WORK-SPECIFIC QUALITY PLAN

FAILURE ANALYSIS SIMULATION MODEL FOR THE APMRD–II (Phase 1)

	Name	Signature	Date
prepared and reviewed by	Patrick Boily, Ph.D. Co-Lead Investigator CQADS/Carleton University		Sep 3, 2015
	Jennifer Schellinck, Ph.D. Co-Lead Investigator CQADS/Sysabee		Sep 3, 2015

Revision Summary		
Revision #	*Date*	*Description of Changes*
R00	May 29, 2015	Original Issue of Quality Plan
R01	Sep 3, 2015	Modifications addressing the NWMO's comments on version R00

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Contents

1. Purpose and Quality Plan Scope

This work-specific quality plan (PQP) addresses how CQADS will both

- implement the quality management activities in regard to the first phase of the Failure Analysis Simulation Model for the APMRD-II Project (FASM), and
- adhere to the quality requirements that are components of the NWMO APM Repository Design Optimization Project QMS (as described in document APM-PLAN-01913-0001-R000) for the same project.

As CQADS facilities (located on campus at Carleton University, in Ottawa) are not ISO certified, the PQP will also address how the FASM Quality Management System will comply with the broader quality management requirements of ISO:9001:2008 and CSA N286-05, as indicated in document APM-PLAN-01913-0001-R000, as well as comply with NWMO quality governance as described in the same document.

Specifically, the PQP describes how the work carried out within the scope of the FASM will be

- planned;
- documented;
- performed under controlled conditions, and
- periodically assessed to establish work item quality and process effectiveness, with an emphasis on meeting the provided NWMO quality requirements and continuously improving the procedures and processes associated with this work.

The PQP, in conjunction with the In-Depth Proposal (CQADS Project #: 15-001-01, February 17, 2015) and Failure Analysis Model Feasibility Study (CQADS Project #:15-001, December 15, 2015), also provides documentation of the products and processes relevant for the FASM.

2. Project Overview and Work Plan

The product, processes, and scope of the FASM, along with an implementation plan, have been described in detail in the In-Depth Proposal and Failure Analysis Model Feasibility Study. They will be further described in the following section of this document, **Detailed Description of Project Procedures and Quality Management Steps**. For ease of reference, a summary of the project's product, processes and scope is also provided here, with attention paid to how these will be integrated with quality management activities.

2.1 Work Product Overview

The primary FASM product will be a report describing the results of the creation of a prototype causal model, created in order to explore strategies for predicting the engineered barrier system's probability of failure. The report will discuss the results of constructing a prototype model considering only a specific causal chain that can influence the state of the engineered barrier system (as opposed to the entire network).

It will then discuss appropriate next steps for the creation of an estimate for the probability of failure – the eventual product to be created in the FASM's subsequent phases. This report will be produced as an output of the prototype creation and analysis process described below, which will integrate quality management processes into its product realization processes in order to ensure product consistency and quality.

2.2 Work Process Overview

To create the report, project members will carry out a prototype creation and analysis process which will involve the selection of a particular causal chain that may influence the state of the engineered barrier system over time, accompanied by:

- the collection and structuring of data relevant to this casual chain;
- the analysis of the relevant data;
- the creation of a conceptual model based on this data;
- the creation of an implemented prototype model based on this conceptual model, and
- the analysis of the behavior of this prototype model.

Quality management activities, processes and procedures relating to planning, control, monitoring and improvement will be incorporated at each stage of this process. These activities, processes and procedures will be described in detail in the following section **Detailed Description of Project Procedures and Quality Management Steps.** More specifically, these project activities will be planned and carried out in order to meet the quality requirements described in document APM-PLAN-01913-0001-R000.

2.3 Work Scope

As noted previously, as well as in the In-Depth Proposal and Failure Analysis Model Feasibility Study, the first phase of the FASM will analyze a specifically selected causal chain (a sub-chain of the entire network) and explore implementation strategies to predict the failure state of the engineered barrier system, using the information and data provided about the chain's nodes.

The resulting prototype model and report will address results relating to this particular causal chain. The causal chain will be selected in consultation with subject matter experts; the emphasis of Phase 1 will be on fine-tuning the data gathering and model construction process.

Any change in scope or changes to key personnel will be discussed with the assigned NWMO Project Manager. If changes are required, a formal request for scope change/additional activities, with supporting evidence, will be submitted to the NWMO, using the NWMO Project Change Control form (NWMO-FORM-WM-008) or equivalent document.

2.4 Work Plan and Project Milestones

The following table summarizes the work plan and project milestones provided in the In-Depth Proposal and Failure Analysis Model Feasibility Study.

Task	Step	Task Category	Task Description	Deliverable (if applicable)	Suggested Timeline
0.		Quality Plan (QP)	Develop QP for Phase 1 (QP will need to be amended for future phases).	Quality Plan	29-May-15
1.	1.	Basic Information and Data Gathering	Learn about the system and gather specific data on the system based on the requirements for the model itself (meetings with and data from SMEs).	Components of Structured Data Repositories	16-Oct-15
2.	2.	Conceptual Prototype (CP)	Select a causal chain for the CP/FP (with input from NWMO and SMEs).	Causal Chain	23-Oct-15
3.			Create CP that captures the gathered data and information.	Conceptual Prototype Model	13-Nov-15
4.	3.	Prototype Creation / Coding	Figure out the specific algorithms to be implemented in the FP (based on theoretical underpinning).		11-Dec-15
5.			Write and modify the core-model-structure code as required by previous iterations.		18-Jan-16
6.			Test and debug the core-model-structure code with selected causal chain data.		15-Feb-16
7.	3.	Full Prototype (FP)	Incorporate the gathered data into the model-structure and setting the parameters to create the FP.		26-Feb-16
8.			Write a first iteration of the input and output parts of the FP.		11-Mar-16
9.			Run a series of functional tests on the FP to confirm that it is operating as expected.		08-Apr-16
10.	3.	Model Analysis for Demonstration Purposes	FP validation.		15-Apr-16
11.			Systems behavior analysis.		25-Apr-16
12.			Scenario behaviour analysis		06-May-16
13.	4.	Report	Write a simple report of the results of the analyis of the FP, as well as next steps.	Report	13-May-16

