National Orphaned/Abandoned Mines Initiative

NOAMI

Orphaned and Abandoned Mines: Risk Identification, Cost Estimation and Long-term Management

Prepared for the:

National Orphaned/ Abandoned Mines Initiative

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Disclaimer

Executive Summary

When considering the cost estimation of remediation activities at an orphaned or abandoned mine site it is imperative that a comprehensive and accurate risk analysis (or assessment) process be completed as it will dictate the level of remediation required. Similarly, such an assessment should also be complete before estimating the cost of long-term management. Failure to conduct such assessments could result in a significant underestimation of such costs. Conversely, without such a risk analysis, substantial monies could be expended without sufficient justification.

Kingsmere Resource Services Inc. was retained by NOAMI to research and document a risk identification/cost estimation framework for use as a tool to allow a wide variety of “Users” such as government agencies, Indigenous organizations, non-governmental organizations, communities and the general public to:

- Identify and characterize risks and liabilities at orphaned/abandoned mines sites;
- Review and discuss methodologies to assess the significance of identified risks;
- Review and discuss methodologies to estimate the cost of mitigating the identified risks;
- Summarize and evaluate long-term management methods;
- Identify types of costs that may arise with long-term management of a site, and explore methods to finance; and,
- Define major areas of potential cost underestimation/overruns, conflict and/or uncertainty and discuss ways to address these issues.

The risk analysis process is a continuous review and action process that includes:

- Risk identification and characterization;
- Risk evaluation (or assessment);
- Risk communication; and,
- Risk (An identification of the type of risk management actions warranted).

The report provides a discussion of each of these stages and provides a series of tools that can be used to assist in completing each stage. In addition, the report provides an example of a simplified spreadsheet and information requirements for estimating the cost of remediation activities at a hypothetical orphaned or abandoned mine site. The report also examines potential areas of uncertainty when conducting the risk analysis process and cost estimation.

Estimating the cost of implementing the risk management plan (remediation activities) must be site specific and be based on a complete and comprehensive risk analysis process. Core elements of cost estimation include a detailed, current and site specific estimate of cost under each of the following headings:

- Equipment and Labour;
- Studies & Planning;

- Water Treatment;
- Infrastructure Decommissioning;
- Physical Earthworks;
- Reclamation;
- Project Management, Monitoring & Reporting;
- Mobilization & Demobilization;
- Staffing Support;
- Transition Phase Monitoring; and,
- Corporate Costs.

Long-term management of orphaned/abandoned mine sites can involve a wide range of activities and will depend on the nature of the site conditions and/or the residual hazards after remediation. As discussed in the report, depending on the type of residual hazards, site-level activities could range from monitoring and simple maintenance to water treatment or other engineered systems used to prevent residual hazards from migrating and reaching human and environmental receptors.

Core elements of the effective long-term management framework of orphaned and/or abandoned mine sites include:

- Information management;
- Site monitoring and maintenance;
- Unforeseen events (i.e. responses when remedies or controls fail); and
- Application/enforcement of legal or other mechanisms to restrict future use.

Very few jurisdictions in the world have developed a formal institutional control management framework that provides for effective long-term stewardship of sites once the responsible party has fulfilled its closure obligations and achieved a closed site status. Even fewer have formally identified funding measures to ensure that future generations do not have to finance the effective long-term stewardship of such sites. The report identifies and discussed five options for funding long-term stewardship costs and summarizes one Canadian example of a long-term management framework and funding mechanism.

Résumé

Avant d’envisager d’estimer les coûts des activités de restauration d’une mine orpheline ou abandonnée, il est impératif qu’une analyse détaillée et exacte des risques (ou évaluation) soit effectuée puisqu’elle déterminera le niveau de restauration requis. De même, une telle évaluation devrait également être effectuée avant d’estimer le coût d’une gestion à long terme. Sans cette évaluation, les coûts pourraient être considérablement sous-estimés. Néanmoins, sans une telle analyse des risques, des sommes considérables pourraient être dépensées sans justification suffisante.

Kingsmere Resource Services Inc. a été retenue par l’INMOA pour rechercher et documenter un cadre d’identification/d’estimation des coûts à utiliser comme outil pour permettre à divers « utilisateurs », tels que les organismes gouvernementaux, les organisations autochtones, les organisations non gouvernementales, les collectivités et le grand public :

- de définir et de caractériser le risques et les responsabilités sur les sites des mines orphelines/abandonnées;
- d’examiner et d’étudier les diverses méthodes pour évaluer l’importance des risques identifiés;
- d’examiner et d’étudier les diverses méthodes pour estimer le coût d’atténuation des risques identifiés;
- de résumer et d’évaluer les méthodes de gestion à long terme;
- de déterminer les types de coûts qui peuvent survenir avec la gestion à long terme d’un site, et d’examiner les méthodes de financement;
- de définir les grands secteurs de sous-estimation/dépassement potentiel de coûts, de conflits et/ou d’incertitude, et de décrire les façons d’aborder ces questions.

Le processus d’analyse des risques est un processus continu d’examen et d’action qui comprend :

- l’identification et la caractérisation des risques;
- l’évaluation des risques (ou évaluation);
- la communication des risques;
- Risque (une identification du type d’actions de gestion des risques justifiées).

Le rapport examine chacune de ces étapes et fournit une série d’outils qui peuvent être utilisés pour aider à réaliser chaque étape. En outre, il donne un exemple de chiffrier et d’exigences d’information simplifiées pour estimer le coût des activités de restauration à une mine orpheline ou abandonnée hypothétique. Il examine également les secteurs d’incertitude potentiels lorsque l’on effectue le processus d’analyse des risques et l’estimation des coûts.

L’estimation du coût de la mise en œuvre du plan de gestion des risques (activités de restauration) doit être spécifique au site et reposer sur un processus d’analyse des risques complet et détaillé. Les

principaux éléments de l'estimation des coûts comprennent une estimation des coûts détaillée, actuelle et spécifique du site sous chacune des rubriques suivantes :

- Équipement et main-d'œuvre;
- Études et planification;
- Traitement de l'eau;
- Déclassement des infrastructures;
- Terrassements;
- Remise en état;
- Gestion de projet, suivi et rapports;
- Mobilisation et démobilisation;
- Soutien à la dotation;
- Suivi de la phase de transition,
- Coûts des sociétés.

La gestion à long terme des mines orphelines/abandonnées peut comprendre diverses activités et dépendra de la nature des conditions du site et/ou des dangers résiduels après la restauration. Tel que mentionné dans le rapport, selon le type de dangers résiduels, les activités au niveau du site pourraient aller du suivi au simple entretien des systèmes de traitement de l'eau ou d'autres systèmes d'ingénieries utilisés pour empêcher les dangers résiduels de migrer et d'atteindre des récepteurs environnementaux.

Les principaux éléments du cadre de gestion à long terme efficace d'une mine orpheline et/ou abandonnée comprennent notamment :

- la gestion de l'information;
- le suivi et l'entretien du site;
- les événements imprévus (c.-à-d. les actions prises là où les solutions ou les contrôles échouent);
- l'application/la mise en œuvre de mécanisme juridiques ou autres afin de restreindre une utilisation future.

A l'échelle mondiale, très peu de gouvernements ont élaboré un cadre formel de gestion de contrôle institutionnel qui prévoit l'administration à long terme des sites une fois que la partie responsable a rempli ses obligations de fermeture et a obtenu le statut de site fermé. Moins encore ont proposé formellement des mesures de financement pour veiller à ce que les générations futures n'aient pas à financer l'administration à long terme de tels sites. Le rapport propose et examine cinq options pour financer les coûts d'administration à long terme et résume un exemple canadien d'un cadre de gestion à long terme et un mécanisme de financement.

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Glossary

During the research conducted to support the development of this document, a review was completed of mine closure and closed mine management frameworks in various jurisdictions. It was evident during the review that a range of definitions was available for most terms. This resulted in the need for a clear and concise definition of the applicable terms as they are applied to this document to ensure clarity in the discussion and to make certain of a consistent understanding by the user. Definitions of the terms used in this document are as follows:

Term	Definition
Abandoned Site	A site at which the operator has rejected custodial responsibility for decommissioning and/or on-going remediation or reclamation. This can be voluntary, or involuntary as in the case of bankruptcy.
Adit	A horizontal or nearly horizontal entrance to an underground mine usually driven into the side of a hill or rock outcrop where local topography allows.
ARD (Acid Rock Drainage)	Base metal, precious metal and uranium mines contain sulphide minerals, either in the ore or the surrounding waste rock. When these sulphide minerals, particularly pyrite and pyrrhotite, are exposed to oxygen and water, a process of conversion of sulphide to sulphate takes place. Water in contact with these oxidizing minerals is made acidic, and in the absence of calcareous materials, such as calcite, the acidic water carries with it toxic metals and elevated levels of dissolved salts. As the reactions proceed, temperature and acidity increase, resulting in an increased rate of reaction. Rainfall and snowmelt flush the toxic solutions from the waste sites into the downstream environment. If acidic drainage is left uncollected and untreated, the drainage can contaminate groundwater and local water courses, damaging the health of plants, wildlife, and fish. (Source: *The Mine Environment Neutral Drainage (MEND) Program*, D.G. Feasby, M. Blanchette, G. Tremblay. In: Proceedings of the 2nd International Conference on the Abatement of Acidic Drainage, Montreal, Canada, September 16-18, 1992.
Catastrophic Failure	A sudden failure without warning (E.g. crown pillar collapse, dam failure, large scale slope slip [slide], etc.), as opposed to a degradation failure
Climate Change	Refers to any significant change in the measures of climate lasting for an extended period of time. Climate change includes major changes in temperature, precipitation, or wind patterns, among other effects that occur over several decades or longer. (Source: U.S. EPA)
Closed Site	A site at which all decommissioning, remediation and reclamation measures and transition phase monitoring have been completed to the satisfaction of a regulatory authority or institution willing to accept custodial responsibility.
COPC	Constituents of potential concern or contaminants of potential concern.
Crown Pillar	A rock mass of variable geometry that is situated above the uppermost underground workings of a mine and that serves to ensure permanently or temporarily the stability of surface elements and underground workings.
Custodial Transfer	Transfer of custodial responsibility for a former mine property to a new custodian willing to accept any residual liability (if it exists) and responsibility for long-term management.
Decline	A gently sloping tunnel that can be used to drive mobile equipment into and out of the underground mine. Generally, declines are spiral tunnels which circles either the flank of the deposit or circles around the deposit. The decline begins with a box cut, which is the portal to the surface.
Decommissioning	The activity of disassembling, dismantling, disposal, removal or otherwise addressing all infrastructures associated with a project or site.

Term	Definition
Degradation Failure	The failure of an aspect over time due to such things as the effects of time, metal fatigue, incremental erosion. Degradation failures, if left unaddressed, can increase the potential of catastrophic failure.
Development (Waste) Rock	Rock removed during the development of the mine and stored on surface. Often referred to as “waste” rock.
Dyke (Dam/dyke)	An embankment constructed to contain wastes (as in mill tailings), contaminated materials (water), to divert flows or to prevent flooding. In the case of mill tailings, containment dikes can be constructed of locally available till material, waste rock, tailings or a combination of each.
Disturbed Land	Land that has been disturbed by human activities to the extent that there is a material difference in the physical, chemical or biological characteristics of the disturbed land. Disturbances can either improve or impair future land use options. Cleared land, re-graded land, waste rock piles, land affected by a surface or groundwater contaminant plume, etc. are examples of disturbed lands.
Ecosystem Services	The benefits that people obtain from ecosystems, and include provisioning services (such as food, fiber, fresh water, fuel wood, medicinal, biochemical, and genetic resources); regulating services (such as climate regulation, disease regulation, water regulation, water purification, degradation of pollutants, carbon sequestration and storage, nutrient cycling); and cultural services (spiritual and religious aspects, recreation and ecotourism, aesthetics, inspiration, educational values, sense of place, cultural heritage).
Endowment for Residual Care	A financial instrument identified or established to cover the costs of any surveillance, monitoring and/or maintenance required of the post-transfer custodian. In certain instances these costs may extend over a very long time period.
End state	The “end state” of a site or portion of a site is the physical condition reached when remediation and cleanup activities are complete.
Engineered Structure	A constructed facility or structure (i.e. building, dam/dyke, overflow channel, concrete shaft cap, etc.) for which engineered plans or drawings (including “As-built” reports) are available and include the appropriate accreditation of the author.
Guidelines	Recommended, non-mandatory controls that serve as a reference when no applicable standard is in place.
Hazard	A source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment and other things of value; or some combination of these.(Source: Risk Management: Guideline for Decision Makers, CAN/CSA-Q850-97 (Reaffirmed 2009), Canadian Standards Association, 2009)
Institutional Controls	Consists of those actions, mechanisms and arrangements implemented to maintain control or knowledge of a closed site. This control may be active (e.g. by means of monitoring, surveillance, remedial work, fences, etc.) or passive (e.g. land use restrictions, markers, records, etc.). Activities undertaken by the post-transfer custodian can range from the simple act of permanently recording the location of a remediated site; to conducting regular inspections that may or may not include active measurements and the collection of samples for analysis; all the way to maintenance of certain aspects of the property.
Legacy Site	An orphaned and/or abandoned mine site which contains residual hazards to safety and/or the environment or ecosystem services.
Long-term	100 years or more.
Manufactured Structure	A constructed facility or structure (i.e. building, dam/dyke, overflow channel, concrete shaft cap, etc.) for which no engineered plans or drawings (including “As-built” reports) are available.

Term	Definition
Mineralized (Waste) Rock	Development (waste) rock which has the potential to release hazardous substances that could have a significant adverse effect on human health or be deleterious to the environment. Mineralized waste rock may be further segregated based on contaminants of concern (e.g., nickel, arsenic), radiological content, and ARD or acid generating potential. Mineralized waste rock is often referred as to special waste rock.
NGO (Non-Government Organization)	An organization that is not part of government (although it may receive funds from government) or a conventional for-profit business usually composed of citizens concerned about a specific set of activities or conditions.
Objectives	Non-statutory limits used to guide decisions. (Example: Environment Canada – "Water quality objectives specify the concentrations of substances permissible for all intended water uses at a *specific location* on a lake, river, or estuary. The objectives are based on the water quality guidelines for the uses at that location, as well as on public input and socio-economic considerations.")
Orphaned Site	A site for which a responsible party (custodian) within the private sector can no longer be located or does not exist.
Raise	A vertical or inclined excavation in an underground mine that leads from one level, or drift, to another or from one drift or level to surface (i.e. vent raise).
Reclamation	Actions intended to return the land surface to an equivalent undisturbed condition. Reclaimed land has achieved the desired condition.
Rehabilitation	The process of reshaping and re-vegetating land to restore it to a stable condition with a land-use that is appropriate for the particular location.
Remediation	Action taken to remove/reduce a hazard and improve safety or to remove, isolate or reduce pollution or contaminants from environmental media such as soil, groundwater, sediment, or surface water.
Risk	The chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment or other things of value. (Source: Risk Management: Guideline for Decision Makers, CAN/CSA-Q850-97 (Reaffirmed 2009), Canadian Standards Association, 2009)
Risk Management Team (RMT)	A group of qualified individuals (appointed or retained) whose primary responsibility is to ensure that the project is provided with a complete risk management information system that ultimately determines how to control and oversee the project's effectiveness and fulfillment. The RMT develops and documents strategies to apply risk management methodologies and risk analysis tools, mitigate identified risks when required, and integrates stakeholder input at all stages of the Risk analysis process.
Shaft	A vertical excavation adjacent to an ore body equipped with a hoist. A shaft is generally used when ground conditions, ground water, ventilation or other worker safety conditions warrant or when haulage to surface via truck is not economical.
Slumping (Sluffing)	Slope (rock) movement that occurs when a coherent mass of loosely consolidated materials or rock layers moves a short distance down a slope typically as a mass and under the force of gravity.
Stakeholder	Any individual, community, group or indigenous organisation with an interest in the state of the site or outcome of a remediation programme, either as a result of being affected by it positively or negatively, or by being able to influence the activity in a positive or negative way.
Stewardship	Responsibility for sustainable management (or development) shared by all those whose actions affect environmental performance, economic activity, and social progress, reflected as both a value and a practice by individuals, organizations, communities, and competent authorities.(Source: from ISO 20121).
Tailings	Uneconomical materials remaining after passing mined ore through a mill or processing facility for the purpose of extraction of the valuable fraction.
Transition Phase Monitoring	Monitoring conducted between the cessation of decommissioning activities and the site achieving closed site status.
Valued Ecosystem Component (VECs)	Environmental attributes identified as having a legal, scientific, cultural, economic or aesthetic value.

