampled by ABMI vary among HF types. The resulting models are used to describe and map status and change in biodiversity.

The GC QMP outlines the GC quality management system as it pertains to these three product scales. For each product, the technical activities associated with each of the products are outlined below in Technical Activities.

7.1 Element 1: Quality Management Policy, Goals, and Objectives

7.1.1 *Quality Assurance Policy*

The GC is committed to the collection, generation, and distribution of high-quality geospatial information to the ABMI and the public. The Centre meets and follows the ABMI's threefold quality assurance policy (Objectivity; Utility; Integrity) in its daily activities. To fulfill this mandate, the following must be implemented when creating geospatial information and products:

- Quality management: developing and testing methods to ensure delivery of high-quality geospatial products; this includes goal setting, training, and corrective activities;
- Quality system and data documentation: creating Standard Operating Procedures (SOPs), data processing logs and metadata documentation for ABMI geospatial information and products;
- Geospatial product management: storing and managing delivery of all products to other ABMI Centres and the public;
- QAQC: Performing quality control and quality assurance on the information and products being delivered to the ABMI and the public.

7.1.2 *Organizational Structure*

Figure 7.1.1 represents the organizational structure of the GC and identifies QAQC responsibilities associated with each job title.

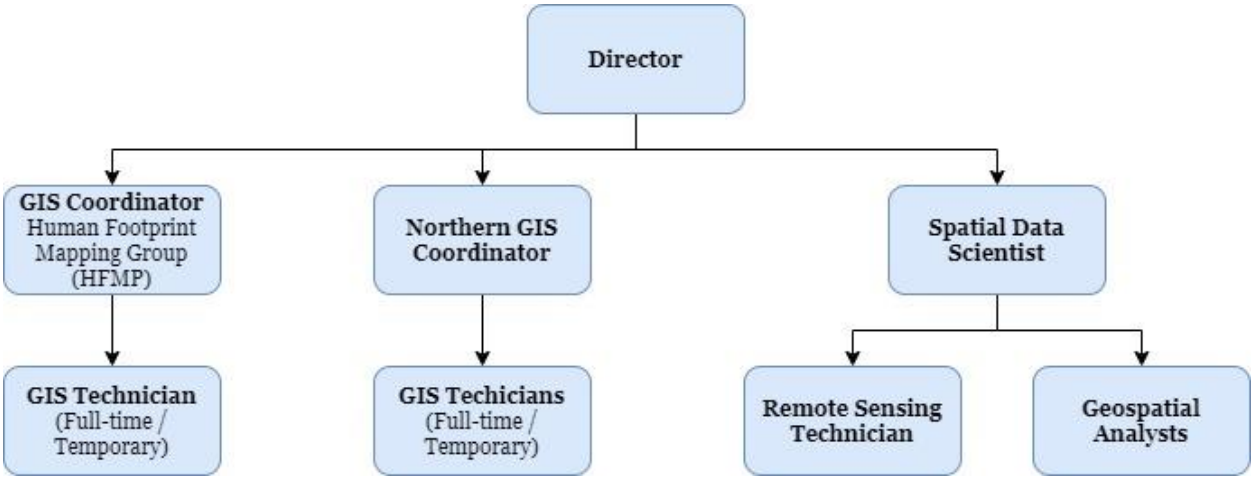

Figure 7.1.1. Geospatial Centre organizational structure.

7.1.3 *Staff Roles, Responsibilities, and Authorities*

Table 7.1.1 outlines staff roles, data tasks, and technical activities as they pertain to the quality management system. More detail is provided below.

Table 7.1.1. Staff roles, responsibilities, and authorities for the GC.

Responsibility	Data task	Technical Activities	Authority
GIS Coordinator - Human Footprint	HFI sample scale (3x7) annual update	Coordination of HF Mapping Group (HFMG) effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	HFI provincial scale annual update	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	HF on ABMI's wetland mapping	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	HF on ABMI's 1x1 terrestrial sample sites mapping	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
Northern GIS Coordinator	GIS/Geospatial Support	Coordination with GoA for receiving data and delivering final edits. Coordinate with BF techs who make the edits following GOA specs.	Northern GIS Coordinator
Spatial Data Scientist #1	Land cover mapping products	Process and download freely available satellite imagery.	Spatial Data Scientist #1

		Develop machine learning algorithms to predict land cover classes (ex. Wetlands, water bodies). R&D for new land cover mapping products.	
	Biodiversity Management Framework support	Calculate indicators for BMF needs. Provide support for mapping and developing new methods for indicator calculations.	Spatial Data Scientist 1
Geospatial Analyst 1	Land cover mapping products	Process and download freely available satellite imagery. Develop new land cover products for Alberta from LiDAR and freely available Digital Elevation Models (DEMs). R&D for future land cover mapping products.	Geospatial Analyst #1
Geospatial Analyst #2	Current vegetation and backfilled (reference) vegetation	Combine vegetation layers from a variety of sources to create the best possible vegetation layers (current and backfilled) for all of Alberta.	Geospatial Analyst #2
	Summary tables of vegetation and HF into broad categories to support modelling and analyses	Summarize human footprint and vegetation at a variety of spatial scales around field sites, and for 1 km pixels throughout Alberta	Geospatial Analyst #2
GIS/Remote Sensing Technician	Land cover Mapping products	Run work flows for DEM creation, seismic lines, and wetland classification. Data management for land cover mapping products.	Spatial Data Scientist
GIS Technicians - Human Footprint	HF 3x7 annual update	Data creation	GIS Coordinator of HFMG
	W2W HF mapping	Data creation	GIS Coordinator of HFMG
	HF on ABMI's wetland mapping	Data creation	GIS Coordinator of HFMG
	HF on ABMI's 1x1 terrestrial sample sites mapping	Data creation	GIS Coordinator of HFMG
GIS Technicians	GIS/Geospatial support	Data edits, creation, mapping	Northern GIS Coordinator

7.1.4 *Technical Activities*

The GC is responsible for six main geospatial products: HF products, current VEG and Backfilled products, and ALPHA Products. For each product, the technical activities associated with QAQC procedures are outlined below.

7.1.4.1 Human Footprint

The ABMI's provincial scale Human Footprint Inventory (HFI) is a complete representation of provincial scale anthropogenic footprint information for the province of Alberta. This comprehensive layer includes all the HF information related to the energy, forestry, and agriculture industries, as well as urban development. This product is updated annually.

The QA/QC responsibilities of the GIS Coordinator to produce the HFI include the following:

- to prepare training materials and to develop interpreting rules, methods, and strategies to ensure correctness and consistency of interpretation within HFMG members;
- to create user accounts at ArcSDE server for GIS Technicians so they are able to access and edit human footprint sublayers;
- to lead interpretation and update effort of the HFMG;
- to provide technical and interpretation support;
- to QC updated layers:
    - control of the correctness of interpretation (EPA, 2001a; GLNPO, 2008);
    - control of correctness of polygon delineation;
- to backup updated layers;
- to finalize sublayers for the final integration;
- sublayer dataset integration into final W2W geodatabase;
- QC of final dataset; and
- HF dataset delivery for upload to ABMI web page.

The QAQC responsibilities of GIS Technician include:

- to follow established interpretation procedure ABMI (2019a);
- to perform self-audits daily including the following QC procedures (ABMI 2015a, 2015b):
    - use document metadata to check for errors or inconsistencies of interpretation;
    - check for accuracy of digitization;
    - check for attribute value;
    - check for completeness of edited sites;
- to QC data collected by another GIS Technician when required;
- to provide feedback to GIS Coordinator, when further discussion is required.

7.1.4.2 Current vegetation and backfilled (reference) vegetation layers

The W2W vegetation layer is the result of the amalgamation of existing information on vegetation, habitat and soil throughout Alberta. The geodatabase includes information describing current vegetation based on a variety of sources and the ABMI 2016 Human Footprint layer. Information describing reference (i.e., pre-human disturbance) vegetation was created by removing human footprint from the landscape and adding the vegetation that was predicted to be present in the absence of HF (i.e., HF was "backfilled" to native vegetation).

The source layers of VEG used to create the integrated VEG layer include: Extended Alberta Vegetation Inventory (AVIE), Grassland Vegetation Inventory (GVI), Primary Land and Vegetation Inventory (PLVI), Central Parkland Vegetation Inventory (CPVI), Ecological Land Classifications layers for mountain national parks (MTNP), vegetation layers for Wood Buffalo National Park (WBNP) and Elk Island National Park (EINP) , Phase 1 (Broad Scale) Forest Inventory (Phase 1) , and the Alberta Wall-to-Wall Land Cover polygon vector layer created by the ABMI Remote Sensing Group (ABMI Land Cover)

The QAQC responsibilities of the GIS Analyst to produce the vegetation layers include the following:

- Acquire the last version of all known source layers and perform topology and attribute table checks,
- Look for new source of data that may improve the product,
- Combine layers and derive the proper information following the process described in the SOP and check results through visual inspection and summary table analysis,
- Work closely with the SC to ensure that the final product meets their needs for modelling and analysis,
- Participate in bi-weekly meeting with the SC to discuss progress, issues and solutions, and
- Update the SOP if new approaches are developed and validated by the SC.

7.1.4.3 ALPHA: Predictive Landcover products

The Advanced Landcover Prediction and Habitat Assessment-S (ALPHA-S; S for satellite) team uses open access Earth observation data and machine learning to map and monitor "natural" (non-human footprint) areas in Alberta. One of the ALPHA program's major products is the ABMI's wetland inventory. This product uses open access satellite imagery and Digital Elevation Models to map wetland class across most of Alberta at a 10 m resolution. The following QAQC procedures are used for Predictive Landcover classification:

- After image classification is completed, a comprehensive assessment of the classified outputs is performed using a combination of data sources by the ABMI's Geospatial Analysts. The data sources include the 3x7km photo-plot data, high resolution SPOT imagery, and existing government databases (such as the Alberta Merged Wetland Inventory);

- Examples of the measures for accuracy typically used include error matrix generation of classified outputs, calculation of accuracy indicators such as overall accuracy, producer's accuracy, user's accuracy, kappa statistics, performing tests for significant differences in classification results etc.; and
- The process of accuracy validation is further extended by performing an internal and external peer review process by earth observation experts and end-users representing key stakeholders.

After the peer review process is completed, a final technical report and metadata documentation are produced and uploaded on the ABMI data portal website for public access.

7.2 Element 2: Quality System Components

The GC must implement a quality management system which ensures ABMI GIS data and data products meet quality management policies and objectives. The GC staff use the following quality management practices and tools to implement its quality system, including (EPA 2001, GLNPO 2008):

- Quality system documentation;
- SOPs;
- Training;
- Annual review and work planning; and
- Hardware and software with built-in checks and verification rules.

For the six main activities of the GC described in Section 1.1.4 (Technical Activities), the GC staff use several tools to implement its quality management system. The following section provides a summary of the components of the quality management system that apply to these three activities.

7.2.1 *Quality System Documentation*

The GC is required to have written and approved quality system documentation (e.g., QMP, SOPs, manuals) which provides details of the GIS QA program. At a minimum, all QA documentation must be reviewed and approved by the Group Leads, with final approval by the GC Director. Approvals by domain experts and/or external reviewers are encouraged, and in many instances, also necessary. All QA documentation is filed by individual Group Leads who are also responsible for version control and archiving documents.

7.2.1.1 Human Footprint

The GC uses the following documents to ensure a high-quality HF product is being created:

- Standard Operating Procedures Human Footprint 3x7 (ABMI 2015a);
- Standard Operating Procedures Human Footprint – wall to wall (ABMI 2015b);

- Standard Operating Procedures Wetlands – Spatial Data – GIS Processing for Human Footprint (ABMI 2016);
- Human Footprint Interpretation Key (ABMI 2019); and
- Standard Operating Procedures – Human Footprint Inventory Metadata (ABMI 2017a).

7.2.1.2 Training Documentation

The Human Footprint Interpretation Key is the standard document for HF interpretation. The Human Footprint Interpretation Key is a peer reviewed document containing:

- terrestrial photos of HF types;
- aerial photos of HF types;
- satellite scene snapshots of HF types;
- visual elements of interpreted HF features on satellite imagery, including: color, structure, texture, shape, size, pattern, shadows; and
- interpretation rules.

7.2.1.3 Current Vegetation and Backfilled (reference) Vegetation Layers

The GIS Analyst uses the following document as reference for maintenance, update and QA/QC of the backfilled vegetation layer

- Alberta Wall-to-Wall Vegetation Layer Including "Backfilled" Vegetation in Human Footprints (Version 6) Document (ABMI 2017b).

This document is annually updated to reflect any changes in data source, approach, methodology or implementation.

7.2.1.4 ALPHA System Products

The GC employs the use of the following documents and peer reviewed publications to ensure high-quality ALPHA system products are created:

- ABMI Wetland Inventory Metadata (ABMI 2021)
- Large scale wetland mapping (Hird et al. 2017)
- Wetland mapping and deep learning in *Remote Sensing* (DeLancey et al. 2020)
- Large scale peatland mapping in *PLOS One* (DeLancey et al. 2019b)
- Surface water detection with RADARSAT-2 in *Canadian Journal of Remote Sensing* (DeLancey et al. 2019a)

Upon completion of all ALPHA products an internal/external peer review process is conducted. This entails sending out the technical/metadata documents and ALPHA system products to subject matter experts for comments and inputs. Most of the external peer review experts include stakeholders at the GOA, industry, and academia. The feedback is provided to the Spatial Data Scientist for implementation, and approval is made by the Team lead.

All metadata, technical documents, and peer reviewed publications are regularly updated for each version of the APLHA product generated. The metadata documentation provides the following: background information of the product, method used, results obtained, terms of use, and references consulted or cited on the project. Examples of ALPHA metadata are the ABMI Wetland Inventory Metadata and related publication (DeLancey et al. 2020, ABMI 2021).

