

**1CP001.07.01**

**FINAL REPORT  
INVESTIGATION AND DESIGN OF REMEDIATION MEASURES  
VENUS TAILINGS SITE**

*Prepared for:*

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**INVESTIGATION AND DESIGN OF REMEDIATION MEASURES**  
**VENUS TAILINGS SITE**

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## **1.0 INTRODUCTION**

### **1.1 General**

On June 16, 1998, Public Works and Government Services Canada (PWGSC) commissioned Steffen, Robertson and Kirsten (Canada) Inc. (SRK) to provide engineering services related to the upgrading and maintenance of previous reclamation measures at the Venus Tailings site, near Carcross, YT. SRK's scope of work was to review relevant background documents, inspect the site, identify deficiencies in the previous reclamation measures, and then prepare a work plan for addressing those deficiencies.

The site visit was completed on July 24, 1998. On August 18, 1998, SRK submitted a letter that presented our analysis of remediation needs at the site, outlined options and recommended a work plan for selecting and designing remediation measures. The recommended work plan was subsequently approved by PWGSC.

This report summarizes results of the work plan and provides a conceptual design for a stabilizing buttress and additional cover material on the surface of the Venus Tailings facility.

### **1.2 Background**

In late 1995, a construction program related to rehabilitation of the Venus Tailings site (km 85 of the Alaska Highway) was undertaken. The program consisted principally of the following two components: installation of a sheet pile barrier wall to minimize the lateral migration of leachate from the tailings; and placement of a multiple layer cap system that eliminates the potential for erosion of the tailings surface, maintains saturated conditions in the tailings and minimizes migration of contaminated water and tailings fines. The sheet pile wall was installed in accordance with design

objectives. However, conditions at the site hampered the installation of the cap system and, as a result, tailings were in some areas mixed in with the cover materials

In late 1997, additional material was placed with the objective of preventing water from ponding on the surface of the facility. While the extent of ponding was reduced, water continues to pond in some areas of the cover.

SRK inspected the site in July 1998, together with PWGSC staff. At that time, wet and soft soils were noted at the toe of the retaining dam, suggesting a potential for instability. The SRK letter report of August 18, 1998 included a work plan recommending:

- Field investigations to assess dam stability, the source of ponded water and the source of high arsenic concentrations in the ponded water;
- Stability analyses and, if necessary, the design of a stabilizing buttress; and
- Assessment of alternatives for removing the ponded water and reducing arsenic concentrations in the discharge from the Venus tailings.

The results of the approved work plan are provided herein.

## 2.0 FIELD INVESTIGATIONS

The field investigation at the Venus Tailings site commenced on August 26, 1998, and consisted of:

- Drilling geotechnical boreholes in the tailings dam and toe area;
- Installing groundwater monitoring wells in the tailings dam and up and down gradient of the tailings;
- Installing drive point piezometers in the tailings and cover;
- Sampling the tailings cover surface to determine arsenic concentrations in surface materials;
- Sampling surface water up and downstream of the tailings;
- Sampling groundwater from the monitoring wells and drive points; and
- Surveying the current tailings surface and dam, installed monitoring points, and surrounding area.

# FINAL REPORT

## Venus Mine Monitoring Program Review

Prepared for:  
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File: 316-030.01  
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August 16, 2013  
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Waste Management Program  
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**Attn: Sierra van der Meer, Director – AANDC Environment, Yukon**

Dear Ms. van der Meer;

**Re: VENUS CLOSED MINESITE – TEN YEAR REVIEW OF THE ANNUAL ENVIRONMENTAL MONITORING PROGRAM**

Hemmera is pleased to provide you with our review of the monitoring program completed at the Venus Mine Site, annually for ten years following its closure.

The attached report is provided in draft, and as such is not signed. If you do not identify a need for any revisions, we will finalize and forward forthwith signed copies along with hard copies for your files.

We have appreciated the opportunity to work with you on this project and trust that this report meets your requirements. Please feel free to contact the undersigned by phone or email regarding any questions or further information that you may require.

Regards,

**Hemmera**

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## EXECUTIVE SUMMARY

This report provides a review of the ten year monitoring program for the Venus Mine site, a decommissioned and orphaned mine site in the Yukon. This mine site was the subject of the Yukon Devolution Transfer Agreement. AANDC (formerly INAC) had a commitment to conduct annual environmental monitoring at this site for ten years following reclamation; i.e. from 2003 to 2012.

