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A RISK-BASED MONITORING FRAMEWORK FOR THE LONG TERM MANAGEMENT OF USED FUEL

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ABSTRACT

The Nuclear Waste Management Organization has a mandate from the Government of Canada to consult with the public and to recommend an approach for managing Canada's used nuclear fuel. Three main fuel management methods are being explored and evaluated by the Nuclear Waste Management Organization: disposal in a Deep Geological Repository (DGR); reactor-site extended storage (RES); and centralized extended storage (CES), either above ground or below ground. The used nuclear fuel management system, whether a DGR or an extended storage system will require monitoring. In this study, a risk-based monitoring framework was developed for the used fuel management program. The proposed approach addresses the unique challenges of used fuel management being implemented in a multi-stakeholder process, including: (i) the complexity of the facilities; (ii) the need to consider both science-based risk and perceived risk in the monitoring plans; and (iii) the difficulty in conducting "invasive" measurements of sealed systems, particularly over a very long time frame.

I. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) has a mandate from the Government of Canada to consult with the public and to recommend an approach for managing Canada's used nuclear fuel. Three main technical methods for managing used fuel are being explored and evaluated by the NWMO:

- disposal in a Deep Geological Repository (DGR);
- reactor-site extended storage (RES); and
- centralized extended storage (CES), either above ground or below ground.

The used nuclear fuel management system, whether a DGR or an extended storage will require monitoring. The purpose of this study is to develop a risk-based monitoring framework for the used fuel management program (Garisto, 2004). This is being carried out using a step-by-step approach with the following two major steps:

- First, the various management methods are reviewed to estimate potential risks at each stage of their development. This step is described in a companion paper (Garisto and Davis, 2005).

- Second, the results of the review are used to develop a monitoring framework, which focuses on the main areas of potential risk. This is the topic of the present paper.

II. PROPOSED MONITORING FRAMEWORK

Monitoring is a set of activities that sample, measure and analyze radiological and chemical substances and physical parameters. The objective of monitoring activities is to demonstrate that adequate measures have been taken to protect the environment and to keep potential impacts to members of the public as low as reasonably achievable, social and economic factors taken into account.

Used nuclear fuel management systems are and will be monitored to satisfy regulatory licence conditions. In addition, there may be a need to go beyond the minimal regulatory requirements, and reflect stakeholders concerns and considerations by the implementing organization, to keep high standards of health and environmental protection. Also, parameters such as temperature, groundwater chemistry and rock mass properties may need to be monitored to confirm the expected evolution of the facility.

This section describes a systematic approach towards the development of a monitoring system, which focuses on areas of potential risk and incorporates stakeholders concerns. Such a system would complement core monitoring which is done to comply with regulatory requirements. Initial discussions of monitoring requirements for the various options appear in NWMO documents (e.g., see CTECH, 2002).

In general terms, the purpose of a monitoring program for all used fuel waste management systems is to demonstrate that the facility is operating within the parameters under which it is expected to operate. Environmental monitoring can be regarded as a continuous activity in which:

- Pre-operational baseline monitoring, environmental risk assessments and operational monitoring, all complement each other;
- Decommissioning baseline, decommissioning impact (or recovery) predictions and monitoring, also complement each other.

Monitoring of used fuel waste management facilities faces several unique challenges. These include:

- The complexity of the facilities: the need to monitor multiple contaminants and pathways; this is addresses in section III;
- The need to consider technical risk and perceived risk in the monitoring plans; this is addressed in section IV;
- The difficulty in conducting "invasive" measurements of sealed systems, particularly over a very long time frame; this is addressed in section V.

The monitoring framework proposed in this report addresses these challenges as follows.

III. HOW TO LINK MONITORING TO RISK?

A risk-based monitoring framework is proposed in this paper. This approach implies that, for example, the parameters and frequency in the effluent monitoring program would depend on the results of the risk assessment for the facility. Such a program would include the routine monitoring of core contaminants, as well as periodic characterization of the effluent, whenever a change in process or procedures occurs. The selection of the core contaminants (both radioactive and chemical) would be based on the results of the risk assessment.