1 Introduction

Kingsmere Resource Services Inc. was retained by the NOAMI Secretariat to research and document a risk identification/cost estimation framework (the Framework) for application on orphaned and abandoned mine sites.

The framework will be used as a tool to allow a wide variety of "Users" such as government agencies, Indigenous organizations, non-governmental organizations (NGOs), communities and the general public to:

- Identify and characterize risks and liabilities at orphaned/abandoned mines sites;
- Review and discuss methodologies to assess the significance of identified risks;
- Review and discuss methodologies to estimate the cost of mitigating the identified risks;
- Summarize and evaluate long-term management methods;
- Identify types of costs that may arise with long-term management of a site, and explore methods to finance; and,
- Define major areas of potential cost underestimation/overruns, conflict and/or uncertainty and discuss ways to address these issues.

1.1 Background

In 2015, NOAMI published the *Key Criteria for the Effective Long-term Stewardship of Closed, Orphaned/Abandoned Mine and Mineral Exploration Sites* (KRS, 2015) which discussed key criteria for the preliminary assessment of closed and/or orphaned/abandoned mine and mineral exploration sites in Canada in order to evaluate their condition in terms of:

- Physical stability;
- Chemical stability;
- Public health and safety risks;
- Ecological risks; and,
- Risk to ecosystem services.

The criteria were designed, to the extent possible, to be field functional for application by a wide range of users such as government agencies, Indigenous organizations, NGOs, communities and the general public (the "Users") and to allow each to arrive at an informed opinion regarding a site's condition, to identify site specific hazards, provide a preliminary assessment of the level of risk posed by a particular hazard and to assess the need for further remediation to reduce the risk and ensure the effective long-term stewardship of the site.

Figure 1 is reproduced from the report *Key Criteria for the Effective Long-term Stewardship of Closed, Orphaned/Abandoned Mine and Mineral Exploration Sites* (KRS, 2015) and provides a simplified diagram of the most salient decisions related to the need for remediation of the identified hazards at a particular orphaned/abandoned mine site and the eventual long-term stewardship of the site.

This document has been prepared as a follow up to the 2015 publication and is designed to assist that same group of potential Users in formally documenting and assessing the following:

- The level of risk posed by the hazards identified on a particular orphaned or abandoned mine site, assess those risks in terms of the need for remediation (or, in some instances, further remediation)
- Methods to estimate the cost of the identified remediation requirements
- The types of costs anticipated, and methods to finance the long-term management of orphaned/abandoned properties once monitoring has demonstrated the site is suitable for transfer into some form of institutional management.

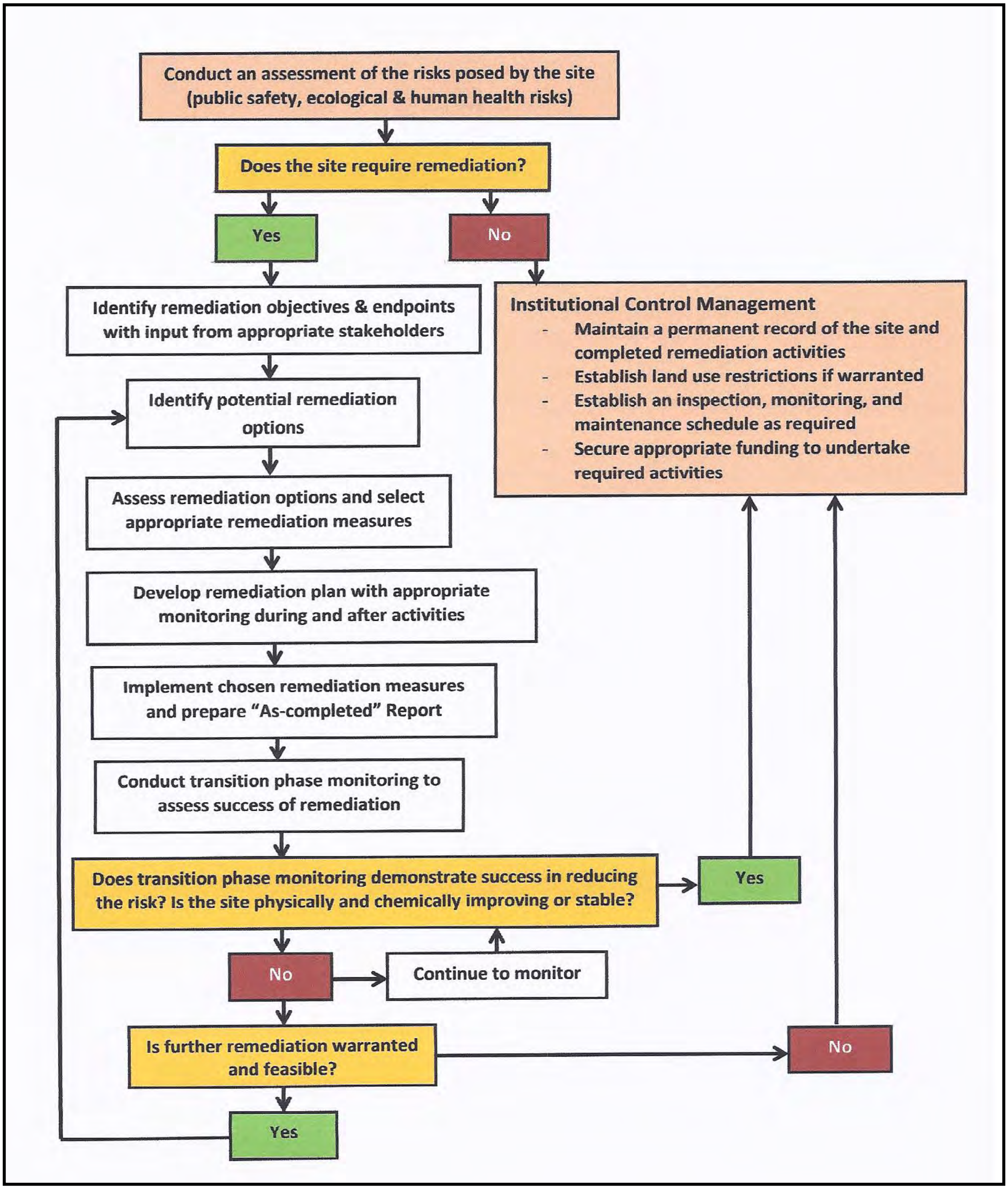

Figure 1 - Achieving Long-Term Stewardship (KRS 2015)

(Note: *When a wide range of stakeholders, including interested members of the general public and local Indigenous communities are included in all relevant stages of the process identified, significant advantages can be achieved*.)

2 Risk Analysis and Management

2.1 Introduction

The *Key Criteria for the Effective Long-term Stewardship of Closed, Orphaned/Abandoned Mine and Mineral Exploration Sites* (KRS 2015) report discussed criteria for the preliminary assessment of orphaned and abandoned mine sites. That report was designed to provide an initial screening of a site to identify site specific criteria, conditions, hazards and risks in order to provide informed opinions on the next steps that should be undertaken.

This report outlines the next step in the effective management of orphaned/abandoned mine sites to assess the need for and extent of remediation required to reduce the identified ecological and public safety risks to an accepted level. An informed decision on the need for remediation measures at an orphaned or abandoned mine site, and the extent of remediation required, must be founded on the level of actual, as opposed to assumed risks posed by each site hazard. All risks, real or perceived must be identified, documented and assessed during the process.

It is imperative that a comprehensive and accurate risk analysis (or assessment) process be completed before preparing an estimate of the costs of remediation activities at an orphaned or abandoned mine site as it will dictate the level of remediation required. Failure to conduct a comprehensive and accurate risk analysis assessment could result in a significant underestimation of such costs. Conversely, without such a risk analysis, substantial monies could be expended without sufficient justification.

2.2 Identifying Site Hazards/Risks

2.2.1 Introduction

A detailed characterization of all aspects of the site is required in order to assess the current level of public safety and ecological risks and allow for informed decisions regarding remediation and long term management by the site Risk Management Team.

2.2.1.1 Site Inspection & Data Acquisition

In order to assemble a detailed characterization, a comprehensive inspection of the site will be required. The preliminary site inspection described in *Key Criteria for the Effective Long-term Stewardship of Closed, Orphaned/Abandoned Mine and Mineral Exploration Sites* (KRS 2015) is the first step in the risk evaluation process and this report attempts to provide the tools to complete a risk evaluation to a level that will allow for informed remediation and long-term management decisions. Dependent on site specific aspects, a detailed inspection may have to be conducted by experienced, accredited individuals such as:

- Civil and/or structural engineers;
- Hydrogeological, geotechnical and geochemical professionals;
- Aquatic, terrestrial and toxicological professionals.

This detailed inspection will help in developing a comprehensive data acquisition program to be conducted at the site, ranging from the collection of geological samples for geotechnical and/or geochemical testing (i.e. waste rock and/or residual tailings material), surface and groundwater monitoring, to a requirement to sample a wide range of biological media. This can only be accomplished through the development of a detailed data acquisition plan, the collection of appropriate samples, the submission of those samples to an accredited laboratory for analysis and an assessment of the results in terms of the potential of site specific COPC to pose an ecological or human health risk. The *Federal Approach to Contaminated Sites* (www.federalcontaminatedsites.gc.ca) provides guidance on the steps to take when establishing a comprehensive data acquisition program.

2.2.1.2 Environmental Site Characterization

Environmental site characterization should follow current accepted practices and guidance for risk assessment at contaminated sites. This allows for consistent application of decision making processes and comparative evaluation. Guidelines or codes of practice may be developed by government or industry organization and adopted for use in this context.

CCME Site Characterization Guide

In 2016 the Canadian Council of Ministers of the Environment (CCME) issued a 4 volume guidance manual for environmental site characterization (CCME 2016). The intent of the manual is to provide guidance on environmental site characterization in support of environmental and human health risk assessment at contaminated sites.

The goal of the guidance manual is to provide a consistent approach to sampling and analyzing complex environmental matrices, such that the data obtained will be representative and of known quality. The guidance provides a summary of key elements that should be performed, and reported upon during site investigations. The guidance also recommends sample handling and storage requirements, analytical methods, and method specific quality control and assurance procedures to ensure that the results of laboratory analyses are reported meet the standards set out in the Canadian Environmental Quality Guidelines with sufficient quality upon which to base decisions.

2.2.1.3 Public Safety Site Characterization

A qualitative assessment of the public safety risks posed by the hazards identified during the site investigation must be conducted by considering each of the following questions:

> Does the identified hazard pose a safety risk above those normally found and accepted in Canadian society and exists as a result of the former mine?

Does the identified hazard pose a safety risk above those normally present in the region (i.e. natural cliffs or steep unstable slopes) and exists as a result of the former mine?

If, in the opinion of the User conducting the public safety risk assessment, the answer to either question is “yes”, the hazard is identified as one which should be considered for further risk analysis and potential remediation.

2.2.1.4 Potential Hazards/Risks

Table 1 provides a summary of various site aspects that could potentially exist at a former mine site with a focus on identifying the hazards that may exist on or at a particular site. The table also identifies the potential risk that could be manifest from each hazard.

Table 1 is designed to identify the hazards/risks that may exist at different mine types (i.e. commodity type, open pit or underground, etc.) and for a range of circumstances (ecosystem type, geology type, etc.). As such, it will likely include more aspects than the User will likely find on the particular site that they are assessing.

The table is designed to focus the User’s attention on expected hazards/risks but should not be considered limiting in any way. If, during the site inspection, the User notes something that could be considered a hazard/risk in the short-, medium- or long-term, but is not included in the list, then it must be recorded and appropriately investigated.

Table 1: Site Hazard/Risk Characterization (Non-exhaustive)

Aspect	Potential Hazard	Potential Risk	Risk Characterization
Site Access	- Condition of access road - Culverts - Road stability - Road construction materials	Public safety Environmental Public safety Environmental	Failure Artificial surface flows/Disruption of natural flows Failure Potential ARD/Heavy metal/Radiological
Exploration Drill Holes/Monitoring Piezometers	- Protruding from ground - Discharging contaminated water - Residual drill cuttings - Subsistence around hole	Public safety Environmental Environmental/Public safety Public safety	Small vehicle collision (snow machines/ATVs) Downstream impact and/or wildlife consumption Potential ARD/Heavy metal/Radiological Further collapse
Exploration Trenches	- Depth - Trench rim stability - Waste rock characteristics - Flooded/partially flooded - Discharging	Public safety Public safety Environmental Environmental Environmental	Fall Fall Potential ARD/Heavy metal/Radiological Wildlife Downstream impact and/or wildlife consumption
Mine Open Pit	- Bench height - Total depth - Pit rim stability - Pit wall stability - Pit wall geochemistry - Fill geochemistry - Flooded - Water quality - Discharging - Egress route from pit	Public safety Public safety Public safety Public safety Environmental Environmental Environmental Environmental Environmental/Human health Public safety	Fall Fall Fall Fall/Collapse Fall/Collapse ARD or metal leaching Water quality/Aquatic community Groundwater/Surface water quality Water quality/downstream water quality/consumption Wildlife
Underground Mine Shaft & Vent Raise(s)	- Closure method - Closure condition - Crown pillar collapse - Other subsidence - Headframe (construction, siding, etc.) - Air quality - Water quality (if flooded) - Discharge from shaft/vent raise	Public safety Public safety Public safety Public safety Public safety/Human health Human health Environmental Environment/Human health	Catastrophic failure Catastrophic failure Catastrophic failure Further collapse Collapse/Asbestos present Confined gases/Radon Groundwater quality/Surface water quality Downstream water quality/Consumption