The Venus Mine tailing deposit is located adjacent to Windy Arm, Tagish Lake, approximately 19 km south of the village of Carcross, Yukon. The tailings deposit is surrounded by the lake to the east, the Klondike Highway at km 86 to the west, and the mill site to the north. Mining related activity at the Venus Mine commenced around 1904, based on discovery of the Venus vein by prospectors on their way to the Klondike Gold Rush. Several punctuated stanzas of mining occurred (1904-1912; 1916-1920; 1966-1971; 1979-1981), and the mining produced silver and gold, with minor amounts of lead, zinc and cadmium. The major portion of mine tailings that occur on site were based on milling activities in the last operational period. The mill was dismantled during the late 1980s and early 1990s.

The major residual feature of the mine site is the tailings deposit. Mineralization in the area of Venus Mine includes irregular bands and pods of pyrite, arsenopyrite, galena and sphalerite, with minor tetrahedrite and chalcopyrite. The deposits are typical of polymetallic sulphide mineralization, and the Venus Mine tailings have been found to be net acid generating. Analysis of the Venus tailings showed that they contain very high levels of sulfide minerals (3 to 20%), very high arsenic concentrations (2.5 to 7% of solids by mass) and various metals that may be important in the context of water quality - such as cadmium, lead and zinc, and to a lesser degree copper, cobalt and nickel. It has been estimated that approximately 54,000 tonnes of tailings are being risk-managed on-site.

In 1995, the rehabilitation of the Venus mine tailings was initiated with the major works comprising the in-place containment of the tailings. The ca. 1.5 ha containment cell consists of a sealed Waterloo Barrier Sheet Pile Wall on the downgradient side of the tailings deposit toward the lake, and a cap constructed over the top of the deposit. The cap consists of a geotextile membrane over top of the tailings, capillary break material, and a silty-clay cap. To control the surface runoff within and above the capping material, a drainage discharge system was installed.

Challenges in construction of the cap lead to the inter-mixing of tailings with clean borrow in some higher elevation areas of the cap. The initial construction of the tailings containment also resulted in the pooling of water over portions of the cap, and this issue was addressed by SRK in 1998.

As part of site remediation, a formal monitoring program was carried out from 2003 to 2012. The program was conducted annually and consisted of (i) visual inspection of the tailings containment cell, focused on signs of settling or leakage; (ii) inspection of the surface drainage and discharge system; and (iii) sample



of surface water up-gradient and down-gradient from the containment cell cap, and analysis for acidity, arsenic, as well as total and dissolved metals. In 2004, the sampling and analysis of groundwater collected immediately up- and down-gradient from the containment cell was added to the monitoring program.

The major conclusions resulting from this review are summarized as follows:

1. There has been a persistent and significant increase in surface water concentrations of especially arsenic and zinc down-gradient from the tailings deposit relative to reference inflow water quality.
2. There has been a persistent and significant increase in groundwater concentrations of arsenic, iron, manganese and calcium in the down-gradient area represented by monitoring well ML relative to reference concentrations in the up-gradient well MU, as well as a slight but statistically significant decrease in pH in groundwater down-gradient from the encapsulated tailings deposit.
3. The down-gradient changes in surface water and groundwater environmental quality are consistent with an influence of metal leaching/acidic rock drainage (ML/ARD).
4. Arsenic levels in annually collected samples collected from the tailings facility Outflow Culvert (VC samples) (0.7 to 1.2 mg/L) and surface drainage to the lake (VO, VL samples) (0.04 to 0.17 mg/L) substantially exceeded the Canadian (CCME) Water Quality Guideline for Freshwater Aquatic Life Protection of 0.005 mg/L.
5. Zinc levels in annually collected samples collected from the tailings facility Outflow Culvert (VC samples) (0.02 to 2.2 mg/L) exceeded the Canadian (CCME) Water Quality Guideline for Freshwater Life Protection of 0.03 mg/L; however, samples from the surface drainage to the lake (VO, VL samples) (0.011 to 0.033 mg/L) only marginally exceeded the CCME FAL in two of ten years (2004, 2007).
6. While arsenic occurs at higher concentrations in the groundwater down-gradient from the tailings facility than up-gradient, the observed sample concentrations were generally within ten-fold of the CCME arsenic water quality guideline for freshwater life protection, except for the groundwater sample collected in 2012.
7. Based on groundwater outflows, none of the other monitoring program groundwater analytes would be anticipated to cause concerns for aquatic life within the lake environment with the possible exception of iron and manganese, for which Canadian (CCME) water quality guidelines for aquatic life protection have not been developed. It is conceivable that iron oxide precipitates are forming at the point of groundwater input into Windy Arm of Tagish Lake, which could result in smothering of bottom habitat and various gas-exchange structures in freshwater biota, based on

the observed groundwater concentrations. The potential for impacts would depend on the location of iron oxide precipitation, its spatial extent, and rate.