The predictions of risk to members of the public, workers and biota are often based on contaminant-transfer models. Pathways confirmation monitoring will also have to take place. The objective of this monitoring would be to confirm that transfer modeling was accurate or conservative. This is achieved by measuring contaminants in the environment for the key media identified in the risk assessment to ensure that they are equal or less than those used in the transfer modeling. Monitoring would focus on contaminants and their transfer pathways that:

- Pose the greatest risk to human receptors or biota;
- Have the greatest uncertainty in their modeling.

For example, such an approach is used by nuclear utilities to plan environmental monitoring around nuclear power stations.

The environmental compartments (media) that are selected for monitoring within a pathway would generally include:

- The initial point of entry to the receiving environment (e.g., air, water, groundwater);
- Environmental compartments with the potential to accumulate contaminants over time (e.g., sediment, where applicable).

A preliminary example of environmental compartments and radionuclides that would be included in a monitoring program based on the “snapshot” of current understanding of risk is provided in Table 1. As can be seen in this table, the major parameters that are monitored change with time. For example, tritium, which is important to monitor during the initial stages of the implementation of DGR and CES, decays with a half-life of 12 years and is therefore not monitored in the long term.

In addition to facility monitoring, there will be a need to address monitoring along transportation routes. For example, Grondin *et al.* (1994) advises monitoring at truck stops in the early stages of the program. In the COGEMA Logistics (2003) transportation system design, stops would be only in designated compounds, which would require monitoring.

Table 1: Main Expected Pathways for Emission Monitoring for DGR and CES (Underground Rock Cavern Alternative)

Stage	In air				In liquid	
	H-3	Alpha/beta particulates	Radioactive noble gases	Gamma	H-3	Gross alpha/beta
Siting	-	-	-	-	-	-
Construction	-	-	-	-	-	-
Operation	✓	✓	-	✓	✓	✓
Extended Monitoring	✓	✓	-	✓	-	-
Transportation*		✓		✓		
Post closure/long term	-	-	-	-	-	✓

*monitoring as per transportation packages regulations.

IV HOW TO DEAL WITH RISK AND PERCEIVED RISK IN A SYSTEMATIC MANNER?

The process of linking risk and monitoring priorities (as described above) is part of the problem formulation stage in a so-called Data Quality Objectives (DQO) process. The DQO process is a multi-stakeholder planning approach, formulated by the U.S. EPA (2000) to develop monitoring plans in support of decision-making. For example, monitoring results can be used to support a decision to continue or modify a given operation. Systematic planning, as described here, is based on a common sense, tiered approach to ensure that the level of detail in monitoring is commensurate with risk and with the importance and intended use of the results. Elements of the DQO process are used in this report to develop a systematic, risk-based approach to monitoring. The proposed framework promotes communication between all stakeholders involved in the program. Through a systematic planning process, a team can develop acceptance criteria for the quality of the data collected and for the quality of the decision made based on these data. A similar process was recently developed by SENES and OPG for the monitoring of potential ecological effects around nuclear generating stations (Wismer *et al*., 2004).

The steps in the systematic monitoring planning process are as follows (see Figure 1):

- Step 1: State the problem.
  This is based on a conceptual model of the potential risks involved (risk assessment, including risk of issues raised by stakeholders, pathways analysis)
- Step 2: Identify the decision.
  This step identifies the key questions associated with the decision that the monitoring study attempts to address and alternative actions that may be taken, depending on the answers to the key questions.
  Examples of key questions include:
  - Does a radionuclide concentration significantly exceed background levels?
  - Does a contaminant pose a human health or ecological risk?

