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Case study – Kemess South Mine site reclamation and closure – contaminated sites assessment and remediation (non-core areas)

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Abstract

The Kemess South Mine site is owned and operated by Northgate Minerals Corporation (NMC), and is a large porphyry gold and copper open-pit mine that is scheduled for closure in 2011. Hemmera was engaged to assess non-core areas of the mine site as defined in the British Columbia (BC) Environmental Management Act to facilitate closure. The Kemess South Mine, like most mine sites, is not a typical contaminated site given the remote location relative to populated areas and the scale of the site. Therefore, applying standard BC Contaminated Sites Regulation approaches and guidelines are not only inefficient and more costly than necessary, but potentially unnecessary to achieve the closure objective and regulatory acceptability. Hemmera implemented a risk-based approach to develop an appropriate level of field investigation and data evaluation that would be responsive to the needs of NMC. Hemmera used a conceptual model approach where contaminant sources and the receiving environment were determined prior to conducting investigations. A data gap field investigation was initiated to support a Screening Level Risk Assessment (SLRA). The results of the SLRA risk assessment identified areas requiring risk management (including further investigation, remediation or more detailed risk assessment) or no further action. Using these results Hemmera completed a remedial action plan as part of the overall strategy to successfully address the contaminated sites aspects of the Kemess South Mine site closure plan. Overall the mine site contamination was not considered extensive based on the application of a site specific risk based approach. Consequently, extensive remediation was not required nor recommended in as part of the overall mine site closure plan.

1 Introduction

The Kemess South Mine site (hereafter “the site”) is owned and operated by Northgate Minerals Corporation (NMC), and is a large porphyry gold and copper open-pit mine that is scheduled for closure in 2011. Hemmera Envirochem Inc. (Hemmera) was retained by NMC in May, 2010 to complete a contaminated sites assessment and develop a Remedial Action Plan (RAP) as part of the Kemess South Mine Site Reclamation and Closure Plan (AMEC, 2007). The mine site is located in north-central British Columbia (BC), approximately 300 kilometres (km) northwest of Mackenzie. The location of the site is presented on Figure 1 and an overall mine site plan is included as Figure 2.

Figure 1 Location of mine

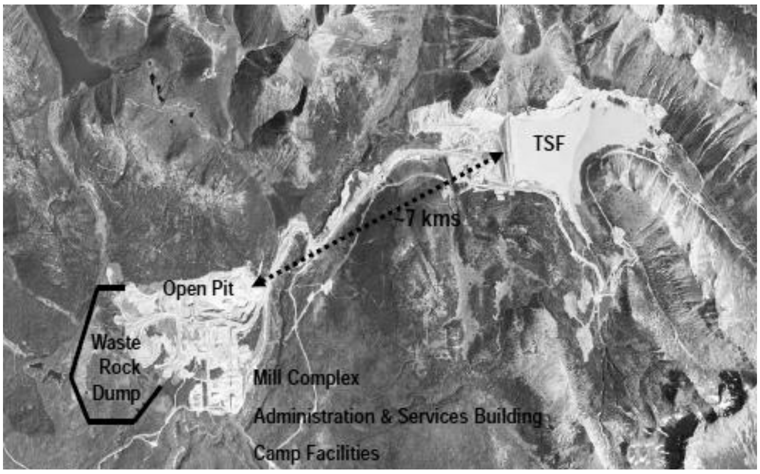

Figure 2 Mine site

The RAP was prepared as part of the overall strategy to successfully address the contaminated sites aspects of closure of the Kemess South Mine site. In British Columbia responsibility for mine closure is shared between the Ministry of Energy, Mines, and Petroleum Resources (MEMPR) and The Ministry of Environment (MOE), such that the MEMPR has jurisdiction over closure of the core areas of a mine site, and the MOE regulates closure of the non-core areas. The areas most relevant to the assessment were the non-core areas of the mine as defined in the *Environmental Management Act* (EMA) issued by the Government of British Columbia (GOBC, 1993) and BC MOE Contaminated Sites Regulation (CSR) (GOBC, 1997). These include the ore processing facilities (i.e. mill), maintenance and fuelling areas and structures, and other associated facilities used to support the operation of the mine. Core areas including the open pit, waste rock piles and tailing storage area were not subject to direct investigation for contamination. However, in keeping with BC MOE guidance, contaminant discharges emanating from these core areas were also considered. Northgate intends to return the mine to its original state as wild lands. Monitoring of environmental conditions within core areas such as the tailings pond, open pit and waste rock piles will continue subsequent to closure.

The objective of this assessment was to develop an appropriate remedial strategy for the risk management of contamination within the non-core areas of the site.