8. Dissolved-phase iron and manganese in the down-gradient groundwater samples were observed to occur at significantly greater concentrations than aesthetic-based drinking water standards.
9. There has been no significant change over the ten year monitoring period in the surface water or groundwater concentrations, with one exception:
  - a. There has been a significant linear increase in electrical conductivity (EC) in groundwater samples from the monitoring well installed up-gradient from the tailings facility (MW3, or MU). The possible cause for this is not evident in the absence of a greater understanding, at a finer spatial scale, of surface water and groundwater flow conditions and interactions at the site.
10. Concentrations of arsenic and zinc in surface water were consistently higher than in groundwater: Average arsenic concentration in the Outflow Culvert water samples over the ten year monitoring period was 0.93 mg/L, while in the groundwater samples down-gradient from the encapsulated tailings deposit was 0.047 mg/L. The arsenic concentrations in samples collected from 2004 to 2012 from the surface drainage to the lake, however, were lower than in the outflow culvert (average of 0.078 mg/L), but nonetheless higher than the CCME arsenic freshwater life guideline.

The further interpretation of these findings in the context of (i) future evolution of ML/ARD, and (ii) potential environmental risks to aquatic life within Windy Arm of Tagish River lead to the following recommendations:

1. Sampling of water and sediment within the lake environment should be conducted in order to better evaluate aquatic ecological risk potential;
2. A detailed review, gap analysis, and re-evaluation of site hydrological and hydrogeological conditions should be completed for the Venus tailings deposit and adjacent areas to create a better understanding of how the encapsulation features are functioning based on the 1995 remedial works.
3. The annual monitoring program should be continued, with minor improvements.

Particulars of and the rationale for these three major recommendations are discussed in more detail in Section 6 of this report.

# Site Characterization and Risk Assessment in Support of Closure Planning for the Venus Tailings Site, Yukon – Final Report

Prepared for

Indigenous and Northern Affairs Canada



Prepared by



SRK Consulting (Canada) Inc.  
1CA030.014  
January 2017

# Site Characterization and Risk Assessment in Support of Closure Planning for the Venus Tailings Site, Yukon – Final Report

January 2017

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Project No: 1CA030.014

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## Executive Summary

SRK Consulting (Canada) Inc. in cooperation with Azimuth Consulting Group Partnership were contracted by Indigenous and Northern Affairs Canada (INAC) to evaluate the causes and potential risks associated with recent changes observed in water quality at the Venus tailings site, near Carcross, Yukon.

The first phase of the work included a detailed review of available information, a site reconnaissance, and an initial workshop to identify critical information gaps. Based on the findings of these activities, a more detailed work plan was developed.

The second phase of work included targeted field investigations to address critical information gaps, and a qualitative human health and ecological risk assessment. The overall objective of this work was to determine what level of remedial action may be required to address known and potential risks at the site. A conceptual site model was also prepared to help inform the risk assessment and remedial planning.

**Field Investigation.** The field program included an embankment slope stability analysis, surface and groundwater investigations, and sampling and analysis of surface and groundwater quality, soil, sediments, and aquatic tissues.

**Stability analysis.** An updated slope stability analysis was performed to determine the risk of global failure of the Waterloo Barrier as a result of the fully saturated conditions in the embankment. The results indicate the embankment meets Canadian Dam Association (CDA) minimum factors of safety for a facility with an assumed HIGH dam hazard classification in active closure.

**Groundwater flows.** Groundwater is not discharging up through the tailings, but appears to be bypassing either to the south or under the tailings mass.

**Water quality.** Elevated concentrations of arsenic are found in the tailing pore water, the small ephemeral stream (station VL) at the south end of the tailings facility, and in two groundwater seeps located some distance downgradient of the tailings. One of the groundwater seeps had arsenic concentrations that were an order of magnitude higher than concentrations in the tailings pore water, and were accompanied by elevated iron, cadmium and zinc concentrations. This suggests that another source of contamination, possibly tailings in the surrounding soils, may be influencing water quality at this location.