Aspect	Potential Hazard	Potential Risk	Risk Characterization
Decline or Adit & Vent Raise(s)	- Closure method	Public safety	Catastrophic failure
	- Closure condition	Public safety	Catastrophic failure
	- Crown pillar collapse	Public safety	Collapse
	- Subsidence	Public safety	Further collapse
	- Collar (construction, siding, etc.)	Public safety/Human health	Collapse/Asbestos present
	- Air quality	Human health	Confined gases/Radon
	- Water Quality (if flooded)	Environmental	Groundwater quality/Surface water quality
	- Discharge from shaft/vent raise	Environment/Human health	Downstream water quality/Consumption
Mine (Waste) Rock	- Slope stability	Public safety	Failure
	- Slumping or sluffing	Public safety	Failure
	- Surface configuration (rough/vegetated)	Environmental	Infiltration of precipitation
	- Surface seeps	Environmental	Seep water quality/Downstream impact/wildlife
	- Infiltration	Environmental	Groundwater quality/Surface water quality
	- Vegetation	Environmental	Contaminant uptake/Wildlife consumption
	- Geochemistry	Environmental/Human health	Potential ARD/Heavy metal/Radiological
Mill (Processing) Facility	- Construction (asbestos siding/insulation)	Human health	Inhalation
	- Condition (external)	Public safety	Failure
	- Condition (internal)	Public safety/Environmental	Failure/liquid discharges
	- Residual process chemicals	Environmental/Human health	Discharge/Inhalation
Heap Leach Pads	- Containment (dam/dyke/berm) slope	Public safety	Failure
	- Containment (dam/dyke/berm) sluffing	Public safety/Environmental	Failure/Discharge
	- Dam/dyke/berm material (geochemistry)	Environmental/Human health	Potential ARD/Heavy metal/Radiological
	- Residual materials (geochemical)	Environmental/Human health	Potential ARD/Heavy metal/Radiological
	- Surface configuration (rough/vegetated)	Environmental	Infiltration of precipitation
	- Surface seeps (containment dam/dyke)	Environmental	Seep water quality/downstream impact/Wildlife
	- Surface discharges	Environmental	Water quality/Downstream impacts
	- Dusting	Environmental/Human health	Contamination downwind/Inhalation
	- Vegetation	Environmental	Contaminant uptake/Wildlife consumption
Tailings Management Facility	- Containment (dam/dyke/berm) slope	Public safety	Failure
	- Containment (dam/dyke/berm) sluffing	Public safety/Environmental	Failure/Discharge
	- General condition	Public safety/Environmental	Failure
	- Dam/dyke/berm material (geochemistry)	Environmental/Human health	Potential ARD/Heavy metal/Radiological
	- Residual materials (geochemical)	Environmental/Human health	Potential ARD/Heavy metal/Radiological
	- Surface configuration (rough/vegetated)	Environmental	Infiltration of precipitation
	- Surface seeps (containment dam/dyke)	Environmental	Seep water quality/Downstream impact/Wildlife
	- Surface discharges	Environmental	Water quality/Downstream impacts
	- Dusting	Environmental/Human health	Contamination downwind/Inhalation
	- Vegetation	Environmental	Contaminant uptake/Wildlife consumption

Aspect	Potential Hazard	Potential Risk	Risk Characterization
Site Infrastructure	- Construction (asbestos siding/insulation)	Human health	Inhalation
	- Condition (external)	Public safety	Failure
Water Treatment Facility	- Condition (internal)	Public safety/environmental	Failure/Liquid discharge
	- Residual process chemicals	Environmental/Human health	Discharge/Inhalation
Buildings	- Construction (asbestos siding/insulation)	Human health	Inhalation
	- Hydrocarbon staining	Environmental	Leaching
	- Condition (external)	Public safety	Failure
	- Condition (internal)	Public safety/Environmental	Failure/Liquid discharges
	- Residual process chemicals	Environmental/Human health	Discharge/Inhalation
Site Electrical	- Transformers (potential PCB)	Environmental/Human health	Discharge
	- Hydrocarbon staining	Environmental/Human health	Leaching
	- Creosote treated poles	Environmental/Human health	Leaching/Inhalation
	- Fluorescent lights	Environmental/Human health	Discharge
Tanks/Containers	- Leakage	Environ./H. Health/P. Safety	Discharge/Inhalation/Volatile
	- Vapour	Environ./H. Health/P. Safety	Discharge/Inhalation/Volatile
	- Hydrocarbon staining	Environmental/Human health	Leaching
	- Accessibility/height	Public safety	Fall
Residual Chemicals	- Leakage	Environ./H. Health/P. Safety	Discharge/Inhalation/Volatile
	- Vapour	Environ./H. Health/P. Safety	Discharge/Inhalation/Volatile

2.3 Risk Analysis

2.3.1 Introduction

As stated earlier, it is important that a comprehensive and accurate risk analysis assessment be followed before preparing an estimate of the costs of remediation activities at an orphaned or abandoned mine site. The risk analysis will inform the level of remediation required.

2.3.2 Risk Analysis

In the context of this report, a hazard is defined as a source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment and other items of value; or some combination of these (CSA 2009). Risk, in this context and discussion, is defined as the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment or other items of value (CSA 2009). Generally, in no order of priority, six types of risk are considered relevant in this discussion, including:

- Public health and safety risks;
- Ecological or environmental risks;
- Ecosystem services and socio-economic risks;
- Reputational risks;
- Legal risks; and,
- Financial risks.

All six types should be considered throughout the risk analysis process.

The risk analysis process is a continuous review and action process that includes:

- Risk identification and characterization;
- Risk evaluation or assessment;
- Risk communication; and,
- An identification of the need for, and type of, risk management actions warranted (Risk Management Plan).

To put it simply, the risk analysis process can be summarized in a series of questions:

- What ***risks exist*** at the site in its current condition?
- How ***good*** or ***bad*** is the risk?
- Is the level of risk ***acceptable*** or is it ***unacceptable***? To whom?
- What can be done to reduce the ***threat*** or enhance the ***opportunity*** for improvement?
- What can go ***right*** or ***wrong***?
- Will an identified issue/solution ***help*** or will it ***harm***?

A useful concept is to divide the risk analysis process into two components:

1. Risk assessment - identify, evaluate, and measure the probability and severity of risks posed by a particular site; and,
2. Risk management - determine what to do about identified risks, implementation of remediation measures and post-remediation management.

2.3.3 Risk Communication

Throughout all stages of the risk analysis process, the opinions and concerns expressed by a wide range of stakeholders including government agencies, Indigenous organizations, traditional land users, NGOs, and the general public must be sought, documented and considered. Experience has shown that, when information is shared about the risks posed by a former mine site, there are some key considerations to take into account. Stakeholders prefer a clear message about the existing risk and the associated uncertainties, including the nature and extent of disagreements that may exist between the various experts.

Assessing and communicating the level of risk is difficult. It becomes more difficult when the audience is composed of a diverse group of stakeholders with a range of views on what constitutes “safe” from a physical, cultural, human health or environment perspective, combined with varying level of technical understanding. Technically-based risk estimates provided by qualified “expert” professionals often do not communicate the level of risk posed by a particular hazard in a manner that can be readily understood by a stakeholder or that satisfies all of the potential stakeholder’s concerns. Furthermore, stakeholder priorities for risk mitigation (remediation) activities may not align with those identified by the technical experts.

A risk analysis that dismisses stakeholders’ priorities or values as irrelevant may result in increased distrust in the motives of government, regulatory agencies or industry. This may decrease public confidence in those institutions and have negative consequences such as adverse statements by the public related to the level of safety or environmental risks posed by a particular site. Awareness and understanding of all relevant stakeholders’ concerns must be the basis of effective remediation and the long-term stewardship of an orphaned and/or abandoned mine sites in a particular area.

2.3.4 Conducting a Risk Analysis

2.3.4.1 Introduction

The need for, and extent of, remediation required at an orphaned or abandoned mine site, must be founded on a structured, technically sound and transparent risk analysis process.

The Risk Management Team (RMT) must endeavour to identify all safety hazards and the vertical and lateral extents of contamination before proceeding with an evaluation of site risks or the development of the risk management or remediation approach; ensure that the appropriate remediation standards are applied; communicate and consult with all stakeholders about the available remedial options and alternatives to ensure the selection of the most effective remediation strategy.

2.3.4.2 Planning

In order to complete a structured, technically sound and transparent risk analysis process, preliminary planning must be undertaken and recorded in a project scoping document. The scoping document should include, at a minimum;

- A written definition of the site and of the property boundaries (including maps, etc.);
- An identification of all potential stakeholders and a preliminary stakeholder analysis and consultation plan;
- A written description of the dominant hazards/risks present on the site;
- A written definition of the scope of decision(s) anticipated throughout the risk analysis process;
- An identification of the Risk Management Team members and their areas of expertise and experience;
- A written summary of assigned responsibilities, authorities and resources dedicated to the process;
- A copy of all relevant legislation, regulations, guidelines and Best Management Practices;
- A written process to initiate the establishment of remediation objectives or "end-states" for the major aspects of the site;
- A documented "change management process"; and,
- A preliminary risk information library (Risk Library).

This initial planning stage of the risk analysis process offers the first opportunity to include effective stakeholder consultations. These consultations must be undertaken early in the process as they set the stage for the direction of the risk assessment and decision making for the remainder of the process.

2.3.4.3 Risk Library

The "Risk Library" is a permanent document or series of documents that contains and retains all the information generated and necessary for making informed risk management decisions, including the rationale for the decisions themselves. As such it will include, but not necessarily be limited to:

- A clear statement of the scope of the project and decisions to be made (the Scoping Document);
- An identification of the risk management team with clearly defined roles and responsibilities;
- An identification of decision-makers or the anticipated decision making process;

- An identification of all stakeholder groups and relevant information (i.e. community information, mandate, contact information, etc.) related to each;
- Minutes of all consultations with stakeholders, including questions that arose during consultations and when, how and the content of responses provided;
- Documentation of all issues related to the project as they arise;
- Documentation of all decisions, assumptions and reasons for decisions including providing details of all analysis undertaken throughout the decision process (including assumptions used in the analysis, the results of the analysis and the uncertainties associated with the results);
- A current version of the Risk Register (or Risk Log), as well as all previous versions; and,
- Any other information deemed relevant by the Risk Management Team.

The Risk Library for a particular site should be started at the beginning of the process and updated or maintained continuously throughout all stages. The Risk Library is an important instrument in the effective long-term stewardship of the site.

2.3.5 Hazard/ Risk Identification

In order to assess the risks resulting from identified hazards on a particular orphaned/abandoned mine site, it is necessary to identify the hazards that exist on the property, assess the level of risk posed by the hazard, assess the likelihood of the risk being realized and characterize the significance of the hazard if it were realized.

The risk identification and evaluation process requires a detailed site inspection and the collection of site specific data (section 2.2). Figure 2 outlines the steps undertaken to complete the risk identification.

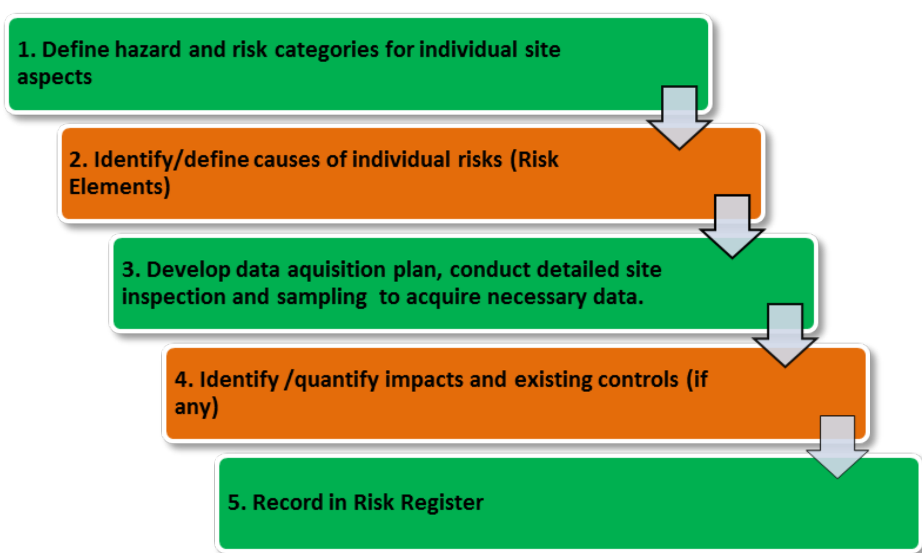

Figure 2 - Risk Identification

The broad categories of risk identified in Step 1 will be site specific and be a consequence of the individual hazards identified on the particular site. Generally, broad hazard/risk categories can be grouped into the following:

Environmental and Human Health Risks (Non-exhaustive)

- Soil;
- Soil Vapour;
- Groundwater ;
- Air quality;
- Surface water;
- Sediment; and,
- Aquatic and terrestrial biota.

Public Safety Risks (Non-exhaustive)

- Structural collapse;
- Surface collapse;
- Subsurface collapse;
- Open holes (vertical and/or horizontal);
- Slope failure; and,
- Vertical falls.

Human health risk, if present, will likely result from identified receptors being exposed to environmental media primarily through consumption and/or inhalation.

Based on the individual hazards present on a particular site, a detailed data acquisition plan must be developed and include both physical and chemical components. Careful attention must be paid during the development and implementation of the data acquisition plan to ensure that all relevant data necessary to complete the risk evaluation is acquired by qualified individuals in an appropriate and safe manner.

The data acquisition plan, site inspection results and any analytical data resulting from this stage of the Risk Analysis Process must be permanently retained in the Risk Library.

2.3.6 Identification of Appropriate "End-state" Criteria

In order to undertake the next step of the risk assessment process (Risk Evaluation) it is necessary to establish or adopt appropriate "end-state" criteria ("end-points or "remediation criteria") for the identified hazards at the site. The establishment of appropriate "end-states" is critically important. They will establish whether a risk exists or the standards which the risk reduction activities, or remediation activities must meet, and by extension, determine the level of remediation warranted, define when the site has achieved the desired closed site status, and perhaps most significantly, establish the costs to conduct the required remediation.

Remediation objectives or "end-states" should be established in consultation with stakeholders early in the risk analysis process and be re-visited regularly to ensure they remain relevant as knowledge of the site and its condition increases.

A long standing debate exists on the topic of 'how clean is clean' and/or 'what is safe' particularly when it comes to the topic of remediation of orphaned and/or abandoned mines. A difficulty may arise in what individual stakeholders believe is a proper balance between the level of risk reduction required and the costs of completing the remediation required to achieve that level. Any discussion on "endpoint" criteria to meet an accepted risk reduction level and the remediation required to meet that goal should include a transparent and rigorous discussion about the costs to conduct the various remediation options.

Aspects that may require the establishment of "end-state" criteria will be site specific but should, at a minimum include:

- Post-remediation land use
- Environmental media such as:
    - Surface (and potentially ground) water quality
    - Sediment quality
    - Soil quality
- Human health considerations
- Ecologically valued components;
- Public safety considerations

2.3.6.1 Post- remediation Land Use

One of the first "end-states" that must be determined is the post-remediation land use for the site. In some instances, it may be unrestricted public access with continued, unfettered traditional use and ecosystem services. In other circumstances, future land use may be limited to industrial development or, in extreme cases; permanent exclusion of the public may be required even after remediation. The post-remediation land use will also assist in establishing the extent of risk reduction activities to be undertaken and by extension, the level of remediation warranted.

The post-remediation land use discussion and determination should be undertaken as one of the first steps in the risk analysis and cost estimation process. Consultations should include as wide a range of stakeholders as possible and include government agencies, Indigenous organizations, traditional land users, NGOs, and the general public.

2.3.6.2 Environmental Guidelines

Most jurisdictions have published guidelines or objectives for ecosystem components such as air quality, soil quality, water quality, sediment quality. Notwithstanding whether the local jurisdiction has published guidelines/objectives or not, it is recommended that Users familiarize themselves with the *Canadian Environmental Quality Guidelines* published by the Canadian Council of Ministers of Environment (www.ccme.ca/publications/ceqg_rcqe.html). These guidelines provide nationally endorsed, science based goals for the quality of atmospheric, aquatic, and terrestrial ecosystems in Canada.

When using most of these guidelines or objectives, it is important to recognize that a "safety factor" is included in the calculation of the published values. For example, during the derivation of both the long-term and short-term exposure guidelines values for parameters listed in the Canadian Water Quality Guidelines for the Protection of Aquatic Life, the critical study (i.e., the lowest acceptable, appropriate toxicity endpoint), is divided by a safety factor of 10 to arrive at the published guideline values (CCME 2007).