  Examples of alternative actions include:
  - Report levels to the authorities
  - Take no action
- Step 3: Identify information needed for the decision.
  This step identifies the kind of information that is needed to resolve the decision statement and potential sources of information (e.g., new data or existing data).
- Step 4: Define the boundaries of the study.
  This includes spatial boundaries that define the physical area to be studied and temporal boundaries that describe the time frame that the study will represent and when the samples should be taken. Practical constraints may be introduced to limit the extent of the study (e.g., potential practical risk, future land use, etc.)
- Step 5: Develop a decision rule (an "*if…then…*" statement).
- Step 6: Specify limits on decision errors.
  In step 6 we face the reality that we do not have perfect information for making decisions based on a set of sample data subject to various errors. Inherent in the use of sample data for making decisions is the fact that those decisions can, and occasionally be wrong. In this step of the systematic process, the probabilities for making decision errors (false positive and false negative) are specified.

For example, if the consequences of decision errors are severe (e.g. risk to human health), it may be necessary to develop a monitoring design that requires large amount of data, analyzed by precise and accurate analytical methods. The balancing of risk of incorrect decisions with the cost of monitoring should be fully explored in the planning stage. This is done in the next step.

- Step 7: Optimize the design for obtaining data.
  This step builds on the previous steps to develop an effective monitoring program that focuses on potential risks.

The development of monitoring plans is an iterative process (see Figure 2). As gaps in the risk assessment are gradually filled, the monitoring plans can be refined.