The objective was met through a three-step process that was driven by a conceptual site model (CSM) approach:

- Develop a geology, hydrogeology, hydrology, geochemistry, and contaminant exposure CSM for the site based on available mine data.
- Use the CSM to develop the sampling plan for site investigation and for migration of contamination from core areas of the site. Historical mine site data was used whenever available.
- Refine the CSM based on data collection and prepare a quantitative Screening Level Human Health and Ecological risk assessment.
- Use the quantitative screening level human health and ecological risk assessment to determine the need for risk management, monitoring, or additional investigation and more detailed risk assessment.

Risk assessments are iterative in nature, and at a detailed level are complex and expensive. The intention was to provide only the level of assessment required to make decisions with confidence as to the need for active remediation or to make the decision that no-action was required.

2 Conceptual site model

The CSM is a working hypothesis about hazard identification at a contaminated site. The CSMs for geology, hydrogeology, hydrology, and geochemistry were developed for this site. They were useful for describing and predicting the movement of contamination and subsequent the development of the contaminant exposure CSM.

The process of constructing a conceptual model for the site began with an understanding of the site's geology. The geological CSM provides an early indication of the spatial distribution of rock and/or soil properties which were important for describing the site. Having established a geologic framework, the saturated hydraulic properties of the geologic units were established and documented in the hydrology CSM. The intrinsic properties of geologic formations and hydrogeology that influence water movement and contaminant transport are permeability, effective porosity, and hydraulic gradient. Movement of surface contamination at the site was often mediated by overland flow of surface water. The hydrology CSM described the surface water flow at the site. Geochemical characterisation of the aqueous and mineralogy of soil and rock documented in the geochemistry CSM were important because they influence behaviour of contamination. Geochemical process that influence geochemical processes at the site included dissolution, precipitation and co-precipitation, ion-exchange, and biological reactions. These CSMs were in turn used to develop a contaminant exposure CSM

The exposure CSM describes all of the known or suspected sources of contamination, considers how and where the contaminants are likely to move (pathways), and identifies receptors likely to be affected by contamination (ASTM, 1995). Contaminants are considered a potential hazard if there is a pathway for exposure and if receptors are present and likely exposed to contamination.

A pictorial representation of the exposure CSM developed for the site (Figure 3) illustrates the different potential source areas, the contaminant release mechanisms, transport pathways, and receptors at the site.

Contaminant release mechanisms at the site may include:

- ARD and metal leaching.
- Wind erosion.
- Surface water erosion during precipitation events.
- Volatilisation.

