WINTER ROAD PROGRESSIVE SOIL REMEDIATION IN THE SUB-ARCTIC, ABANDONMENT AND RECLAMATION PLANNING AND THE WINTER ROAD ENVIRONMENTAL MANAGEMENT SYSTEM (WREMS)

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ABSTRACT

The winter road now known as the Tibbitt to Contwoyto Winter Road was built by Echo Bay Mine in 1982 to service the then-new Lupin Gold Mine on Contwoyto Lake. The Tibbitt to Contwoyto Winter Road Joint Venture (JV) was formed by Echo Bay Mines and BHP Billiton Diamonds in 1999. Diavik Diamond Mines joined the JV in 2001. Echo Bay left the JV in 2006 following the closure of the Lupine Gold Mine. The approximately 600 km road is used each winter to supply mines and exploration camps in the Slave Geological Province to the northeast of Yellowknife. Since the preparation of an environmental baseline for the renewal of the License of Occupation under which the JV operates the winter road, environmental studies associated with the road have been placed on a web-based Winter Road Environmental Management System known as WREMS. As part of the JV's environmental commitment to continuous improvement, the JV has retained EBA Engineering Consultants Ltd. (EBA) to undertake the progressive remediation of a number of historic petroleum hydrocarbon impacted sites on the winter road. The results of this progressive remediation are being stored on WREMS and incorporated into Winter Road Abandonment and Reclamation planning. These types of studies are valuable as they provide various stakeholders with certainty that the proposed remediation techniques will work in the Sub-Arctic.

INTRODUCTION

The approximately 600 km road is used each winter to supply mines and exploration camps in the Slave Geological Province to the northeast of Yellowknife. Since the JV had environmental baseline studies undertaken as part of the renewal of the License of Occupation for the road in 2001, all environmental studies associated with the road have been placed on a web-based Winter Road Environmental Management System known as WREMS. WREMS is a tool used for by the JV team to document the environmental performance of the road. The site has document and photograph catalogues, key contact details and a map tool for detailed viewing of the road. WREMS has been particularly valuable for recording work historically conducted on the road, recording environmental policy and management plans and accessing reports on progressive remediation and abandonment and reclamation planning. As part of the JV's environmental commitment to continuous improvement, the JV has requested EBA Engineering Consultants Ltd. (EBA) involvement in the progressive remediation of a number of historic petroleum hydrocarbon impacted sites on the winter road. Together with Nuna Logistics Inc., EBA has used a number of innovative techniques to remediate sites along the road. Techniques have been innovative due to the arctic conditions and remote locations of the sites. Prior to implementing the 2006 field program,

EBA had reviewed a number of remediation approaches at the JVs request and conducted a winter pilot bioremediation project.

ENVIRONMENTAL SETTING AND PROJECT DESCRIPTION

The JV assumed responsibility for the progressive remediation of historic petroleum hydrocarbon-contaminated soils located at Lockhart Camp on kilometre 160 of the Winter Road (see Figure 1). The camp is located close to the tree line northeast of Yellowknife in the Northwest Territories (see Photos 1 and 2). Lockhart is considered to be located in a polar continental climate, with long winters and short, cool summers. Daily temperatures are often below -30ºC during the winter and can reach +25ºC in the summer. The camp receives 200 to 400 mm of precipitation per year with approximately half falling as snow. Prevailing winds are most frequently from the east and average 15 km/hr throughout the year.