This precautionary safety factor has been chosen to account for differences in sensitivity to a chemical variable due to differences in species (intra- and interspecies), exposure conditions (laboratory versus field, varying environmental conditions), and test endpoints, as well as a paucity of toxicological data, cumulative exposures, and policy requirements (in particular, extrapolating from a low-effect toxicological threshold to a protective environmental management benchmark) (CCME 2007).

As a result, it is important for the Risk Management Team to objectively evaluate whether a site specific concentration of a measured parameter poses a significant risk to the local ecosystem and not to conclude that just because a measured parameter on a particular site exceeds a published guideline value, that there has been, or will be, a significant risk.

2.3.6.3 Ecological Risk Assessment

An ecological risk assessment (ERA) is a process of evaluating the potential adverse effects on non-human organisms, populations or communities to human induced stressors. An ERA entails the application of a formal framework, analytical process, or model to estimate the effects of human actions on natural organisms, populations or communities and interprets the significance of those effects in light of the uncertainties identified in each study component. It results in an evaluation of the probability of adverse health consequences to ecological receptors such as fish, terrestrial vegetation, soil-dwelling organisms, mammals and birds caused by the presence of contaminants at a site.

An ERA is used to determine whether and to what extent remediation or other risk management efforts are warranted to mitigate current or future ecological risks, or risks to ecosystem services. It provides a basis for determining whether remediation or other risk management measures are warranted (i.e., are there ecological risks?) and to what extent (e.g., which parts of a site should be remediated?). The costs of remediation or other risk management measures may ultimately be much lower using a risk-based approach compared to an approach based on comparison of contaminant concentrations to environmental quality guidelines.

The Canadian Council of Ministers of the Environment (CCME 1996) has provided general guidance concerning its views on what constitutes an ecological risk assessment (ERA). The recommended framework is similar to that proposed by Environment Canada (Env. Can. 1997) and recommends three levels of investigation.

The first level, a Screening Level Assessment (SLA or Tier 1) is essentially a qualitative assessment of potential risks to important ecological receptors. The second level, the Preliminary Quantitative Risk Assessment (PQRA or Tier 2) focuses on filling gaps identified at the screening level. The third level, a Detailed Quantitative Risk Assessment (DQRA or Tier 3) includes more detailed data and modelling.

The rigour of the risk assessment adopted for a particular situation must be commensurate with the degree and extent of potential harm and may progress to a more stringent level (i.e., from Tier 1 to Tier 2 or from Tier 2 to Tier 3) depending on the findings at each level. Each level in this tiered approach has the same structure and builds upon the data, information, knowledge and decisions generated from the preceding level. Thus, each level is progressively more rigorous and complex.

Each level of the assessment includes the following elements:

- Receptor Characterization: At this phase of the assessment, the potential receptors are identified and the pathways of exposure are defined.
- Exposure Assessment: The purpose of this stage is to quantify the contact between the receptor and the contaminant of concern.
- Hazard Assessment: This phase of the ERA examines the potential effects of a contaminant to a receptor.
- Risk Characterization: The risk characterization stage combines the information collected in the exposure assessment and the hazard assessment, and the potential for adverse ecological effects is estimated.

Adverse ecological effects are characterized by the value of a simple screening index (generally considered to be 1). This index is calculated by dividing the expected exposure concentration or dose by the selected toxicity reference value for each ecological receptor. An ERA is concerned with estimating effects on populations, communities and ecosystems (multi species). Estimation of population level impacts is a complex issue and involves some level of scientific judgement.

2.3.6.4 Human Health Risk Assessment

A human health[1] risk assessment (HHRA) evaluates the probability of adverse health consequences caused by the presence of contaminants in the environment. In a HHRA, receptor characteristics (e.g., portion of time spent in the study area, source of drinking water, composition of diet) and exposure pathways (e.g., ingestion of berries) are taken into consideration to quantify the risk of adverse health effects. Unlike an ecological risk assessment (ERA), which is concerned with population effects, the HHRA focuses on effects on individuals.

The *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0* (revised 2012) (http://www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/part-partie_i/index-eng.php) has been developed to ensure that remediation or risk management is applied to those sites and properties posing significant human health risks. The purpose of a PQRA is to quantify the degree of potential human health risk posed by the presence of contamination at a subject site.

The purpose of the guidance document is to prescribe, to the degree possible, standard exposure pathways, receptor characteristics, toxicity reference values (TRVs), and other parameters required to quantitatively and consistently assess the potential chemical exposures and human health risks at federal contaminated sites. The primary purpose for PQRA is to rank the potential human health risks posed by federal contaminated sites relative to one another (for decisions regarding funding, etc.) and, therefore, consistency across multiple provincial and territorial boundaries is essential for fair and equitable evaluation.

Once completed, the results of the Ecological and Human Health Risk Assessment will provide an informed assessment of those aspects or hazards present on the site that pose a human health risk and an knowledgeable opinion of the significance of the risk. This information will contribute to an informed decision on whether or not further remediation of the hazard is warranted.

2.3.6.5 Public Safety

Although somewhat subjective, an assessment of the public safety risk posed by the hazards identified during the site investigation is performed by considering each of the following questions:

> Does the identified hazard pose a safety risk above those normally found and accepted in Canadian society and exist as result of the former mine?

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[1] The term “human health” may have multiple interpretations dependent on context. In the context of this report and its specificity to orphaned and abandoned mines, The Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 is the interpretation guideline. Users of this document are not restricted to that guideline and may consider social and cultural health impacts as part of their risk assessment

> Does the identified hazard pose a safety risk above those normally present in the region (i.e. natural cliffs or steep unstable slopes) and exist as a result of the former mine?

If, in the opinion of the person conducting the public safety risk assessment, the answer to either question is “yes”, the hazard is identified as one which should be considered for further remediation.

Many jurisdictions have specific legislation, regulations or, in some instances guidelines that define actions or conditions required to address public safety issues at decommissioned mine sites. Any individual, organization or institution charged with developing the “endpoint” of remediation activities to remediate public safety risks should familiarize themselves with relevant, local legislation, regulations and guidelines related to mineral exploration and mine closure requirements, and engineering standards. These include the Canadian Dam Association, *Dam Safety Guidelines 2007 (Revised 2013)* as well as industry Best Management Practices (BMP), in order to establish related end-states.

Each of the mine-specific hazards identified on the site should be compared against the appropriate criteria specified in the relevant applicable legislation, regulations or guideline in terms of whether or not it meets, or is more robust than, the specification contained in these documents. In the event that legislation, regulations or guidelines do not address a particular site aspect, the User should research industry Best Management Practises for guidance.

For those hazards resulting from mine specific aspects, the legislation, regulations guidelines and BMP will include but are not limited to:

- Requirements on the decommissioning of drill holes and drill hole casings;
- Requirements to ensure appropriate crown pillar integrity in the long-term;
- Requirements to install regulatory approved, engineered “caps” on all vertical mine openings to surface (i.e. shafts and raises);
- Requirements to install regulatory approved, engineered bulkheads or “development rock plugs” in all horizontal mine openings to surface (i.e. adits and declines);
- Requirements to establish appropriately configured egress routes from decommissioned open pits (i.e. sloping ramps to allow wildlife and human to exit the pit);
- Specified bench heights in decommissioned open pits to limit the distance of an accidental fall;
- A specified distance of clear, unrestricted line of site to vertical drops (i.e. open pit rims);
- Requirements for the installation of barriers to limit access to vertical drops (i.e. large boulders, construction of berms and swales);
- Requirements to ensure appropriate side slope angle and slope stability on rock piles, dams and dams/dykes;
- Requirements related to allowable gamma radiation.

In the event that, in the opinion of the person or group conducting the public safety risk assessment, a particular hazard identified on the site does not meet or exceed the specified criteria, the hazard should be identified as one which should be considered for remediation.

2.3.6.6 Stakeholder Involvement

Notwithstanding the method used to set site remediation objectives and/or end-states and post-remediation land use (or land use restrictions), there is a need for stakeholder involvement. The opinions and concerns expressed by a wide range of stakeholders including the eventual custodian of the property, the local public and traditional land users should be taken into account when assessing the need for remediation and setting remediation objectives and "end-states".

Experience has shown that significant advantage can be achieved when a wide range of stakeholders, including interested members of the general public and local Indigenous communities, are included in all relevant stages of the process used to arrive at the site remediation end-state decisions. Open and forthright involvement of these groups often increases public trust and confidence in the management of the site and can serve to limit negative opinions by the public related to the level of safety or environmental risks posed by a particular site. When possible and where available, participation funding also contributes to effective stakeholder participation and may enhance overall trust in the process and process outcomes.

It is also important to document and permanently retain a record in the Risk Library of the groups/organizations involved in establishing remediation end-states, the processes used to arrive at each decision, and the reasons for each decision.

2.3.6.7 Budget Considerations

Remediation costs are a significant component of risk reduction and remediation activities and should not be excluded from a comprehensive discussion and determination of "end-states". Failure to establish and document the approved "end-state" or remediation objectives in advance of undertaking site remediation activities could result in the implementation of remediation strategies well in excess of what would be required to reduce site risks to an acceptable level, or underestimating overall costs for certain valued ecological components. Such actions will result in significant impacts on the budgeting process and to the overall schedule and cost of completing the remediation project.

The early establishment and documentation of approved appropriate "end-states" or remediation objectives is critically important. They establish the standards which the risk reduction activities, or remediation activities, must meet and by extension, the budget implications and costs to conduct the required remediation.

2.3.7 Risk Evaluation (Assessment)

Once all site risks have been identified and the site investigation and resulting data received, the Risk Management Team must evaluate each separate on- and off-site risk and determine or rank the significance of each in the "as-is" condition against the established "end-state" criteria.

Figure 3 provides a summary of the actions undertaken to complete this task.

Figure 3 - Risk Evaluation

2.3.7.1 Risk Ranking

In order to rank the significance of each identified risk, site specific "significance" and "likelihood" criteria must be developed by the Risk Management Team in consultation with appropriate stakeholders and submitted to the relevant regulatory agencies for review.

"Likelihood" is the chance or probability that a particular risk will occur and can be expressed as either a probability for a single event or condition to occur (e.g., >25% chance of occurrence), or a frequency of occurrence for repeated events (e.g., >2X / year event). The "significance" ranking is a ranking based on the potential consequence if the risk were realized. Ideally, in order to minimize the potential for bias, both the "likelihood" and "significance" descriptors should be developed before the detailed site risk characterization activities are undertaken, and re-verified once the site specific data/information is available.

Table 2 and Table 3 are provided as **sample** descriptors of the "likelihood" of an identified risk being realized and the potential "significance" (or consequence) of the same risk if it were realized. In both instances **the descriptors presented in the tables are hypothetical.** In a real live project, the Risk Management Team would establish the descriptors (e.g. frequency and probability) based on site specific factors and the overall philosophy and objective(s) of the Risk Management Plan.

Table 2: Sample "Likelihood" Descriptors

Likelihood	Frequency *(Multiple Events)*	Probability *(Single Event)*
Certain (C)	Expected to occur more than once a year. (e.g. >1:1 or > 100% chance of occurrence/year)	Greater than 25% chance of occurrence
Likely (L)	Expected to occur several times during the next decade. (e.g. ≈1:3 or 10 - 30% chance of occurrence/year)	10 to 25% chance of occurrence
Possible (P)	Expected to occur once during the next decade. (e.g. <1:10 or 1 - 10% chance of occurrence/year)	1 to 10% chance of occurrence
Unlikely (UL)	Not expected to occur during the next decade. (e.g. ≈1:1000 - 1:100 or 0.1 - 1% chance of occurrence/year)	0.1 to 1% chance of occurrence
Rare (R)	Extremely unlikely to occur during the next 100 years or longer. (e.g. <1:1000 or <0.1 chance of occurrence/year)	Less than 0.1% chance of occurrence

Table 3: Sample "Significance" Descriptors

Significance	Very Low (VL)	Low (L)	Moderate (M)	High (H)	Very High (VH)
Environment	Impact not likely measurable within ecosystem.	Negligible impact on local environment. Exceeds natural variability.	Localized or reversible environmental damage.	Widespread or irreversible environmental damage.	Widespread and irreversible environmental damage.
Public Health	Negligible health impacts.	Medical aid injury.	Permanent disability; isolated lengthy lost time injury.	Fatality; permanent disability for several individuals.	Multiple fatalities; permanent disability for numerous individuals.
Public Safety	Incident (scrapes & cuts)	Medical aid injury.	Permanent disability.	Fatality.	Multiple fatalities.
Socio-economic	Minimal interruption of socio-economic aspect	Temporary interruption of socio-economic aspect	Short term, on-site loss of socio-economic aspect	Short term, on-site and off-site loss of socio-economic aspect	Permanent loss of significant socio-economic aspect

Table 4 provides a theoretical matrix to rank each risk identified on the site. For each risk assessed, the intersection of the Significance column and Likelihood row defines the Class of Risk which in turn defines the level of management action required (Table 5). As with the previous two tables, **the descriptors presented in the Tables 4 and 5 are hypothetical**. In reality, the Risk Management Team would establish the descriptor based on site specific factors and the overall philosophy and objective(s) of the Risk Management Plan.

Table 4: Sample "Risk Ranking" Matrix

Likelihood	Significance				
	Very Low	Low	Moderate	High	Very High
Certain	Class II	Class III	Class IV	Class IV	Class IV
Likely	Class II	Class III	Class III	Class IV	Class IV
Possible	Class I	Class II	Class III	Class IV	Class IV
Unlikely	Class I	Class I	Class II	Class III	Class IV
Rare	Class I	Class I	Class II	Class III	Class III

Table 5: Sample "Risk Response" Descriptors

Risk	Response
Class I	Risks that are below the risk acceptance threshold and do not require remediation.
Class II	Risks that lie on the risk acceptance threshold and require active monitoring
Class III	Risks that exceed the risk acceptance threshold and require remediation
Class IV	Risks that significantly exceed the risk acceptance threshold and require urgent action

2.3.8 Risk Register

A "Risk Register", also referred to as a Risk Log, forms a part of the Risk Library and is a tool used by the Risk Management Team to track identified risks and issues as they arise and are addressed throughout the life of the project.

The Risk Register assists in the risk management process in four key ways as follows.

1. Identifies individual risks,
2. Evaluates the significance of identified risks,
3. Defines possible remediation solutions to the identified risks; and ,
4. Summarizes monitoring and analysis of the effectiveness of any subsequent steps taken.

The Risk Register contains information about site and project risks, analysis of potential severity/significance of each identified risk, a ranking of each and a preliminary evaluation of the possible solutions to be applied. A spreadsheet is often the best way to present and manage this information as key information can be found easily and applied by members of the Risk Management Team.

The Risk Register should be created during the early stages of the project and updated on a regular basis with all previous versions retained in the Risk Library. It is generally shared between project stakeholders, allowing those involved in the project to be kept aware of issues and providing a means of tracking the response to the identified issues. It can also be used to flag new project risks and to make informed suggestions on the course of action may be required to resolve the issues.

Table 6 provides a **sample of a partially completed, hypothetical** Risk Register for a hypothetical site.

