

ENVIRONMENTAL ASSESSMENT AND REMEDIATION OF ABANDONED MINES IN THE YUKON TERRITORY

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ABSTRACT

A program to conduct environmental assessments of abandoned mine sites was completed to identify acid generation potential, human health and safety risks, inventory non-hazardous and hazardous wastes, and characterize on-site soil and water contaminants. This paper describes the objectives established and methods used in evaluating abandoned mine sites for further assessment and possible remediation. A priority ranking scheme was established to define high, medium, and low priority sites, as well as those requiring no further work.

Field investigations of forty nine abandoned mines identified ten high-priority sites requiring action to remediate or manage health and safety, environmental, and aesthetic concerns. Thirty-three abandoned mine sites were designated as a medium or low priorities for remedial action. Six sites presented an insignificant risk to humans and the environment and did not require any further assessment or remedial work.

BACKGROUND

In 1993, preliminary assessments of 98 abandoned Yukon mine exploration and development sites were completed under the Arctic Environmental Strategy - Action on Waste program. These assessments were intended to provide a general overview of historical activities, describe site infrastructure, workings and wastes, describe existing environmental or safety concerns on each site, and provide general recommendations for remediation or mitigation work, as appropriate.

Depending on the site, the preliminary assessments identified conditions ranging from no obvious environmental or safety concerns to safety risks posed by open adits, portals,

and/or deteriorating buildings and other structures, and environmental concerns stemming from:

- abandoned fuel in drums and tanks,
- potential acid-generating tailings and waste rock dumps, and/or
- presence of leached metals in mine water.

At some sites, the overview assessments identified probable off-site transport of contaminants by wind or surface water. These assessments did not include sampling of rock, tailings, soil, or water.

Indian and Northern Affairs Canada (INAC) determined that further investigation was warranted where actual or potential environmental and safety concerns had been identified. On behalf of INAC Environmental Services of Public Works and

Government Services Canada (PWGSC) was to complete Phase II-level assessments of 49 abandoned mine sites and make recommendations with respect to remediation requirements and options. Accordingly, assessments of selected mine sites were completed:

- to identify specific environmental and human safety risks associated with each abandoned mine site, and
- to provide recommendations and preliminary cost estimates for remediation or mitigation of those risks.

SITE-SPECIFIC ASSESSMENT OBJECTIVES

INAC Waste Management Program and Environmental Services, PWGSC defined the following assessment objectives for each of the abandoned mine sites:

- Identify the potential for acid generation at waste rock and tailings disposal areas;
- Assess the human health and safety risks associated with open mine adits, pits or other mine openings, and stored or loose explosives;
- Confirm types and quantities of non-hazardous, non-combustible solid wastes and recommend suitable disposal options. Document mine site landfills and dumps and recommend cost-effective reclamation or capping options;
- Sample suspect contaminated soils to identify the nature and areal extent of contamination. Recommend cost-effective remediation options (based upon CCME (1997) Industrial criteria for soils and CCME (1991) Freshwater Aquatic Life criteria for surface and mine water);
- Sample and analyse the contents of all above-ground storage tanks, drums, or other containers containing petroleum products or other liquid hazardous wastes. Recommend cost-effective disposal options for petroleum or other liquid hazardous wastes; and
- Assess the physical condition of all on-site buildings and infrastructure. Document obvious instances of structural instability, particularly where there is potential risk to human health and safety. Recommend actions to eliminate safety risks.

ASSESSMENT SCOPE AND METHODS

For each mine site, the assessment was restricted to areas developed or occupied specifically for mine exploration or mining purposes and to environmental components directly affected by those activities. Access roadways to mine sites were not included in the assessments.

Each mine site assessment was broken down into sequential tasks:

- All available, relevant background site information was compiled and reviewed, including:
 - * historical land use and mine development information,
 - * area mineralization (with emphasis on mineral precursors of acid mine drainage),
 - * site and area hydrology,
 - * quality of on-site and adjacent receiving surface water bodies,
 - * regional climate and precipitation,
 - * vegetation,
 - * fish and wildlife resources,
 - * site topography, and
 - * soils and incidence of permafrost.
- From available information, knowledge gaps regarding existing or potential safety and environmental risks at the site were identified and used to develop a site-specific assessment plan.
- Field investigations were carried out to verify or determine actual site safety hazards and environmental concerns and to identify appropriate remedial actions:
 - Waste Rock Dumps and Mine Tailings** were characterized and sampled. Test pits in waste rock and tailings disposal areas were excavated to a depth of 0.3 - 1.0 metres. Horizons in the test pit walls were logged, noting colour/weathering, rock composition, primary and secondary mineralization, particle size distribution, and moisture content. Each horizon was sampled, and all samples' field paste pH and paste conductivity were measured to characterize the current state of oxidation. Each test pit was photographed and its location recorded on a field map. Representative samples were retained for subsequent tests of acid mine drainage (AMD) potential using Acid-Base Accounting and leachate analyses. Volume estimates of waste rock and remedial measures were identified as required.
 - Mine Openings** (including adits, portals, and open pits) were inspected and assessed for accessibility, hazards, and closure requirements.
 - Solid Waste Dumps** were visually inspected to identify physical stability, types of waste materials, and potential for erosion. Soil and leachate samples were analysed for total metals, PAHs, and PCBs. Potential locations for new landfills were assessed for soil type, capping requirement, volume, accessibility, and susceptibility to erosion.
 - Non-Hazardous Site Debris** was inventoried, categorized to type (e.g., metals, combustibles), and estimated for volume.
 - Stained Soil Areas** were sampled and delineated.
 - Mine Water, Seeps, and Surface Receiving Waters** were sampled to identify relative contributions of leachable metals to receiving water bodies. Water samples were collected upstream and downstream of the site