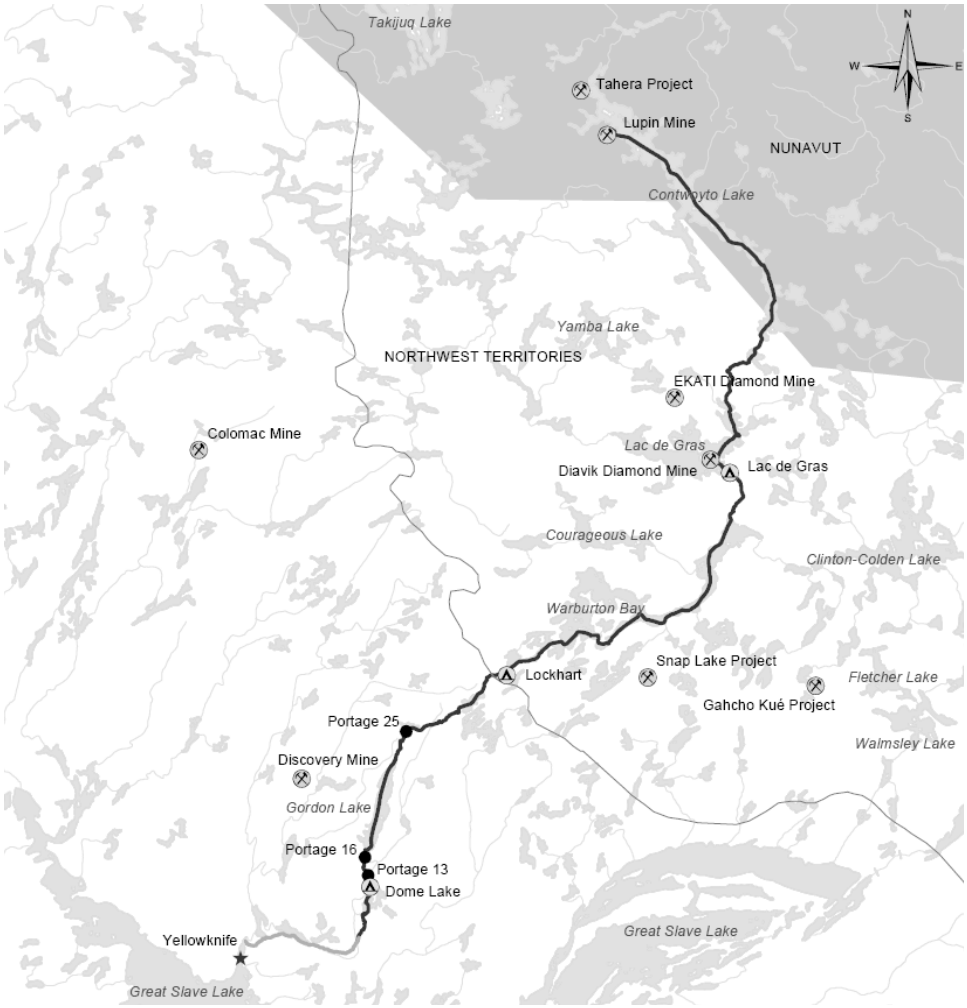


Figure 1: Tibbitt to Contwoyto Winter Road

Photo 1: Tibbitt to Contwoyto Winter Road

Photo 2: Lockhart Camp

The JV encountered approximately 3,000 m^3 of diesel impacted medium grained sandy soils at Lockhart Camp in the summer of 2003 during the upgrade of diesel fuelling facilities at the site. Impacted soils were excavated and subsequently stockpiled on an impermeable liner at the site. Testing of stockpiled soils in the summer of 2006 indicated F2 (C10-C16) petroleum hydrocarbon concentrations ranging from 700 mg/kg to 2,500 mg/kg. These concentrations exceeded applicable Government of the Northwest Territories Industrial Land Use soil standards.

At the request of the JV, EBA assessed a number of different options for remediating soil at the site. Due to the remote location of the site, especially during the summer when the winter road is not available, the remediation of impacted soils at the site required site-specific innovations. Techniques assessed included offsite disposal, thermal treatment and bioremediation.