*** Note that the Centre will be closed from 18-Jul-15 to 28-Aug-15, and from 21-Dec-15 to 04-Jan-16.

3. Detailed Descriptions of Project Procedures and Quality Management Steps

This section provides a detailed description of the project procedures summarized above, including:

- The steps taken to meet CSA N286-12 and ISO 9001:2008 quality control and quality assurance requirements for each of these procedures, including the monitoring, error correction, verification and validation steps taken during each of these procedures
- How the conceptual model creation and implemented model creation procedures will meet CSA N286-12 and ISO 9001:2008 design specific requirements relating to:
  - Model Design Reviews
  - Parameter/ Data Quality Control
  - Computer Model Design Tools and Requirements
  - Change Management
  - Verification of Model Design or Technical Work
  - Regulatory Requirements

3.1 Quality Management Overview

Proper quality management plan implementation requires:

- procedures, test plans, and protocols used to ensure consistency, repeatability and traceability of work activities;
- quality control measures relating to accuracy, precision and reliability, and an implementation plan;
- strategies for monitoring, inspection and/or reviewing the quality of project products, and notification of the NWMO Representative of any deficiencies in the goods and services, and
- the execution of any identified corrective measures, and subsequent confirmation and reporting of the results of the corrective measures to the NWMO Representative.

Detailed information concerning plans and procedures for consistency and quality control, monitoring, verification, and deficiency detection and correction plans follows.

Any deficiencies found after quality assurance checks, tests or verifications have been performed, shall be documented and reported to the NWMO representative along with the planned corrective action. The NWMO will review and accept the corrective action before it is implemented.

In addition to these procedures and resulting reports, quarterly status meetings (July, October, January, May) will be held between CQADS and NWMO, the location of which to alternate between NWMO offices in Toronto and the CQADS office in Ottawa. At these meetings, any inspections, checks or verifications which may have been undertaken to assure the quality of the work and any deficiencies which might have been observed and subsequently reported will be reviewed and discussed. Minutes from the meeting will summarize the progress on the project and will document any QA issues. The minutes will be reviewed and approved by the NWMO.

The minutes from the meeting will summarize the progress on the project and shall document the quality assurance activities (e.g. checks, tests, verifications) and any Quality Assurance issues.

3.2 Overarching Quality Control and Assurance Procedure

The procedures required for the creation of the prototype model, including specific quality control and assurance steps, will be described in detail below, in the Project Specific Procedures section. In addition to this, a more broadly applicable quality control and assurance procedure has been developed which will further be applied to all the described specific procedures, in addition to procedure specific quality control and assurance steps. This broad quality control and assurance procedure will be described below.

Quality Management Documents produced during these steps: Checkpoint Reports.

3.2.1 Temporal Checkpoints

At pre-defined time intervals (20%, 50%, and 80% of the way through a procedure):

- For each specific procedure described, monitoring and assessing will occur at the checkpoint as follows:
    - Assessment of overall progression and efficiency/effectiveness of current procedure steps and tools, by considering and answering the following questions (with Checkpoint Report documenting the outcome of this process):
        - Is progress (time-wise/content-wise) as expected?
        - Have the procedure steps to this point achieved their intended goals? Generated their intended outputs?
        - Have the procedure steps up to this point been too complicated or problematic in some other way? Are future steps in the procedure likely to become too complicated or similarly problematic?
        - Are the available tools, technologies and methodologies assigned to this procedure performing at sufficient levels?
    - Assessment of current and projected availability of appropriate inputs/outputs (including knowledge transfer)
- If problems or unacceptable discrepancies are identified, the following steps will be taken (with actions taken documented in the Checkpoint Report):
    - Consider possible outcome of identified issue or discrepancy
    - Consider time required for resolving issue: is time required worth it, relative to the identified issue or discrepancy?
    - In the case of efficiency issues, are possible alternative solutions or strategies as complete as the non-efficient processes?
    - Is there a different technology or capabilities available to address these issues?
    - If appropriate and possible, address the identified issues using some or all of the following strategies:
        - reallocate resources
        - modify procedures (e.g. simplify)
        - revise timeline expectations
        - if needed identify process or sub-process steps that need to be modified, and modify appropriately
        - identify and implement cost-effective/time-effective alternatives
        - change approach using currently available tools

3.2.2 Procedural Checkpoints

Procedural Checkpoints are mandatory at the end of each procedure and optional during the procedure. For these checkpoints:

- Same considerations as for temporal checkpoints, but considers, more broadly, how the current procedure and its expected or generated outputs could affect the outcome of the project at large.
- Assessment at this point will also consider the following possible issues in the larger project context (bracketed letters indicate broad project areas potentially requiring attention, where I = implementation, PM = project management and M = methodology),
    - Given the progress and output of this procedure, is the project going where it's supposed to go (i.e. are the goals of the project being met):
    - Is progress of the project at this point too slow (PM)(I)
    - Based on the outcome of this process, is the project problem ill-posed or unanswerable (M)
    - unsuitability of processes (PM)
    - dependencies are out of whack (incompatible I/O) (PM) (I)
    - unresponsive SMEs (PM)
    - complexity through roof/overfitting issues (M) (I)

Based on the identified issue and corresponding area of relevance, if problems or unacceptable discrepancies are identified, steps similar to the steps for the temporal checkpoint issues will be take, but with a focus on the broader issues of implementation, project management and methodology.

3.3 Project-Specific Procedures

The first phase of the FASM encompasses several major project steps, comprised of: data collection and structuring, data analysis, the selection of a prototype causal chain, the creation of a conceptual model, the creation of an implemented model (simulation) and the analysis of that model. In addition to the specific quality management steps described below for each of these project procedures, it should be noted that the project steps themselves have been selected from a quality management perspective, with the intention that carrying out these steps in the described sequence will allow for the methodical and meticulous construction of the final implemented model, such that the resulting model will be an accurate and consistent representation of the system in question.

Specific project procedures and quality management steps for each of these procedures are shown in the following sections.