7.2.2 *Standard Operating Procedures*

The GC uses a series of SOPs to achieve overall data quality goals and objectives (Table 7.2.1). These SOPs are not only critical to ensure that data processing activities are performed correctly and consistently, but also provide the basis for staff training programs. The series of SOPs produced and maintained by the GC provides a systematic approach to verify and document that ABMI GIS data and data products are consistent, complete, and of known acceptable quality.

SOPs may be developed collaboratively, particularly for procedures with complex workflows. SOPs are written by each Team Lead, who also oversees their development and implementation. All SOPs are reviewed and approved by the GC Director. External reviews are conducted where necessary at the discretion of the GC Director. See Table 7.2.1 for a list of SOPs currently maintained by the GC.

Table 7.2.1. List of SOPs developed for GIS data products produced by the GC.

SOP Title	SOP Number	Centre Responsible	Date
Human Footprint wall to wall (ABMI 2015b)	ABMI_GC_HG_w2w_SOP	GC	2015
Human Footprint 3x7 (ABMI 2015a)	ABMI_GC_HF3x7_SOP	GC	2015
Wetlands-Spatial Data-GIS Processing for Human Footprint (ABMI 2016)	ABMI-SC-SOP-003	SC	2016
HFI2018 – Metadata (ABMI 2020)	Report	GC	2020
Alberta Backfilled Wall-to-Wall Vegetation Layer (Version6) Metadata (ABMI 2017b)	Report	SC	2017

7.3 Element 3: Quality Training System

Personnel qualifications and training requirements for each of the three main GIS activities associated with the GC are presented in the following sections.

7.3.1 *Human Footprint*

7.3.1.1 Training Policy

It is required that all personnel involved in human footprint mapping are fully capable of:

- efficient use of GIS software; and
- correct and consistent interpretation of HF types.

7.3.1.2 Training Processes

The GIS Coordinator is responsible for providing comprehensive training of interpretation rules for GIS Technicians.

Training consists of:

1. reviewing existing data layers as an example of previous interpretations;
2. learning about HF categories and types based on: terrestrial photos, aerial photos, satellite scene snapshots;
3. reviewing all visual elements of interpreted HF features: color, structure, texture, shape, size, pattern, shadows;
4. learning all interpretation rules associated with HF types;
5. hands-on interpretation of HF types using the training dataset; and
6. assessment of hands-on interpretation on the training dataset.

Results are verified by the GIS Coordinator, and GIS Technicians as necessary using:

- terrestrial photographs of interpreted HF types;
- notes; and
- Unmanned Aerial Vehicle (UAV) photographs of interpreted HF types when possible.

After completion of HF mapping training GIS Technicians are able to:

- understand existing data layers including: data sources, data structures, list of attributes;
- understand available imagery sources, including: source, spatial resolution, and horizontal accuracy of the imagery;
- recognize and distinguish different HF categories;
- create new HF polygons with correct attributes;
- create logs and records required to maintain consistent HF database.

7.3.2 *Current Vegetation and Backfilled (reference) Vegetation Layers*

The GIS Analyst must have advanced knowledge of

- The data sources used for the backfilled layer,
- GIS software,
- Topology Validation processes,
- Python programming language,
- Workflow design, and
- Attribute data manipulation either in Python or R.

The GIS analyst will use all opportunities to improve his/her skills and knowledge using GC resources.

7.3.3 *ALPHA system products*

The personnel hired to work on the ALPHA products are experts in remote sensing and GIS applications. A good understanding of remote sensing basics and application are important. Examples of such are satellite image classification (pixel based and object-based classification), accuracy assessments, machine learning development using open-source tools (such as R, Google Earth Engine, Tensor Flow), satellite image pre-processing, and LiDAR data processing. Additional skill sets needed for this role are technical report writing, performing R&D related tasks, and GIS data manipulation using ESRI'S ArcGIS products. On the job staff training is provided by working closely with staff that have capacity in the diverse fields required. The analysis and generation of radar, optical, or topographic input variables needed for image classification experiments are vital to the production of geospatial products provided by the GC. Other forms of capacity building include technical workshop and conference attendance, taking online courses, and external hands-on training in fields related to earth observation and data science.

7.4 Element 4: Contractor Requirements

Contractors are used to audit 3x7 air photo interpretation layers for accuracy and consistency. Contractors must:

- have appropriate levels of certification, experience, and skill sets;
- be referred by the GOA and other vendors;
- respond to Requests for Proposals (RFP) which requires corporate resumes, certifications, and identification of desired skill sets.

7.5 Element 5: Documents and Records

Metadata and SOP documents are updated annually, and when a new version of a dataset (e.g., Human Footprint 2012, HFI 2014, HFI 2015, HFI 2016, HFI 2017, HFI 2018) is released publicly.

The Human Footprint progress report is a sub table incorporated into ArcSDE data structure. The progress report is continuously updated by GIS Technicians as they finish a task and by the GIS Coordinator when QC is performed.

Base Feature update records are kept of the progress of each edited NTS block, but as GOA makes final changes and incorporates the data into the provincial data set, no other records are kept. Instructional documentation was provided by the Government of Alberta and has not changed since the project began.

7.6 Element 6: Information Management

The GC uses ESRI ArcGIS (version 10.1 – 10.7.1) to process and create GIS products. ArcServer (version -, 10.5.1, 10.7.1) is used for data storage. The 3x7 Air Photo Interpretation group also uses Datem (version 7.0). Both software types are the industry standards and enable collaboration with GOA.

7.7 Element 7: Systematic Quality Assurance Planning

Within the GC, annual work planning is performed for each group as to which geographical areas are going to be worked on for the coming term.

Within each group, the QAQC performed each time is the same for each geographical area dependent on the specific projects.

7.7.1 *Human Footprint*

Progress/status meetings are held on a biweekly basis to identify digitization and data creation issues and discuss progress updates with the data capture process. All new findings, including incorrect interpretation, omissions, errors in topology, are documented and correct interpretation is discussed. Accuracy measures – scheduled topology checks, increased frequency of cross validation, are implemented into the interpretation if uncertainty in the existing interpretation occurs.

7.7.2 *Current Vegetation and Backfilled (reference) Vegetation Layers*

Weekly or biweekly update meetings with the SC are organized to discuss progress, issues and solutions and to ensure that the final products meet their needs for modelling and analysis.

7.7.3 *ALPHA System Products*

The ALPHA Technical meetings are held on a weekly basis to monitor and incorporate changes to data analysis techniques used in the production of ALPHA system products. The steps used and results obtained are reviewed at the meetings and a common consensus on the way(s) forward agreed upon.

In addition to the ALPHA technical meeting, a GC Team Leads meeting comprising all leads in the GC is performed monthly. During the GC Team Leads meetings issues relating to each component of the GC are discussed and plans are agreed to regarding technical and administrative matters.

7.8 Element 8: Quality Implementation of Work Processes

A description of the implementation of the quality management system for each of the six main activities associated with the GC follows.

7.8.1 *Human Footprint*

HF work processes are detailed in Table 7.8.1.

Table 7.8.1. Human Footprint work processes.

Step 1. Satellite Imagery
• ArcSDE mosaic database containing SPOT imagery is created on geospatial server by GIS Coordinator. • GIS Coordinator creates accounts for GIS Technicians within ArcSDE database to allow access. • GIS Coordinator instructs GIS Technicians how to connect into ArcSDE containing SPOT imagery.
Step 2. Data preparation
• Base layer for current year update is created on ArcSDE server by importing of the last year 3x7 dataset into new database by GIS Coordinator. • ArcSDE database containing all previous year datasets (1999 to the latest minus one). • GIS Coordinator creates accounts for GIS Technicians within ArcSDE database to allow access and editing. • GIS Coordinator instructs GIS Technicians how to connect into ArcSDE databases containing both current and previous years' 3x7 datasets.
Step 3. ArcGIS workstation setup

• Imagery:
  ○ Historical orthophoto mosaic SDE (1949-1963)
  ○ Historical orthophoto mosaic SDE (circa 1980s)
  ○ Valtus orthorectified aerial photomosaic (1999-2003)
  ○ IRS satellite imagery GDBs (2001-2004)
  ○ SPOT5 satellite imagery GDBs (2005-2012)
  ○ SPOT6 satellite imagery SDEs (2013-2020)
  ○ Valtus Views ArcServer online mosaic of orthorectified aerial photomosaic
• Datasets:
  ○ current 3x7 dataset - ArcSDE
  ○ previous years 3x7 dataset - ArcSDE
  ○ ABMI site boundaries - ArcSDE
  ○ temporary centre lines layer – ArcSDE

Step 4. Editing feature updates

• Set the working scale to 1:5,000
• Delete the HF from the reference map if it disappears from the satellite imagery following these rules:
  ○ former HF no longer recognizable on Imagery sources:
  ▪ no visual difference detected between area of former HF and its surrounding areas (no difference in visual elements of: color, structure, texture, shape, size, pattern, shadows)

- this must be confirmed on at least five imagery sources dating back from the current mosaic
- Add new HF(s) to the layer if new HF(s) is/are found following these rules:
  - if new HF feature is adjacent to existing HF polygon, TRACE tool must be used to create new feature on places where boundaries are shared by both polygons.
  - if new HF feature is overlaid on existing polygon, CLIP tool must be used to avoid creation of overlapped polygons (e.g., new road on top of agriculture).
- Edit the HF feature if situation on the landscape has been changed.
- Correct the HF feature if interpretation errors are found for the current 3x7 dataset.
- Correct the human footprint feature if interpretation errors are found for the previous year 3x7 datasets.
- Digitize centreline of linear features and measure average width of HF.
- Create polygon feature by buffering (use half of the width value) of centrelines.
- Copy and paste buffered polygon from temporary centreline layer into current 3x7 layer.

7.8.2 *Current Vegetation and Backfilled (reference) Vegetation Layers*

- Using Alberta Backfilled Wall-to-Wall Vegetation Layer (Version6) Metadata (ABMI 2017f) as reference,
- Implementing workflows described in reference document using Python scripts to facilitate QC process,
- Checking intermediate or final layers (topology validation, visual validation, attribute table validation),
- Documenting meeting minutes with SC and requested changes in approach or methodology,
- Developing action items list based on meeting minutes,
- Following up on action items,
- Maintaining interaction with the SC, and
- Developing documentation and/or updating the reference document after changes have been approved by the SC.

7.8.3 *ALPHA System Products*

The generic work process for developing ALPHA system products is as follows:

- Step 1: Define project aim and objectives – this includes performing extensive literature review of existing scientific approaches that could be relevant to the project in question.
- Step 2: Input data preparation – this entails determining the type of satellite data required; the spectral, spatial, and temporal resolutions of input data needed; availability of training and validation data for image classification and accuracy assessment respectively; and results presentation approach.
- Step 3: Define workflow or methodology for project implementation – this involves defining the steps taken to implement the project. This includes R&D related activities to establish the right approach for generating geospatial products.

- **Step 4:** Prepare metadata and technical documentation of ALPHA system
- **Step 5:** Internal and external peer review process – the generated products and documents are sent out to subject matter experts and stakeholders at the GOA, academia, and industry for review and comments. All comments are taken into consideration before being made available to the public. This is an important QC process that validates the products as this takes into consideration valuable input from key stakeholders and potential end users.

7.9 Element 9: Quality Assessment and Response System

Technical Assessments are evaluation processes focused on specific technical practices and procedures, such as data checking. The purpose is to measure the performance or effectiveness of technical systems and their elements (with respect to documented specifications and objectives). The following is a summary of the assessment system used by the GC.

7.9.1 *Human Footprint*

During the creation of the HF dataset, there are several assessment tools in place to identify and correct errors as detailed in Table 7.9.1.

Table 7.9.1. Quality control process applied during creation of HF dataset

Self-assessment tools	QC process
Self-audit (Daily)	• use document metadata to check for errors or inconsistencies of interpretation • check for accuracy of digitization • check for attribute value • check for completeness of edited sites
Peer audit (Weekly)	• randomly select 10% of the sites edited in the previous week • Check all items as in QA self-audit
GIS Coordinator Check – Topology	• Topology Rules: Must Not Overlap • Error Inspector: To find errors for all rules • Fixes: Clip/Merge if there is an overlap • Fixes: Delete if smaller than cluster tolerance
GIS Coordinator Check – (Weekly)	• overall QC on randomly selected 10% of the sites edited in the previous week • report back to GIS Technicians when corrections are needed • report back to entire HFMG if interpretation trends need to be corrected

GIS Coordinator Check – (Final)	• overall QC on the rest of sites that have not been QC-ed yet • QC of corrected features to ensure corrective action was taken

GIS Professional outside of HFMG – (Audit)	• randomly selected 10% of ABMI sites to be QC-ed by professional outside of HFMG
	• **Geometry check** – quality of digitization is QC-ed:
	• Quality Categories:
	  ○ acceptable
	  ○ acceptable with modification
	  ○ not acceptable
	• **Attribution check** – quality of digitization is QC-ed:
	• Quality Categories:
	  ○ acceptable
	  ○ not acceptable
	
	Both checks – geometry and attribution, must have 80% features in acceptable categories for final geodatabase to pass the audit. Audit results are used to make corrections on audited features and also applied to entire sample group.

7.9.2 *Current Vegetation and Backfilled (reference) Vegetation Layers*

7.9.2.1 Self-Audit

- Visual inspection of layers,
- Topology check (ARCGIS) topology validation process,
- Check workflow and Python script for errors, and
- Check attribute tables using R scripts.

7.9.2.2 SC Audit

The final product is used by the SC for statistical analysis and modelling. Issues in their results that could be linked to the creation of the product itself are reported to the GC.