Table 6: Sample - Risk Register

Site Aspect	Hazard/Threat Title (Description of Risk)	Specific Location	Risk Element	Effect/Impact (Demonstrated or anticipated)	Risk Ranking															Level of Confidence	Potential Mitigation	Comments
					Public Health & Safety			On-Site Environment			Off-Site Environment			Human Health			Socio-Economic					
					Significance	Likelihood	Risk Ranking	Significance	Likelihood	Risk Ranking	Significance	Likelihood	Risk Ranking	Significance	Likelihood	Risk Ranking	Significance	Likelihood	Risk Ranking			
Access road	Diversion of natural flow paths	XX^{0} YY" N ZZ^{0} VV" W	Changes to watershed flows	None identified	VL	P	I	L	R	I	L	L	III	NA	NA	0	NA	NA	0	1	Remove culvert & restore natural flows	Monitor post-removal flows
3 drill holes discharging water	Surface discharge with combined flow rate of approximately 3 L/s - flows into Bryson Creek		Discharge water quality - exceeds established water quality objectives for Fe, Se, Ni, and Z	Negative impact to water quality in Bryson Creek and Bryson Lake fisheries	VL	P	I	M	C	IV	M	C	IV	L	p	II	H	C	IV	2	Plug drill holes & investigate alternate route for discharge water	Bryson Creek is potable water sources and Bryson Lake was commercially harvested (fish)
Tailings Management Area	Small water erosion channels in containment dam/dyke sidewall	CC^{0} BB" N YY^{0} XV" W	Dam/dyke integrity	Potential of tailings exiting facility and entering Bryson Creek	VL	P	I	M	C	IV	M	C	IV	L	P	II	M	L	IV	2		
	Wind-blown tailings	NE of facility	1 to 3 cm of wind-blown tailings deposited east and northeast of facility for a distance of approximately 500 m - exceed Soil Quality Objectives for Ni and Z	Potential uptake of contaminants by vegetation	VL	P	I	L	C	III	VL	UL	I	NA	NA	0	NA	NA	0	1		
	Seep from containment structure - total volume estimated at 1 L/hr. - infiltrates within 2 m of seep	CC^{0} BB" N YY^{0} XV" W	Seep water quality - exceeds established Surface Water Quality Objectives for Fe, Se, Ni, and Z	Potential degradation of groundwater	VL	P	I	?	?	?	VL	UL	I	?	?	?	?	?	?	3		Additional ground water quality investigation required
Shaft #1	Temporary steel plate installed over shaft	AA^{0} BB" N ZY^{0} XV" W	Integrity of steel cover questionable – evidence of recent failure	Potential of catastrophic failure –resulting in an opening of 2m x 4m mine shaft	H	P	IV	VL	UL	I	VL	UL	I	NA	NA	0	NA	NA	0	1	Install permanent shaft cap	Site is accessible and there is evidence of recent public visitation

Level of Confidence: 1 - High level of confidence (Empirical data based)
2 – Medium level of confidence (Field evidence to support)
3 – Low level of confidence (Observation only)

2.4 Risk Management Plan (Remediation Plan)

2.4.1 Introduction

The risk management plan is essentially an identification and documentation of the remediation activities that are required to address and reduce risk identified by the Risk Management Team as requiring remediation (usually those rated as Class III or higher as a minimum). The preparation of the plan is overseen by the Risk Management Team, but often requires the engagement of qualified professionals in various fields. The plan should be developed and shared with the stakeholders before any substantial physical site remediation is undertaken.

2.4.2 Developing the Plan

Figure 4 provides a description of the broad activities necessary to develop and implement the Risk Management Plan (remediation plan).

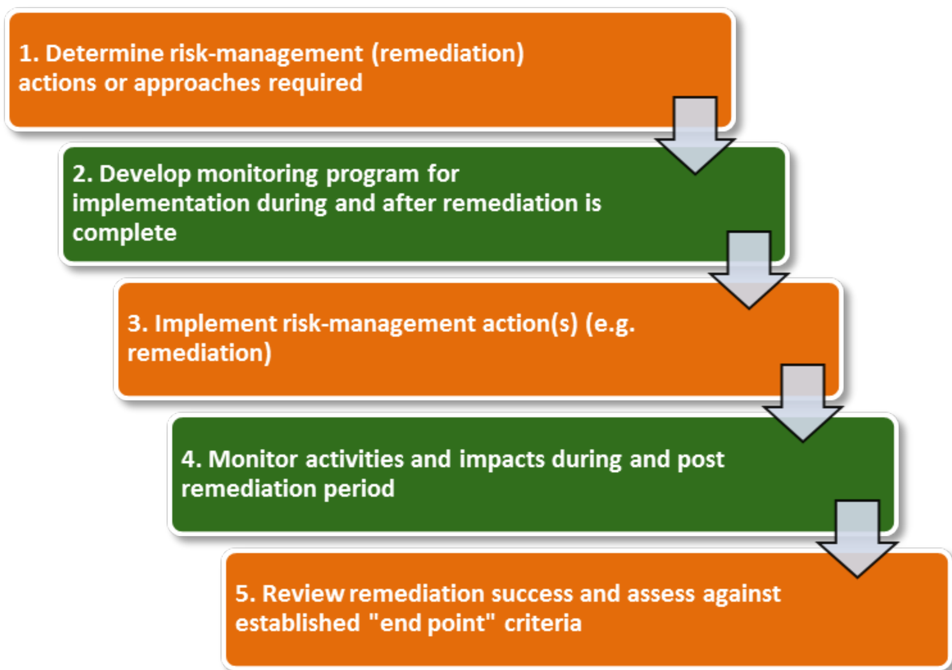

Figure 4 - Risk Management Plan

There are several key considerations to ensure that site remediation is completed in the most time effective and cost-efficient method practicable, beginning with the retention of professionally qualified personnel.

2.4.2.1 Qualifications of Consultants

Generally, when conducting the risk analysis process, the Risk Management Team will have to retain the services of certain professionals to undertake site assessments and to prepare proposed risk management or remediation strategies for the various hazards/risks on a particular site. The professionals retained for such work must be qualified [i.e. Professional Engineer (P.Eng.), Professional Geoscientist (P.Geo.), etc.] and, in some instances, have retained formal Qualified Person designation by the jurisdiction in which they are operating.

In order to maintain an unbiased and cost effective project, it is also essential that any independent professional retained by the Risk Management Team not be affiliated in any way with the remediation contractor(s) or any of the subcontractors or suppliers that would potentially stand to profit from the remediation activities.

2.4.2.2 Qualifications of Risk Management Team

The Risk Management Team must also have in-house expertise (or the authority to retain independent third party expertise) to competently review, and in some instances challenge, the conclusions and proposed remediation actions put forward by the retained professionals preparing the plan as well as those of agencies having regulatory oversight or approval and/or permitting authority. Lack of this competency can result in the implementation of remediation strategies in excess of what is required to reduce site risks to an acceptable level providing a profit to a remediation contractor and a loss to the government and taxpayer or providing strategies that may be less expensive, but do not reduce site risks in the long-term.

2.4.2.3 Assessing Remediation Options

Once the extent of site hazards /risks has been determined, the RMT must evaluate the various methodologies available to effect the remediation. Various options should be compared and contrasted based on the factors of cost, timeline, and certainty in order to ensure that the most appropriate remedial approach is chosen. These factors must also be weighed against the objectives, risk and cost tolerance and the expectations of stakeholders. Above all, the selected approach must be free of bias when those that may profit from a given process, technology or management option are the ones that will be doing the work.

Implementing the identified remediation actions will result in a certain level of environmental and safety risk. During the risk management plan development, it is important that the environmental, health and safety impacts of the remediation activities themselves be fully assessed in order to ensure that there is a net positive benefit from implementation.

The following provides an example of a preliminary set of questions (in no order of priority) that should be answered for each remediation activity proposed:

- Can the proposed remediation activity be demonstrated to be a permanent solution to reduce the identified hazard?
- Does the proposed remediation activity have a low or negligible potential of introducing a new hazard or risk to public safety, human or ecosystem health?
- Does the proposed activity have a greater than 90% chance of successfully reducing the significance of the current existing risk?
- Has the proposed remediation activity been employed successfully in other jurisdictions?
- Has it been employed successfully in an ecosystem similar to that at the site?
- Can it be safely undertaken and completed at the site (OH&S)?
- Will the anticipated benefit be reversed by 'natural' events or activities (i.e. PMP, beaver dams, climate change, etc.)?
- Will the disturbed ecosystem return to a stable condition within 1 year, 5 years or 10 years? Is the timeframe acceptable to all stakeholders?
- Is the proposed remediation action a passive solution that does not require ongoing maintenance?
- Does the proposed remediation activity have or require regulatory support or approval?
- Does the proposed remediation activity have unambiguous local stakeholder support?
- Does the total estimated cost of the proposed remediation (including approvals as well as post-remediation monitoring and maintenance) exceed the value of the resource or feature currently at risk?

A complete set of similar project specific questions should be developed, recorded and the responses maintained in the Risk Library by the RMT.

2.4.2.4 Passive Remediation Strategies

The choice of the preferred remediation strategies to address a particular risk must take into account the cost and difficulty of long-term stewardship activities. Risk management decisions affect the "end state," or the physical condition reached when remediation is complete. The end state, in turn, essentially determines how any residual hazards will need to be managed in the long-term, and thus establishes implicit or explicit long-term stewardship obligations. The end state and resulting long-term stewardship activities, in turn, are the basis for identifying the needs and opportunities for advances in technologies to improve protectiveness and/or lower costs.

The principle that undue burdens should not be placed on future generations supports application of passive strategies to site closure and remediation activities, rather than the use of engineered structures, which require significant ongoing maintenance. As a result, modern decommissioning and remediation strategies consider the implementation of passive control principles wherever possible.

For example, filling a mine shaft or raise with waste rock is a passive decommissioning strategy when compared with permanently closing the same shaft with an engineered concrete bulkhead (cap). The concrete cap does pose a certain level of risk of catastrophic failure (although, initially very small) but eventually the concrete bulkhead will degrade, requires maintenance and eventually requires replacement, increasing the long-term stewardship costs.

The implementation of passive decommissioning and remediation strategies on a site will significantly reduce the need for maintenance in the long-term and therefore reduce potential costs that may have to be assumed by future generations in order to undertake required activities.

2.4.3 Regulatory Reviews and Permitting

In most jurisdictions, some level of regulatory review of the proposed remediation activities will be required. The decommissioning and reclamation of some larger or more complex sites could potentially trigger a requirement for the proponent to complete a full environmental assessment in some jurisdictions. In addition, while permits and/or formal approval may not be required for all of the remediation activities, some site remediation will require activity specific permits or approvals such as forestry, land use, borrow source access and removal or aquatic habitat permits (to allow for shoreline disturbances, etc.)

2.4.4 Uncertainties

Although a detailed risk characterization and evaluation process may be completed on a site, once remediation activities commence at that site there is a high potential that additional hazards/risks will come to light. It is difficult to accurately forecast or estimate the extent of previously unidentified hazards/risks; however, management processes to address such developments must be incorporated in the overall project planning framework (i.e. change management).

2.4.5 Post - Remediation Monitoring

A transitional phase monitoring program of the site is required post-remediation to ensure that the target risk has or is being reduced. This allows for a comparison of site conditions over time to the established “end-state” criteria. Post-remediation monitoring may eventually demonstrate that the site has reached a state that will allow for the custodial transfer of the property to some form of long-term management framework. Such a monitoring program generally consists of regular scheduled site inspections, the sampling and analysis of various media or a combination of both.

Ideally, the monitoring program should be reviewed by as wide a selection of stakeholders as possible and be conducted by qualified individuals, with traditional land users and/or members of the general public involved in some manner. In addition, regular reporting of the inspection and monitoring results should be available to, and easily accessible by, the public. Such reports should provide the raw monitoring data as well as interpretation of the data in a format and language that can be understood by non-technical readers.

3 Remediation Cost Estimation

3.1 Introduction

Estimating the cost of implementing the risk management plan (remediation activities) must be site specific and be based on a complete and comprehensive risk analysis process.

One must fully consider the type and extent of remediation activities to be undertaken on the site, labor & equipment rates at the location and time the activities are undertaken, and "overhead costs" (generally considered to include administration, management, supervision, permitting and approvals, etc.) at the time the activities are undertaken.

3.2 Published Guidelines and Toolkits

Over the past decade, numerous jurisdictions within Canada and internationally have published guidelines on estimating the costs of mine closure. Some examples include:

- *Mine Reclamation Costing and Spreadsheet, Version 3.5.2*, B.C. Ministry of Energy and Mines, Mines and Mineral Resources Division, January 2015
- *Planning for Integrated Mine Closure: Toolkit,* International Council on Mining and Metals (ICMM), London, United Kingdom
- *Mine Closure and Reclamation Cost Estimation Guidelines: Indirect Cost Categories,* Alaska Department of Natural Resources & Alaska Department of Environmental Conservation, April 2015
- *Reclamation Bond Estimation and Administration Guide*, USDA – Forest Service, April 2004

Although these guidelines have been developed primarily for estimating the cost of closure at operating mines to support closure bond valuation, much of the information presented offers useful, applicable tools and guidance that can be applied to orphaned/abandoned mines.

3.3 Typical Data Needs

Table 7 provides a preliminary list of the typical data needs for estimating the cost of remediation.

Table 7: Typical Data Needs

Data Needs	Data Type
Description of post-remediation land use	Terrestrial Aquatic Ecosystem services
Remediation plans and studies	Aspect specific plans Aspect specific engineered drawings Environmental investigations Special studies (material characterization, hydrocarbon contamination, gamma surveys etc.)
Site specific physical information	Haul distances Slopes and grades Stream crossing requirements
Mine related aspects	Size and type of opening to surface (underground mine) Type & condition of crown pillar(s) Geotechnical assessment of openings to surface Geotechnical assessment of open pit rim, walls and benches
Total disturbed hectares/acres	Size (area and height) of tailings management facility Size (area and height) of all waste rock storage areas Extent of impacted areas (i.e. downstream/downwind environments) Geochemical and geotechnical characteristics of waste rock Size (area and height) of heap leach facilities Geochemical and geotechnical character of residual materials Buildings/foundations Road/ditches/laydown areas
Containment facilities	Type of containment (dams/dykes, berms, ponds, etc.) Size (area and height) of containment Conditions (i.e. vegetation cover, flooded, windblown)
Treatment requirements (water, soil, etc.)	Type of treatment required Cost of treatment Duration of treatment
List of facilities that require decommissioning & removal	Size Construction type Potential disposal locations Anticipated equipment required for demolition Disposal fees
Total area requiring reclamation	Soil amendment costs Application costs Seed/seedling requirements Seed/seedling availability Seed/seedling costs
Clean sources of “borrow” material	Location Availability Volumes Geochemical characterization Geotechnical characterization Swell factors Costs
Total material handling requirements	Volumes Swell factors Material properties

Data Needs	Data Type
Anticipated equipment requirements	Type required Production capabilities of available equipment Location Ownership/rental rates Operating costs
Fuel Costs	Anticipated fuel consumption On site storage costs Cost (FOB the site)
Labour Rates	Labourers Equipment operators Support individuals (mechanics, etc.) Supervision
Logistical Support Costs	Administration Transport to/from site On-site support facilities Camp (if required) Sewage/grey water treatment
On-site project management costs	During remediation Post-remediation Personnel requirements Analytical costs
Monitoring Costs	During remediation Post-remediation Personnel requirements Analytical costs Reporting costs
Mobilization/Demobilization Cost	Site access type and condition Equipment Labour Support materials
Overhead Costs	Overall project management Approvals and permits Reporting General administration

Data used to estimate costs must be **site specific** and include information that is **relevant to the location and the time** that the activities are undertaken, particularly for such things as labour, equipment and fuel. Such costs can change significantly over a relatively short period of time and from region to region.