3.3.1 Data Collection and Structuring Procedure

3.3.1.1 Data Collection and Structuring Procedure: Objectives

- Develop a consistent, usable, document reference library.
- Provide an overview of the state of the library and the information it contains. In particular, keep a log of what records/documents are available (or not) in the library, and also what information we are seeking and have found.
- Obtain copies of records to place in library.
- Evaluate the information in the library to keep the overview of the library and its information accurate and current.

3.3.1.2 Data Collection and Structuring Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Determine cataloguing procedure, including reference catalogue format, fields, citation style, and naming procedure.
2. Make a list of potential data source categories including data from papers (internal NWMO papers, white papers, published externally) journal articles, papers from other nuclear organizations (including Canadian predecessors), and data from experts.
3. Gather records from data source categories (e.g. PDF files of papers, emails from SMEs, recordings of SME communication, notes from SME communication) and ask key people at NWMO for additional relevant documents.
4. Collect and structure the information in data fact sheets by:
    - developing a data fact sheet format,
    - identifying key system objects,
    - extracting information from research documents pertaining to the objects, and
    - encoding this information in the data fact sheet.

Procedure inputs: Reference documents, research documents, information from NWMO SMEs
Procedure outputs: Data source list, library catalogue, reference library, data fact sheets

3.3.1.3 Data Collection and Structuring Procedure: Quality Management Steps

In addition to the general quality management steps that will be applied to this procedure (listed as part of the General Quality Control and Assurance Procedure), specific quality management steps, encompassing monitoring, deficiency detection and correction, verification, and validation, will be described below..

Quality management documents produced during these steps: Cataloguing Procedures Review Report, Data Source Review Report, Data Collection Log, Data Fact Sheet Verification and Validation Log, Data Fact Sheet Quality Check Report.

3.3.1.3.1 During Creation of Catalogue Procedures

Cataloguing procedures developed in step 1 are to be reviewed and agreed upon by two internal members. This review will be documented in the cataloguing procedures review report (verification).

3.3.1.3.2 During Data Collection Preparation

- Outputs of step 2 (the data source list) will be reviewed internally by a second party to ensure completeness and accuracy and a data source review report created (verification).
- The final list of data source categories from Step 2 will also be reviewed by the NWMO lead and SMEs to ensure completeness and accuracy (validation).

3.3.1.3.3 During Collection of Records

Create a log (data collection log) of attempts to collect record, noting time collected, collector, record name and record availability status (monitoring and traceability)

3.3.1.3.4 During Work on Data Fact Sheets

- Use controlled grammar to ensure consistency and accuracy across data fact sheets (consistency and repeatability).
- For each statement within the data fact sheets, within the data fact sheet record the items from the library that were used to construct the statement. Also record who entered the fact onto the fact sheet (traceability).

3.3.1.3.5 Upon Completion of a Particular Data Fact Sheet

- Conduct a check to verify that citation and logging have been carried out.
- Check for errors, omissions, or deficiencies (e.g. loss of relevant information and/or addition of irrelevant information). If errors, omissions, or deficiencies have been identified, correct as follows:
  - if loss of relevant information due to aggregating has been identified, correct by splitting the statement, or by adding appropriate qualifiers to the subject and/or object in the original statement (deficiency correction),
  - if a transcription error has been identified, correct by replacing the incorrect transcription with the corrected version. (deficiency correction), and,
  - if a statement in a data fact sheet cannot be adequately expressed using the current grammar and/or vocabulary, then highlight for review (deficiency correction).
- Create a data fact sheet verification and validation log entry to confirm that checks have been carried out.

3.3.1.3.6 Upon Completion of Data Fact Sheets

Upon completion of first 5 data fact sheets:

- create a new data fact sheet using the same input and compare the two results (accuracy, precision and reliability),
- compare data fact sheet content with the controlled grammar and identify loss of relevant information and/or addition of irrelevant information due to items on a data sheet not corresponding to the controlled grammar (deficiency identification),
- compare data fact sheet with original source to see if statements have been transcribed incorrectly (accuracy, verification),
- compare data fact sheet with original source to see if there is complete or incomplete coverage of information on data sheet (accuracy), and
- create a data fact sheet quality check report documenting the outcome of these steps.

3.3.1.3.7 Data Fact Sheet Validation

*O*nce verification, deficiency detection, and deficiency correction steps have been carried out, provide *d*ata *f*act sheets to NWMO SMEs for external review, to confirm that the*se fact sheets* conceptualize the system in an expected manner and are focusing on aspects of the system considered relevant by SMEs (*v*alidation).

3.3.2 Data Analysis Procedure

3.3.2.1 Data Analysis Procedure: Objectives

- Generate a compilation of causal statements that accurately reflect the causal information contained in the data fact sheets (output of the data collection).
- Generate statements that are readily usable in the causal chain selection and model conceptualization processes.

3.3.2.2 Data Analysis Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Aggregate and review the data fact sheets
2. Extract causal statements from data fact sheets
3. Assemble causal statements into causal chains
4. Create a list of possible prototype model causal chains from the assembled causal chains (input into casual chain selection process)
5. As well, for the causal chain components, assess which factors may influence the state of these components or cause the relevant events (input into model conceptualization process)

Procedure inputs: data fact sheets
Procedure outputs: causal statements, causal chains

3.3.2.3 Data Analysis Procedure: Quality Management Steps

In addition to the general Quality Management steps that will be applied to this procedure (listed as part of the General Quality Control and Assurance Procedure), specific quality management steps, encompassing monitoring, deficiency detection and correction, verification, and validation, will be described below.

Quality Management documents produced during these steps are: Causal Statement Verification and Validation Log, Causal Statement Quality Check Report.

3.3.2.3.1 During Work on Causal Statements

- Use controlled grammar to ensure consistency and accuracy across causal statements (consistency & repeatability).
- For each causal statement, record the data fact sheets from the library that were used to construct the statement. Each statement should have a list of one or more keys corresponding to items on a data sheet (traceability).