7.9.2.3 Response System

Any issue is assessed by the GC with the help of the SC if needed. The assessment consists of:

- Identifying the source of the issue,
- Quantifying the impact of the issue on the product, and
- Finding the best solution to deal with the issue.

If the issue cannot be corrected in the final product, for example an issue inherent to the source data, it will be described in the SOP as a known limitation of the product.

If the issue can be corrected, the proper solution is applied. If the solution involves a change in the approach or workflow, the SOP will be updated to reflect that change.

7.9.3 *ALPHA System Products*

The Geospatial Analysts use the following tools/approaches to ensure the ALPHA system products are accurate and devoid of errors:

- Accuracy assessment procedure: using independent validation datasets (such as the 3x7 photo plot data or external government approved dataset like the Alberta Merged Wetland Inventory) the accuracy of classified images are performed. It is important to ensure that the input data used for image classification or developing the model for landcover discrimination is independent of the data used for assessing the accuracy. In every technical document produced, a section on how the accuracy was assessed is included for end-users
- Technical review meeting: these meetings are important in establishing the adoption of methodologies used per project. Once the method has been reviewed and approved during the technical meetings, it's then implemented and geospatial products generated.
- External and internal peer review: once completed, technical documents and the data are sent out for subject matter peer review by internal and external stakeholders. This review process allows for a high-quality product that's been validated by key stakeholders and potential end-users.

7.10 Element 10: Commitment to Quality Improvement

The GC is responsible for producing datasets that are both continuous and require a lot of time to produce. Further, the GC is committed to the continual improvement of the GIS products being produced. Though the core product remains the same, procedures are constantly updated based on improvements with software, better imagery and error catching methods.

7.10.1 *Human Footprint*

The HFMG is committed to the continual improvement of GIS HF products through the implementation of processes such as status meetings, training, and audits, and through work and external audits with the Technical Team members of the Alberta Human Footprint Monitoring Program.

7.10.2 *Current Vegetation and Backfilled (reference) Vegetation Layers*

We are committed to:

- using the best and most up-to-date data source for this layer,
- improving the creation process of the product in collaboration with the SC,
- improving the QA/QC process, and
- updating documentation.

7.10.3 ALPHA System Products

The GC strives to improve the quality of all ALPHA system products by taking into account inputs and comments from subject matter experts through technical meetings and peer review activities. In addition, the team is constantly reviewing existing and emerging technological advancements to better improve the ALPHA system product quality.

7.11 GC QMP References

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CHAPTER 8: APPLICATION CENTRE QMP

Approvals

Approved by: _____ _____
Application Centre Co-Director Date

Approved by: _____ _____
Application Centre Co-Director Date

Centre QMP Revision History Log

Revision Date	Author	Changes
2016-04-01	Katherine Maxcy	AC QMP created
2016-10-05	Katherine Maxcy, Monica Kohler, Tom Habib, Corrina Copp	AC QMP updated following internal review.
2017-11-20	Katherine Maxcy, Monica Kohler, Tom Habib, Corrina Copp	AC QMP updated following internal review. Minor revisions made.
2021-11-05	Monica Kohler, Erin Bayne	Major changes made. Incorporated the Bioacoustic Unit back into the AC QMP. Updated organizational structure, references, staff roles, and documentation.

8 Application Centre Overview

The ABMI has monitored terrestrial and wetland ecosystems across the province for more than a decade; this has resulted in a massive biodiversity database, reliable measurement protocols, and innovative ways to summarize complex ecological information. While these data have enormous value to environmental managers and land-use decision makers, through the Application Centre's (AC) mandate of applying monitoring data to specific management issues, the ABMI has extended its relevance beyond the core business of measuring and reporting on the state of biodiversity. The AC operates a number of initiatives and projects that apply biodiversity, human footprint, and other data, and leverages the ABMI's scientific and institutional capacity to aid researchers, land-use decision-makers, and Indigenous communities in pursuing biodiversity questions. This work is achieved by leveraging the ABMI's scientific and institutional capacity and through collaborative efforts with partner organizations and researchers.

There is a great diversity of both current and historical initiatives within the AC with varying levels of independence versus integration with other ABMI Centres. Many AC initiatives implement all phases of the data management cycle— separate from the ABMI data cycle— through the delivery of applied research projects. These projects can include project design, data collection and management, data analysis and modelling, and reporting for applied research projects.

The AC Quality Management Plan (QMP) provides an overview of AC practices that ensure the data and data products produced through AC activities can be appropriately interpreted and used by others to support further research and decision-making with a known level of certainty. Wherever data activities align with the core ABMI program, standard ABMI data quality management practices are implemented; all other AC data activities are governed by the present QMP document.

The AC QMP outlines the roles, responsibilities, resources, and procedures that govern data quality management in the AC. The QMP will be reviewed annually under the leadership of the AC Director. Ongoing initiatives for improving data quality management in the AC are focused on ensuring adequate resources for data storage and developing a procedure for archiving completed projects.

8.1 Element 1: Quality Assurance Policies, Goals, and Objectives

8.1.1 Quality Assurance Policy

Following other ABMI Centres, the AC adheres to a threefold quality assurance policy:

1. Objectivity: all AC data and data products are to be presented in an accurate, understandable, clear, and unbiased manner.
2. Utility: the AC provides quality data and information for intended use.[6]
3. Integrity: until released to the public, all AC data and information are protected from unauthorized access to ensure they are not corrupted or falsified.

To meet these policy objectives, the AC has established the following quality management objectives (FREP 2005; GLNPO 2008):

- Resources[7]: AC management will ensure there are adequate resources allocated to quality management. Essential resources for maintaining and improving the quality of biodiversity information and research products include: appropriate staffing and

[6] Data quality is a critical aspect of an environmental monitoring program. However, data quality can only be determined by the context in which the data are used (Ferretti 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martín and Ballard 2010).

[7] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources.

- Ongoing activity: Quality management will be embedded in daily AC activities (e.g., training, Standard Operating Procedures [SOPs], scientific peer review), creating an expectation of quality and excellence.
- Systematic planning: Quality management activities will be systematically incorporated into all AC activities, and monitored and planned as a standing agenda item in regular AC meetings.
- Quality system documentation: All quality management activities will have documentation to ensure users can evaluate the data relative to their own needs (Shampine 1993). This includes a QMP, approved by the AC Director, which describes how the AC will meet its quality objectives.
- Data Management Committee: The AC participates in the ABMI-wide Data Management Committee, which is responsible for ensuring proper data organization, management, and delivery across the ABMI.
- Cost effectiveness: Quality management activities will be implemented as cost effectively as possible without compromising data quality (DWR (Department of Water Resources) 1998).

8.1.2 *Organizational Structure*

All members of the AC team play a role in QAQC activities, with responsibilities determined by the needs of the particular initiative or project, rather than a single, centre-wide data workflow (see Figure 8.1.1 describing the AC organizational structure). The AC also engages with a variety of collaborators who use ABMI data products or generate new data related to specific research projects. These Research Collaborators are often actively involved in data QAQC, depending on their contributions to specific data activities (Table 8.1), and their projects are governed by contracts or grant agreements (see below).

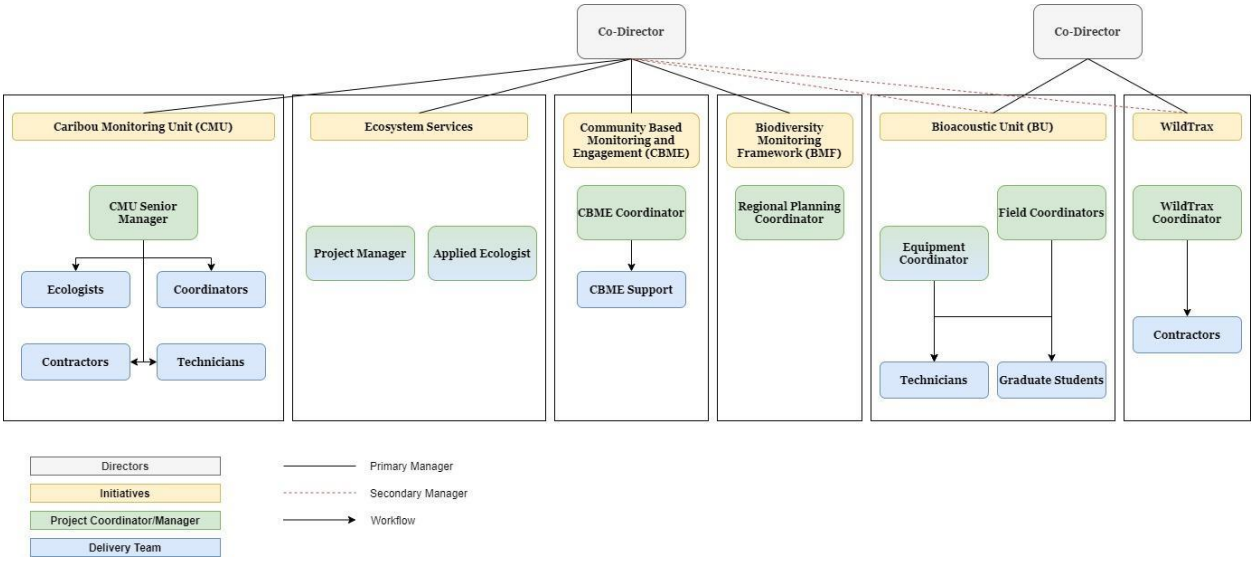

Figure 8.1.1. Application Centre organizational structure.

8.1.2.1 WildTrax – Operations and Business Development

WildTrax operations and business development are jointly delivered by the Information and Application Centres. For more information, please see Chapter 10: WildTrax QMP.

8.1.2.2 Caribou Monitoring Unit (CMU)

The CMU has been operational since approximately 2014. Its focus is on research and development to build tools for informed Woodland Caribou management and recovery. It operates a number of field and analysis-based projects across western and northern Canada.

8.1.2.3 Community-Based Monitoring and Engagement

The AC operates a Community-based Monitoring and Engagement (CBME) initiative that builds connections and collaborative projects with Indigenous communities in Alberta and other areas of Canada. This includes delivering knowledge exchange events, facilitating access to information, coordinating training sessions and collaborative field work, and developing Indigenous-focused biodiversity content.

8.1.2.4 Biodiversity Management Framework

The Biodiversity Management Framework (BMF) is a provincial initiative led by Alberta Environment and Parks (AEP) that is developing biodiversity indicators as part of the provincial Land Use Framework. The AC provides coordination and project management services to the BMF Science Technical Committee on ongoing indicator refinement and development.

8.1.2.5 Ecosystem Services

The AC has operated a suite of projects related to ecosystem services since 2012, including a three-year Ecosystem Services Assessment project, an ongoing project on Beef and Biodiversity, and currently a Grasslands Pilot project to support advancement of market exchanges for ecosystem services. Many of these projects have focused on advancing the science for scoring and tracking biodiversity and other ecosystem service credits for potential use in ecosystem service markets.

8.1.2.6 The Bioacoustic Unit

The BU was established in 2015 as a collaborative initiative between the ABMI and the Bayne Lab in the Department of Biological Sciences at the University of Alberta; the AC is currently leading the ABMI's participation in the BU (Figure 8.1.1). The BU collects, analyzes, and reports on data collected on acoustic wildlife (such as birds and amphibians) across Canada. It is the authority on best practices for using acoustic technology in the province, and offers a range of services to support the application of acoustic technology by the ABMI and other organizations. Chapter 9.0 of the ABMI QMP outlines the BU's quality management activities.

8.1.3 *Staff Roles, Responsibilities, and Authorities*

Table 8.1.1. The data tasks and associated quality management activities for current AC projects, and the responsibilities of AC personnel.

Personnel	Data Task	Technical Activities	Responsibility
Project Managers	Manage contractor services	Manage data-related contractor services, including setting data quality standards.	Approves contractor services
	Manage technical contributions of contractors and collaborators	Develop work plan/deliverables; monitor progress; review invoices/deliverables to ensure they meet data quality objectives set out in grant or contract agreements.	Recommends approval of deliverables and invoices to AC Directors
All AC members	Data storage & back up	Regularly-scheduled (weekly) data back-ups to ABMI server.	Completes update weekly
	Processing ABMI GIS data	Process or combine ABMI layers using ArcGIS or R for project-specific analyses and develop metadata.	Complete data processing and associated metadata
	Production of technical reports and papers	End products of data analysis; external expert review.	Submits completed report with metadata to ABMI Publications Archive

	Use of external data	Review and evaluate standards provided for externally created datasets.	Confirms data for use in applied research projects
Applied Ecologist	Modelling and analysis	Use external and internal data sources to model various ES, write code documentation, publish methods in peer-reviewed journal.	Manages external data sources
WildTrax Coordinator	Data transfer and security	Download data from ARUs and update database; ensure adequate back-ups.	Confirms completion of database and back-ups
	Processing audio data (human listeners)	Identify bird & amphibian species from sound files and confirm IDs.	Confirms completion of identifications
	Contract management	Check and approve invoices for audio processing to confirm accuracy.	Approves contractor invoices
	Processing audio data (computer recognizer)	Identify bird & amphibian species from sound files with computer recognizers; QAQC with human verification.	Confirms completion of identifications
	Data QAQC	Check for missing files; correct file names; flag corrupt files; confirm file data matches expectations based on deployment/retrieval data sheets.	Confirms completion of QAQC
	Data export to researchers/ABMI	Export tabular data and associated metadata to end-users.	Confirms data for release
	Protocol Developments and Revisions	Creates new protocols for all aspects of BU workflow; Updates existing protocols as required; posts protocols to website for public use.	Ensures that protocols are up to date and correct
Caribou Monitoring Unit (CMU) Manager	Works with CMU coordinators to manage technical deliverables of contractors and internal ABMI collaborators	Review data and other deliverables to ensure they meet data quality objectives set out in grant or contract agreements.	Oversees data collection and QAQC

Applied Science Coordinator (CMU)	Field data transfer for aerial wildlife surveys and remote camera programs	Download data, compile into database.	Oversees & confirms data compilation is complete
	Data QAQC for aerial wildlife surveys and remote camera programs	Check data for errors, missing values, etc.	Oversees & confirms completion of QAQC
	Store data for Regional Industry Caribou Collaboration (RICC) data portal	Check data for errors, ensures correct versions are stored and displayed on portal.	Oversees data portal updates and ensures correct data is accessible to RICC group
	Work with information centre to manage RICC data	Check data for errors, missing values, etc., reformat, if necessary, upload to database.	Oversees data collection and collation
	Manages data for additional CMU research projects	Check data for errors, missing values., etc., and store in database.	Oversees & confirms data compilation is complete
Caribou Monitoring Unit Coordinator/Ecologist	Works with CMU manager to manage technical deliverables of contractors and internal ABMI collaborators	Review data and other deliverables to ensure they meet data quality objectives set out in grant or contract agreements.	Oversees data collection and QAQC

1.1.1 *Technical Activities*

All technical activities undertaken by the AC are described in Table 8.1.