3.4 Cost Estimation Tools

A few proven mine closure cost estimating spreadsheet/software applications have been developed and are available in the public domain. While generally designed for active mine closure, they can be used for estimating costs at orphaned/abandoned mines. Two such models are the *Nevada Standardized Reclamation Cost Estimator* (SRCE) (http://www.nvbond.org) and the *New South Wales - Rehabilitation Cost Calculation Tool* (www.resourcesandenergy.nsw.gov.au/). Both were developed to facilitate accuracy, completeness and consistency in the calculation of costs for mine site reclamation.

The *Nevada Standardized Reclamation Cost Estimator* was developed as cooperative effort between the:

- Nevada Division of Environmental Protection,
- Nevada Bureau of Mining Regulation and Reclamation,
- U.S. Department of Interior, Bureau of Land Management, and
- Nevada Mining Association.

It is an easy to use, Excel-based model that provides a reliable, accurate and systematic tool for estimating mine rehabilitation and closure costs. The model includes a live database of unit costs and can be readily updated or modified.

When using such models it is important to recognize that they are developed for application in a specific jurisdiction and therefore reflect local conditions and/or requirements. Notwithstanding this, such models provide the User with a framework and generally include a very wide range of actions/activities that should be considered when developing a site specific cost estimate for an orphaned /abandoned mine site.

Estimating the total costs of remediation can be made more efficient through definition of common categories of activities and by using a spreadsheet for presentation and analysis. Spreadsheets facilitate the estimation of the cost of remediation at a specific point in time chosen by the estimator and enable the estimation of future costs for long-term media treatment, post-remediation, long-term monitoring and maintenance costs. In addition, change management (i.e. changes in labor rates, fuel cost, etc.) are easily incorporated in subsequent versions of the spreadsheet and allows the estimator to run varying scenarios.

Each site's workbook should consist of a series of spreadsheets that provide a list of the current equipment rates and labour costs used in the calculations and a detailed, site specific estimate of cost under each of the following headings:

- Equipment and Labour
- Studies & Planning;
- Water Treatment;
- Infrastructure Decommissioning;
- Physical Earthworks;
- Reclamation;
- Project Management, Monitoring and Reporting;
- Mobilization and Demobilization;
- Staffing Support;
- Transition Phase Monitoring;
- Corporate Costs; and,
- Summary Table.

Table 8 provides a summary of select contents for inclusion in each of the listed spreadsheets. These examples are for a hypothetical site, and are not intended to be definitive, as each spreadsheet and workbook will be project, site and time specific.

Table 8: Total Project Cost of Closure

(TPC - June 2016) for a Hypothetical Site

Equipment & Labour Rates

Equipment Costs	Cost (with Operator)		Capacity/Size	Original Cost		Adjusted for locations (+35%)	Costing Source
Loader	244	$/hr.	938G Cat	$180.64	$/hr.	$243.86	2016 Construction Association Handbook
Tracked Dozer	470	$/hr.	D8R Cat	$347.96	$/hr.	$469.75	2016 Construction Association Handbook
Grader	275	$/hr.	140 H Cat	$203.77	$/hr.	$275.09	2016 Construction Association Handbook
Semi-Truck (approx. 850 km) [1]	3,500	$/trip					Local Transport Company (2016)
Haul Truck	328	$/hr.	725 Cat	$242.67	$/hr.	$327.60	2016 Construction Association Handbook
Half Ton Pickup Truck (Service truck)	12	$/hr.					Hourly rate estimate using 2016 daily rate
Skidder	335	$/hr.		$200.00	$/hr.	$260.00	XYZ Drillers (2016) adjusted rate by 30% - not supporting exploration
Tracker Hoe	322	$/hr.	322C Cat	$238.62	$/hr.	$322.14	2016 Construction Association Handbook
Tracker Hoe @shears	383	$/hr.	322C Cat + shear	$283.62	$/hr.	$382.89	2016 Construction Association Handbook
Plasma Cutter	150	$/hr.					
Portable Generators	50	$/hr.					
Side-by-Side	10	$/hr.	2 people				
Support Equipment (misc.)	10	$/hr.					
Boat	10	$/hr.					

Personnel	Wage (Benefits included)	
General Labourer (hired locally)	30	$/hr.
Health, Safety & Environment Specialist	125	$/hr.
HSE Technician	75	$/hr.
Environmental Technician	75	$/hr.
Environmental Engineer	125	$/hr.
Structural Engineer	175	$/hr.
Geotechnical Engineer	175	$/hr.
Project Manager	195	$/hr.
Mobilization/Demobilization[1]	$4,675	/trip
Contingency	0.15	(15%)

Notes:

[1] From community (including pilot car n if load over 9' 8") - local supplier

2016 Construction Association Handbook source: Local Heavy Equipment Association - 2016 Equipment Rental Rates & Membership Roster (April 1, 2016)

Studies & Planning

Activity	*Labour Hours*	*Labour Cost/hr.*	*Sub Total Labour*	*Special Studies & Materials*	*Total*	*Notes*
Assemble existing data	160	$125	$20,000.00	$800.00	$20,800.00	Surveys limited to areas of risk
Conduct site audit (engineering & de-construction specialist)	80	$175	$14,000.00	$12,000.00	$26,000.00	
Conduct site audit (hydrocarbon spills & HSWDGs)	80	$75	$6,000.00	$800.00	$6,800.00	Surveys limited to areas of risk
Conduct required "baseline" investigations & sampling				$165,000.00	$165,000.00	
Conduct required special investigations				$165,000.00	$165,000.00	Tailings chemistry, hydrology
Conduct Risk Analysis	80	$175	$14,000.00	$40,000.00	$54,000.00	Workshops costs
Prepare Decommissioning Plan	160	$195	$31,200.00	$0.00	$31,200.00	
Develop HSE Plan for decommissioning & reclamation activates	40	$175	$7,000.00	$0.00	$7,000.00	
Develop Task Specific Job Hazard Assessment (JHAs)	40	$75	$3,000.00	$0.00	$3,000.00	
Community Information Meeting/Communication			$0.00	$0.00	$50,000.00	Local First Nation and community meetings. Includes local traditional users of the site.
Annual report during transition phase monitoring (5 years)	400	**$175**	$70,000.00	$0.00	$70,000.00	
Annual community meetings during transition phase (2 years)				$0.00	$10,000.00	1 per year
Final Closure Report (post transition monitoring period)				$20,000.00	$20,000.00	Final Closure Report (post transition monitoring period)
Subtotal					**$628,800.00**	

Notes:

Water Treatment

Aspect	Activity	Equipment Required	Hours	Equip. Cost/hr.	Sub Total Equipment	Labour Hours	Labour Cost/hr.	Sub Total Labour	Total	Notes
Pumping	Pumping to treatment facility	gallon /minute	1000	$10	$10,000	0	$30	$0	$10,000	
Infrastructure	Construction								$1,215,000	Quote from XYZ Engineering
	Operations									
	Decommissioning									
Treatment Chemicals									$0	Included in XYZ quote
Operations	Treatment facility operations	Service Truck	1000	$125	$125,000	2000	$30	$60,000	$185,000	
Maintenance and repair									$0	Included in XYZ quote
	Subtotal								**$1,410,000**	

Notes:

Infrastructure Decommissioning

Aspect	Activity	Equipment Required	Hours	Equip. Cost/hr.	Sub Total Equipment	Labour Hours	Labour Cost/hr.	Sub Total Labour	Total	Notes
Bulk Fuel Storage	Remove inventory	Service Truck	4	$12	$48	2	$30	$60	$108	Limited quantity of residual fuel in tank
	Remove tankage & plumbing	Service Truck	4	$12	$48	2	$30	$60	$108	
	Remove contaminated soil	Tacked Hoe	2	$322	$644		$0	$0	$644	No current evidence of spills
	Remove liner	Tacked Hoe	2	$322	$644		$0	$0	$644	
	Dispose of liner	Haul Truck	4	$12	$48		$0	$0	$48	
HS&WD Goods	Remove inventory	Service truck	2	$12	$24	4	$30	$120	$144	Remnants in barrels
	Remove contaminated soil	Tracked Hoe	1	$322	$322	1	$30	$30	$352	No current evidence of spills
	Testing of soil prior to transport to landfill				$3,200	4	$125	$500	$3,700	Testing, of selected area. Transportation of soil
	Remove mineralized cuttings	Loader	4	$244	$975	9	$75	$675	$7,650.46	Approximately 9 45 gallon drums of cuttings
Mill	Salvage materials	Service Truck	24	$244	$5,853	48	$30	$1,440	$7,293	2 people @ 24 hours each
	Decommission tankage & plumbing	Service Truck	40	$244	$9,755	80	$30	$2,400	$12,155	2 people @40 hours each
	Dismantle	Hoe @ shear	120	$383	$45,946	80	$30	$2,400	$48,346	2 people @40 hours each
		Plasma cutter	80	$150	$12,000	80	$30	$2,400	$14,400	2 people @40 hours each
		Haul Truck	80	$328	$26,208				$26,208	
	Off-site removal of materials	Service Truck	40	$244	$9,755	80	$10	$800	$10,555	All drill core to be left on-site
Tailings	Remove remnants of tailings line	Service Truck	16	$12	$192	32	$30	$960	$1,152	2 people @ 16 hours each
		Service Truck	40	$12	$480	80	$30	$2,400	$2,880	Costs assume fence to be removed
		Service Truck	40	$12	$480	80	$30	$2,400	$2,880	All drill core to be left on-site
Camp Buildings	Dismantle	Hoe @ shear	10	$383	$3,829			$0	$3,829	2 people @40 hours each
		Plasma cutter	10	$150	$1,500			$0	$1,500	
		Haul Truck	20	$383	$7,658					
	Disposal									Not yet defined
Storage Buildings	Dismantle	Hoe @ shear	40	$30	$1,200	80	$125	$10,000	$11,200	2 people @40 hours each
		Plasma cutter	40	$125	$5,000	80	$125	$10,000	$15,000	
		Truck	40	$10	$400					
	Disposal									Not yet defined
Access Road	Removal of access trail culverts	Loader	4	$244	$975	8	$30	$240	$1,215	South muskeg crossing
	Removal of swamp mats	Loader	16	$244	$3,902	32	$30	$960	$4,862	North muskeg crossing
		Haul truck	16	$328	$5,242	0	$30	$0	$5,242	
	Removal of sand and geotextile liner	Loader	40	$244	$9,755	32	$30	$960	$10,715	South muskeg crossing.
		Haul truck	40	$328	$13,104	40	$30	$1,200	$14,304	South muskeg crossing
Misc.	Remove meteorological station	Service Truck	4	$12	$48	8	$30	$240	$288	2 people @ 4 hours each
	Seal and cut off piezometers	Service Truck	40	$12	$2,480	105	$30	$3,150	$5,630	Includes plugs and cement.
	Misc. Drill Site remediation	Service Truck	8	$125	$1,000	8	$75	$600	$1,600	Drilling and support equipment owned by contractor
	Subtotal								**$214,652**	

Notes:

Physical & Earthworks

Aspect	Activity	Equipment Required	Hours	Equip. Cost/hr.	Sub Total Equipment	Labour Hours	Labour Cost/hr.	Sub Total Labour	Total	Notes
TMF area	Dam armouring	Loader	200	$244	$48,772.80	0	$0.00	$0.00	$48,772.80	No scarification conducted.
		Haul Truck	200	$328	$65,520.90	0	$0.00	$0.00	$65,520.90	
	Re-contour central area	Skid Steer	32	$335	$10,720.00	0	$0.00	$0.00	$10,720.00	
	Scarify	Grader	4	$244	$975.46	0	$0.00	$0.00	$975.46	Includes ancillary areas (i.e. Septic pits, etc.)
	Re-vegetation	Grader	2	$244	$487.73	0	$0.00	$0.00	$487.73	
Mill terrace	Re-contour area	Grader	4	$244	$975.46	0	$0.00	$0.00	$975.46	Includes ancillary areas (i.e. Septic pits, etc.)
	Scarify area	Grader	2	$244	$487.73	0	$0.00	$0.00	$487.73	
Waste rock	Re-contour area	Dozer	16	$470	$7,515.94	0	$0.00	$0.00	$7,515.94	Includes ancillary areas (i.e. Septic pits, etc.)
	Scarify area	Grader	4	$275	$1,100.36	0	$0.00	$0.00	$1,100.36	
Camp area	Re-contour area	Grader	4	$328	$1,310.42	0	$0.00	$0.00	$1,310.42	Includes ancillary areas (i.e. Septic pits, etc.)
	Scarify area	Grader	2	$328	$655.21	0	$0.00	$0.00	$655.21	
Bulk Fuel area	Scarify area	Grader	1	$275	$275.09	0	$0.00	$0.00	$275.09	
Access Road	Scarify roads	Grader	8	$275	$2,200.72	0	$0.00	$0.00	$2,200.72	Approximately 7.5 km X 5 m corridor
	Replace duff	Grader	8	$275	$2,200.72	0	$0.00	$0.00	$2,200.72	
Borrow areas	Re-contour area	Hoe	16	$322	$5,154.19	0	$0.00	$0.00	$5,154.19	
	Subtotal								**$148,352.70**	

Notes:

Reclamation

Aspect	Activity	Equipment Required	Hours	Equip. Cost/hr.	Sub Total Equipment	Labour Hours	Labour Cost/hr.	Sub Total Labour	Special Studies & Materials	Cost	Total	Notes
Mill, TMF, Camp and major disturbed areas	Hydro-seeding (if required)	Hydro-seeder	60	$250	$15,000.00				Seed & medium	$8,000.00	$23,000.00	Assumes truck pull unit purchased for $15,000 and placed on a trailer.
	Subtotal										**$23,000.00**	

Notes:

Project Management, Monitoring & Reporting

Activity	***Equipment Required***	***Hours***	***Equip. Cost/hr.***	***Sub Total Equipment***	***Labour Hours***	***Labour Cost/hr.***	***Sub Total Labour***	***Total***	***Notes***
Project Management					500	$195.00	$97,500.00	$97,500.00	Camp facilities used until removed
Disposal records					40	$75.00	$3,000.00	$3,000.00	
Administration					250	$75.00	$18,750.00	$18,750.00	
HSE Oversight & Monitoring and Risk Assessment					500	$75.00	$37,500.00	$37,500.00	
Groundwater Sampling (one complete round)								$56,133.00	Consultant to collect Samples.
Subtotal								**$212,883.00**	

Notes:

Mobilization & Demobilization

Activity	***Equipment Required***	***Trip***	***Equip. Cost/Trip***	***Special Studies & Materials***	***Total***	***Notes***
Off-site haul of materials and debris		17	$3,500.00		$59,500.00	Contaminated soil, equipment, materials, silt fencing
Mob and demob equipment		16	$3,500.00		$56,000.00	
Equipment fuel		6	$3,500.00	$10,000.00	$21,000.00	Includes temporary fuel storage during activities
Landfill Disposal Fees					$2,000.00	Recycling to be maximized
Subtotal					**$138,500.00**	

Notes:

Staffing Support

Activity	*Unit Type*	*Number of units*	*Cost/Unit/Day*[1]	*No. of days/trips*	*Total*	*Special Studies & Materials*	*Notes*
Accommodations	Local hotel	20	$147.00	50	$147,000.00		Rate obtained May 27, 2016
Meals		20	60.00	50	$60,000.00		Rate obtained May 27, 2016
Transportation to & from site		2	1,200.00	50	$120,000.00		Van rental
Subtotal					**$327,000.00**		

Notes: 1 Based on rate for 1 single, shared bathroom between 2 rooms, and $60/day for meals for long term guests - North Group of Companies

Transition Phase Monitoring (2 year period)