3.3.2.3.2 Upon Completion of a Particular Set of Causal Statements

- Conduct a check to verify that statements are accurate and appropriately formed, entering this check into the causal statement verification and validation log (verification).
- If errors, omissions or deficiencies have been identified, correct as follows:
  - if loss of relevant information due to aggregating has been identified, correct by splitting the statement or by adding appropriate qualifiers to the subject and/or object in the original statement (deficiency correction),
  - if a transcription error has been identified, correct by replacing the incorrect transcription with corrected version. (deficiency correction),
  - if, after all statements have been extracted from a data sheet:

- an item is referenced by more than one causal statement, then review these statements for consistency (deficiency correction), or.
- an item is not referenced by any causal statements, then confirm it should not be incorporated into a (controlled grammar) statement (deficiency correction), and

- if a statement in a data fact sheet cannot be adequately expressed using the current grammar and/or vocabulary, then highlight for review (deficiency correction).

3.3.2.3.3 Upon Completion of Extraction of Causal Statements

Upon completion of extraction of causal statements from the first 5 data fact sheets:

- create a new causal statement using the same input and compare the two results (accuracy, precision and reliability),
- compare the causal statement with the controlled grammar, and
- create a causal statement quality check report documenting the outcome of these steps.

3.3.2.3.4 Causal Statement Validation

- Once verification, deficiency detection and deficiency correction steps have been carried out, provide causal chains to NWMO SMEs for external review (validation). This is the final major validation stage of the project, and it is important at this point for SMEs to feel fully confident about the focus, content and scope of the information output from the data analysis step.
- Confirm with NWMO that compilation of statements is reasonable. Similarly for the possible causal chains.
- NWMO SMEs are to verify that the outputs of the data analysis accurately reflects their knowledge of the system and also, from a scope perspective, are relevant to the aspects of the system that they wish to consider in this modeling project.

3.3.3 Causal Chain Selection Procedure

3.3.3.1 Causal Chain Selection Procedure: Objectives

The selection and high-level definition of a representative causal chain that can be used to create a prototype model.

3.3.3.2 Causal Chain Selection Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Obtain possible causal chain candidates from the data analysis process.
2. Review causal chain candidates and rank these candidates based on metrics including: known available information relevant to chain, estimated relevance to engineered barrier system, and completeness of chain.
3. Create descriptions of causal chain candidates and circulate to SMEs prior to review.
4. Meet with SMEs to confirm selection of causal chain for prototype model.

Procedure inputs: causal chain data from data analysis step, information from SMEs
Procedure outputs: selected causal chain

3.3.3.3 Causal Chain Selection Procedure: Quality Management Steps

In addition to the general quality management procedures listed as part of the General Quality Control and Assurance Procedure, specific quality management procedures, described below, will occur for the Causal Chain Selection Procedure steps.

Quality management documents produced during these steps are: Causal Chain Review Report.

Quality management steps are as follows:

- NWMO SMEs and project lead are to validate that the chosen causal chain is an appropriate chain with respect to its ability to broadly represent expected causal chains in the full model, to adequately test the modeling methodology and allow both NWMO and CQADs to assess the viability of the larger modeling project (validation).
- A causal chain review report will be created based on the outcome of the preceding step.

3.3.4 Conceptual Model Design and Creation Procedure

3.3.4.1 Conceptual Model Design and Creation Procedure: Objectives

A comprehensive conceptual description of the model which can then be implemented in the chosen modeling environment, where this model description is comprised of:

- a description of a series of nodes, representing causal events, connected to other nodes, with the connections representing the influence of one causal event on its connected events, and with the nature of causation indicated by the type of connection,
- a set of probabilities associated with each node, determining the probability that the node will fire, and
- a set of underlying rules (model of relevant factors) determining the conditions under which the nodes will fire.

3.3.4.2 Conceptual Model Design and Creation Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Design and develop underlying model framework and concepts required to create the conceptual model.
2. Review the collected and structured engineered barrier system data, including system description, data fact sheets and causal chain data.
3. Based on this data, create model nodes that represent the selected causal chain.
4. Determine and establish relevant types of connections between nodes (e.g. and/or connections) based on causal relationships.
5. For each node, determine conditions under which node should fire, using collected system data.
6. For each node, determine probabilities associated with node firing, using collected system data.
7. For each node, determine if an underlying model incorporating relevant factors should be created to calculate when the node should fire.
8. For relevant nodes, create mathematical/logical models underlying the node, using collected engineered barrier system data.

Procedure inputs: data fact sheets, causal statements, engineered barrier system data
Procedure outputs: conceptual model, conceptual model assumptions

3.3.4.3 Conceptual Model Design and Creation Procedure: Quality Management Steps

In addition to the general quality management procedures listed as part of the General Quality Control and Assurance Procedure, specific quality management procedures, described below, will occur for the Conceptual Model Design and Creation Procedure.

Quality management documents produced during these steps are: Model Design Review Reports, Conceptual Model Redesign Reports (if necessary), Model Component-Causal Statement Comparison Checklist, and Conceptual Model Verification Report.

3.3.4.3.1 Conceptual Model Design Reviews and Model Design Verification

The purpose of the model design reviews in the case of the conceptual model will be to confirm that the conceptual model is designed in such a way that it accurately captures the information represented in the data fact sheets and causal statements generated in the preceding steps of the process.

Conceptual model design reviews will correspond approximately to the following design completion points:

- concept

- preliminary
- 50% complete
- 80% complete
- just prior to final report

The design (underlying model framework and concepts) will be reviewed first by members of the conceptual model creation team and then by someone internal to the project but not a part of the conceptual model creation team in order to verify the comprehensiveness of the design, and also to detect any conceptual issues and errors which may be present.

A model design review report will be generated encompassing the reviews at each of these points, and incorporating design review results to ensure that the review is comprehensive and errors of omission are minimized.

Design reviews shall include a documented summary of the testing performed and the results against the established acceptance criteria for the FASM completion points.

3.3.4.3.2 Change Management During Conceptual Model Design and Creation

If problems are found with the existing design of the conceptual model, a redesign exercise will be implemented. At this point, NWMO will be informed of the redesign requirement, and the reason for the redesign. Upon completion of the redesign exercise, a conceptual model redesign report will be created and NWMO will be updated regarding the new model design.

Once delivered to and accepted by the NWMO, any required changes to accepted designs, documents, tools, materials, parts, processes, services and practices shall be subjected to review before delivery of the updated deliverable. More specifically, a review will be undertaken to identify any subsequent effects or implications of the change, particularly with respect to NWMO use of the deliverable.