**Soil.** Soil in the areas surrounding the tailings, including the old mill area, has arsenic concentrations that consistently exceed soil quality guidelines for the protection of environmental and human health by a factor of more than 100-fold. Exceedances of applicable guidelines also exist to a lesser degree for other metals, including antimony, cadmium, iron, lead, and zinc. Further work to delineate the extent of contaminated soils is in progress.

**Lake sediment.** Sediment samples from some locations in Tagish Lake contain concentrations of arsenic, cadmium, lead, and zinc in excess of their respective sediment quality guidelines. The sediment core contained a layer of fine-grained light grey substrate, consistent with the appearance of tailings deposited to a lake. Concentrations of various metals were elevated in the uppermost horizon of the core. This indicates the flux of these elements to the upper sediment in Tagish Lake is increasing over time relative to the rate of sediment deposition. The extent of contaminated sediments in Tagish Lake and the relative

contribution from ongoing release of contaminants from the Venus tailings site versus historical releases from this site or other potential sources in the area (for example, the old Venus mill site), has not been determined.

*Aquatic tissues.* Lower trophic levels of the aquatic food web, including periphyton, gastropods, and slimy sculpin that inhabit the littoral zone at the Venus tailings site have bioaccumulated higher concentrations of site-related metals than aquatic organisms at reference locations in Tagish Lake. Lake trout collected in the vicinity of the site do not show any difference in metal content in comparison to reference sites.

**Preliminary Risk Assessment.** A preliminary qualitative human health and ecological risk assessment was undertaken to systematically evaluate and characterize the potential human health and ecological risks associated with environmental contamination at the site. The level of detail of the preliminary risk assessment would not satisfy all of the requirements for risk assessments submitted for review under federal or territorial contaminated sites regulatory frameworks, but is sufficiently rigorous to identify relative priorities in the context of remedial planning and site management decisions. Risks were characterized as the likelihood, based on available data and best professional judgement, that the findings of a detailed quantitative risk assessment would trigger the need for risk management.

- Risks to human health from direct contact with contaminated soil were characterized as likely to require management action.
- There are potential risks to slimy sculpin from contact with contaminated sediments and dietary exposure. However, there is currently not enough information to determine, with sufficient certainty, if management actions are required to address these issues.
- Risks that were characterized as unlikely to require management action include risks to humans from consumption of water from Ditch Creek or Tagish Lake, risks of effects to lake trout and other species of sport fish, and risks to large or herbivorous animals or people that eat these animals.

# Example Remediation Options, including Cost Estimates for the Venus Tailings Site, Yukon – Final Report

Prepared for

Indigenous and Northern Affairs Canada



Prepared by



SRK Consulting (Canada) Inc.  
1CA030.014  
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# Example Remediation Options, including Cost Estimates for the Venus Tailings Site, Yukon – Final Report

January 2017

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## Executive Summary

Indigenous and Northern Affairs Canada (INAC), in cooperation with the Carcross/Tagish First Nation (CTFN) contracted SRK Consulting (Canada) Inc. to identify and develop costs for a range of potential remedial actions that could be implemented to address potential human health or ecological risk identified for the Venus tailings site near Carcross Yukon. The objective of defining example remediation options was to provide a basis for evaluating the cost-benefits of further investigation versus implementation of remediation measures. The example options were also intended to form a basis for gathering input from various stakeholders, including CTFN on potential remediation measures for this site.

Example options are described as follows:

- Example 1 addresses likely risks identified in the risk assessment, through remediation of the contaminated soils and maintenance to the existing tailings cover. The proposed access road to reach contaminated soils along the shoreline would also provide a secondary benefit of preventing aquatic organisms (i.e. sculpin) from being directly exposed to seepage water discharging along the shoreline.
- Example 2 addresses likely risks, as described above, but also incorporates measure to reduce potential risks associated with contaminant loading from the site through additional groundwater diversion measures.
- Example 3 addresses the both likely and uncertain risks by relocating these materials to an off-site engineered containment facility.

Estimated costs for these options ranged from \$3.6 million for Example 1 to \$17.7 million for Example 3.

It is emphasized that further work to address some of the uncertainties identified in the risk assessment is required before final decisions regarding remedial actions can be made. Additionally, there are many other possible remediation measures that could be considered. However, the project is now at a stage where further input from other stakeholders, including clarity on future land use objectives is required to support further evaluation of options.