1.1.2 *Quality System Implementation:*

The AC Directors ensure that all applicable elements of the quality system are understood and implemented by providing:

- staff training;
- adequate resources for continuous implementation;
- quarterly reviews of staff performance;
- inclusion of quality management discussions at regular staff meetings;
- explicit quality management planning in project and staff work plans, service contracts, and grant agreements.

1.2 Element 2: Quality System Components

The AC uses the following quality management practices and tools to implement its quality system.

8.1.4 *Quality Management Plan*

The AC QMP describes the general processes that govern data management in the AC, including the policies and objectives, and the technical and management activities required to meet them. AC staff will be encouraged by the AC Directors to refer to the QMP on an ongoing basis. The AC QMP is approved by the AC Directors.

8.1.5 *Project Work Plans*

The Project Coordinator or Manager of each AC project creates, in consultation with the AC Director, a project work plan. Project work plans specify project organization, goals, objectives and milestones, deliverables, scheduling, communications, personnel and responsibilities, and budget information. Data quality provisions include specifying how data-related activities and products are documented, including deliverables such as technical reports, databases or data layers, and associated metadata requirements. Project work plans will identify the personnel responsible for quality management activities in each project and will align with individual staff work plans.

Project work plans are reviewed annually at a minimum, to track progress, ensure data quality provisions are being followed, and to assist future planning.

8.1.6 *Standard Operating Procedures and Protocols*

AC projects and units use technical protocols and SOPs specific to the needs of each project or unit (Table 8.2). This documentation ensures that data are collected and managed so that they are complete, consistent, and of a known and acceptable quality.

Table 1.2.1. Standard Operating Procedures and Technical Protocols implemented by AC projects and units.

Project/Unit	Title	Year	Location [*URL if public, SharePoint or other storage location otherwise*]
ERM	Field protocol grasslands	2014	http://abmi.ca/home/publications/201-250/236.html?mode=detail&subject=reclamation
ERM	Field protocol forests	2014	http://abmi.ca/home/publications/351-400/354.html?mode=detail&subject=reclamation
ERM	Field protocol cultivated lands	2017	https://abmi.ca/home/publications/451-500/483
Rare Plants	Field protocol	2014	http://www.abmi.ca/home/publications.html?keyword=rare%20plants

CMU	Terrestrial field data protocol. (Mammal and bird survey using remote detectors)	2016	http://abmi.ca/home/publications//401-450/432.html
Bioacoustic Unit	ARU Deployment (Lankau 2015a)	2016	http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/Lankau_2015_ARU_Deployment_Protocol.pdf
Bioacoustic Unit	Data transfer and security	2016	Internal BU Library
Bioacoustic Unit	Data Handling Protocol (Bioacoustic Unit 2015)	2016	Internal BU Library
Bioacoustic Unit	Acoustic Analysis Protocol 2015 (Lankau et al. 2015)	2015	http://bioacoustic.abmi.ca/wp-content/uploads/2015/11/BU_Acoustic_Recording_Analysis_Protocol-V10-23Nov2015-2.pdf
Bioacoustic Unit	ARU maintenance protocols for SM2 and SM3 models (Lankau 2015b; c)	2015	http://bioacoustic.abmi.ca/wp-content/uploads/2016/01/BU-SM3-Maintenance-Protocol-2016.pdf http://bioacoustic.abmi.ca/wp-content/uploads/2016/01/BU-SM2-Maintenance-Protocol-2016.pdf
Bioacoustic Unit	BU Sensitivity Testing Protocol (Lankau 2015d)	2015	Internal BU Library, Draft
Bioacoustic Unit	ARU Deployment and Retrieval Data Sheets	2016	Internal BU Library. http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/BU_ARU_PickUp_Datasheet_2015.pdf
Bioacoustic Unit	ARU Settings File (SM2, SM3 and SM4 models)	2017	http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/ARU-Settings.zip
Bioacoustic Unit	Data Intake Protocol	2017	In Development
Bioacoustic Unit	Data Sharing Agreements	2017	In Development
Bioacoustic Unit	Recognizer Protocol (McLeod 2016)	2016	http://bioacoustic.abmi.ca/resources/protocols/
Bioacoustic Unit	Data QAQC	2015	BU staff; currently in preparation
Bioacoustic Unit	Recognizer Files	2016	http://bioacoustic.abmi.ca/resources/protocols/

8.1.7 *Data and Model Documentation*

AC staff and/or collaborators publish technical reports or peer-reviewed publications that document data collection methods or modelling procedures. AC staff maintain documentation of interim data products or models in development, including but not limited to model code and data processing and analysis code (e.g., NetLogo, Python, R). When data or data products from AC projects are released to the public or to collaborators, they are accompanied by appropriate documentation, as determined in project work plans.

8.2 Element 3: Quality Training System

The success of the AC QMP depends on the commitment of the personnel who implement the program on a daily basis. Through its hiring and training process, the AC ensures that all staff involved with data management have the education, experience and on-the job training required to successfully implement the QMP.

8.2.1 Personnel Qualifications

The AC makes every effort to recruit employees capable of meeting the education, experience, and technical skill requirements of AC projects and activities. Along with other ABMI Centres housed at the University of Alberta, the AC must follow and adhere to the University of Alberta staff hiring rules and regulations. Personnel qualifications are established by the Position Classification Plan, which describes the job specifications and the education and experience necessary to fill the position. The qualifications of all job applications are reviewed by the AC Directors and at least two other AC staff members to ensure applicants meet the minimum job requirements. The AC Directors and at least two staff members within the AC interview qualified applicants and assess their qualifications as they relate to the posted job description. It is the responsibility of the AC Directors to ensure staff members who need specialized training receive it.

8.2.2 Personnel Training

The AC Directors are responsible for ensuring personnel are qualified to perform their roles, including aspects related to the QMP. As needs are identified by the AC Directors or staff, resources are made available for training and professional development, including training related to quality management (e.g., courses, seminars, conferences).

8.3 Element 4: Contractor Requirements

The ABMI AC engages a diverse group of collaborators, including academic research collaborators, independent contractors, for profit enterprises, and not-for-profit organizations, to deliver its applied research projects and the services of WildTrax. Each AC project and unit has specific collaborator and contractor needs, and collaborators and contractors may be involved in any step of the data and reporting cycle, including collecting field data, processing samples, creating geospatial data, data analysis and interpretation, and reporting.

The AC ensures contractors and collaborators are providing data and data products of known and acceptable quality through the following general mechanisms.

8.3.1 Project Work Plans

Annual work plans are used to define the research program of each project and unit. These work plans are used, in part, to define data needs and collaborator roles and responsibilities.

They form the foundation for collaborator contracts and grants (below) by formalizing project- or unit- specific expectations around data and data product quality and intended uses.

8.3.2 *Contracts and Grants*

The AC uses contracts and grants with Research Collaborators and service providers to define expectations for the quality of data to be delivered by collaborators according to the project work plan (above) and to assess delivered products against those expectations. Relevant documents include the following:

- ABMI Agreement Template;
- Contract for Services with Individuals or Small Businesses Template;
- ABMI Grant Template;
- ABMI Data Sharing Agreement Template.

Project Managers within the AC are responsible for defining the quality standards and metrics, as per the project needs, in the grant or contract and evaluating the deliverables according to those criteria. The final authority on the content of grants and contracts and on the payment of grants and contract invoices is held by the AC Director.

8.4 Element 5: Documents and Records

AC Research Coordinators and Managers are responsible for identifying and maintaining documents and records pertaining to data quality and management as required for each AC project and Unit. The AC refers to existing standards documents for guidance on the creation of documentation of data and data activities. This includes the following:

- GIS data management: a metadata standards document for GIS data, specifying what information needs to be included in the metadata of a given spatial dataset, such as a short description of the data represented, descriptions of all attribute fields, spatial reference information (i.e., coordinate system), and administrative information (source, data-sharing limitations, file format, etc.). See "Ecosystem Services Assessment 2013. GIS Metadata and Model Documentation Standards and Guidelines" (Habib 2013) for further details.
- Models: Documentation of simulation models is guided by ODD ("Overview, Design, Details") protocol,[8] adapted for the types of models that are currently being developed by the AC. This standard includes an overview of the model purpose and objectives, explanations of sub-processes comprising the model, and detailed information on variables (type, name, description, and units), data requirements, equations used in the model, and any other pertinent information to allow readers to understand and run the models.

[8]Grimm et al. 2006. A standard protocol for describing individual-based and agent-based models. Ecological Modelling 198:115-126.

- External data sources: When data are acquired from external sources, including research collaborators, data sharing agreements or Memoranda of Understanding (MOU) are established that describe the data being provided and any conditions of use.
- Technical reports: Technical reports created within the AC are sent out for expert review at the discretion of Research Coordinators, Manager and/or AC Director, to ensure reports receive independent and rigorous review when necessary.

8.5 Element 6: Information Management

The AC utilizes a range of software in various data applications, depending on the specific needs of each project. The most frequently used software applications include the following:

- Geographical Information Systems: ArcGIS and Python, QGIS;
- Statistical analysis and data manipulation: R Software for Statistical Computing, STATA, Microsoft Excel, Microsoft Access;
- Modelling software: NetLogo;
- Database software: Microsoft Access, Microsoft Excel, Oracle, SQL, PostgreSQL, Epicollect;
- ABMI Tablet Program;
- Data processing: WildTrax; and
- Project Management: ClickUp, Basecamp, SharePoint, Trello, WildTrax.

All AC staff maintain up-to-date software installations as they are released by the software provider, after ensuring that new software updates will not impact existing workflows. Because the majority of AC projects are short-term and independent, there are limited implications of software changes for long-term data management and quality control. However, Research Coordinators are responsible for ensuring that software versions used to conduct analyses are recorded in all data reporting.

The AC Directors ensure resources are available for staff to maintain up-to-date software, as required, and to maintain and upgrade hardware as required.

8.6 Element 7: Systematic Quality Assurance Planning

Depending on the nature of the project, long-term and annual project work plans outline the data operations for planned activities, including the following:

- project goals, including those related to data collection and data use;
- identification of project schedule, resources (including budget), and milestones;
- roles and responsibilities of AC staff, other ABMI staff and Research Collaborators as they pertain to data collection and management;
- expectations for data quality and related assessment methods and performance criteria; and
- descriptions of planned data analyses and evaluations.

The AC is currently drafting a procedure for archiving completed projects.

In addition to project work plans, all AC personnel develop an annual personal work plan specifying their tasks for the year, including data activities and quality management.

8.7 Element 8: Quality Implementation of Work Processes

All AC staff are responsible for ensuring that work is performed according to project work plans, that appropriate protocols and SOPs are in use or being prepared as required for each project, and that Research Collaborators are fulfilling their obligations under the executed contract or grant.

Annual personal work plans for each employee state their role in data quality management activities, including how much time they will allocate to each task. Personal work plans must align with project work plans to ensure all project objectives, including data quality management tasks, have sufficient staff resources to be completed.

8.8 Element 9: Quality Assessment and Response System

On an annual basis starting in 2016, the AC will convene under the leadership of the AC Directors to review and assess the adequacy of the quality management system, including a review of the QMP. Both noteworthy actions or processes and areas for improvement will be identified. The outcome of this meeting will be a plan that outlines necessary actions, staff accountability, and expected implementation timelines for responding to identified issues with the quality management system.

Technical data quality management system reviews will be conducted in the course of reviewing and renewing annual project work plans. Previously identified data quality objectives and assessment methods will be reported on by the individual responsible for data activities, and reviewed by the project team. Identified improvements to the project-specific data quality management system and a plan for implementation will be documented in the subsequent project work plan.

8.8.1 Performance Evaluations

Performance reviews in which all full-time BU employees meet with the BU Director to review and assess the previous year's performance will be conducted annually. This process serves to highlight strengths and challenges so that actions may be taken to improve weaknesses and augment processes to overcome challenges faced. Contractors and seasonal staff will be assessed during their employment to ensure they are doing work correctly. Their overall performance will also be assessed at the end of the contract to determine if they should be considered for future work with the BU.

8.9 Element 10: Commitment to Quality Improvement

All AC staff are encouraged to participate in the quality assessment processes identified above. In addition to internal AC processes, AC personnel seek out best practices for data quality management activities through communications with other ABMI Centres, through both informal discussions as well as formal processes such as Data Management Committee meetings.

8.10 AC QMP References

Chapman, A. D. 2005. Principles of data quality. Report available at: www2.gbif.org/DataQuality.pdf.