Activity	*Equipment Required*	*Hours*	*Equip. Cost/hr.*	*Sub Total Equipment*	*Labour Hours*	*Labour Cost/hr.*	*Sub Total Labour*	*Special Studies & Materials*	*Total*	*Notes*
Site inspection (5 years)	Truck and Boat	24	$22.00	$528.00	40	$125	$5,000.00		$5,528.00	Costs for four inspection per year post closure
Sample analysis (5 years - three stations)	Truck and Boat	0	0	$0.00	40	$75	$3,000.00	$12,000.00	$15,000.00	
Ground water assessment (Year 3)								$24,000.00	$24,000.00	
									$0.00	
Subtotal									**$44,528.00**	

Notes:

Corporate Closure Costs

Activity	*Equipment Required*	*Hours*	*Equip. Cost/hr.*	*Sub Total Equipment*	*Labour Hours*	*Labour Cost/hr.*	*Sub Total Labour*	*Special Studies & Materials*	*Total*	*Notes*
Maintaining Office Space									$0.00	Managed from local office
Human Resources Costs									$0.00	
Permit fees, land use authorizations etc.								$18,000.00	$18,000.00	Assumed costs for duration of decommissioning and reclamation
Institutional Control Costs										
Monitoring									?	Jurisdiction specific
Maintenance									?	Jurisdiction specific
Unforeseen Events (Financial Assurance)									?	Jurisdiction specific
Subtotal									**$18,000.00**	

Notes:

Summary

Aspect of Plan	Sub Total	Contingency (15%)	Total	Notes
Studies & Planning	$628,800.00	$94,320.00	$723,120.00	
Water Treatment	$1,410,000.00	$211,500.00	$1,621,500.00	
Infrastructure Decommissioning	$214,652.36	$32,197.85	$246,850.21	
Physical Earthworks	$148,352.70	$22,252.91	$170,605.61	
Reclamation	$23,000.00	$3,450.00	$26,450.00	Natural encroachment should be sufficient on road
Project Management, Monitoring & Reporting	$212,883.00	$31,932.45	$244,815.45	
Mob. & Demob.	$138,500.00	$20,775.00	$159,275.00	
Staffing Support	$327,000.00	$49,050.00	$376,050.00	
Transition Phase Monitoring	$44,528.00	$6,679.20	$51,207.20	
Site Costs Sub-total	**$3,147,716.06**	**$472,157.41**	**$3,619,873.47**	
Corporate Costs	$18,000.00	$2,700.00	$20,700.00	
Project TOTAL	$3,165,716.06	$474,857.41	$3,640,573.47	

During the planning process, each subsequent version of the cost estimation spreadsheet should be retained in the Risk Library for future reference. The most recent versions of the spreadsheet can also be used as an effective tool to track expenditures during remediation activities.

3.5 Uncertainties

In the case of abandoned or orphaned mine sites, there may be limited knowledge of the site during operation which can significantly increase the level of uncertainty of site aspects. Certain aspects, such as the integrity of the crown pillar and the potential risk of a crown pillar collapse, or previously buried hazardous substances and waste dangerous goods are difficult, if not impossible, to identify and assess without an invasive or expensive investigation.

Although a competent and detailed risk characterization and evaluation process may have been completed on a particular site, once remediation activities commence there is a high potential that additional hazards/risks will be identified as the work progresses.

It is impossible to accurately forecast or estimate the extent of such hazards/risks and therefore the cost to remediate them; however contingencies to address such developments must be incorporated into the overall project budgeting process.

4 Long-term Management

4.1 Introduction

Dependent on risk, long-term management of orphaned/abandoned mine sites can involve a wide range of activities and will depend on the nature of the site conditions and/or the residual hazards after remediation. Depending on the type of residual hazards, site-level activities could range from monitoring and simple maintenance to groundwater pump-and-treat systems or other engineered systems used to prevent residual hazards from migrating and reaching human and environmental receptors.

The knowledge of the site's existence and its history should be permanently retained in order to ensure its sustainable long-term management. The funding of that management must also be sustainable and costs may include physical storage of records, scheduled monitoring (air, water, soil) and maintenance programs (shaft cap replacement) and, in specific cases, may require long- term water treatment with annual costs over multiple years.

The consideration of long-term management for a site should be a prerequisite part of any site characterization, assessment and risk management plan. Incorporating long-term stewardship considerations into site-specific remediation decisions will assist in the definition of the level of remediation required and improve the ability to implement and fund long-term stewardship.

4.2 Long-term Management Framework

Core elements of the effective long-term management framework of orphaned and/or abandoned mine sites include:

- Information management;
- Site monitoring and maintenance;
- Unforeseen events (i.e. responses when remedies or controls fail); and
- Application/enforcement of legal or other mechanisms to restrict future use.

The long-term stewardship of a site should include maintenance of the site records in order to retain knowledge of past operations, remediation activities, land use restrictions, maintenance and monitoring results. It should include a management plan that identifies future requirements such as monitoring and maintenance. Typically this requires some form of institutional control and mechanisms for funding of the components.

4.2.1 Information Management

No matter how low the level of risk at a site, knowledge of the site's existence and its history must be permanently retained in order to ensure its continued sustainable management. Maintaining a record of what remediation activities have been completed at the site (e.g. Risk Library), the results of post-remediation monitoring and maintenance and a schedule of future monitoring and maintenance requirements is also critical.

Significant thought must be given to the most effective method/media of archiving this information, methods to ensure that the information can be retrieved at a future date, and the permanence of the institution charged managing the information. Jurisdictional public archives are also experiencing this challenge and may provide technical advice or direction, and are potential depositories for the information. Effective information management must also ensure long-term public access to information about individual sites, their residual risks and the results of recent and past inspections and monitoring.

4.2.2 Monitoring and Maintenance

With any level of remediation or maintenance activity at a site, some level of regular inspection is required in order to ensure that conditions at the site do not deteriorate, resulting in an increase in public safety, human health or ecological risk. Some sites may be exempted from inspection if residual risks are considered negligible and the site has returned to a near pre-development state.

An effective long-term management plan must include a requirement for regular schedule inspections and monitoring specifically designed for early detection of potential changes and/or failures in order to minimize the cost of further rehabilitation, should it be required. Such inspections, if conducted by qualified professionals, will identify developing degradation failure in a timely manner which may allow for additional remediation, which in turn, should reduce the risk of a catastrophic failure at a future date.

Each property must be inspected at a frequency prescribed by a site-specific schedule based on conditions, the level of residual risk that exists on the site and the potential for failure of a particular aspect. Inspections may also include sample collection and analysis in order to assess the recovery or stability of certain aspects of the site. In addition, employing community members trained in monitoring the site would offer several benefits, such as employment to the community and trust in the monitoring results.

In addition to inspections, certain aspects on some properties (e.g. concrete shaft caps) will require maintenance (repair or replacement) at some point in the future. Modern remediation strategies are generally based on the implementation of passive control principles wherever possible which significantly reduces the need for maintenance on a site and therefore any potential costs that may have to be assumed by the long-term custodian. The cost of maintenance of properties for which a custodian has accepted responsibility is predictable and can be calculated on a site-specific basis. For example, the concrete bulkhead used to permanently seal a mine shaft during closure can be engineered and constructed to last approximately 75 years. Therefore, the cost of maintaining that aspect of the site would be the replacement cost at that time.

A permanent funding mechanism is required to ensure that such inspections, monitoring, reporting and, in certain circumstances, maintenance are fully funded over the long-term.

4.3 Estimating Long-Term Management Costs

Table 9 provides a summary of the most relevant aspects that must be considered when estimating the potential costs of long-term management at an orphaned/abandoned site once it has been remediated and reached a closed site status.

Table 9: Long-term Management Cost Considerations

Item	Costs Consideration
Monitoring	Schedule of inspections (frequency) Site inspection mobilization/demobilization costs Future changes in site accessibility (future access) Future site condition (i.e. full vegetation cover may limit ability to inspect) Labour/professional fees Pre-inspection background research requirements (review of historical documentation, inspections reports, etc.) Safety planning Implementation of required safety programs Equipment (safety, sampling, survey, etc.) Environmental media analytical costs (Water, soil)
Maintenance	Site feature requiring maintenance (shaft cover, adit grate, signage, other) Engineering and/or design costs Labour/professional fees Site mobilization/demobilization Future changes in site accessibility (future access) Construction costs Materials sourcing
Unforeseen Event	Site feature (facility type, regulatory changes, etc.) Potential of failure Significance of potential failure (low impact, high impact, catastrophic) Reparation/Remediation cost
Funding	Structure of funding mechanism Management of funding mechanism Rate of Inflation Investment type (rate of return)

When estimating such future costs, a type of Net Present Value (NPV) calculations are generally used as they are currently the accepted method. In order to ensure that no unnecessary burden is placed on future generations, conservative discount rates must be used in such calculations. Similarly, if the future funding of the monitoring and maintenance activities is based on investment and/or interest income, conservative values must be used when calculating the rate of return.

4.3.1 Application/Enforcement of Restrictions

Legal or other mechanisms to restrict future use of some closed sites may be required (e.g. development "freezes", land use restrictions, etc.). Although the costs to address this issue may not be excessive or may be internalized (to government) there will be costs and therefore methods are required to fund such actions over the long-term.

In addition, such "end state" or "end use" requirements may dictate remediation options and if the future use is to be restricted there may be physical or regulatory controls on the site. In such a situation, physical controls may be required such as posting warning signs or fences that will need periodic inspection and maintenance and therefore have a long-term cost. The cost of physical controls must be a component of the risk assessment, management and remediation plan and be a consideration in decision making and cost estimations.

4.3.2 Unforeseen events

Long-term stewardship of orphaned/abandoned mine sites must also consider the potential for unforeseen events and the potential consequences if such events were to be realized (i.e. responses when remedies or controls fail). Unforeseen events could include physical site events such as a crown pillar collapse, the failure of a containment dam/dyke, the collapse of a pit wall, the premature degradation of a shaft cover, or animal or human damage. They could also include such things as changes in regulatory requirements or prescribed limits, or if the financial assumptions used in the NPV or investment rate of return calculations (if the future funding is based on investment and/or interest income) become insufficient to maintain the monitoring and maintenance fund.

It is difficult to accurately forecast or estimate the extent of unanticipated future costs at any individual property. Modern mine decommissioning, reclamation and remediation strategies are based on the implementation of passive control methods wherever possible, which significantly reduce the potential for such costs to arise.

An effective long-term management framework must ensure sufficient funds are available to assess the significance of such an event if it occurs, as well as to fund additional remediation if it is warranted. A jurisdiction would have to determine what they consider sufficient funds, as the requirement would be site specific and could include a worst case scenario (i.e. the potential failure of all site components) or the highest cost potential failure event and calculate the cost to remediate such an event using the cost estimating spreadsheet. Some options for unforeseen event funding could include a dedicated orphaned mine contingency fund or financial assurances similar to those required of operating mines.

4.4 Challenges

A number of key challenges face governments when establishing long-term (institutional control) management frameworks and the cost of such programs, include, but are not necessarily limited to:

- Ensuring the continued effectiveness of long-term stewardship for long periods of time regardless of political and societal change and potential property ownership changes.
- Building partnerships with provincial, local, and Indigenous governments to plan for long-term stewardship activities, post-remediation land use, enforcement of hazard controls, and information management requirements.
- Providing sufficient, reliable funding for necessary long-term stewardship activities for multiple decades (or more) into the future.
- Developing processes for meaningful public involvement in long-term stewardship plans and decisions.
- Ensuring the retention of information about individual sites and associated residual risks. (Risk Library)
- Ensuring long-term public access to this information as well as the results of any inspections and/or maintenance conducted on such sites.
- Developing mechanisms for the sustainability of long-term stewardship, focusing on vigilance, continuity, adaptability to societal changes, and responses to advances in science and technologies.

The definitive question is whether the resources needed for long-term stewardship will be available once the remediation has been completed and attention on the site wanes? What makes the establishment of long-term management frameworks an unusual and difficult problem, particularly for governments, is the time horizon involved. At some sites (particularly those contaminated with radionuclides and other long-lived contaminants), long-term stewardship activities will be required for many decades, if not hundreds of years. Thus, a robust and reliable long-term management framework may have to endure changes in property use and ownership, changes in societal priorities, as well as changes in political and government institutions. Assuring funding over long time periods is an unprecedented and daunting challenge - one that calls for innovative solutions (or innovative adaptations of familiar solutions).

The need for long-term stewardship has become more widely accepted in Canada. However, in most jurisdictions, major decisions remain about how to structure, fund, determine exactly what activities should or need to be included, and determine who will be responsible for ensuring that the identified activities are undertaken.

Very few jurisdictions in Canada, the U.S. or Australia have developed a formal institutional control management framework that provides for custodial transfer and effective long-term stewardship of sites once the operator or, in the case of orphaned/abandoned sites, the agency charged with remediation, has fulfilled its closure obligations. Further, most jurisdictions in those same countries have not even formally identified an administrative unit within existing government institutions with direct responsibility for institutional issues following closure (e.g. records maintenance or site monitoring and maintenance activities).

The Province of Saskatchewan is one exception. In 2007, that province implemented a formal, institutional control program (ICP) that defines the conditions under which it will accept custodial responsibility for former mine sites that have achieved a closed site status and provide for the long-term stewardship of each site, and has identified an administrative unit to oversee the implementation of this program. Appendix A provides a more detailed about the Saskatchewan example and includes a discussion of that program’s funding mechanisms.

It is important to note that, in Saskatchewan, the institutional control program is a stand-alone legislated entity and once the decommissioning and reclamation of each orphaned/abandoned mine site (under the oversight of the Province of Saskatchewan) is completed and transition phase monitoring has demonstrated that the site is chemically and physically stable it must be transferred into the institutional control program. The transfer would be done under the same conditions as a closed mine site with an identified, current owner/operator.

4.5 Funding Long-Term Management

4.5.1 Introduction

Very few jurisdictions in the world have developed a formal institutional control management framework that provides for custodial transfer and effective long-term stewardship of sites once the responsible party has fulfilled its closure obligations and achieved a closed site status. Even fewer have formally identified funding measures to ensure that future generations do not have to finance the effective long-term stewardship of such sites.

In 2006, NOAMI commissioned the report *Rehabilitating Abandoned Mines in Canada: A Toolkit of Funding Options* (Cowan Minerals, 2006). The report identified five principal options:

- Direct government funding from general revenues;
- Government funding through tapping existing revenue streams generated by mining, e.g. mining tax/royalties;
- Government funding through the imposition of a levy on current future mineral production;
- Federal and provincial cost sharing arrangements from general revenues; and
- Government –industry partnerships.

Detailed discussion of each of the options is provided in the report which is available on the NOAMI website http://www.abandoned-mines.org/wp/wp-content/uploads/2015/06/ToolKitFunding2006.pdf. A brief discussion of the identified options and additional ones is provided below.

4.5.2 Unilateral Government Funding

Government funding for the monitoring and maintenance of orphaned and abandoned mine sites in this model is provided by annual budget appropriations made from the General Revenue Fund of either a provincial, territorial or the federal government. Such funding for the long-term stewardship must be considered tenuous at best as it faces a number of challenges including, but not necessarily limited to:

- Government budget appropriations are subject to annual review and approval.
- The budget review and approval process is conducted internal to government with little opportunity for or consideration of stakeholder or public input.
- Government funds are limited, prioritized and susceptible to change due to budget unpredictability.
- Government priorities change in response to the general state of its revenues.
- Government priorities can also change between elections.
- The financing of any required maintenance activities would be subject to review and approval within the annual budget cycle of the year it will occur often decades in the future.
- Government budgeting processes do not easily incorporate unforeseen events or emergency responses.