For all required changes, information shall be provided to ensure an adequate understanding of the original product and proposed revision to this original product, to facilitate assessment of the effect of the change.

Any deficiencies found after quality assurance checks, tests or verifications have been performed, shall be documented and reported to the NWMO representative along with the planned corrective action. The NWMO will review and accept the corrective action before it is implemented.

These change management strategies will also apply more generally to any significant changes in the direction of the project as a whole.

3.3.4.3.3 Accuracy, Consistency, Completeness of Implemented Model Relative to Conceptual Model

At regular intervals during the conceptual model creation process (20%, 50%, 80%) a check to confirm that the conceptual model is consistent with the causal statements and data fact sheets will be carried out (model component-causal statement comparison checklist).

3.3.4.3.4 Verification of Created Conceptual Model

As they are created, all components of the model will be reviewed by a second member of the conceptual model creation team, to verify decisions made regarding the model structure and their consistency with outputs of previous procedures, as well as to detect any mismatches between the structure of the model and the data upon which that component of the model is based.

Upon completion of the model, the model components and assumptions will further be verified as a whole by comparing against the output of previous procedures to confirm overall consistency with:

- the information used to construct the model, and
- the established design of the model structure.

The final structure of the model will be verified by review by an external project member who has not participated in the creation of the conceptual model.

The results of the model verification exercise will be documented in a conceptual model verification report.

3.3.4.3.5 Validation of Created Conceptual Model

Upon completion of the model, NWMO SMEs will do a high-level review of the conceptual model to confirm that it encompasses a sufficient amount of the system to be considered a good prototype test, and also to broadly confirm that the structure of the model is consistent with their understanding of the system and focused on aspects of the system considered relevant to the failure of the system.

3.3.5 Implemented Model Design and Creation Procedure

Because the implemented model involves software development, the Implemented Model Design and Creation Procedure incorporates the software design requirements detailed in document NWMO-PROC-EN-0002, Technical Computing Software Procedure. This includes a software plan, which is included in Appendix A of this PQP. Additional details about the implemented model design and creation procedure are supplied in the section below.

3.3.5.1 Implemented Model Design and Creation Procedure: Objectives

- Create an implemented model that accurately reflects the information contained in the conceptual model and functions in a manner that is consistent with this information.
- Create an implemented model that can be used to explore causal chain scenarios.
- Create an implemented model that allows for assessment of the feasibility of creating a causal model of the engineered barrier system.

3.3.5.2 Implemented Model Design and Creation Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Choose a modeling environment.
2. Develop an implemented model framework and structure.
3. Define correspondences between the conceptual model structure and the implemented model structure.
4. Refine the implemented model structure based on these required correspondences.
5. Using these identified correspondences, design the implemented model.
6. Referring to the conceptual model, implement the model by coding it into the chosen model environment, following the software development requirements as described in NWMO-PROC-EN-0002, Technical Computing Software Procedure.
7. Test the implemented model to confirm correct functionality, again following the software development requirements as described in NWMO-PROC-EN-0002, Technical Computing Software Procedure.

Procedure inputs: conceptual model
Procedure outputs: implemented model

3.3.5.3 Implemented Model Design and Creation Procedure: Quality Management Steps

In addition to the general quality management procedures listed as part of the General Quality Control and Assurance Procedure, and the quality management procedures described in NWMO-PROC-EN-0002, Technical Computing Software Procedure, the specific quality management procedures describe below will occur for the Implemented Design and Creation Procedure (see also the included Software Plan in Appendix A).

Quality management documents produced during these steps are:

- model design review reports
- implemented model redesign reports (if necessary)
- model scenario and parameter description
- implemented model-conceptual model comparison checklist
- implemented model verification report
- quality management documents required by, and described in, NWMO-PROC-EN-0002, Technical Computing Software Procedure (see also the included Software Plan in Appendix A)

3.3.5.3.1 Implemented Model Design Reviews and Model Design Verification

The purpose of the model design reviews in the case of the implemented model will be to confirm that the implemented model is designed in such a way that it accurately represents the objects and object relationships represented in the conceptual model, and furthermore, does not incorporate additional representations or assumptions that are not contained in the conceptual model.

Implemented model design reviews will take place at the following FASM completion points:

- concept
- preliminary
- 50% complete
- 80% complete
- just prior to final report

The design of the implemented model will be reviewed by members of the conceptual model creation team, members of the implemented model team, and then by someone internal to the project but not a part of the conceptual or implemented model creation team, in order to verify the comprehensiveness of the design, and also to detect any conceptual issues and errors which may be present.

A model design review report (model design review report) will be generated that encompasses the reviews, with incorporated design review results, at each of these points to ensure that the review is comprehensive and errors of omission are minimized.

Design reviews shall include a documented summary of the testing performed and the results against the established acceptance criteria for the FASM completion points.

3.3.5.3.2 Computer Model Design Tools and Requirements

Computer-based tools (at this time MATLAB is anticipated to be the primary tool) used in the model implementation process shall be appropriate for the project and used in accordance with NWMO-PROC-EN-0002, Technical Computing Software. See the Software Plan, included in Appendix A, for further details.

For analyses that could impact nuclear safety the software must be Nuclear Grade and the Technical Computing Software requirements for Nuclear Grade Software shall apply. However, as discussed further in the Software Plan (Appendix A), the modeling that will be conducted in this prototype project is exploratory-type work and will not impact nuclear safety.

3.3.5.3.3 Change Management During Implemented Model Design and Creation

A change management plan for the software developed during model implementation is discussed in the Software Plan (Appendix A).

Separate from this, if problems are found with the design of the implemented modeling framework, a redesign exercise will be implemented. At this point, NWMO will be informed of the redesign requirement, and the reason for the redesign. Upon completion of the

redesign exercise, an implemented model redesign report will be created and NWMO will be updated regarding the new model design.

Once delivered to and accepted by the NWMO, any required changes to accepted designs, documents, tools, materials, parts, processes, services and practices shall be subjected to review before delivery of the updated deliverable. More specifically, a review will be undertaken to identify any subsequent effects or implications of the change, particularly with respect to NWMO use of the deliverable.