Figure 1: The Monitoring Planning Process

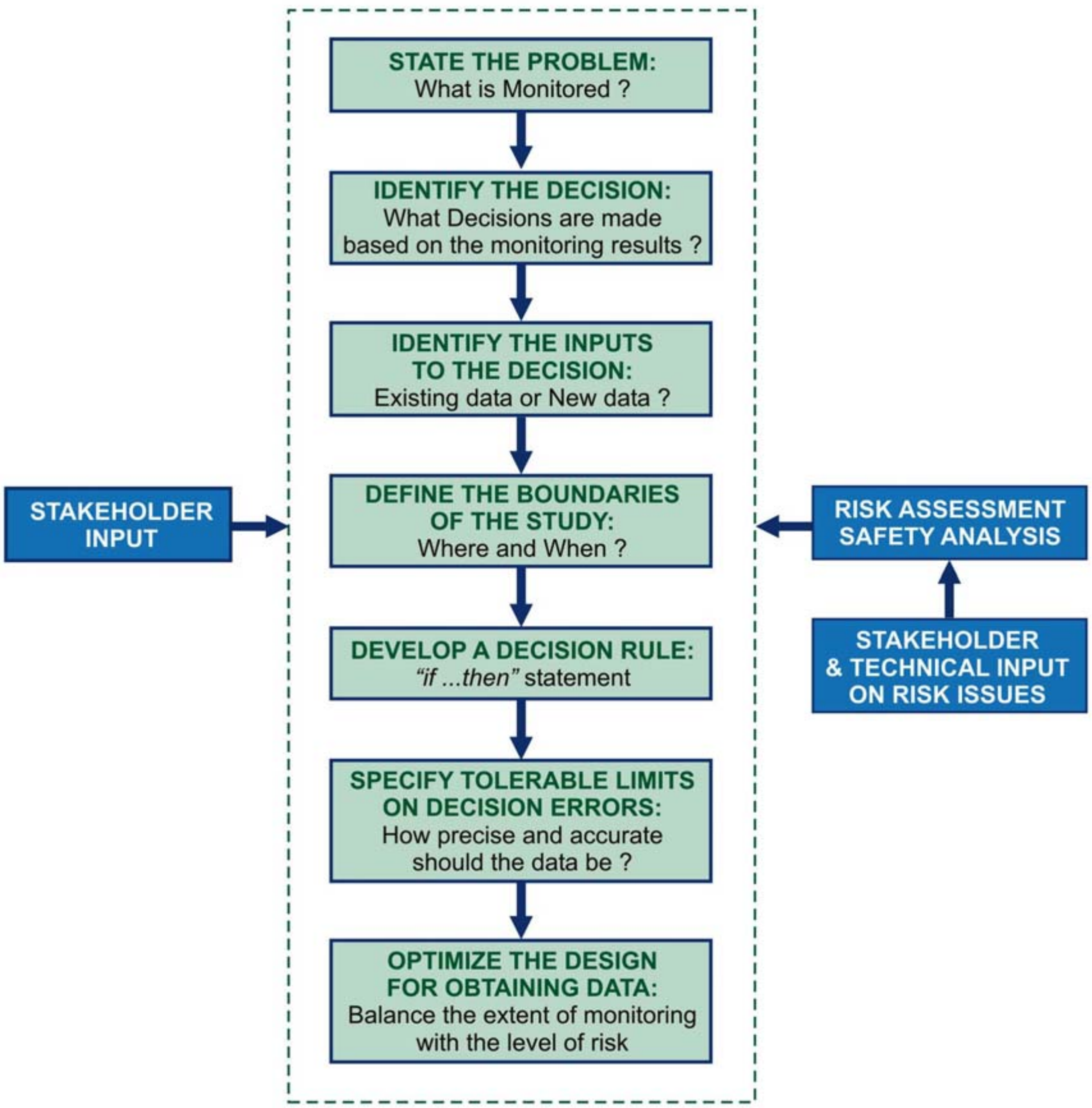
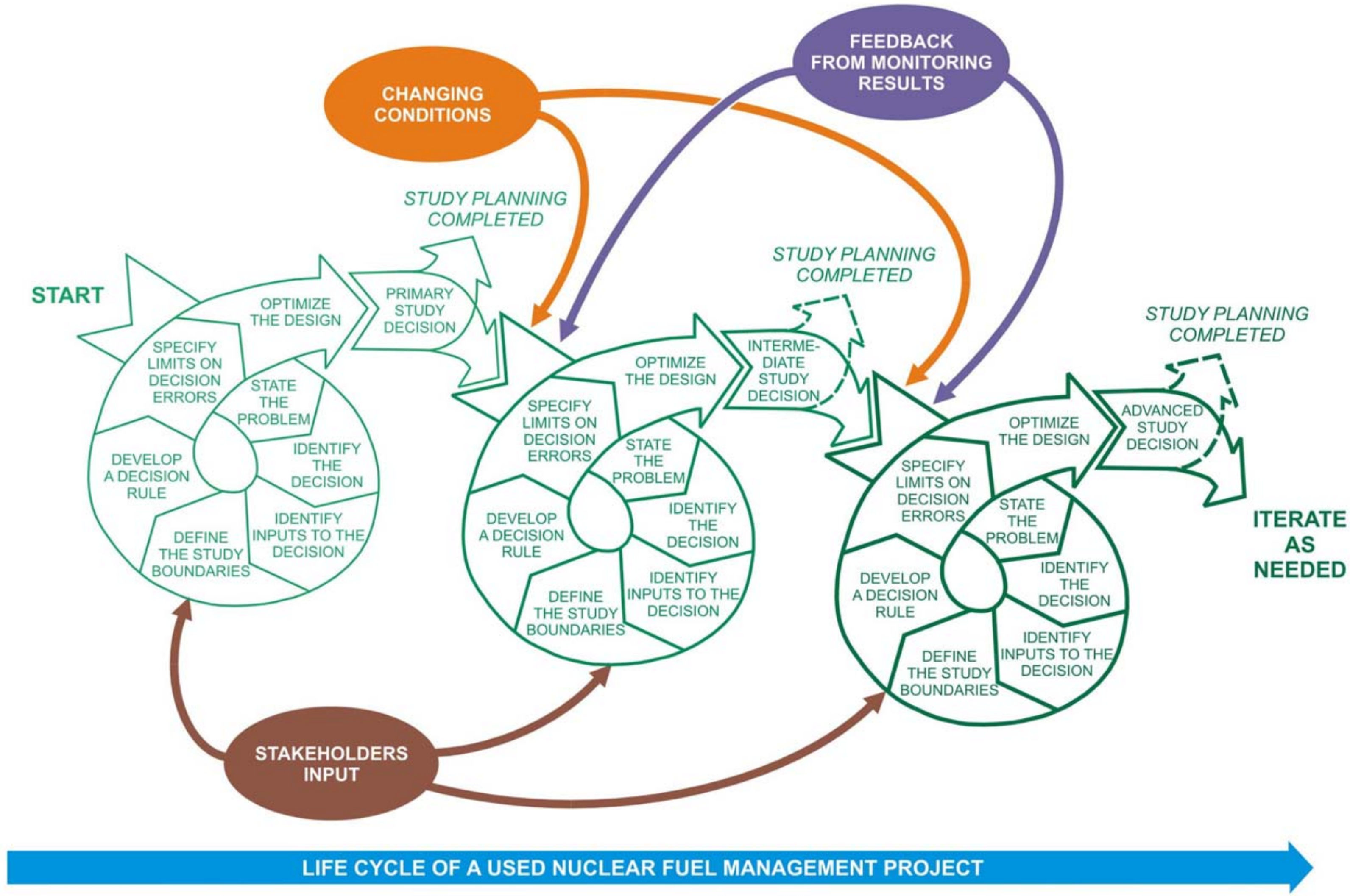