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CHAPTER 9: WILDTRAX QMP

Approvals

Approved by: _____ _____

Application Centre Co-Director Date

Centre QMP Revision History Log

Revision Date	Author	Changes
2021-10-31	Corrina Copp	WildTrax QMP created.
2021-11-26	Corrina Copp, Monica Kohler, Erin Bayne	WildTrax QMP updated after internal review.

9 WildTrax Overview

The ABMI has monitored terrestrial and wetland ecosystems across the province for more than a decade; this has resulted in a massive biodiversity database, reliable measurement protocols, and innovative ways to summarize complex ecological information. While these data have enormous value to environmental managers and land-use decision makers, through the Application Centre's (AC) mandate of applying monitoring data to specific management issues, the ABMI has extended its relevance beyond the core business of measuring and reporting on the state of biodiversity in Alberta. The AC operates a number of initiatives and projects that apply biodiversity, human footprint, and other data, and leverages the ABMI's scientific and institutional capacity to aid Alberta's researchers, land-use decision-makers, and Indigenous communities in pursuing biodiversity questions. This work is achieved by leveraging the ABMI's scientific and institutional capacity and through collaborative efforts with partner organizations and researchers.

The AC and Information Centre (IC) co-deliver the WildTrax platform of ABMI -- an online platform for managing, processing, and sharing environmental sensor data from Autonomous Recording Units (ARUs) and cameras. WildTrax houses camera and ARU data from users across Canada, including the ABMI, and undergoes continual development to improve the workflow for these data types.

The WildTrax Quality Management Plan (QMP) provides an overview of WildTrax practices that ensure the data and data products produced through WildTrax activities can be appropriately interpreted and used by others to support further research and decision-making with a known level of certainty. Wherever data activities align with the core ABMI program, standard

ABMI data quality management practices are implemented; all other WildTrax data activities are governed by the present QMP document.

The WildTrax QMP outlines the roles, responsibilities, resources, and procedures that govern data quality management. The QMP will be reviewed annually under the leadership of the AC and IC Directors. Ongoing initiatives for improving data quality management in WildTrax are focused on ensuring adequate resources for data storage, and implementing accepted standards for data management and processing.

9.1 Element 1: Quality Management Policy, Goals, and Objectives

9.1.1 *Quality Assurance Policy*

Following other ABMI Centres, WildTrax adheres to a threefold quality assurance policy:

1. Objectivity: all WildTrax data and data products are to be presented in an accurate, understandable, clear, and unbiased manner.
2. Utility: WildTrax provides quality data and information for intended use.[9]
3. Integrity: until released to the public by the data owner, all WildTrax data and information are protected from unauthorized access.

To meet these policy objectives, WildTrax has established the following quality management objectives (FREP 2005; GLNPO 2008):

- Resources[10]: WildTrax management will ensure there are adequate resources allocated to quality management. Essential resources for maintaining and improving the quality of biodiversity information and research products include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources.
- Ongoing activity: Quality management will be embedded in daily WildTrax activities (e.g., training, Standard Operating Procedures [SOPs], scientific peer review), creating an expectation of quality and excellence.
- Systematic planning: Quality management activities will be systematically incorporated into all WildTrax activities, and monitored and planned as a standing agenda item in regular AC meetings.
- Quality system documentation: All quality management activities will have documentation to ensure users can evaluate the data relative to their own needs

[9] Data quality is a critical aspect of an environmental monitoring program. However, data quality can only be determined by the context in which the data are used (Ferretti 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martín and Ballard 2010).

[10] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

(Shampine 1993). This includes a QMP, approved by the AC and IC Directors, which describes how quality objectives will be met.

- Cost effectiveness: Quality management activities will be implemented as cost effectively as possible without compromising data quality (DWR (Department of Water Resources) 1998).
- Adaptability: Given the rapid pace of technological advancements with ARU and camera data, WildTrax's approach to data management will be adaptive and incorporate new approaches.

9.1.2 *Organizational Structure*

WildTrax was established in 2018 in order to process remote sensor data, including ARU and remote camera data. The platform is jointly managed by the ABMI's AC and IC. WildTrax stores, manages and processes, and reports on data collected via remote sensors on wildlife across Alberta. All members of the WildTrax team play a role in QAQC activities (see Figure 9.1.1 describing the WildTrax organizational structure).

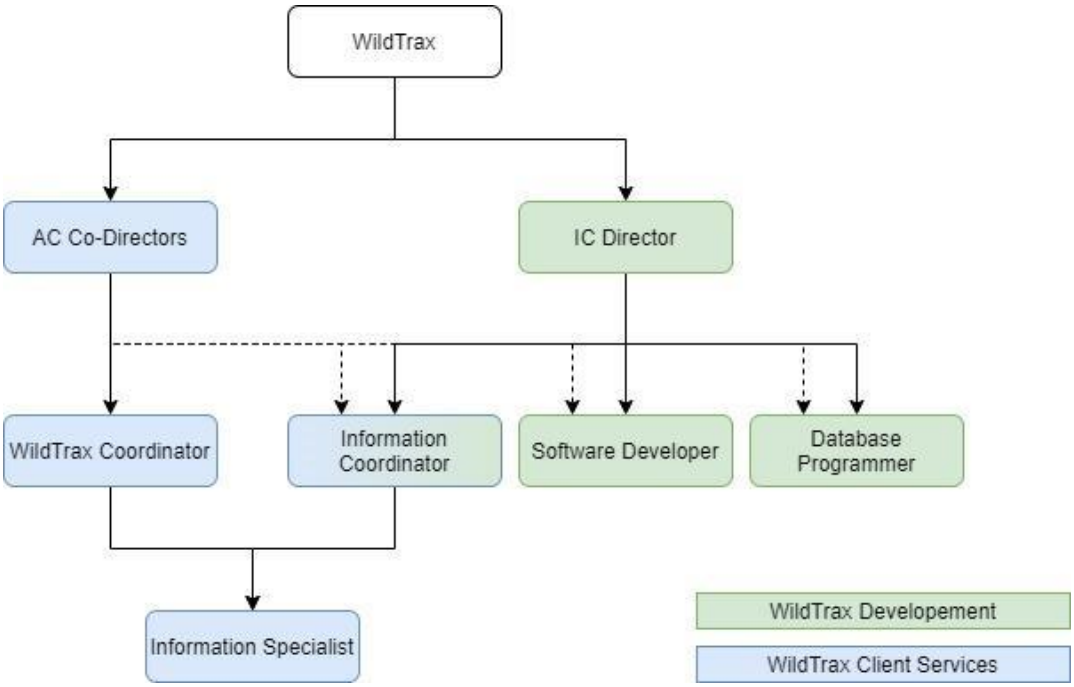

Figure 9.1.1. WildTrax organizational structure.

9.1.2.1 Operations and Business Development

The AC delivers the operational branch of ABMI's WildTrax platform for ARUs. This includes the full cycle of client services for external users of WildTrax, including quote generation, contracts, and addressing user questions and bugs. As part of this work, the WildTrax Coordinator

manages the team of data transcribers who process data from ARUs and remote cameras for all of ABMI's monitoring activities as well as full-service users.

The IC delivers the operational branch of ABMI's WildTrax platform for Remote Cameras, with support from the AC Director. This includes the full cycle of client services for external users of WildTrax, including quote generation, contracts, and addressing user questions and bugs. As part of this work, the Information Specialist manages the team of data taggers who process data from remote cameras for all of ABMI's monitoring activities as well as full-service users.

9.1.2.2 Platform Development

The IC delivers the platform development to support user needs.

9.1.2.3 Research

The BU and SC coordinate research to support platform and processing enhancements such as AI, data QAQC, etc.

9.1.3 Staff Roles, Responsibilities, and Authorities

Table 9.1.1. The data tasks and associated quality management activities for current WildTrax projects, and the responsibilities of WildTrax personnel.

Personnel	Data Task	Technical Activities	Responsibility
Application Centre Co-Directors	Platform Administration	Review development priorities and implementation schedule.	Approves development priorities
	QMP and SOP Review and Approval	Review and approve the WildTrax QMP and all SOPs.	Approves final QMP and SOP
IC Director	Platform Administration	Review development priorities and implementation schedule.	Approves development priorities
	QMP and SOP Review and Approval	Review and approve the WildTrax QMP and all SOPs.	Approves final QMP and SOP
WildTrax Coordinator	Processing audio data (human listeners)	Identify bird & amphibian species from sound files and confirm IDs.	Confirms completion of identifications
	Contract management	Check and approve invoices for audio processing to confirm accuracy.	Approves contractor invoices
	Processing audio data (computer recognizer)	Identify bird & amphibian species from sound files with computer recognizers; QAQC with human verification.	Confirms completion of identifications
	Data QAQC	Check for missing files; correct file names; flag corrupt files;	Confirms completion of QAQC

		confirm file data matches expectations based on deployment/retrieval data sheets.	
	Data export to researchers/ABMI	Export tabular data and associated metadata to end-users.	Confirms data for release
Information Coordinator	Project Management	Coordinate and facilitate the implementation of new features and functionalities into WildTrax.	Ensures the SOP is followed.
Information Specialist	Remote Camera data Intake	Handle the receiving of remote camera data, and the upload of data to WildTrax.	Confirms data upload to WildTrax
	Remote Camera data Processing	Coordinate project deliverables, manage hired taggers, and provide communication with the client.	Confirms the completion of tagging on projects
	Training	Coordinate and provide training to hired taggers.	Confirms taggers are aware of remote camera tagging processes and SOPs.
	Contract Management	Support for the hiring of taggers.	Hires taggers to complete project deliverables
Software Developer	Feature/function implementation	Support new feature/function implementation.	Ensures SOP is followed
	Website Synchronization	Manage technical WildTrax web releases with new features/functions.	Confirms website is up to date after releases. Ensure SOP is followed
Database Manager	Data Security	Administer access control over local, database, and web servers.	Ensures the SOP is followed
	Database management	Manage the WildTrax database and tables.	Confirms database is up to date. Ensures SOP is followed
	Server management	Coordinate and manage server use	Confirms server is up to date. Ensures SOP is followed

9.1.4 *Technical Activities*

All technical activities undertaken by WildTrax are described in Table 8.1.

9.1.5 *Quality System Implementation:*

The AC Co-Directors ensure that all applicable elements of the quality systems are understood and implemented by providing:

- staff training;
- adequate resources for continuous implementation;
- quarterly reviews of staff performance;
- inclusion of quality management discussions at regular staff meetings; and
- explicit quality management planning in project and staff work plans, service contracts, and grant agreements.

9.2 Element 2: Quality System Components

WildTrax uses the following quality management practices and tools to implement its quality system.

9.2.1 *Quality Management Plan*

The WildTrax QMP describes the general processes that govern data management, including the policies and objectives, and the technical and management activities required to meet them. WildTrax staff will be encouraged by the AC Directors to refer to the QMP on an ongoing basis. The WildTrax QMP is approved by the AC Directors.

9.2.2 *Quality System Documentation*

WildTrax is required to have written and approved quality system documentation (e.g., QMP, SOPs) which provide details of the QA program. At a minimum, all QA documentation must be reviewed and approved by the AC and IC Directors. Approvals by domain experts and/or external reviewers are encouraged, and in many instances, also necessary. All QA documentation is filed with the Information Coordinator, as well as being published publicly on wildtrax.ca.

9.2.3 *Standard Operating Procedures*

WildTrax uses technical protocols and SOPs specific to operations, data processing and management (Table 8.2). This documentation ensures that data are collected and managed so that they are complete, consistent, and of a known and acceptable quality.

Table 9.2.1. Standard Operating Procedures and Technical Protocols implemented by AC projects and units.

Title	Year	Location *[URL if public, SharePoint or other storage location otherwise]*
Definitive User Guide: Organizations	2021	https://www.wildtrax.ca/home/wildtrax-guide/2-Organizations.html
Definitive User Guide: Projects	2021	https://www.wildtrax.ca/home/wildtrax-guide/3-Projects.html
Definitive User Guide: Acoustic Data	2021	https://www.wildtrax.ca/home/wildtrax-guide/5-Acoustic-data.html
Definitive User Guide: Camera Data	2021	https://www.wildtrax.ca/home/wildtrax-guide/6-Camera-data.html
Definitive User Guide: Point Count Data	2021	https://www.wildtrax.ca/home/wildtrax-guide/7-Point-count-data.html
Definitive User Guide: Data Downloads and Data Discover	2021	https://www.wildtrax.ca/home/wildtrax-guide/8-Data-Downloads-and-Data-Discover.html
WildTrax Data Management	2021	In Development
WildTrax Development	2021	In Development

9.2.4 *Pre-processing Tool Documentation*

WildTrax publishes and provides freely available pre-processing tools for WildTrax members to utilize (https://www.wildtrax.ca/home/resources.html). WildTrax maintains documentation pertaining to the functions of these tools, which are updated as required.

9.2.4.1 wildRtrax

WildTrax uses Git, which is a version control software, in conjunction with Github, which is a platform that hosts repositories of code and associated files. Code related to WildTrax pre-processing tools is maintained on public repositories on Github, for easy accessibility and transparency. Currently, wildRtrax (MacPhail and Becker 2021) supports the pre-processing of acoustic recordings from ARUs.

9.2.4.2 Microsoft Megadetector

WildTrax uses the Microsoft MegaDectector to identify those images with an animal, people, and vehicles (Beery et al. 2019). Note that it does not identify animals, it just detects that something is there. Using machine learning, the Microsoft MegaDectector draws a bounding box around the identified object and provides a classification and probability. WildTrax subsequently tags images with nothing in them, or images with humans and vehicles. Those images tagged as None are hidden from the taggers view. On top of the Microsoft MegaDectector, WildTrax has developed and incorporated an auto-cow recognizer to remove images of domestic cattle.