and from seeps emanating from waste rock, tailings, pit walls, and adits. Samples were analysed for total metals, pH, conductivity, hardness, and sulphate.

- G. **Hazardous Materials** were inventoried and sampled for confirmation, if necessary. Explosives or suspected explosive storage areas were identified but not disturbed.
- H. **Drums and Storage Tanks** were sampled and analysed for chlorinated compounds, PCBs, and selected heavy metals to assess disposal alternatives including on-site/regional incineration or removal for off-site disposal.
- I. **Buildings and Site Infrastructure** were inspected for presence of hazardous materials, structural soundness, and volume of waste for landfilling.
- J. **Borrow Sources** for capping material were identified and assessed for accessibility, grain size, and volume.
 - Reports included a photographic record of all salient features, and a scale site plan to locating adits and other mine openings, waste rock and tailings disposal areas, drums and storage tanks, areas of stained soil, sampling points, site infrastructure, site drainage and receiving waters, and any other relevant features. Site-specific remediation and/or risk management actions were recommended which complied with applicable federal and territorial regulations and criteria, incorporated available technology, and were appropriate for local conditions and sensitivities. Preliminary cost estimates and a schedule to remediate or manage site-specific environmental and safety risks were provided.

PRIORITY RANKING

Table 1 shows the risk types that were associated to the various assessment components investigated in this study. The purpose of this was to evaluate priority ranking and requirement for further action.

Based on the risk type A priority ranking scheme was developed to define high, medium, and low priority sites, as well as those requiring no further work:

High Risk Sites which had a potential regulatory concern, at least one significant health and safety concern, may have had a significant environmental concern, and were readily accessible to the public. Significant health and safety concerns were those for which interactions between humans and the artificial disturbances created by site operations and their remnants were potentially harmful. A site was considered readily accessible if a) it could be reached by two-wheel drive vehicle or b) had an on-site or nearby feature that was frequently visited. Environmental and aesthetic concerns were frequently characteristic of high priority sites.

Medium Risk Sites which had at least one significant health and safety risk but were not readily accessible to the public. Access required four-wheel drive vehicles or aircraft. These sites had significant remnants of mining activity and had at least a minor environmental concern.

Low Risk Sites which had a minor health and safety or environmental risk, and where the primary concern was aesthetic. These sites may or may not be readily accessible to the public.

No Action Required Sites which have been fully decommissioned and for which no remnants or hazards are remaining from mining activities.

PROGRAM RESULTS

Significant results and recommendations for each of the 49 abandoned mine sites were condensed into the priority listing for remedial or risk management action. A separate list of sites needing further study prior to remediation was also generated.

Ten sites were designated high priority for remedial action. Table 2 outlines the site features or characteristics of those sites lists leading to a high priority ranking for health and safety, environmental, and aesthetic reasons.

Assessment Component	Risk Type
Waste Rock Dumps and Mine Tailings	Human Health & Safety, Environmental, Aesthetic
Mine Openings	Human Health & Safety
Solid Waste Dumps	Environmental, Aesthetic
Non-Hazardous Site Debris	Aesthetic
Stained Soil Areas	Environmental (low / high)
Mine Water, Seeps, Surface Receiving Waters	Environmental (low / high)
Hazardous Materials	Human Health & Safety
Drums and Storage Tanks	Human Health & Safety, Environmental
Buildings and Site Infrastructure	Human Health and Safety, Aesthetic

Table 1. Risk type equated with individual assessment components.