## **Venus Mine Tailings Facility Operation, Maintenance and Surveillance Manual**



PRESENTED TO  
**Crown-Indigenous Relations and Northern Affairs Canada**

AUGUST 10, 2018  
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	Reporting an Environmental Emergency	1-800-668-6767
Fisheries and Oceans Canada		1-867-393-6722
Yukon Water Board		1-867-456-3980
Natural Resources Canada		1-867-667-3957
Transport Canada (Prairie and Northern Region)		1-888-463-0521
Yukon Environmental and Socio-Economic Assessment Board		1-867-668-6420
Environment Yukon		1-867-667-5652
Yukon Government - Energy, Mines and Resources		1-867-667-3130
Yukon Water Resources Branch		1-867-667-3171
<b>Local Authorities: Town of Carcross</b>		
Carcross	Carcross Fire Department	1-867-821-2222
	Carcross Ambulance	1-867-821-4444
	Carcross RCMP	1-867-536-5555
	Yukon Spill Line	1-867-667-7244
	YG Report a Fire Line	1-888-798-3473
Yukon Emergency Measures Office		1-867-667-5220
Director – Yukon OH&S		1-867-667-5450

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### APPENDICES

- Appendix A Limitations on the Use of this Document
- Appendix B Site Inspection Form

## ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
CDA	Canadian Dam Association
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
DTA	Devolution Transfer Agreement
EBA	EBA Engineering Consultants Ltd.
EPRP	Emergency Preparedness and Response Plan
MAC	Mining Association of Canada
OMS	Operations, Maintenance and Surveillance
PWGSC	Public Works and Government Services Canada
SRK	SRK Consulting (Canada) Inc.
Tetra Tech	Tetra Tech Canada Inc.



## **LIMITATIONS OF REPORT**

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## 1.0 INTRODUCTION

### 1.1 General

This Operations, Maintenance and Surveillance (OMS) Manual has been prepared by Tetra Tech Canada Inc. (Tetra Tech) for Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), in relation to the Tailings Facility at the abandoned Venus Mine Site, located south of the community of Carcross, Yukon, adjacent to the South Klondike Highway.

This OMS Manual has been prepared in general accordance with guidelines published by the Mining Association of Canada (MAC, 2011) and the Canadian Dam Association (CDA, 2013; CDA, 2014; CDA, 2016).

### 1.2 Purpose of the OMS Manual

This OMS Manual provides a framework for the maintenance and monitoring (surveillance) of the Tailings Facility and associated water management structures, including the following items:

- Roles and responsibilities of parties associated with maintenance and monitoring at the site;
- Procedures for managing changes in personnel, site conditions or facility performance, and corresponding updates to the OMS Manual;
- Identification of key components of the Tailings Facility;
- Procedures to monitor performance of the Tailings Facility and implement maintenance activities as required to ensure that the Tailings Facility functions in accordance with its design and applicable regulatory requirements;
- Documentation and reporting requirements; and
- Emergency planning and response procedures.

### 1.3 OMS Manual Updates

This OMS Manual is the property of CIRNAC, which holds sole authority of distribution of this document.

It is the responsibility of CIRNAC to update this OMS Manual when required, or to retain a third party to update the OMS Manual on their behalf.

This OMS Manual should be reviewed as part of routine monitoring, Dam Safety Inspections and Dam Safety Reviews, and/or if significant changes occur at the site, to assess the applicability of the content to existing site conditions. Revisions to the manual should be undertaken within a reasonable timeframe and re-issued.

Revisions to the OMS Manual should be made with consideration of major changes to applicable maintenance or monitoring plans or regulations. If changes to these plans or regulations are required, the OMS Manual should be updated.

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<b>Subject</b>	<b>2018 Data Gap Analysis and Site Investigation Workplan for the Venus Mine</b>
<b>Attention</b>	Carcross Tagish Management Corporation (CTMC)
<b>From</b>	Jacobs Engineering Group Inc. (Jacobs)
<b>Date</b>	September 2018
<b>Project Number</b>	707121
<b>Revision No.</b>	1
<b>Reviewed by</b>	Liz van Warmerdam/Jacobs

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## **1. Introduction**

The Carcross/Tagish Management Corporation (CTMC) retained CH2M HILL Canada Limited (CH2M), now Jacobs Engineering Group Inc. (Jacobs), as the lead consultant to complete a series of pre-determined tasks in anticipation of future remediation activities associated with site closure at the Venus Mine (Venus or the Site). In the June 8, 2018 Revised Work Proposal, we outlined six tasks to be completed by the Jacobs team, which included a gap analysis and Site investigation work plan; the subject of this Data Gap Analysis Technical Memorandum (TM). This TM identifies and briefly discusses the data gaps identified by the Jacobs team, and outlines the Site investigation workplan proposed to address the data gaps in order to provide the CTMC with a better understanding of the Site conditions, and the risks associated with the current state of the Site. These findings will then be communicated to CTMC with the completion of an updated Site Characterization and Risk Evaluation Report, which is the sixth and final task outlined in the Revised Work Proposal.