9.2.5 *Data Verification and Validation*

Data verification and quality assurance is a central component to WildTrax activities. Prior to release publicly or to a client, the WildTrax Coordinator implements several quality assurance procedures on the data submitted to and processed in WildTrax. The data is inspected for taxonomic, metadata and processing errors. Potential inconsistencies and errors are flagged prior to release or submission to the appropriate data authority. When the inconsistencies and errors are verified and solved, they are rectified and the data sets are updated.

9.2.6 *Training*

The success of the quality management system depends on commitment by the employees who are required to implement the program on a daily basis. To facilitate awareness of the quality management system, a quality awareness training program is implemented by the WildTrax Team. Components of this training program include (but are not limited to):

- Mentorship and shadowing for new employees within the organization;
- Training for new contractors;
- General training seminar providing an overview of the WildTrax QA program including: QA policies and objectives, description of roles and responsibilities, and a description of the QA documentation (e.g., QMP, SOPs, online videos) and where these documents can be accessed; and
- Training materials such as species guides, videos, libraries, and reference materials.

9.2.7 *Quality System Audits and Technical Systems*

QA management system reviews (or quality system audits) are performed internally to evaluate the effectiveness of a quality management program (EPA 2001, GLNPO 2008). Internal audits of data management workflows (e.g., data receiving, data verification, data modification) are conducted by the WildTrax and Information Coordinator to ensure:

- adherence to the QMP;
- the existence of procedures to develop quality objectives and acceptance criteria;
- the existence of procedures to develop and approve quality assurance documentation;
- the existence of procedures to develop and approve SOPs;
- procedures, criteria, and schedules for designing and performing audits;
- the existence of a tracking system for ensuring corrective changes to the data are adequately reported;
- sufficient management support; and
- adequacy of allocated resources to achieve QA goals and objectives including appropriate level of financial and capacity devoted to the implementation of the quality system.

9.3 Element 3: Quality Training System

The success of the WildTrax QMP depends on the commitment of the personnel who implement the program on a daily basis. Through its hiring and training process, WildTrax ensures that all contractors involved with data management have the education, experience and on-the job training required to successfully implement the quality management system.

9.3.1 *Personnel Qualifications*

WildTrax makes every effort to recruit contractors capable of meeting the education, experience, and technical skill requirements of WildTrax remote sensor projects (Table 9.4). All contractors are required to undergo formal testing to ensure high quality data standards. Please see section 1.4.3 Recruitment Requirements for further information.

Table 9.3.1. General qualifications and training requirements for technicians.

Type of Qualification	Minimum Requirement	Before or After Hiring
Post-Secondary Education	Science based program, min. 2 years	Before
Computer Competency	Basic computer skills: Word, Excel, web navigation	Before and after
Species ID Skills (*taxonomists only*)	Ability to identify all Alberta birds, mammals, and amphibians	Before and after
Processing Skills	Ability to follow defined process for tagging	Before and after

9.3.2 *Taxonomic Identification Training Requirements*

Taxonomic identification is done by two types of staff: internal BU staff including technicians and graduate students, and external contractors. Training also varies between staff doing bird community identification and those doing single species projects. Staff working on single species projects are required to be able to identify their target species as well as any similar sounding species. All staff doing bird community identification are required to know all species within a community. See Section 9.5 Element 4: Contractor Requirements for details on the recruitment process. The protocol detailing the training procedures is currently in development.

9.4 Element 4: Contractor Requirements

WildTrax engages independent contractors to deliver its services to clients. The WildTrax Coordinator ensures that contractors are processing data of known and acceptable quality through the following general mechanisms.

9.4.1 *Project Work Plans*

Work plans are used to define the research program, and key expectations and deliverables. These work plans are used to provide clear timelines for contractors. They form the foundation for client contracts and grants by formalizing WildTrax service agreements, outlining specific expectations around data and data product quality and intended uses.

9.4.2 *Contracts and Grants*

WildTrax uses contracts and grants with various groups to provide WildTrax services, and define expectations for the quality of data to be delivered by WildTrax according to the project work plan (above) and to assess delivered products against those expectations. Relevant documents include the following:

- ABMI Agreement Template;
- Contract for Services with Individuals or Small Businesses Template;
- ABMI Grant Template; and
- ABMI Data Sharing Agreement Template.

The WildTrax Coordinator is responsible for defining the quality standards and metrics, as per the project needs, in the grant or contract and evaluating the deliverables according to those criteria. The final authority on the content of grants and contracts and on the payment of grants and contract invoices is held by the AC Director.

9.4.3 *Recruitment Requirements (ARUs)*

WildTrax hires (on a contractual basis) data transcribers with previous experience identifying vocalizing species by sound. Applicants must have a minimum of two years' experience with point counts or bioacoustic data transcription in order to be eligible for the hiring process. In order to begin working for WildTrax, applicants first must demonstrate their identification skills with identifying vocalizing animals (birds, amphibians) by sound and spectrograph, their attention to detail with data entry and their ability to comprehend protocols. The evaluation of transcribers' ability to accurately identify species and estimate abundance is currently in development in the Standardized Bioacoustic Transcription Report. A three-phase hiring process takes place. The exams are changed on a yearly basis to reflect the data entry taking place for the transcription season (habitat types, regions and clientele needs).

- Recruitment Exam (Phase 1)
    - Applicants have 3 hours to successfully complete the following tasks to continue to the next stage of the hiring process:
        - Learn the Bioacoustic Unit Acoustic Recording Analysis Protocol (sent 3 days prior to the Recruitment Exam)
        - Successfully identify 75 bird species and 8 amphibian species ('Successful' is defined as scoring higher than 85%); and

        - Transcribe five 1-minute recordings:
            - Identifying as many species and individuals as possible on the recording. The applicant is evaluated on their identifications using the Standardized Bioacoustic Transcription Report (*in development*) which determines their similarity to a consensus of observers having >200 audio hours of transcription experience.
- Placement Exam (Phase 2)
    - Applicants must successfully pass the Recruitment Exam in order to move onto the Placement Exam
    - Applicants have 90 minutes to transcribe 3-minute dawn recordings following BU standards outlined in the Standardized Bioacoustic Data Transcription Report (*in development*). Applicants must produce a minimum of five 3-minute recordings to a maximum of ten 3-minute recordings to a degree deemed acceptable by BU standards
- Probation Period (Phase 3)
    - When the applicant successfully completes and passes the two phases of the hiring process, they will move onto the Probation Period. This phase requires the contractor to process 400 audio minutes within 3 calendar weeks. This allows the applicant to "ease into" the data transcription process by ensuring species are correctly identified and metadata is being entered.
    - The WildTrax Coordinator reviews all biotic data being entered and identifies any spatial, temporal, species identifications or abundance estimation discrepancies. The threshold data quality produced by the applicant is still under review (Standardized Bioacoustic Data Transcription Report (*in development*)) but is at minimum required to have <25% error rate overall.
    - Should the applicant meet all these requirements, they will be offered the Primary Contract.
    - Contractors who have previously worked for WildTrax and have a minimum of 60 audio hours of experience only need to complete the Placement Exam (Phase 2) in order to be offered the Primary Contract.

Throughout the course of the Primary Contract, contractors are required to submit a quiz on a monthly basis consisting of a minimum of ten 3-minute recordings on a busy dawn chorus (species richness between 5 – 20). Contractors are required to pass each monthly exam at a similarity index consensus of experienced observers similar to the exams. Should the contractor produce results from the exam that demonstrate high variability or less than average results, the WildTrax Coordinator will identify and communicate areas where the contractor needs to work on to sustain high data quality standards.

Contractor productivity is also evaluated on a bi-weekly basis to ensure that data production is in line with the contract requirements (tailored for each observer prior to the start of the Primary Contract). The WildTrax Coordinator evaluates productivity (audio minutes produced /

week) and provides feedback to the contractors. Contractors are also required to provide a form of communication to the WildTrax Coordinator a minimum of every 2 calendar weeks describing any questions, concerns, issues and errors conducted during listening.

The ARU Contracting process schedule can be found in Appendix 4.0, which ensures ARU data quality, and that it is being processed in a timely manner.

9.4.4 *Recruitment Requirements (Cameras)*

WildTrax hires (on a contractual basis) image taggers with previous experience identifying mammal species. In order to begin working for WildTrax, applicants first must demonstrate their identification skills and ability to follow outlined processes. All taggers are provided testing deployment to complete. These deployments are then evaluated for accuracy and precision. Testing deployments consist of several species to ensure adequate testing of the species most likely to be observed while tagging.

Throughout the course of the contract, contractor data is assessed for errors. Within the first two weeks of starting, 5 random deployments are chosen for each image tagger for assessment of tagging accuracy. Additionally, to improve the accuracy of manual tagging and the consistency between taggers, QA/QC checks are completed to provide each individual tagger with feedback. Assessment criteria include:

- All images available for tagging have been tagged.
- "Staff/Setup" tags have been applied correctly (where applicable).
- Accurate application of "Unknown", "None" and species ID tags.
- Tags for age, sex and number of individuals are applied correctly
    - Age tags correctly applied for all species, not including domestic animals, humans and non-mammals.
    - Sex tags for adult deer, moose and elk are applied correctly and not before May 15 or after September 30th unless sex clearly identifiable.
    - The juvenile tag is applied to first year juveniles only. For Deer, Moose, Elk, and Caribou, those juveniles appearing to be ~1 year, as of May 1 or later, will be classified as an Adult. Prior to May 1st, these individuals will be tagged as juveniles.
    - Sex tags are not applied to juveniles, unless clearly identifiable.
    - Sex tags are not applied to species other than moose, elk and deer unless it is very obvious (i.e., a mother bear with cubs, caribou, etc.).
    - number of individuals applied correctly to all species, not including domestic animals, humans and non-mammals.
- Use of "Out of Range" and "START" / "END" tags accurately.
- "Nice" tag applied at least once for each deployment with images of wildlife.

Specific written feedback is provided to each remote camera tagger to facilitate correction of errors and to improve tagging accuracy. If several errors are made, an additional round of QAQC checks will be conducted two weeks following the initial assessment.

9.5 Element 5: Documents and Records

The WildTrax team is responsible for identifying and maintaining documents and records pertaining to data quality and management as required. WildTrax refers to existing standards documents for guidance on the creation of documentation of data and data activities. This includes the following:

- User Documentation: Detailed instructional material for internal and external use on how to use the WildTrax platform and its different functionalities.
- Methodological and metadata documentation: Documents describing the details of WildTrax processing methods and metadata for data generated through WildTrax.
- Field Protocols: Documentation describing the deployment of remote camera and acoustic sensors.
- Grant and contracts: Contract agreements with clients specifying commitments and specifications for data ownership/control.
- External data sources: When data are acquired from external sources, including research collaborators, data sharing agreements or Memoranda of Understanding (MOU) are established that describe the data being provided and any conditions of use.
- Statistical code and annotations: Where codes such as R code for wildRtrax workflows is developed, annotations and records will be maintained in a GitHub Repository.
- Technical reports: Technical reports created within the AC are sent out for expert review at the discretion of Research Coordinators, Manager and/or AC Director, to ensure reports receive independent and rigorous review when necessary.

9.5.1 *QA Documentation Reviews, Approvals, and Revisions*

QA documents must be reviewed and accepted (at a minimum) by the WildTrax team, with final approval by the AC and IC Directors. The need for additional reviews (either internal or external) will be assessed on a case-by-case basis. Signature approval indicates that a QA document has been both reviewed and approved by management.

SOP's will be systematically reviewed every year to ensure that procedures remain current and appropriate. The review date will be added to each SOP that has been reviewed. If an SOP describes a process that is no longer followed, the SOP will be withdrawn from the active file and archived.

9.5.2 *Document Storage and Archival System*

WildTrax QA documents are maintained and versioned on Google Drive. Working drafts are maintained on Google Drive while final QA documentation, signed off by the WildTrax team,

Domain Expert and IC and AC Directors, are posted to the ABMI-wide ClickUp site and are subsequently updated on the ABMI website Quality Management Page.

9.6 Element 6: Information Management

WildTrax utilizes a range of software in various data applications, depending on the specific needs of each project. Tools and software are updated regularly to ensure the use of the most recent versions available.

9.6.1 *Computer Hardware and Software*

The WildTrax team relies on a range of software for a variety of tasks:

- Geographical Information Systems: ArcGIS and Python;
- Statistical analysis and data manipulation: R Software for Statistical Computing, Microsoft Excel;
- Database software: PostgreSQL;
- Project Management: ClickUp, Trello.

9.6.2 *Infrastructure Description*

WildTrax collects and curates large amounts of remote camera and acoustic recording data, specialized software and hardware architecture are required to support data management and user interaction (Sólymos et al. 2015). The system needs practical, logical, and cost-effective methods to organize, link, and store these data sets in a systematic framework. Below is a basic summary of the WildTrax infrastructure.

9.6.2.1 Servers

WildTrax uses multiple servers to store client data. Servers include Amazon s3 and Cirrus cloud storage. Amazon s3 is used to store images derived from remote cameras and mp3 files derived from ARUs.

Data File Server:

- Repository of static data files. Files stored here do not typically change often and need a consistent location, such as acoustic recordings and image files. These servers are designed for large storage capacities;
- Cirrus, AWS

Database Server

- Uses postgres and other database software. Write access is under strict control to the Software Developers. Databases on this server are for long-term data storage and require quality database design, documentation, and administration. In some cases, where there is user input, files can change quickly, thus a well-designed back-up system is required.

- Linode

Website Server

- Provides the "front-end" to accessing the data and products generated by the organization. This server is closely tied to the data file and database server.
- AWS, linode

9.6.2.2 PostgreSQL Database

PostgreSQL database is the DBMS application used by the IC to store and analyze remote camera and acoustic data in WildTrax. It defines, creates, queries, updates and manages these data.