For all required changes, information shall be provided to ensure an adequate understanding of the original product and proposed revision to this original product, to facilitate assessment of the effect of the change.

Any deficiencies found after quality assurance checks, tests or verifications have been performed, shall be documented and reported to the NWMO representative along with the planned corrective action. The NWMO will review and accept the corrective action before it is implemented.

These change management strategies will also apply more generally to any significant changes in the direction of the project as a whole.

3.3.5.3.4 Implemented Model Parameter/ Data Quality Control

As Phase 1's main objective is prototype development, model behaviour will need to be explored using a wide variety of hypothetical parameters in addition to the parameters that are set based on collected data. The origin of any parameters and parameter values used to generate model behaviour data during modeling activities, along with their source (e.g. literature, databases, analytical results), will be identified and documented. Any assumptions made in the selection of those values and any limitations of the data will also be specified.

Where it is deemed relevant to analysis of prototype behaviour, parameter settings for particular scenarios will also be reviewed by SMEs.

3.3.5.3.5 Accuracy, Consistency, Completeness of Implemented Model Relative to Conceptual Model

At regular intervals during the model implementation process (20%, 50%, 80%) a check to confirm that the implemented model is consistent with the conceptual model will be carried out (implemented model-conceptual model comparison checklist).

3.3.5.3.6 Implemented Model Verification and Validation

The verification and validation of the implemented model is discussed in detail in the Plan for Verification and Validation Activities section of the Software Plan (Appendix A).

3.3.6 Implemented Model Analysis Procedure

3.3.6.1 Implemented Model Analysis Procedure: Objectives

- Determine the hypothetical probability of engineered barrier system failure occurring for the causal chain selected, assuming the causal chain represented the system as a whole.
- Develop and confirm the feasibility of the chosen model behaviour analysis methods and techniques.

3.3.6.2 Implemented Model Analysis Procedure: Steps, Inputs, and Outputs

Procedure steps:

1. Devise appropriate scenarios for model testing and analysis.
2. Generate data by running the model under the chosen scenarios.

3. Identify appropriate existing techniques and develop any new techniques required to analyze the data.
4. Carry out an analysis of the data using the identified techniques.
5. Using the results of the data analysis, determine the probability of failure for the specific causal chain.

Procedure inputs: implemented model, scenario plan
Procedure outputs: model data, model analysis results, model analysis report

3.3.6.3 Implemented Model Analysis Procedure: Quality Management Steps

In addition to the general monitoring procedures listed as part of the General Quality Control and Assurance Procedure, specific quality management steps, described below will occur for the Implemented Model Analysis Procedure.

Quality management documents produced during these steps are: Model Scenario Run Log, Model Analysis Verification Log.

Quality management steps:

- Have an independent person check the appropriateness of the choice of analysis techniques (verification).
- During scenario runs, maintain a model scenario run log that notes who has run the model, which model version has been used, the parameters that have been used and the name of the data files that have been generated (traceability).
- Have an independent person check and document (using the model analysis verification log) that the output of the analysis has been generated correctly (verification). Specifically confirm that:
  - correct scenarios have been run and parameters entered correctly, and
  - correct output data has been used to generate analyses.
- Confirm with NWMO that the level of accuracy and form of the failure of probability is as expected (validation).

4. Additional Project Quality Requirements Project Overview and Work Plan

Additional quality requirements relevant for this project, as provided in document APM-PLAN-01913-0001-R000 include:

- Worker Competence, Roles, and Responsibilities
- Subcontractor Requirements
- Reporting Requirements
- Management Responsibility and Commitment
- Quality Policy and Objectives
- Record Management and Control
  - Structured Repository for Document Management
  - File Naming Conventions
  - Version Control
  - File Plan and File Retention & Disposition
  - Storage and Disposal of Secure Records and Data

These requirements will each be addressed in detail in the following subsections.

4.1 Worker Competence, Roles, and Responsibilities

The following individuals will be involved in this phase of the project: Dr. Jennifer Schellinck (Co-Lead Investigator), Dr. Patrick Boily (Co-Lead Investigator), Dr. Katrina Rogers-Stewart (Data Structuring, Conceptual and Prototype Modeling), and Shintaro Hagiwara (Ph.D. Student: Model Testing and Verification, Data Analysis). Copies of their c.v. were included in the initial proposal (see Appendix B of that document). In the event that a project member has to be replaced or added to the team, CQADS will notify the NWMO in writing and provide them with a copy of the additional member's c.v.

4.2 Subcontractor Requirements

If any of the project work is subcontracted, the lead investigators of the project will clearly communicate quality management requirements and be fully responsible for the quality of work carried out by their subcontractors.

More specifically the lead investigators will:

- provide a copy of this quality plan and other key documentation to the subcontractor to facilitate management of the quality of work performed by the subcontractor and ensure compliance with the requirements of this quality plan;
- require that the subcontractor read this quality plan and the NWMO APM Repository Design Optimization Project Quality Plan (document APM-PLAN-01913-0001-R000);
- either require that the subcontractor create a quality plan that encompasses their work on the project and that adheres to the quality plan and procedure requirements described within the NWMO APM Repository Design Optimization Project Quality Plan and this quality plan, participate in the creation of relevant components of a larger quality plan that likewise adheres to these quality plan requirements or, if their work is already fully documented in this quality plan, provide a document stating how they will meet the requirements already outlined in this quality plan;
- review the resulting quality plan or document and confirm that it meets the requirements of the NWMO APM Repository Design Optimization Project Quality Plan and this quality plan, and request revisions of the quality plan until it meets these requirements, and
- regularly meet with the subcontractor to review quality plan activities and assure compliance with the quality plan.

4.3 Reporting Requirements

Upon delivery of each project deliverable, a written report summarizing relevant Quality Assurance activities undertaken during creation of that deliverable (e.g. reviews, checks) will be provided to NWMO. Any other relevant quality assurance records will also be submitted at this time. See the procedure descriptions for additional information about quality management reports and documents to be provided.

4.4 Management Responsibility and Commitment

Compliance with the Quality Plan is the joint responsibility of Drs. Patrick Boily and Jennifer Schellinck.