Figure 2: Repeated Application of the Monitoring Planning Process Throughout the Life Cycle of a Project



SOURCE: Adapted from U.S. EPA, 2000

V. HOW TO DEAL WITH INVASIVE MEASUREMENTS OF A SEALED SYSTEM?

An approach to address long-term monitoring issues of DGR was developed by Thompson and Simmons (2003) and is adopted here for DGR and could be used for the long-term monitoring of a deep underground rock-cavern CES facility. (Note that the reference depth in the below-ground option for CES is 50 m (CTECH 2003). Here, we consider a potentially deeper CES facility).

In this approach, several parameters were identified as those that can be measured *and* that would be indicative of repository performance, including:

- Temperature;
- Stress changes, rock displacements and acoustic emission; micro-seismic events;
- Groundwater movement and pressure; and
- Groundwater chemistry and radio chemistry.

> The first three of these are expected to show measurable responses to the operation of the repository over relatively short time periods. Responses are expected to be detectable during the period of repository operation. Monitoring of groundwater chemistry is not expected to indicate the occurrence of events, such as waste containers with undetected manufacturing defects, during the period of repository operation.

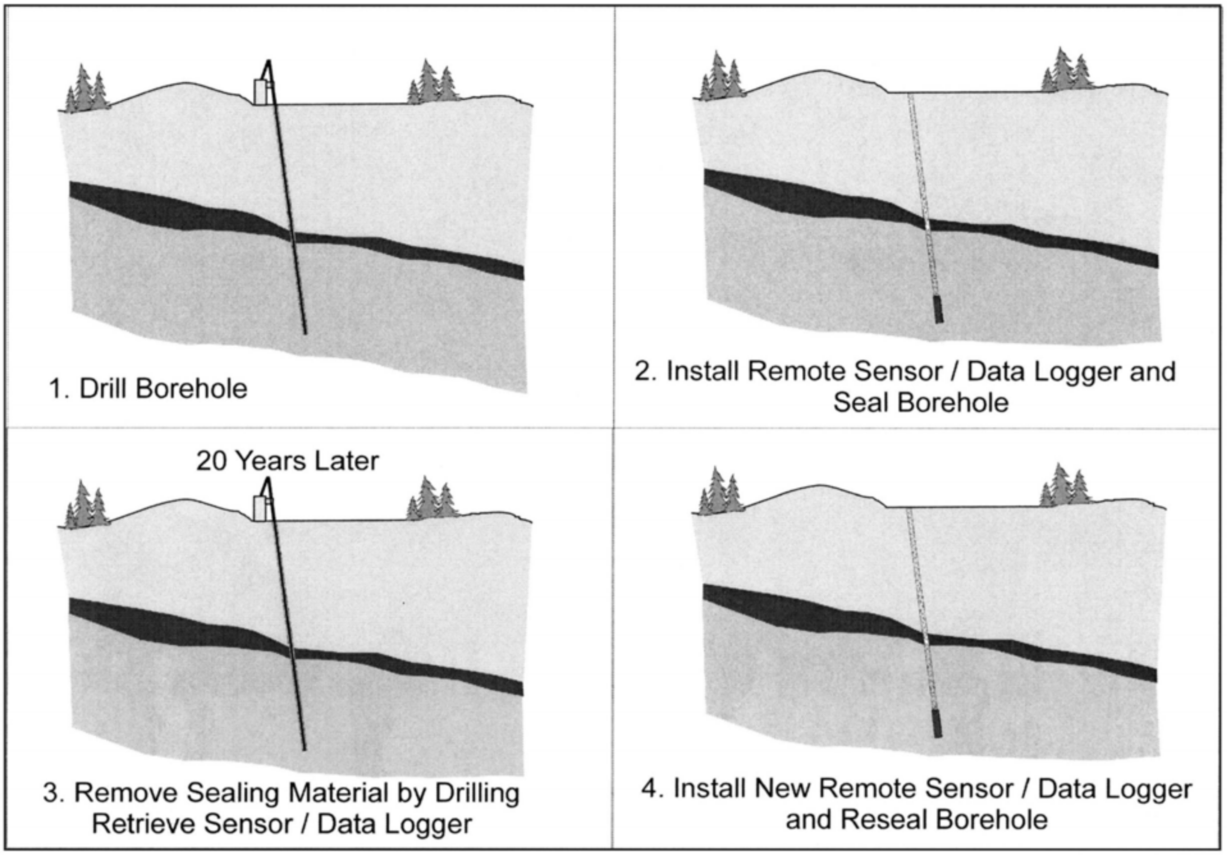
Both non-invasive and invasive methods are proposed to monitor these parameters.