2006 PILOT PROJECT

Following review of available remedial techniques, in late 2005 the JV determined that a pilot soil remediation project should be conducted on impacted soils at Lockhart Camp. Twenty buckets of impacted soils were collected from the centre of the stockpiled soil with a front loader with each bucket containing approximately 35 kg of soil. Approximately 40 kg of impacted soil was placed in each tray and mixed prior to treatment. The six trays were located in a warehouse at Yellowknife airport with an indoor air temperature of approximately 15ºC. Soils in each tray were stirred, and baseline samples were collected at the start of the experiment for non-halogenated volatile and petroleum hydrocarbon analysis. Baseline F2 concentrations ranged from 640 to 4,600 mg/kg. EBA examined the remedial effect of a chemical oxidation product, microbial amendment and fertilizer on five of the trays; no amendment was added to the control tray. Each tray was sampled and stirred and one litre of water was added to each tray once every two weeks to maintain soil moisture. Table 1 provides pilot test results.

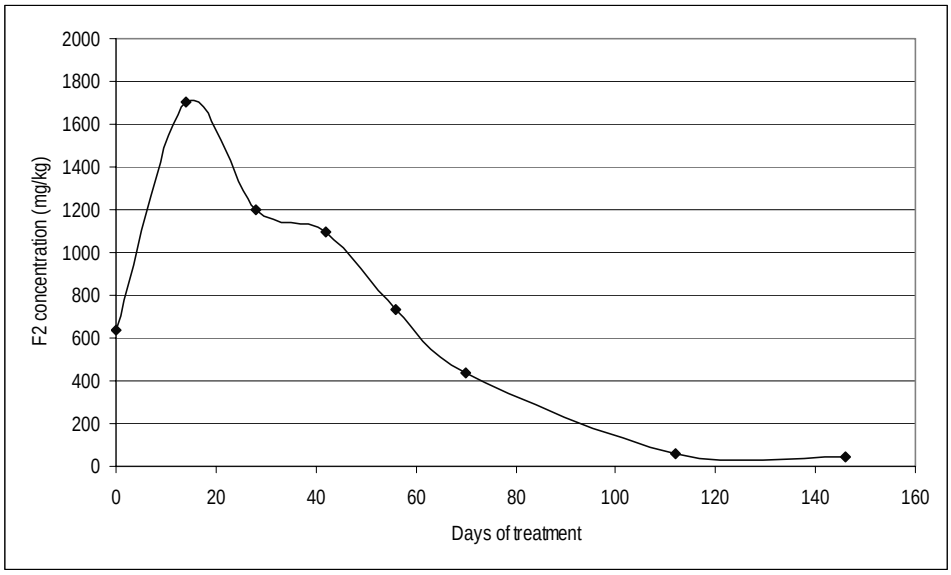
Table 1: 2006 pilot test results

Tray	Treatment	F2 concentrations (mg/kg)			Decrease (%) (Final / Baseline)
		Baseline concentration (October 3, 05)	Week 2 concentration (October 17, 05)	Final concentration (February 27, 06)	
1	Control	640	1700	41	94
2	2 chemical oxidant applications	4600	1300	140	97
3	1 chemical oxidant application	640	1500	130	80
4	1 chemical oxidant application + fertilizer	720	1200	170	76
5	Microbial amendment	930	1400	92	90
6	Fertilizer	850	1700	180	79

After two weeks a 72% F2 decrease was measured in Tray 2 following a first chemical oxidant application. However, no initial F2 decrease was measured in Tray 3 and no F2 decrease was measured in Tray 2 following a second chemical oxidant application. The results of this study indicated that

chemical oxidation products were not an effective or economic option for the remediation of the relatively low-level petroleum hydrocarbon contamination present at Lockhart Camp.

The application of a microbial amendment (Tray 5) and fertilizer (Tray 4 or 6) arguably did not produce any better results than the results observed in soils treated in the control tray (Tray 1), where no remediation products were applied to the soil (see Graph 1). The soil was simply stirred and watered. The F2 concentration dropped from 640 to 41 mg/kg (94% decrease) over the duration of the pilot test. The results indicated that in the presence of oxygen and water, natural processes within these sandy soils could effectively reduce F2 concentrations to below applicable Government of the Northwest Territories Industrial Land Use soil standards.