The WildTrax PostgreSQL database contains species tag information and their associated metadata such as organization, visit, location, task, and image or sound file information. PostgreSQL databases extract, transform, and load external data into database tables such as historical tagging data. PostgreSQL also facilitates data validation and constraints, and reporting in WildTrax.

9.6.2.3 WildTrax - Acoustic Platform

The ABMI uses ARUs to collect large quantities of breeding bird data (in the order of 10s of gigabytes). The WildTrax acoustic platform is a database created in PostgreSQL, and is designed to manage ARU data, and allow for its interpretation in one location. This system was designed based on the old BU Access database, building on existing database tables and QC processes in addition to incorporating new features to create efficiencies. The system was designed to enhance data quality, management, and organization.

ARU data management and processing is completed by the WildTrax Coordinator (see Chapter 10: WildTrax QMP). To address bugs and inefficiencies present in the previous field season, this database is updated annually. All raw .wac and .wav ARU data is stored on the University of Alberta's Cirrus cloud storage. All MP3s and spectrograms are stored using Amazon Simple Storage Service (S3).

9.6.2.4 WildTrax - Remote Cameras

The WildTrax Remote Camera platform is a database created in PostgreSQL. The platform is intended to manage remote camera data, and is designed to upload, process, extract and manage all camera trap images and data. Within WildTrax there are embedded quality control steps for each step (i.e., uploading, tagging). The system was designed to enhance data quality, management, and organization.

Website modifications are indicated by website users, and the SC. The website users (taggers) provide feedback on website usability to the WildTrax team, who in turn provide this information to the Information Coordinator for implementation by the Software Developers (e.g., interface changes, additional features) (see ABMI-IC-SOP-028 WildTrax Development). If

additional information needs to be gathered during tagging as deemed by the SC experts, they discuss the necessary modifications with the Information Coordinator and Software Developer, and the Software Developer implements the changes (e.g., classifying the relative location of animals to the pole in the image during the second pass of tagging).

Remote camera data management and processing is completed by the Information Specialist (see Chapter 10: WildTrax QMP). To address bugs and inefficiencies present in the previous field season, this database is updated annually. All image data is stored on the University of Alberta's Cirrus cloud storage. All images are stored using Amazon Simple Storage Service (S3).

9.6.2.5 WildTrax - Point Count Platform

The WildTrax point count platform is a database created in PostgreSQL, and is designed to help manage point count data, and allow for its interpretation in one location. Given point count data does not require processing, this platform is specifically designed to enhance data management and organization.

Point count data management is completed by the Bioacoustic Equipment Manager. All data is stored within database tables on Linode.

9.6.3 *Managing Files Archives*

- Camera trap photos are uploaded and stored on external hard drives and on an Amazon Cloud Server. This process is managed by the Information Coordinator and the Digital Data Coordinator.
- ARU files are uploaded and stored on external hard drives and on the BU Cirrus cloud server. Mp3 files extracted and spectrograms created (jpegs) for analysis in WildTrax are stored on Amazon S3 Cloud Storage. This process is managed by the WildTrax Coordinator.

9.7 Element 7: Systematic Quality Assurance Planning

The primary mechanisms used by the WildTrax Team to support systematic quality assurance planning include:

- WildTrax Work Planning: the identification of project schedules, resources (including budget), and milestones;
- Data intake planning: The WildTrax Coordinator is responsible for planning the intake and management of WildTrax data along with the data owner.
- Data Processing planning is done by the WildTrax Coordinator along with the PI and any partners and clients whose data WildTrax handles.
- Data QA/QC planning is done by the WildTrax Coordinator along with the PI, and any partners or clients whose data WildTrax processes

- Quality Assurance Documents: the required annual review and updates of quality assurance documents such as QMPs and approved SOPs ensure there is continuous planning and quality improvement associated with all aspects of the data management cycle.;
- Project Management Systems: WildTrax uses Trello and ClickUp to plan QAQC data workflows and track progress.

9.7.1 QA/QC Planning

Quality assessment (QA) and control (QC) planning are handled by the WildTrax Coordinator in conjunction with the IC and other partners. QA/QC plans for the different stages need to adjust for when the data comes out of the field and is available for the first stage of checking, when data is needed for processing, when processing is finished and when data is needed for analysis and public release (where applicable).

9.7.2 Quality Assurance Documents

The required annual review and updates of quality assurance documents such as this QMP and approved SOPs (managed by the WildTrax Coordinator) ensures there is continuous planning and quality improvement associated with all aspects of the data management flow managed by WildTrax.

9.8 Element 8: Quality Implementation of Work Processes

WildTrax staff are responsible for ensuring that work is performed according to project work plans, that appropriate protocols and SOPs are in use or being prepared as required for each project, and that Contractors are fulfilling their obligations under the executed contract. For example, ARU processing bonuses are outlined in the contract, and used to ensure tasks are being completed in a timely manner, and data is of high quality (see Appendix 4.0).

Annual personal work plans for each employee state their role in data quality management activities, including how much time they will allocate to each task. Personal work plans must align with project work plans to ensure all project objectives, including data quality management tasks, have sufficient staff resources to be completed.

9.8.1 Standard Operating Procedures

The main system of implementation for WildTrax QA management activities is through the development and execution of SOPs. SOPs detail the operational tasks associated with acoustic data management, processing, and validations. Table 4 provides a current list of SOPs that have been developed as part of WildTrax processing, and data management activities. Please note some SOPs are at early stages of development. The AC Co-Directors ensure that all staff have access to SOPs and that SOPs are up to date.

9.8.2 *Training*

As discussed in Section 4, WildTrax personnel are trained in QA procedures, understand their specific roles and responsibilities. The active engagement of staff and contractors in the QA planning process raises the awareness and understanding of the quality management system at the earliest stages of planning.

The WildTrax Coordinator is responsible for training staff within WildTrax. The WildTrax Coordinator trains on data entry, data transfers and all QA/QC procedures, and trains and supervises contractors in how to transcribe species data accurately.

9.8.3 *Communication*

WildTrax management staff meet regularly to discuss all aspects of WildTrax. This includes SOP development, management of data contracts, and contractors.

9.9 Element 9: Quality Assessment and Response System

To evaluate the performance of the WildTrax quality management system, WildTrax uses the following assessment tools: taxonomic identification audits, QA/QC system assessment, and performance evaluations.

9.9.1 *Taxonomic Identification Audits*

The WildTrax Coordinator checks a subset of all species detections for new transcribers. The WildTrax Coordinator also reviews and confirms detections of rare species or species of interest to ensure high data quality is maintained. Procedures for formal taxonomic audits are in development.

9.9.2 *QA/QC System Assessment*

The WildTrax Coordinator is responsible for QA/QC system assessment. Currently the focus is on maintaining and formally documenting current quality control and assessment systems. In addition, the WildTrax Coordinator is working on making QA/QC systems more efficient and thorough.

9.9.3 *Performance Evaluations*

Contractors and seasonal staff are assessed during their employment to ensure they are doing work correctly. Their overall performance will also be assessed at the end of the contract to determine if they should be considered for future work with the BU.

9.10 Element 10: Commitment to Quality Improvement

WildTrax is fully committed to a process of continual improvement of our data management activities and services to produce, and curate high-quality, well documented information that

is trusted by all users. WildTrax team members will identify issues that affect data quality negatively, and improve future quality by:

- ensuring that all protocols, procedures, and SOPs are updated annually, or as required;
- with oversight by the AC Co-Directors and the WildTrax Coordinator, prevent quality breakdown by having quality and consistent training at all levels of processing, and identification;
- identifying areas for improvement through data QA/QC activities like data verification, post-collection data review, and taxonomic audits;
- incorporating research to improve data collection methods;
- working with partners and clients to communicate changes in data intake procedures and data standards so that data consistency is maintained; and
- making data handling and QA/QC more efficient so that increasing quantities of data can be handled and properly cared for in a cost-effective way.

9.11 WildTrax QMP References

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APPENDIX

Appendix 1.0 Monitoring Centre Non-Protocol Related Training

The following table lists the AITF safety training documents that staff are instructed on.

Table A1.1. List of ABMI Monitoring Centre safety training SOPs.

SOP Title	ABMI Centre	Last Update	Applicable Region *
Journey Mgmt COP	Monitoring Centre	2021	All
Trailer	Monitoring Centre	2021	All
Winching	Monitoring Centre	2020	North
Working with Helicopters	Monitoring Centre	2021	Remote
Loading on top-decks	Monitoring Centre	2021	North
	Monitoring Centre	2015	North
Loading Argos on Trailers	Monitoring Centre	2021	North
Camping in Remote Areas	Monitoring Centre	2021	Remote
Chainsaws	Monitoring Centre	2018	North Full-Time Staff Only
Communications in the Field	Monitoring Centre	2021	All
Working Alone	Monitoring Centre	2021	All
Inflatable Boats	Monitoring Centre	2021	Wetland Crews
Field Safety Checklist	Monitoring Centre	2020	All
Navigation and Compass	Monitoring Centre	2015	All
GPS and Trimble Use	Monitoring Centre	In progress.	All
Private Land Access	Monitoring Centre/ IC	In progress.	All
ITA Corporate Policies	Monitoring Centre	In progress.	All
Biohazards	Monitoring Centre	2021	All

*These values are a general guideline only with numerous exceptions for specific regions, sites, season and a crew's assigned equipment.

The following table lists the safety training courses that are certified through third-party organizations. Certificates are issued and kept on record for a minimum of 2 years.

Table A1.2. MC training courses.

External Training*	ABMI Centre	Company Name	Certificate Course (Y/N)	Requires Period Renewal (Y/N)	Protocols or Region Training is Required For**
Flat Water Paddling	Monitoring Centre	Paddle Canada	Y	N	Wetlands
ATV	Monitoring Centre	Alberta Safety Council	Y	Y	North
ARGO	Monitoring Centre	Alberta Safety Council	Y	Y	North Full-time Staff
Bear Awareness and Avoidance	Monitoring Centre	Alberta Safety Council	Y	N	North
Fire Safety	Monitoring Centre	Danatec	Y	N	All
H2S Aware	Monitoring Centre	Danatec	Y	N	North
Defensive Driving	Monitoring Centre	Danatec	Y	N	All
Wilderness First Aid	Monitoring Centre	Inroads Mountain Sports	Y	Y	Remote
Standard First Aid	Monitoring Centre	St. John's Ambulance	Y	Y	All
Snowmobile	Monitoring Centre	Alberta Safety Council	Y	Y	North Winter
WHIMIS	Monitoring Centre	Danatec	Y	Y	All
TDG	Monitoring Centre	Danatec	Y	Y	Wetland
Avalanche	Monitoring Centre		Y	Y	Winter site-specific
ATV Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	North – 1 per Field Base or Contractor
ARGO Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	As Needed
Bear Awareness Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	North – 1 per Field Base or Contractor
Flat Water Paddling Instructor	Monitoring Centre	Paddle Canada	Y	Y	Wetland – 1 per Field Base or Contractor
Pleasure Craft Operator	Monitoring Centre	BOATsmart	Y	N	As Needed

Driver License	Monitoring Centre	Government of Alberta	Y	Y	All
H2S Alive	Monitoring Centre	Enform	Y	Y	As Needed
OSSA	Monitoring Centre	Keyano College	Y	Y	As Needed
CSO	Monitoring Centre	Keyano College	Y	Y	As Needed

* Records of training are kept on file

** These values are a general guideline only with numerous exceptions for specific regions, sites, season and a crew's assigned equipment. Field Coordinators will use their experience and judgement to determine which courses are needed by specific staff and, when in doubt, will give additional training

Table A1.3. Archived hardware

Hardware	Requires software management	SOP	Centre Responsible
Riverforks E3A-CM Bioacoustic Monitor	N	User Manual Field Manual Riverforks Calibration SOP (awaiting approval)	MC
ARUs (SM2 Units)	Y	Wildlife Acoustics, Song Meter SM2 Bioacoustics Recorder User Guide. Wildlife Acoustics, Inc.	MC

Table A1.4. Archived software

Software name	Version	SOP	Function/Use	Centre Responsible
Bulk Rename Utility	2.7.1.3	NONE	Mass file naming program.	MC
Automated Recording Unit Firmware	SM2: SYS3-3-9.SM2	https://wildlifeacoustics.com/download/firmware-updates	Ensures the units are working properly.	MC
ARU Program	SM2: SMConfigInstaller-3.2.4.exe	https://wildlifeacoustics.com/download/firmware-updates	SC uses the program to delineate when protocols are being collected.	SC | IC | MC | BU

Appendix 2.0: Data Management Committee Terms of Reference

Terms of Reference
ABMI Data Management Committee

May 2017

Objective

The Data Management Committee's goal is ensure proper data organization, management, and delivery. In order to accomplish this, the committee is responsible for identifying and understanding ABMI's data management needs; developing strategies to improve data management shortcomings within ABMI; and implementing new policies and processes relating to any of the data services provided by the Institute.

Committee Membership

The Data Management Committee is comprised of representatives from all ABMI Centres. Two permanent members and one alternate will represent each Centre. The alternate will attend the meetings when one or both of the permanent members are not available. Members are expected to participate in at least three meetings per year. If a permanent member cannot attend the meeting, it is their responsibility to contact their Centre's alternate and make the necessary arrangements.

All members will be expected to come prepared for the meetings, having done preliminary readings/work when applicable.

Each of the permanent members is accountable for sharing the recommendations made by the Data Management Committee with their respective business units. It is also their responsibility to represent their business unit's interests within the committee.

Each of the permanent members is accountable for facilitating and coordinating edits and updates to their respective Centre's QMP.

Execution and implementation of workplans, strategies, or processes developed by the Data Management Committee will remain the responsibility of individual business units. Ultimately, it will fall on ABMI Management Team to decide whether or not to follow the committee's recommendations.