Mine Site	Site Feature or Characteristic	Risk or Concern
Arctic Caribou	Buildings Non-Hazardous Waste Materials Drums With Hydrocarbon Product Unstable Waste Rock Disposal Area Open Adit	Health & Safety Aesthetic Concern Health & Safety, Environmental Health & Safety Health & Safety
Becker Cochrane	Rails and Supporting Structure Non-Hazardous Waste Materials Open Adits	Health & Safety Aesthetic Concern Health & Safety
Big Thing	Site Structures, Dam, Track & Trestle Non-Hazardous Waste Materials Drum With Product Mine Seepage, Site Drainage Acidic Waste Rock Open Adits and Raise	Health & Safety, Aesthetic Concern Aesthetic Concern Environmental, Health & Safety Unknown Environmental Environmental Health & Safety
Formo	Buildings Non-Hazardous Waste Materials Mine Seepage, Site Drainage Slumping Waste Rock Dump	Health & Safety Aesthetic Concern Unknown Environmental Environmental
Mactung	Site Equipment, Loading Ramp Non-Hazardous Waste Materials Stained Soil Waste Rock Potentially Acid-Generating Open Adit	Health & Safety, Aesthetic Concern Aesthetic Concern Environmental Low Environmental Health & Safety
Paddy	Collapsed Bridges, Site Structures Unstable Waste Rock Dump and Roads Non-Hazardous Waste Materials Adit Seepage & Site Drainage Open Adit	Environmental, Health & Safety Environmental, Health & Safety Aesthetic Concern Low Environmental Health and Safety
Peso	Site Structures Non-Hazardous Waste Materials Drums With Product; Oil With Halogens Acid-Generating Waste Rock	Health and Safety Aesthetic Concern Environmental Environmental
	Open Adits	Health and Safety
Runer	Structures on Oversteepened Pad Non-Hazardous Waste Materials Explosive Magazines Unstable Waste Rock Piles, Trenches	Health and Safety Aesthetic Concern Health and Safety Health and Safety
Stump	Site Infrastructure Non-Hazardous Waste Materials Drum With Product Mine Seepage & Site Drainage Open Adits & Shaft	Health and Safety, Aesthetic Aesthetic Concern Environmental, Health and Safety Low Environmental Health and Safety
Venus	Buildings, Loadout Structure, Trestle Non-Hazardous Waste Materials Drums & Pails With Product Mine Seepage & Site Drainage Acid-Generating Waste Rock Open Adits & Headframe	Health and Safety, Aesthetic Concern Aesthetic Concern Environmental, Health & Safety Unknown Environmental Environmental Health and Safety

Table 2. Features and characteristics of high priority mine sites.

Twenty-two abandoned mine sites were designated as a medium priority for remedial action, and eleven sites were a low priority. Six sites presented an insignificant risk to humans and the environment and did not require any further assessment or remedial work.

Table 3 summarizes the occurrence of concerns at all sites and within high, medium, and low risk sites and sites where no further action was required. The most frequent concerns were 1) environmental/safety concerns associated with waste rock dumps and tailings, 2) safety concerns associated with buildings and site infrastructure, and 3) primarily aesthetic concerns associated with non-hazardous site debris. Just over half of the sites had safety concerns from accessible mine opening and environmental concerns from metals-contaminated mine water, seeps and receiving water bodies. The predominant concerns at high-risk sites were those associated with waste rock dumps and tailings, buildings and site infrastructure, mine openings, non-hazardous site debris, and metals-contaminated mine water, seeps and receiving water bodies.

Six of the high-priority mine sites required further assessment to finalize clean up objectives and costs (Table 4).

At Big Thing, Formo, and Venus, more detailed water chemistry data was needed to quantify the potential impacts on receiving water bodies in light of natural or already-impaired background levels. Geotechnical investigations were required at Formo and Paddy to assess the potential for slope failure and identify measures to eliminate the safety and environmental consequence of failure. At Peso, Acid-Base Accounting tests of the waste rock revealed a high AMD potential. A kinetic test was needed to more accurately predict the quantity and quality of AMD and thereby refine the proposed reclamation design. Finally, a tailings pond at the Werneke site required further investigation of ongoing and future AMD development.

CONCLUSION

The method of assessment and evaluation of remedial options in this program incorporated a consistent and cost effective approach in the identification of human health and environmental risks associated with abandoned mine sites. The basis of this program was the application of a prioritization scheme suitable for a range of sites and remote locations in northern Canada.

Concern	Occurrence All Sites (%)	Occurrence At Sites Within Each Risk Category (%)			
		High Risk Sites	Medium Risk Sites	Low Risk Sites	No Action Req'd
Waste Rock Dumps or Mine Tailings	71	100	59	45	67
Buildings & Site Infrastructure	80	100	100	64	0
Mine Openings	53	90	68	0	25
Non-Hazardous Site Debris	88	90	100	100	17
Mine Water, Seeps, Surface Receiving Waters	53	70	55	45	25
Drums and Storage Tanks with Product	41	50	50	36	0
Stained Soil Areas	27	40	32	18	0
Non-Hydrocarbon Hazardous Materials	16	30	18	9	0
Solid Waste Dumps	0	0	0	0	0

Table 3. Occurrence of concerns associated with rated risk levels.

Mine Site	Required Assessment
Big Thing	Hydrology and chemical impact study
Formo	Chemical impact on receiving water and geotechnical/erosion assessment
Paddy	Geotechnical assessment
Venus	Basin water quality assessment and monitoring
Peso	AMD kinetic study
Wernecke	Off-site tailings assessment

Table 4. Sites requiring further assessment.