Graph 1: Control tray F2 concentrations

Based on the results of this pilot project, a full-scale field remediation project was implemented at Lockhart Camp in the summer of 2006.

2006 FIELD REMEDIATION PROJECT

Approximately 800 m^3 of stockpiled impacted soil was landfarmed at Lockhart Camp in the summer 2006 between July 10 to 18, 2006. Approximately half of the impacted soil was placed on a liner with dimensions of 23 m by 35 m, the soil was approximately 0.5 m thick (see Photo 3). The lined landfarm was split into six cells of approximate dimensions of 12 m by 12 m.

Photo 3: Spreading soil on lined landfarm

A further 400 m^3 of impacted soil was placed over an unlined landfarm with dimensions of 46 m by 30 m. The soil was approximately 0.25 m thick (see Photo 4). The unlined landfarm was split into twelve cells of approximate dimensions of 15 m by 23 m.

Photo 4: Discing soil on unlined landfarm

Soil remaining on the stockpile liner at the site was placed into four windrows with maximum heights of 6 m. The stockpiled soil was observed to be frozen during excavation of windrows (see Photo 5).

Photo 5: Excavating stockpile windrows

Baseline soil samples were collected from each cell from each landfarm area and the stockpile windrows between July 13 to 16, 2006. For the thicker lined landfarm, soil samples were collected from a 0 to 0.25 m shallow layer and for a 0.25 to 0.5 m deep layer. For the unlined landfarm, soil samples were collected only from a 0 to 0.25 m layer. A cell sample was formed by collecting five discrete grab samples for each layer and mixing in the field. Mean baseline soil concentrations ranged from 1,004 to 1,687 mg/kg. The objective of the remediation project was to reduce hydrocarbon concentrations to below 760 mg/kg. This is the F2 petroleum hydrocarbon concentration required by the Government of the Northwest Territories for coarse grained surface soils considering eco soil contact for Industrial Land Use. Results from the 2006 field remediation project are provided in Table 2.

Landfarmed soils were aerated with a 10-inch agricultural disk pulled behind a front loader once per week between July 13 and August 23, 2006. The mean air temperature recorded at the site during this period was approximately 14 ºC although the midday air temperature was often recorded over 20 ºC.

End-of-season soil samples were collected from the landfarmed and windrowed soils on August 23, 2006. A 62 to 73% decrease in F2 petroleum hydrocarbon concentrations was observed in shallow (0 to 0.25 m) landfarmed soils at the site. These soils were remediated to below the adopted Industrial Land Use standard within 40 days during the summer of 2006. Deeper soil samples collected from the lined landfarm still contained a mean soil F2 concentration of 797 mg/kg, marginally exceeding the Industrial Land Use standard of 760 mg/kg. These results would indicate that the shallow (0 to 0.25 m) soils have remediated at least twice as quickly as deeper (0.25 to 0.5 m) landfarmed soils. The top shallow remediated layer of soil on the lined landfarm will be removed early in the summer of 2007, and the deeper soils will be landfarmed for another season at the site. The soils remediated on the unlined landfarm at the site will be stockpiled early in the summer of 2007 for future use at the site. A small decrease in F2 petroleum hydrocarbon concentrations was measured in composite samples collected from

the stockpiled windrow although, importantly, windrowed soils were no longer frozen. These windrowed soils will be spread over the unlined landfarm area during the summer of 2007 for remediation.