CQADS will work closely with NWMO to ensure that the project meets NWMO's requirements, particularly the technical and quality requirements. The Project Team is committed to providing quality deliverables that will completely satisfy the NWMO expectations.

4.5 Quality Policy and Objectives

As part of its quality management process, CQADS is committed to ensuring the continual integration of the NWMO's functional requirements into the project deliverables through ongoing communication and collaboration. CQADS' principal goal in this respect is for the FASM products to fully satisfy the NWMO's expectations and functional requirements, guaranteeing that these deliverables will comprehensively support the development of their quality systems.

The specific related quality objectives for this work include:

- the provision of a prototype model that will allow the NWMO to accurately evaluate the value and potential of the proposed full-scale model of the barrier system;
- the creation of a model which clearly defines its level of accuracy and/or uncertainty, as well as functionality, such that it can be applied appropriately and correctly to answer questions at an appropriate level of detail.

Due to the R&D and prototypical nature of the project, the quality objectives are only qualitatively measurable. Quantitative measures will be provided for the proposed full-scale model of the barrier system in a second phase, should the NWMO decide that the prototype model shows sufficient potential.

4.6 Regulatory Requirements

Work conducted by CQADS will be completed in full compliance with all regulatory requirements. Specific regulatory requirements for the APM DGR are identified in the APM DGR System Requirements APM-PR-01110-0001-R001.

4.7 Records Management and Control

The requirements for records management and control are further separated in 5 categories.

4.7.1 Structured Repository for Document Management

Project files will be maintained in structured file and data repositories with version control systems, in a manner that meets the records management system functional requirements outlined in NWMOs Document Management and Records process document (NWMO-PROC-AD-0002, Records Management).

4.7.2 File Naming Conventions

Internal documents will be given file names based on a filing naming convention that provides relevant semantic information relating to document purpose, document type, and document version control.

Documents provided to NWMO will be given file names consistent with NWMO file naming requirements and conventions (e.g. documents will be identified by date and sequential revision number (e.g. R00, R01, R02, etc.).

4.7.3 Version Control

Where documents evolve over the course of the project, the different document versions will be archived. In the case of reports and documentation, major revision history will also be noted within the document. For model files, a summary of the major changes from version to version of the model will be kept in an index file. For data generated by models, model parameter settings and other relevant model information will be recorded.

4.7.4 File Plan and File Retention & Disposition

A file plan listing relevant document types and their planned retention and disposition policies, consistent with APM-LIST-08133-001 but specific to this project, will be maintained. File Plan document types will include:

- project correspondence with NWMO
- project deliverables
- computer code
- computer program input and output
- project reports and memoranda, including quality assurance reports (e.g. Quality Assurance Activity Report, Project Progress Report, Nonconformance and Corrective/Preventative Action Reports)
- documents produced during verification activities (e.g. review and verification records)
- minutes of meetings

Records with quality assurance importance will be provided to the NWMO in a suitable electronic format either no later than the end of the project or on an annual basis if the project extends for more than 1 year.

Project documents and records will remain archived at CQADS for five years following the completion of the relevant phase of the project, at which point they will be disposed of in a secure manner (see Secure Record and Data Storage and Disposal, below)

4.7.5 Storage and Disposal of Secure Records and Data

Electronic documents pertaining to the project and identified by the file plan will be stored on a secure server. Records with quality assurance importance will be stored securely and systematically in accordance with APM-LIST-08133-001. Computers used to house models, project documents and project deliverables will be backed-up to a secure server at least once per week.

All paper copies of relevant identified documents will be stored in secure locations prior to being archived (at which point they will be moved to the designated CQADS archive location, see File Retention and Disposition, above). Disposal of paper documents will involve shredding and recycling of the material.

Quality Assurance records will be retained for seven years.

Appendix A. Software Plan for Prototype Model Software (v001)

This Software Plan provides a description of software development activities associated with the development of the implemented prototype model software. As noted in document Technical Computing Software Procedure (NWMO-PROC-EN-0002), the software plan for Standard Grade software must identify:

- Software name and version number.
- Purpose of software, including problem definition.
- Software grade and justification.
- Key roles and accountabilities, including identifying the *Primary Holder*.
- Key deliverables, tasks, schedules, and methods.
- Verification and validation activities (or a plan describing these activities).
- Configuration management, change control method, and which components will be controlled.
- Associated Reference Datasets, if any, and their configuration management and change control if different from the software.

These software development plan elements will be provided below.

A.1 Problem Definition and Purpose of Software

A.1.1 Problem Definition

The general objective of this project as a whole is to estimate the failure probability of the Mark II canister and engineered barrier system immediately surrounding the canister. In order to achieve this objective, we will be using a combination of statistical analysis, mathematical modeling, and simulations.

More specifically, we will take the approach that our model is meant to answer a specific question, as well as to provide outputs that can be fed into other models, as may be required by already-developed NWMO models.

The model will be built to answer the following question: What is the probability that the engineered barrier system (or part(s) thereof) will fail under a particular set of circumstances, taking into account all of the agreed-upon complexities of the barrier system and possible conditions under which it might be placed?

In later phases, we will model the engineered barrier system and, to a limited extent, the interface between it and the geosphere, using a binary fail/non-fail model (rather than a partial failure model). Within this context, we will also look at a reasonable number of scenarios, determined in collaboration with the NWMO.

For the current Phase 1 Prototype, we shall consider a specifically selected causal chain. The causal chain will be selected in consultation with SMEs; the emphasis at this stage is on fine-tuning the data gathering and model construction process.

A.1.2 Purpose of Software

The purpose of the software in Phase 1 is to provide a proof of concept of the modeling framework to be used in subsequent stages and also to allow for analytic strategies to be fully developed and tested. In order to do this, the software will simulate the behavior of the selected sample causal chain (which is part of the larger NWMO barrier system) and use the simulation to calculate the probability of failure for this sample causal chain.

A.2 Software Grade and Software Grade Justification

The software grade for the prototype model is Standard. The appropriate software grade for this software is considered to be standard because the prototype model is not intended to represent the behavior of the actual barrier system, but rather act as a prototype to allow for the development of an appropriate modeling methodology,

to confirm that modeling the barrier system is feasible, and to provide a means for discussing the appropriate functionality of the full model.