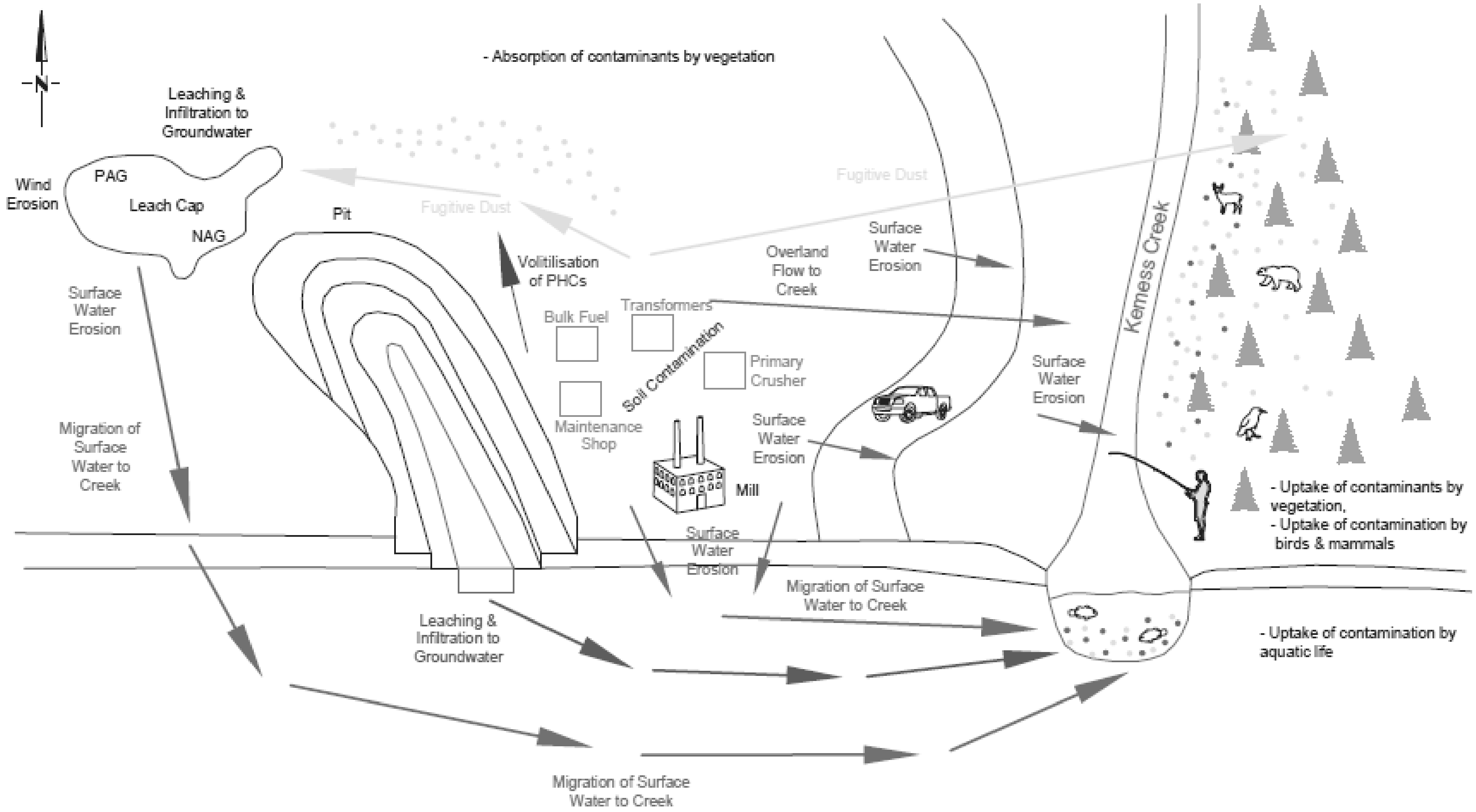

Figure 3 Conceptual site exposure model

Contaminant transport may include:

- Areas where sources coincide with or are adjacent to areas of sensitive habitat (riparian areas, sensitive ecosystems).
- Vertical infiltration of contaminants into water at source areas.
- Groundwater contaminant migration.
- Overland flow of surface water containing leached contaminants and contaminated soil or other particulates.
- Migration of fugitive dust from source areas with the wind.
- Migration of vapours from volatile contamination with the wind.
- Uptake of contamination by plants, soil invertebrates, and animals and subsequent transfer through the food web.

Locations where receptors may come into contact with contaminated soil, groundwater, surface water, sediment air, animals, or plants include:

- Source areas.
- The site in general.
- Creeks at the site and flowing from the site.
- Undisturbed areas adjacent to the site such as the forest.

Exposure routes of entry can include:

- Eating or drinking contaminated materials.
- Breathing contaminated air.
- Absorbing contaminants through the skin, roots.
- Ingesting contaminated food.

General receptors identified at the site include:

- Humans using the area.
- Areas of sensitive habitat (riparian areas, sensitive ecosystems) at and near the site.
- Vegetation (where ecological stress coincides with sources).
- Sensitive ecological receptors on-site (including but not limited to listed species).

The CSM evolved as more data was collected and analysed. The CSM was used to develop the sampling plan. The intent of sampling is to capture the information necessary to confirm or refute the preliminary conceptual model. Data will only be collected where it is not already available.

3 Site investigation

During the development and revision of the CSM, data gaps that prevented a further development and level of understanding regarding the environmental system and contamination were identified. The identification of data gaps within the CSM framework was based on an understanding of the physical setting, contaminant nature and extent, contaminant fate and transport mechanisms, and potential receiving environments for the environmental system. The investigation sought to fill in these data gaps. The intent of the investigation was to provide a confirmation of identified sources, an assessment of transport pathways, and characterisation of the receiving environment. The receiving environment is defined as locations where human and ecological receptors may come into contact with contamination as a result of contaminant migration.

Two phases of field investigation, including planning, mobilisation, investigation, and data evaluation were completed by the end of July 2010. The investigation identified ten areas of environmental concern (AECs) and a number of contaminants of concern (COCs) including total and dissolved metals, volatile petroleum hydrocarbons (VPH), light extractable petroleum hydrocarbons (LEPH), heavy extractable petroleum hydrocarbons (HEPH), and polycyclic aromatic hydrocarbons (PAH) (Hemmera, 2010a).