Table 2: 2006 field remediation project results

Treatment	Depth	Volume (m^3)	Mean F2 concentrations (mg/kg)				Decrease (%)
			Number of analysed samples	Baseline concentration (July 13 - 16, 06)	Number of analysed samples	End of season concentration (August 23, 06)	(Final / Baseline)
Lined landfarm[a]	0 – 0.25 m	200	8 (composite[b])	1004	5 (composite[b]) 6 (grab)	379	62
	0.25 – 0.5 m	200	3 (composite[b])	1113	3 (composite[b])	797	28
Unlined landfarm[a]	0 – 0.25 m	400	13 (composite[b])	1364	10 (composite[b]) 6 (grab)	363	73
Windrows	-	2200	7 (composite[b])	1687	7 (composite[b])	1436	15

Footnotes:

[a]Landfarmed soils disced once per week between mid-July to mid-August, 2006

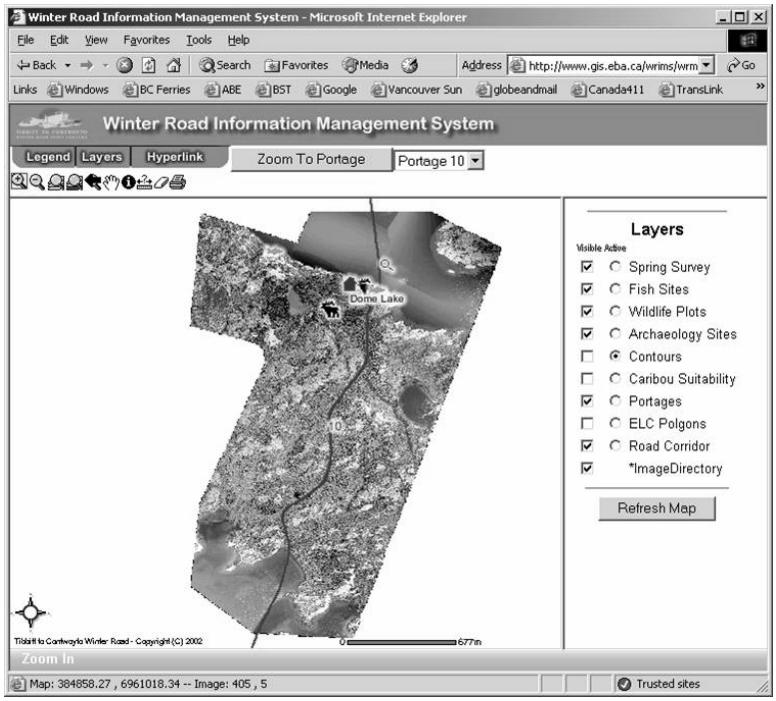
[b]Composite samples formed by mixing five grab samples

WREMS AND ABANDONMENT AND RECLAMATION PLANNING

The reports for these 2006 remediation studies have been incorporated into the document database of the web-based Winter Road Environmental Management System (WREMS). WREMS was created by the Tibbitt to Contwoyto Joint Venture (JV) in 2003 to assist with the environmental management of the Winter Road.

Screen Shot 1: WREMS environmental policy information

The main objective of WREMS is to describe the principles and policies of the Tibbitt to Contwoyto Winter Road Joint Venture environmental management plan which govern the operation of the Winter Road. The system outlines the Winter Road's current management and organizational structure and defines current regulatory requirements. WREMS also provides an overview of roles and responsibilities, communications, regulatory compliance, monitoring programs and audits.



Screen Shot 2: WREMS GIS mapping tool

WREMS includes a document database together with searchable photographic data and a mapping tool. The system includes custom menus, query tools and data in multiple formats such as map books, ArcView Project and scalable web GIS. WREMS stores all data associated with the environmental management of the Winter Road in a current centralized database. The data stored on WREMS is available to all of the JV members and can be accessed remotely over the internet.

SUMMARY

The type of progressive remediation and reclamation studies conducted on behalf of the JV during 2006 are particularly valuable in combination with WREMS as they provide a detailed record of the progressive ongoing remediation work being conducted on the Winter Road. These studies will be cross-referenced in updated Abandonment and Reclamation Plans for the Winter Road. These types of studies, in combination with environmental management systems such as WREMS, are valuable as they provide confirmation to various stakeholders that remedial technologies referenced in abandonment and reclamation plans for the Tibbitt to Contwoyto Winter Road will work in the Sub-Arctic.

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