> Non-invasive methods use remote methods or shallow boreholes. Invasive methods require the drilling of boreholes from the surface or from the excavated access shafts or ramps and tunnels. In both methods it is important to minimize the perturbations caused by monitoring installation to the repository system being monitored. However, boreholes drilled close to the outer edge of the repository (within a potential perturbation zone) could compromise the passive safety of a repository. Therefore, invasive monitoring boreholes within this zone need to be backfilled and sealed prior to closure. If such boreholes are used for surface-based post closure monitoring, they can be periodically unsealed for measurements (see Figure 3).

The above approach implies that for DGR, even if the sealed repository is “out of sight” (because it is located deed underground), it can stay “visible” to the monitoring system.

At this point in time, it is not considered prudent to install monitoring systems within the waste emplacement rooms, as these would jeopardize the long-term performance and safety of the repository. Instead, a program of component demonstration testing is proposed, that would begin during underground evaluation of the site and would continue until repository closure. Data on the performance of the container and emplacement room sealing system would be obtained from controlled tests in locations where the containers could later be removed. These component tests would be separate from the emplacement rooms. They would be located either in a single test area, or in strategically- located and spatially distributed test rooms within the repository.

Figure 3: Application of Remote Data Logger/Sensor Assembly to Long-Term Repository Monitoring (Extracted from Thompson and Simmons, 2003)



SOURCE: Extracted from Thompson and Simmons, 2003

VI CONCLUSION

Conceptual designs developed for the used-fuel management methods considered by the NWMO would all meet Canadian regulatory safety and environmental requirements. Regulatory compliance, however, does not imply that these concepts can be implemented under zero-risk conditions. Like any major industrial project, a nuclear used-fuel facility may result in a small risk to human health or the environment. This is the case even though all relevant regulations are met and particular care is taken to reduce the risk to as low as practically possible.

Potential risks may occur at different times and through different pathways for the different used-fuel management methods being considered by the NWMO. This report shows how an understanding of these risks can be used to develop a monitoring framework that focuses on the main risk pathways that are expected to affect the performance of the used-fuel management systems. Such a monitoring framework is based on the principle of “more risk => more monitoring” and is expected to complement routine monitoring done to demonstrate regulatory compliance.

The monitoring framework discussed in this report is systematic, risk driven and iterative. It is based on a multi-stakeholder input process. It is expected that monitoring results will be used not only to determine compliance, but also to determine whether any aspects of the used-fuel management system (including monitoring) need to be modified to improve performance.

The iterative monitoring framework (Figure 2) enables the process to adapt to changes in stakeholder needs and in actual facility performance throughout the long life cycle of the project

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