Table 1 AECs and COCs identified in non-core areas

AECs	COCs – Soil	COCs – Groundwater
AEC 1 – Mill site	Metals	PAH
AEC 2 – Maintenance shop and bulk plant	Metals, VPH, LEPH, HEPH	Metals
AEC 3 – Security and helipad	Metals, LEPH	None
AEC 4 – Pumphouse 1	Metals	None
AEC 5 – Ball diamond laydown area	Metals	None
AEC 6 – Bulk explosives (BLX) plant	Metals, HEPH	Nitrate, nitrite, ammonia
AEC 7 – Pumphouse 2	Metals	None
AEC 8 – Contractor laydown area	Metals, LEPH, HEPH	None
AEC 9 – Landfarm	HEPH	Not Assessed
AEC 10 – Roadways	Metals	Not Assessed

4 Risk assessment

The process of conducting a quantitative Screening Level Human Health and Ecological Risk Assessment (SLHHERA) began in August 2010. The risk assessment followed the standard approach as recommended by the British Columbia Ministry of Environment (BCMELP, 1998; BCMOE 2001, 2007, 2008), Health Canada (Health Canada, 2004, 2007, 2009a, 2009b), and Environment Canada (CCME, 1996a, 1996b, 1997) for screening level risk assessments. The assessment was prospective in nature; for it was conducted assuming that the mine site was closed and that no risk management of contamination was implemented. The primary objective of the risk assessment (Hemmera, 2010b) was to assess whether concentrations of chemical constituents related to site activities occurred at concentrations that potentially pose adverse risk to human and ecological receptors. The assessment would therefore identify those areas of the site which required no further action beyond that recommended in the mine site closure plan. Extensive ecological data from the environmental impact assessment prepared prior to mining operations, and from annual mine site monitoring was available and was utilised in the risk assessment.

The human health risk assessment exposure CSM included was developed for the site illustrating sources receptors and receptors. High use and occasional use receptors included:

- Security workers.
- Environmental monitors.
- Maintenance workers.
- First nations.

Transport mechanisms were mediated by groundwater, surface water, and air and exposure to soil, surface water, and for certain receptors ingestion of wildlife was assumed to occur. The risk to human receptors exposed to contaminants at the site after mine closure was determined to be acceptable.

The terrestrial ecological risk assessment considered risk to wildlife, plant and soil invertebrates. Based on the site's location and characteristics, inferred feeding guilds likely present at the site, as well as records of observed wildlife at the site, the following general types of biota were identified as requiring evaluation in the terrestrial ecological risk assessment:

- Soil invertebrates.
- Plants.
- Wildlife.
- Threatened and endangered species.

A terrestrial ecological exposure CSM was developed to facilitate the assessment of risk to terrestrial ecological receptors. Risk to terrestrial ecological receptors was identified at a number of AECs. Hazard quotients for larger mammals with foraging ranges greater than the size of the site (caribou, wolverine, grizzly bear) were all below a value of one (HQ<1), representing low risk (Hemmera, 2010b). Hazard quotients for smaller mammals and birds that might use more localised areas of the site exceeded a value of one in all of the individual AECs, with the exception of AEC9. Smaller mammals and birds HQs in the individual AECs ranged from HQ = 1 to HQ = 69, representing intermediate risks; however HQs exceeded a value of ten only in AEC1, AEC2, and the "Surrounding Areas" (the wild land habitat immediately surrounding the active site).

All of the HQs exceeding one noted above were based on assumed exposure to site maximum soil and plant tissue concentrations, and modelled invertebrate and small tissue concentrations based on maximum site soil concentrations. Had the ERA utilised more realistic average (mean or 95% UCLM) exposure concentrations for COPCs, HQs in the range of one to ten in many of the AECs would likely have been below a value of one. Such statistics and calculations were often not possible given the small number of samples ($n < 10$) in some AECs.

HQs were as high as 69 (for Vagrant shrew) at AEC 1, HQ = 15 for Vagrant shrew at AEC 2, and HQ = 29 for wild land immediately surrounding the mine site.

The aquatic studies summarised in this risk assessment indicate that the aquatic ecosystem is healthy at areas of the site unaffected by selenium. Although metals (copper, cadmium, iron, zinc, and aluminium), nutrients (nitrate and sulphate) and turbidity and total suspended solids in excess of water quality guidelines have been measured in creeks at the site, this has not had a significant effect on the aquatic ecosystem health. Selenium levels in Waste Rock Creek and lower Attichika Creek may pose a risk to aquatic life particularly Dolly Varden char. Further more detailed assessment of the affects of selenium continues. Remedial measures to reduce the level of selenium have been implemented and additional monitoring will continue to evaluate the effectiveness. It is anticipated that mine closure actions will further reduce the level of selenium entering Waste Rock Creek.