Timeline/Schedules

The Data Management Committee will meet 3 times a year, but other meetings may be scheduled if the need arises.

Meeting will happen in September, January, and April. Tentatively all meetings will be scheduled on the 2nd Monday of each month.

Deliverables

Every 2 years, as part of the first meeting of the season (September), the committee will brainstorm a list of ABMI's current data management needs. These needs will be ordered and prioritized based on the members' assessment and 1 or 2 topics will be selected to be addressed in the coming year.

Achieving resolution for the selected topics will become the committee's primary mandate for the year, and meetings will be prioritized to discuss actions related to those topics.

Meeting Structure

- Members will alternate taking meeting minutes.
- Minutes should always include major decisions and recommendations made by the committee, specific action items agreed by the team and individual accountability for completing the assigned tasks.
- Emphasis in the agenda will be to discuss the topics/needs selected.
- Agendas will be standardized and produced by the committee Chair.
- All members are welcome and encouraged to add topics to the agenda, by contacting the Chair.
- All agenda updates need to be done at least 24hrs before the meeting, no additional information will be added to the agenda after that.

Appendix 3.0: Preparation of Standard Operating Procedures

Title: Guidance for Preparing Standard Operating Procedures
SOP Document Number: ABMI-IC-SOP-001
Version Number: 1.3

Date: 08/07/2013

Approvals

Version Number 1.3

Approved by: Jim Herbers _____ Date:
(Information Director)

Approved by: Jillian Kittson _____ Date:
(Information Coordinator)

Approved by: _____ Date:
(Domain Expert – Joan Fang)

Revision History Log

Version #	Revision Date	Author	Changes
1.0	05/05/2011	Katherine Maxcy	Drafted
1.1	05/10/2011	Katherine Maxcy	Integrated edits/comments from Jim Herbers
1.2	11/16/2011	Jillian Kittson	Document Approval/minor edits
1.3	08/07/2013	Jillian Kittson	Document Review/Edit storage, archive, and review sections/Approval

Introduction

As a world class monitoring program, the Alberta Biodiversity Monitoring Institute (ABMI) is an integral part of the environmental monitoring system in the province of Alberta. The ABMI's integrity and credibility as an institution depends highly on its ability to provide timely, efficient, and open access to quality data. The Information Centre (IC), as the data custodian for the ABMI, is principally responsible for managing and storing the data collected by the various data authorities (e.g., ABMI Monitoring Centre and Processing Centre), and disseminating this data to end-users, including the ABMI Science Centre and public users of the data via the ABMI website. The IC is responsible for data quality management.

As part of the IC's overall quality management system, a series of Standard Operating Procedures (SOPs) are required to provide a systematic approach to verify and validate that ABMI data is of an acceptable quality. This document provides guidance for the preparation of ABMI IC SOPs associated with data management processes and portal operations.

Overview

An SOP is a set of written instructions that describe routine or repetitive work processes performed by an organization (EPA 2007). The development and consistent use of SOPs provide employees with the information to perform a job properly, thereby promoting consistency in the quality and integrity of the end result, in this case, ABMI data and associated products (EPA 2007). As part of an overall quality assurance framework, a system of SOPs is necessary to achieve overall data quality goals and objectives (Montana Water Quality Planning Bureau 2004). The series of SOPs produced and maintained by the ABMI's IC provides a systematic approach to verify and document that ABMI biodiversity data is consistent, complete, and of known acceptable quality.

Purpose

This guidance document describes the structure, format, and content requirements of SOPs used to guide work processes associated with ABMI data management. Included as part of this guidance document are:

- guidelines for determining which work processes require SOPs;
- requirements for SOP review and approval;
- frequency of revisions and reviews;
- document control;
- tracking and archiving; and
- SOP format.

SOP Process

SOP Preparation

SOPs are written sets of instructions detailing procedures for all of the IC's routine and/or repetitive data management tasks (e.g., data loading procedures to the ABMI database). These instructions are summarized in a concise, simple step-by-step format, yet with sufficient detail to allow the procedure to be successfully performed by a qualified person new to the task. Flow charts or work flow diagrams are used whenever possible to illustrate the process(es) being described.

The ABMI IC Director, Information Coordinator, or domain experts (e.g., data programmers) will identify the need for an SOP. Domain experts (i.e., a person experienced with the procedure and the organization's structure) prepare the SOP. A team approach may be used for multi-tasked processes where the experiences of a number of individuals are required. Before developing a new SOP, consultation must occur with the appropriate ABMI staff and domain experts to review the needs and requirements for the SOP.

SOP Review, and Approval

SOPs must be reviewed and accepted by domain experts who perform the work and use the process. Ideally, the SOP is tested by domain experts during the review process to ensure the appropriate level of detail has been provided in the SOP. A second party (e.g., Information Coordinator) must also review the SOP for completeness. Finally, the IC Director perform a third level of review to verify that the SOP complies with data quality management guidelines, and has sufficient quality controls to meets the objective(s) of the procedure. Before the SOP is finalized, approval is required by the IC Director.

Signature approval indicates that an SOP has been both reviewed and approved by management. The title page for each SOP requires three levels of review and acceptance: domain expert, Information Coordinator, and IC Director.

SOP Frequency of Revisions and Reviews

To be useful, SOPs need to be current; therefore, SOPs need to be updated and re-approved whenever procedures change. Revised SOPs will be indicated by the date/revision number on the title page.

SOPs will be systematically reviewed every year to ensure that procedures remain current and appropriate. The review date will be added to each SOP following the review. If an SOP describes a process that is no longer followed, the SOP will be withdrawn from the active file and archived.

The annual review will be scheduled and controlled by the Information Coordinator. The Information Coordinator may review the SOP or assign the task to a domain expert.

Document Control

The SOP numbering system has been developed for the ABMI IC specifically, but could be expanded to the other Centres of the ABMI (e.g., Monitoring Centre, Science Centre) if required. The SOP numbering system for the ABMI begins with this same abbreviation "ABMI". This is followed by a dash and a two-letter abbreviation for the Centre that is preparing the SOP and that is also the primary user of the SOP, including:

- AC – Application Centre
- IC – Information Centre
- MC – Monitoring Centre
- PC – Processing Centre
- SC – Science Centre

After the Centre identifier, a dash is entered followed by three digits ranging from 001 to 999, allowing for 999 Centre SOPs and a total of 4995 ABMI SOPs. See the SOP identification number of this report located at the top right-hand corner of the page as an example. This report is given the number ABMI-IC-SOP-001 which fully translates to the Alberta Biodiversity Monitoring Institute (ABMI) - Information Centre (IC) – Standard Operating Procedure (SOP) - 001. The SOP naming convention distinguishes ABMI SOP documents from other documents produced by the ABMI.

Below the SOP identification number is the Version number (Version #). The version number will be tracked and changed, as necessary, by the Information Coordinator when the SOP is approved. Major revisions are indicated by the next whole number (e.g., Version 2.0, 3.0, 4.0 …). These revisions will be tracked using a revision history log which must be filled in whenever an alteration to the version number is made (including approval for the first time). Version numbers can also increase incrementally as indicated by the decimal place in the Version # (e.g., Version # 1.1, Version # 1.2, etc.) for minor modifications to the SOP. Overall, the version number allows the Information Coordinator to track the number of times a procedure has been revised; it also allows the user to verify that the current SOP is not a draft.

Below the Version # is the date the SOP was revised. As required by the ABMI's QMP, SOPs will be reviewed annually. A record of these revisions is tracked using the Revision History Log located at the beginning of the document. This revision history allows the Information Coordinator to schedule annual reviews. It also allows users to determine if the SOP is current.

The final piece of document control information included in an SOP is page numbering. The current page and total number of pages must be included to ensure users can verify that the SOP is complete.

SOP Document Storage and Archival System

Storage of SOPs, including current versions, old versions, and SOPs no longer in use, is managed by the Information Coordinator. The Information Coordinator is responsible for ensuring that the most recent version of each SOP is used and made available for use on the

ABMI Quality Management Document Page in ClickUp. The Information Coordinator will maintain copies of all SOPs (active versions, archived versions and SOPs no longer in use) on their computer in the IC and on the ABMI file server for auditing purposes or for historical review. Electronic access is limited to a read-only format, thereby protecting against unauthorized changes made to the document.

A master list of all SOPs is maintained by the Information Coordinator. This file indicates the SOP number, version number, date, title, author, status, and any other important information about previous versions. Annual review of SOPs will be tracked with electronic reminders sent to the Information Coordinator email address.

SOP Coordination and Management

The Information Coordinator is responsible for managing the SOP system including:

- overseeing the development and review of IC SOPs;
- developing an SOP awareness and training system (as outlined in the QMP [ABMI-IC-QMP 2013]) the intent of which is to ensure all IC personnel are trained in QA procedures, and that the QC activities as described in the SOPs are adhered to;
- performing periodic audits of SOPs to monitor and improve quality control operations;
- developing and managing the SOP document storage and archival system;
- developing and managing a SOP tracking system.

SOP Format

A consistent format is used for ABMI SOPs to ensure ease and efficiency of use. While the format can be adapted depending on the work process that is being described, all SOPs must contain these sections:

1. Introduction – a brief introduction to the work processes being described in the SOP.
2. Summary of procedure – a brief description of the SOP and its purpose, and a point form list of steps associated with the procedure.
3. Personnel responsibilities – in order to ensure the SOP is followed and enforceable, roles and responsibilities associated with specific tasks in the SOP are assigned to project managers. This is important to ensure that there is data accountability at all stages of the data management process (Martin and Ballard 2010).
4. Software requirements – given data management is largely a digital process, there are a number of pieces of software that may be used for data management tasks. A list of software requirements associated with a particular procedure must be listed.
5. Procedures – broken down into a series of steps, instructions for each task within a step are fully described in point form. Included in the series of steps are tasks specifically related to quality control activities. Quality assurance activities are always included as the last step in the Procedures section.
6. References – list of all literature and reports cited in the SOP.

A “Definitions” section is helpful to the implementation of SOPs.

References

ABMI-IC-QMP. 2011. Quality Management Plan – Data Processing. Version Number 1.0.

EPA (Environmental Protection Agency). 2007. Guidance for preparing Standard Operating Procedures (SOPs). EPA QA/G-6. Report available at: www.epa.gov/quality.

Martín, E. and G. Ballard. 2010. Data Management Best Practices and Standards for Biodiversity Data Applicable to Bird Monitoring Data. U.S. North American Bird Conservation Initiative Monitoring Subcommittee. Online at http://www.nabci-us.org/.

Montana Department of Environmental Quality. 2004. Guidance for preparing a standard operating procedure. Report available at: http://www.deq.mt.gov/wqinfo/qaprogram/sops.mcpx.

Appendix 4.0: ARU Contracting Process Cycle

To ensure ARU data is being processed in a timely manner, and to ensure data quality and data processing and contracting services follow a cycle system lasting a period of 2 months or 8 weeks (table 1).

- In the first week of the cycle, tasks will be prepared and uploaded to a series of projects.
- In the second week of the cycle, the contractors will be notified of the number of tasks available and can choose how much they want to process. Selection and attribution of tasks will depend on their experience level in the region. If they are new to a region and wish to process tasks from that area, they will be required to pass a standardized test. These regions are under further review but will be roughly the Bird Conservation Regions.
- The remaining 6 weeks would be for processing and auditing. Auditing will now be conducted in tandem with processing; as species and tasks are completed, a project administrator will notify the contractors of any species identification errors or auditing that needs to be done. The same minimum data quality standards will still apply. Tags (e.g., confidence set to 'To Be Checked') and tasks (e.g., status set to Review) that require attention will be flagged accordingly.
- In the middle of each cycle (~week 6), a 1-1.5-hour group meeting will be hosted, and it will be free to join for anyone who is interested. The meetings will be for having discussions around species identifications, general processing questions, WildTrax development updates, and bugs and fixes, and any other topics contractors feel are necessary in order to successfully complete processing. The meetings will take place in the following weeks with dates and attendance TBD depending on what projects they're working on.
    - 1st week of September (cycle 1 projects)
    - 1st week of November (cycle 2 projects)
    - 1st week of January (cycle 3 projects)
    - 1st week of March (cycle 4 projects)
- If all tasks for a project are completed on or before the end of the cycle, a 5% bonus will now be applied to the total for that project. For example, if 100 audio minutes for a project were processed, the payout would be 100 audio minutes x $1.43 / audio minute x 0.05 = $150.15. The same 1 minute of audio for Malfunction and Bad Weather regardless of recording length will still apply. Additionally, contractors will bid for which recordings they would like to process by sending the WildTrax Coordinator an email after the assignment becomes available.

Table A2.1. "Cycles" table for ARU contracting to ensure data is being processed and high-quality data is provided.

	August	September	October	November
Week 1	Processing / auditing	Processing / auditing GROUP MEETING	Contract Intake, Data Upload	Processing / auditing GROUP MEETING
Week 2	Processing / auditing	Processing / auditing	Task assignments	Processing / auditing
Week 3	Processing / auditing	Processing / auditing	Task assignments	Processing / auditing
Week 4	Processing / auditing	Processing / auditing	Processing / auditing	Processing / auditing
	December	**January**	**February**	**March**
Week 1	Contract Intake, Data Upload	Processing / auditing Group meeting	Contract Intake, Data Upload	Processing / auditing Group meeting
Week 2	Task assignments Processing / auditing	Processing / auditing	Task assignments Processing / auditing	Processing / auditing
Week 3	Processing / auditing	Processing / auditing	Processing / auditing	Processing / auditing
Week 4	Processing / auditing	Processing / auditing Tasks due, invoices submitted	Processing / auditing	Processing / auditing Tasks due, invoices submitted