A.3 Key Roles and Accountabilities

The main key role relevant in the case of this software development is the Primary Holder. For this project, the Primary Holder will be Dr. Patrick Boily.

A.4 Key Deliverables, Tasks, Schedules, and Methods

A.4.1 Key Deliverables

As discussed in the project proposal and section 2.1 of this quality plan (**Work Product Overview**) the software developed for this project will be used to generate the key deliverable of the prototype project. The primary FASM product will be a report describing the results of the creation of the prototype causal model, created in order to explore strategies for predicting the engineered barrier system's probability of failure. The report will discuss the results of constructing the prototype model, considering only a specific causal chain that can influence the state of the engineered barrier system (as opposed to the entire network).

A.4.2 Key Tasks and Schedule

1. Choose a modeling environment (likely MATLAB)
2. Develop an initial implemented model structure and framework:
   2.1. Define correspondences between the conceptual model structure and the implemented model structure
   2.2. Refine the implemented model framework based on required correspondences
3. Define software functional requirements and main software modules and components
4. Define the specific structure of the implemented model framework relative to the causal chain being modeled
5. Implement the model by coding it into the chosen model environment by:
   5.1. Coding
   5.2. Unit Testing and Code Walkthroughs
   5.3. Functional Testing
6. Develop User Interface by:
   6.1. Coding
   6.2. Unit Testing and Code Walkthroughs
   6.3. Functional Testing
7. Validate the scope, appropriate application, and accuracy of the implemented model

Software Development Start Date: May 30th, 2015
Software Development End Date: March 30th, 2016

A.4.3 Development Tools, Techniques, and Methods

Tools:

- Matlab
- Data Structure Tagging System
- Stand-Alone Version Tracking Software (likely GOGS)
- Ticketing Software (likely Apache Bloodhound)

Techniques and Methods (including but not limited to)

- Spreading Activation Networks (Causal Network Models)
- Linear Algebra Representations of Networks
- Bayesian Analysis and Monte-Carlo Simulations
- Stochastic Modeling

A.5 Plan for Verification and Validation Activities

A.5.1 Plan for Verification Activities

The following verification methods will be used on this software:

- Code Walkthrough: Coders will carry out weekly code walkthroughs with conceptual modelers during implementation of components to confirm consistency between code and conceptual model.

- Unit Testing: Upon completion of particular code components (e.g. functions, objects), coders will generate a list of appropriate unit tests. Testers will implement these tests and submit results to coders. This process will be repeated until unit tests have confirmed required behaviour of code components
- Function Testing: Required functioning of code components will be defined within the functional requirements. A list of functional tests will be created at this time. Similar to unit testing, testers will implement these tests and submit results to coders. This process will be repeated until function tests have confirmed required behaviour of code components
- Limited Integrated Testing: As this is a prototype, only limited integrated testing will be carried out. However, some testing will be undertaken in order to confirm that the compiled stand-alone application is functional in the typical client computing environment.

A.5.2 Validation Plan and Activities

As noted in document Technical Computing Software Procedure (NWMO-PROC-EN-0002), validation involves determining the accuracy and applicability of the software results with respect to its intended application.

It evaluates such things as:

- the level of accuracy of physical approximations,
- the applicability of physical correlations,
- the appropriateness of numerical method approximations, etc.

For the FASM's first phase, the prototype model will not be directly validated, as it is not intended to represent the behaviour of the engineered barrier system as a whole (a partial model of the system is not expected to behave in a manner consistent with that of the full system). Careful inspection of the model results by a CQADS resource/researcher with knowledge of the physical system but who was not directly involved in the construction of the model will serve as indirect validation of the model.

After internal validation the implemented model will be presented to the NWMO to ensure that the overall functionality of the model is as expected, and can be adequately extended to a fully implemented model.

A.6 Configuration Management and Change Control Method

A.6.1 Configuration Management Method

For this project, configuration management, including version control of identified components of the software, as well as maintenance of the integrity and traceability of these components, will be carried out using a revision control and source code management system with the appropriate functionality to meet the configuration management requirements described in Technical Computing Software Procedure (NWMO-PROC-EN-0002).

Specifically, a server with a standalone GitHub clone (likely GOGS) will be customized and then used to provide a Software version control including production of version tracking records that contain (as described in Technical Computing Software Procedure (NWMO-PROC-EN-0002)):

- identification of the version of the software that was modified and the new version
- software grade
- reasons for the change
- significance of the change and the basis for this categorization
- identity of who made the change
- release date of the new version
- modified software components
- description of changes, possibly by reference to other documents
- methods used to verify or validate the new version
- location where software is archived
- list of updated software documentation.

Each configuration will also be uniquely identified using a defined naming convention, which will be defined and documented within the revision control and source code management system.

A master copy of the software will also be stored and maintained on this server, with appropriate controls set to prevent unauthorized access or changes to this copy. The master copy will be updated by authorized personnel to ensure its ongoing maintenance and integrity.

A.6.2 Change Control Method

A.6.2.1 Method for Error Tracking and Submitting Change Requests

For this project, error tracking and submission of change requests will be carried out using a ticketing system with the appropriate functionality to meet the error tracking and change request requirements described in Technical Computing Software Procedure (NWMO-PROC-EN-0002).

Specifically, a server with a standalone ticket tracking system (likely Apache Bloodhound) will be customized and then used to provide the following functionality:

- The recording, analyzing, approving, and tracking of errors or other change requests
- Submission of change requests to the Primary Holder that have been prepared by the users, developers or testers
- Submission of change requests that include: the version to be modified and new version identification; the reasons for changes; and the list of software documents that need to be updated.
- Ability for change requests to be reviewed and approved by the Primary Holder.

A.6.2.2 Maintenance of Error Tracking and Change Request Log

Within the ticketing system, the Primary Holder will maintain a list of known errors in accordance with the Change Control methods defined above.

A.6.3 Controlled Components

The following components will be controlled:

- Implemented Model Software Code (MATLAB)
- Software Documentation for Implemented Model