5 Remedial action plan

The RAP (Hemmera, 2010c) was submitted to NMC in September 2010. The overall objective of the RAP was to select an appropriate remedial solution for identified AECs associated with non core areas of the site. Hemmera utilised a risk-based approach to characterise AECs, evaluate the potential impact of contamination at the site, and to develop remedial solutions for the AECs. The risk-based approach encompasses not only investigation of potential sources of contamination, but also concurrently evaluates contaminant pathways and receptors to provide an assessment of risk for evaluating remedial options. This risk based approach was built upon the foundation of CSMs. The CSMs were the basic elements of the remediation at the site. The CSMs for geologic, hydrologic, geochemical aspects of the site were useful for describing and predicting the movement of contamination. This aided in the development of remedial options for AECs with contamination levels causing risk to human health or the environment.

Table 2 Remedial action plan for each AEC with identified risk

AEC	COCs	Remedial Action Plan
AEC 1 – Mill site	Metals, LEPH/HEPH, PAH	Further investigation during decommissioning to characterise stained surface areas for disposal purposes.
AEC 2 – Maintenance shop and bulk plant	Metals, HEPH, EPHs, VPH	Further investigation during decommissioning to characterise stained surface areas for disposal purposes in the maintenance shop storage area, and further surface and subsurface investigation in bulk fuelling area during decommissioning will be completed.
AEC 3 – Helipad and security	Metals, LEPH/HEPH	Petroleum hydrocarbon stained surface areas will be removed and disposed of in the contaminated sites landfarm proposed for the pit area to mitigate the risk. Further soil sampling during the excavation to delineated surface impacts for remediation will be completed.
AEC 4 – Pumphouse 1	Metals	Further soil sampling during the excavation to delineated impacts for excavation and disposal in pit will be completed.
AEC 5 –Ball diamond laydown area	Metals	No unacceptable risk to human health and the environment was identified during HHERA. No further action is required. No further assessment required.
AEC 6 – Bulk explosives (BLX) plant	Metals, HEPH, Nitrate, Nitrite, Ammonia	Further soil and groundwater sampling during the excavation to delineated surface impacts for remediation will be completed. Land farming of PHC and the rest will be disposed of in the pit.
AEC 7 – Pumphouse II	Metals	Metals impacted and surface stained soil resulting from tailing spills and leaks in the vicinity of the pumphouse will be excavated and disposed of in the pit following characterisation within the staging area. Further soil sampling during the excavation to delineated impacts recommended for excavation and disposal will be completed.
AEC 8 – Contractor laydown area	Metals, LEPH/HEPH	Excavation of petroleum hydrocarbon stained surface areas, will be removed and placed of in the contaminated sites landfarm proposed for the pit area. Petroleum hydrocarbon - landfarm. Some additional investigation in select areas not accessible during initial investigation activities should be completed.
AEC 9 – Landfarm	BTEX, VPH, LEPH/HEPH	It is expected that the landfarm will be decommissioned within a year, however, should the evaluation indicated a significant monitoring, and amendments are required, the landfarm will be relocated to the petroleum hydrocarbon landfarm proposed for the pit area. Sampling of soil in the surrounding area during decommissioning and/or relocation will be completed.
AEC 10 – Roadways	Metals	Roads are considered core areas and not subject to remediation under this scope of work. There exists a potential migration of contaminants from roads to non-core areas that should be addressed as part of the mine site closure, however, no remediation is recommended at this time. Mine site closure investigation and planning review to determine if migration concerns are addressed, and if further assessment and remediation is required.

The contaminated site assessment, contaminated sites investigation, and SLHHERA all followed a conceptual model approach to identify AECs on the site, and risk levels that exceed regulatory criteria. Subsequently remedial options were developed to risk manage contamination that pose a risk to human or ecological receptors. Overall the non-core area mine site contamination was not considered extensive or at the levels observed at other mine sites investigated by Hemmera (2010c). Consequently, extensive risk management will not be required nor recommended. The majority of remediation proposed in the remedial plan consists of surface impacts that can be remediated by removal and deposition / bioremediated at on-site areas that will mitigate or treat the contamination. These conditions will be further assessed and monitored during the implementation of the remedial plan.

6 Discussion and conclusions

The CSM was a primary planning tool that was used to support the decision making process in risk managing contaminated land and groundwater on a large scale at the Kemess South Mine. The CSM enabled organisation of available information about the site in a logical and clear manner facilitating the identification of data gaps and thus supporting the investigation. The CSM was easily revised as additional data became available. The focus of the CSM for risk assessment was changed from characterising contamination sources and contaminant migration to characterising receptor exposure to sources and contaminant migration to exposure points facilitating the assessment of risk to human health and the environment. The CSM was also used to aid in assessing remedial options.

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