4.5.3 Bi-Lateral Government Funding

Bi-lateral government funding for the long-term stewardship of sites is a funding model based on a negotiated, formal agreement between individual provinces or territories and the federal government. While this model may provide more certainty in funding, it too is somewhat tenuous and would depend on budget appropriations from the General Revenue Fund of two separate levels of government. As a result, the model will face many of the same challenges identified in the unilateral government funding model discussed previously, but from multiple levels of government.

4.5.4 Mineral Sector Levy

In this option, revenue to fund the long-term stewardship of orphaned and abandoned mines would be raised by imposing a levy on currently producing mineral operations (industry). Essentially an additional tax on producers, the revenue from such levies could then be used to establish a permanent fund within government, an externally managed trust fund or liquidated annually to cover the annual cost of the stewardship program. Such a funding mechanism also faces a number of challenges including, but not necessarily limited to:

- A requirement to establish some form of formal structure to manage, invest and expend funds in an appropriate manner.
- Industry would likely view the levy as an additional tax.
- As the total number of sites requiring long-term stewardship increased over time, the cost to undertake prescribed monitoring and maintenance will increase and therefore levies will have to increase at a rate commensurate to the level of activity undertaken.
- The financing of any required maintenance activities would likely require an increase in the levy the year the maintenance was scheduled to occur.
- Estimating the cost and therefore levy amount to provide sufficient funds to address unforeseen events or emergency responses would be subjective and potentially high.
- Government tax policies can change significantly between elections resulting in the very real potential of the levy being reduced or eliminated by future governments.
- Resource economies are volatile which could have a significant impact on production and/or operations and therefore on the revenue generated by the levy.

4.5.5 Public-private Partnerships

Public-private partnerships (P3) have been proposed as a funding mechanism for long-term stewardship. A P3 is a contractual arrangement between a public agency (federal, provincial or local) and a private sector entity. Through this agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public. In addition to the sharing of resources, each party shares in the risks and rewards potential in the delivery of the service and/or facility.

At the former Britannia Mine site in British Columbia the initial 21 years of the remediation of is focused on a water treatment plant needed to treat contaminated mine water, water diversion structures to reduce water infiltrating the abandoned mine and reaching contaminated soil, and remediation of the shoreline. The management of the treatment plant was established in 2005 through a public-private partnership (P3) with EPCOR Water Services Inc. to design, construct, finance, and operate the plant over a 21 year period. EPCOR covered the initial capital cost (estimated at $15.5 million) and receives payment from the B.C. government based on the ability of the plant to meet environmental regulations as well as a formula that accounts for the volume of water processed (Pembina, 2012).

Funding for this remediation project was secured through a $30 million legal settlement between the B.C. government and four mining companies that were held responsible for the contamination as well as an additional $69 million from the British Columbian government. As part of the $30 million settlement, the province has assumed responsibility for the site and provided indemnification to the mining companies for the environmental liabilities.

After the 21 year contract term is completed, ownership of the facility will be returned to the province of British Columbia; however no decision has been made on what long-term management model will be employed for managing the water treatment plant and associated site facilities after the current P3 contract expires.

Private-public partnerships in Canada are generally based on a complex contractual agreement between government and a private sector entity for a fixed time period (usually less than 30 years). The fiscal health and life expectancy of the private sector partner as well as the fixed time frame of the contractual agreement precludes them from being an effective model for the successful long-term stewardship of orphaned/abandoned mines in Canada.

4.5.6 Trust Funds

A trust is a legal arrangement where money is kept in an account and administered by a trustee. The person or institution opening the trust, also known as the settlor, can dictate exactly how that money is administered. These accounts can be established with funds from government, industry, levies, non-government organizations, or some combination of the above and can be self-sustaining through prudent investment. With clearly defined objectives and governance structures, a trust can continue to deliver on its stated goals for long periods of time (Pembina 2012).

There are a number of examples where large funds have been established for the purpose of funding the management of site remediation and future site remediation (e.g. U.S. Abandoned Mine Land Reclamation Fund, the Canadian *Nuclear Fuel Waste Act*). For example, the *Nuclear Fuel Waste Act* requires Canada's nuclear electricity producers to establish trust funds to finance the long-term management of used nuclear fuel. These funds will accumulate and may only be used for the purpose of implementing the management approach selected by the Government of Canada, once a construction or operating licence has been issued under the *Nuclear Safety and Control Act*.

The legislative obligations are the responsibilities of the individual companies named (i.e. Ontario Power Generation, Hydro-Québec, Atomic Energy of Canada Limited and NB Power Nuclear Corporation) and not the Nuclear Waste Management Organization (NWMO). Each year, the NWMO makes public the audited financial statements of the trust funds when they are provided by the financial institutions. At the end of 2015, trust fund balances were at $3.7 billion.

Careful consideration is required in structuring a trust in order to provide for the long-term stewardship of closed mine sites particularly in the “how” and the “who” that will manage the investment and disbursement of fund monies.

5 Conclusion

This report has documented a risk identification/cost estimation framework for use as a tool to allow a wide variety of "Users" such as government agencies, Indigenous organizations, non-governmental organizations (NGOs), communities and the general public to identify and characterize risks and liabilities at orphaned and abandoned mines in Canada.

It is imperative that a comprehensive and accurate risk analysis (or assessment) process be completed as it will dictate the level of remediation required and therefore a competent estimate of the costs of remediation activities at an orphaned or abandoned mine site and estimate of the cost of long-term management of the site. Failure to conduct such assessments could result in a significant underestimation of costs. Conversely, without such a risk analysis, substantial monies could be expended without sufficient justification. The report describes a risk analysis process and series of tools that can be used to assist in completing the process. In addition, it provides an example of a simplified spreadsheet and information requirements for estimating the cost of remediation activities at a hypothetical orphaned or abandoned mine site

Long-term management of orphaned/abandoned mine sites can involve a wide range of activities and will depend on the nature of the site conditions and/or the residual hazards following remediation. As discussed in the report, depending on the type of residual hazards, site-level activities could range from monitoring and simple maintenance to water treatment or other engineered systems used to prevent residual hazards from migrating and reaching human and environmental receptors.

Very few jurisdictions in the world have developed long-term management systems (i.e. a formal institutional control program) or defined processes to transfer a site into a management framework that provides for effective long-term stewardship once the site has achieved a closed site status. Even fewer have formally identified funding measures to ensure that future generations do not have to finance the effective long-term stewardship of such sites. This was identified in the NOAMI report *Case Studies and Decision-Making Process for the Relinquishment of Closed Mine Sites* (Cowan Minerals, 2013). That report lays out a five step approach for regulators and industry to consider when evaluating if a site could, or should, be returned to the Crown. The steps are as follows:

1. Submitting the Application
2. Site Assessment
3. The Long-Term
4. Funding
5. Implementation

Steps 1 and 2 were completed in 2015 with the NOAMI report *Key Criteria for the Effective Long-term Stewardship of Closed, Orphaned/Abandoned Mine and Mineral Exploration Sites (Kingsmere Resource Services, 2015).* This report completes Step 3 and provides additional discussion of the NOAMI report *Rehabilitating Abandoned Mines in Canada: A Toolkit of Funding Options* (Cowan Minerals, 2006) to complete Step 4.

The last step of the decision-making process is Step 5: Implementation (Cowan Minerals, 2013). This step identifies the need for most jurisdictions to develop a formal management system to ensure that the work gets done; to manage funds; to provide secure data management systems, establish emergency response protocols for unanticipated events and for dealing with the public for a variety of circumstances, e.g. notification, volunteer work.

In order to complete the final step (Step 5), NOAMI may wish to consider investigating global Best Management Practices, requirements, considerations and commitments necessary, to develop, operate and fund the transfer of responsibility for, and implementation of, formal long-term management systems (or institutions) for orphaned and abandoned mines in Canada.

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Appendix A The Saskatchewan Example

Closed Mine Long-term Management Funding
The Saskatchewan Example

1 Introduction

In 2007, the Province of Saskatchewan implemented a formal, institutional control program (ICP) that defines the conditions under which it will accept custodial responsibility for former mine sites that have achieved a closed site status and provide for the long-term stewardship of each site.

It is important to note that, in Saskatchewan, once the decommissioning, reclamation of an orphaned or abandoned mine site is completed and transition phase monitoring has demonstrated that the site is chemically and physically stable, custodial responsibility for the site will be transferred into the institutional control program under the same conditions as a former mine site with and identified operator.

2 Saskatchewan Institutional Control Program

The *Reclaimed Industrial Sites Act* (RISA) granted the Saskatchewan Ministry of Economy, Energy and Resources (SME) the legislative power to establish the Institutional Control Program (ICP). The stated purposes of which are:

- to set out the conditions by which the Government of Saskatchewan will accept responsibility for land that, in consequence of development and use, requires long-term monitoring and, in certain circumstances, maintenance;
- to ensure that the required monitoring and maintenance are carried out on that land;
- to provide a funding mechanism to cover costs associated with the monitoring and maintenance on that land; and
- to ensure that certain records and information are preserved with respect to that land.

The ICP has two primary components, the *Institutional Control Registry* and the Institutional Control Funds, namely the Monitoring and Maintenance Fund (ICMMF) and the Unforeseen Events Fund (ICUEF). A site holder wishing to initiate the transfer of a closed site into the ICP is required to submit an application, which describes the site, the results of the transition phase monitoring, and a detailed assessment of any remaining liabilities on the site, to SME. Assuming the application meets the ministry's approval, the ministry will enter into discussion with the site holder to determine the amount to be deposited into the ICMMF and the ICUEF. Once the application is approved, the site holder is required to submit a registration fee and the prescribed fund deposits.

3 Saskatchewan Institutional Control Funding

The Saskatchewan Institutional Control Program has two primary components, the *Institutional Control Registry* and the Institutional Control Funds, which include the Monitoring and Maintenance Fund (ICMMF) and the Unforeseen Events Fund (ICUEF).

3.1 IC Monitoring and Maintenance Fund

One of the prescribed conditions for acceptance into the Saskatchewan IC Registry is that a site holder must have submitted a monitoring and maintenance plan that identifies both the monitoring and maintenance obligations that need to be undertaken once the site is accepted into the ICP and the present value of future costs associated with those obligations. SME has established the Institutional Control Monitoring and Maintenance Fund (ICMMF) and manages the funds as monies separate from the province's General Revenue Fund.

The site holder's contribution to the ICMMF must be of a value to generate sufficient revenue to pay those future costs in perpetuity. The contribution is calculated based on the net present value of the obligation at a forecast inflation rate and on forecast investment return rates. The total ICMMF contribution is the sum of the individual contributions for each monitoring and maintenance obligation at the site.

SME manages the ICMMF in its entirety, but each site-specific deposit on account is tracked individually. Responsibilities include maintenance costs anticipated at the time the closed site is accepted into the ICP, and for any other general costs that should have reasonably been anticipated at the time the closed site was accepted into the ICP, and costs incurred for the purpose of determining the required monitoring and maintenance of the closed site. SME can only access site-specific monies for site-specific monitoring and maintenance and cannot access monies on deposit for one site to fund expenditures at a separate (different) site.

A comprehensive monitoring and maintenance plan with sound cost estimates significantly reduces the risk of a cost overrun on monitoring and maintenance activities. Should such an event occur, a root-cause analysis should be performed to determine cause and responsibility. Funding sources for such events may include the Institutional Control Unforeseen Events Fund (ICUEF), a financial assurance, the former site holder, or the province.

Understandably, concerns were raised by stakeholders, in particular the mineral industry, that the fund should be prudently managed and that their site-specific monies not be expended elsewhere, subjecting them to cost liabilities at a future date after having made initial deposits in good faith.

The RISA grants SME the authority to invest monies in an account of the ICMMF, which are not presently, required for the purposes of that account, in any security or class of securities authorised for investment pursuant to the *Pension Benefits Act, 1992*. SME has established an Institutional Control Funds Investment Advisory Committee comprised of stakeholders including former site holders and industry representatives to provide investment advice, review, and recommendations to manage the monies. Once the fund accrues to a sufficient level to bear administrative costs of third-party management, the longer-term investment strategy will likely include a diversified portfolio of bonds, equities, and assets, prudently managed to meet investment objectives.

3.2 IC Unforeseen Events Fund

In addition to the contribution to the ICMMF, a site holder must include a contribution to the ICUEF. The contribution to the ICUEF must be of sufficient value to generate revenue to pay the costs of future unforeseen events and eventually release a site holder from a financial assurance requirement.

It is difficult to accurately forecast or estimate the extent of unanticipated future costs at any individual decommissioned property. However, modern mine decommissioning and reclamation strategies in Saskatchewan are based on the implementation of passive control methods wherever possible. These methods significantly reduce the potential for such costs to arise. Unforeseen events could include such things as the failure of a containment dyke, the collapse of a pit wall, the premature degradation of a shaft cover, or a change in regulatory requirements. The ICUEF will fund these contingent events.

However, a site holder cannot be granted complete absolution from site responsibility. The Environment management and Protection Act (EMPA) provides for absolute liability of a person responsible for a discharge to continue indefinitely. The authority to waive this liability does not rest with the Minister of Environment as no such authority is provided in the EMPA. It is for this reason that neither the Minister of Environment nor the Minister of Economy can issue a deed of custodial transfer that states that the operator is completely absolved from responsibility for environmental contamination at a particular site.

The ICP will limit the province's liability to be held responsible for future clean-up costs arising from unforeseen circumstances or company dissolution that are not provided for in EMPA or identified in the Application for Release from Decommissioning and Reclamation approved by Saskatchewan Ministry of Environment and upon which the basis of the custodial transfer was undertaken. Only in the case of the original operator no longer being in existence would such costs have to be addressed by public means.

As with the ICMMF, concerns were raised by stakeholders and in particular, industry site holders, that the money be prudently managed. The ICUEF is, in effect, a "rainy day fund" to manage the cost contingencies of unforeseen events. Notably, this fund, with no forecast withdrawal, can reach significant levels in the future. With continued deposits and interest earnings from sound financial management, the province and stakeholders agree that the fund could reach significant levels in the future such that further financial assurance or deposits will not be required. While SME will manage the ICUEF in its entirety, unlike the ICMMF, it will not be tracked by individual site-specific monetary deposit.

3.3 Financial Assurance

A financial assurance requirement has been implemented to minimise the ICP's financial risk during the initial years, while the ICUEF is building in value. In negotiation with industry, while implementing a condition to reduce its risk, the province also took steps to minimise the financial impact on good corporate citizens through the acceptance of corporate guarantees. It is understood that, once the ICUEF has reached a sufficient level to manage the total cost for unforeseen contingent events, the financial assurance requirement will be removed. For SME to accept a closed site into the ICP and thus, the Registry, a site holder must post a financial assurance in an amount equal to the cost of a maximum failure event that could occur at the closed site or any such reduced amount agreed on by the minister. The maximum failure event is to be identified in the monitoring and maintenance plan submitted to the minister in the application for entry into the Registry. The maximum failure event is site specific and typically references a failure of the largest engineered structure that exists on the site.

3.4 Registration Fee

The final cost component of the ICP is the prescribed registration fee of $500. This is a fixed fee prescribed in the *Reclaimed Industrial Site Regulations* and is designed to provide for processing of applications, document transfer, and program administration.

The total cost to transfer a site to the Registry is site specific and largely based on the type and condition of the various aspects and residual risks present on the site; however, the cost for most sites is anticipated to be under C$ 100,000.

All closed mine sites in Saskatchewan, including the orphaned/abandoned mines currently being remediated under the Saskatchewan Research Council CLEANS program will be required to be entered into the *IC Registry*, pay the prescribed registry fee and contribute to the Monitoring and Maintenance Fund (ICMMF) and Unforeseen Events Fund (ICUEF).