## **2. Background**

The Venus mill and tailings impoundment are an abandoned mine facility located 19 kilometres (km) south of the community of Carcross, Yukon at Kilometre 86 of the Klondike Highway. The Venus claim was initially staked at the turn of the 20<sup>th</sup> Century by Jack Stewart and Jack Pooly. Development of the mines Venus #1 and Venus #2 did not occur until after Colonel J.H. Conrad purchased the claim from Stewart and Pooly in 1904 (Golder, 2006).

This TM focuses on Venus #2, including the mill and tailings impoundment. Gold and silver within the quartz veins were the primary metals mined from the Site. The mill was constructed in 1970, with a capability of milling 300 tonnes of ore per day and is estimated to have processed 65,231 tonnes of ore, until the mine was closed 1 year after the mill's construction. In 1981, with the construction of the new Venus mill in British Columbia, approximately 15,000 tons of tailings were moved from the tailings impoundment to be re-milled at the new facility (Tron Duik Consultants, 1992).

Both the mill and tailings impoundment are located on the western shore of the Windy Arm of Tagish Lake (Figure 1), at 600 metres above sea level (masl). The Site contains the concrete foundations of the mill used to process metals from the Venus #2 mine in the early 1970s, as well as a tailings impoundment of approximately 1.5 hectares in size (SRK, 2017).

# Human Health and Ecological Risk Assessment for the Venus Tailings Site – 2018 Update

Prepared for:



Carcross Tagish Management Corporation  
Suite #15 – 1114 Front Street  
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FINAL

April 2019



Azimuth Consulting Group Partnership  
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Project No. CT-18-02/Venus ERA

**Report Distribution**

<b>Version</b>	<b>Dates</b>	<b>Distribution</b>
Draft for client review	Report issued: Jan 18, 2019 Comments received: Jan 26, 2019	CTMC: K. Gardner, R. Lewis, N. Lepine
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Final	Issued on April 18, 2019	CTMC: K. Gardner, R. Lewis, N. Lepine

## EXECUTIVE SUMMARY

Azimuth Consulting Group Partnership (Azimuth) has been working on behalf of the Carcross Tagish Management Corporation (CTMC) to determine if contaminants in the area around the former Venus mill and tailings storage facility (the Site) pose risks to human health, animals that use the site or organisms living close to the site in Tagish Lake. The studies and information summarized in this report will help guide decisions on how best to manage the Site to ensure people and the wildlife that use it are protected. This Executive Summary should be read in conjunction with the remainder of the report and is subject to the same limitations as described therein.

**Background** – Mining in the Conrad district dates back to the early 1900's. Gold and silver were the primary resources sought, and several mines were established on the eastern slope of Montana Mountain from Conrad to the British Columbia border because of the rich mineralization in the region. Despite the mineral wealth in the region, mining operations were not successful over the long-term. The first period of mining in the Conrad district lasted until 1920. Mining at Venus resumed 1970, along with construction of a new mill (the focus of this risk assessment). This phase of mining and milling was also short-lived, and by the early 1980s, mining activities in the Conrad district had ceased.

Mineral ore from the Venus mines was naturally elevated in metals such as arsenic, cadmium, lead, and zinc, in addition to the gold and silver resources that were sought after. The processing and handling of ore, combined with the disposal of tailings at the Site, resulted in elevated concentrations of metals in soils and groundwater near the Site and in sediments found close to the Site in Windy Arm of Tagish Lake. In 1995, the Government of Canada *rehabilitated* the tailings

### *Metals in the Environment near Venus*

*Mining activities in the Conrad district date back to the early 1900's. Some metals occur at naturally-high concentrations in the soil and rock, but mining and milling of ore and uncontrolled release of tailings resulted in areas of localized contamination.*

area by installing a sheet pile barrier and an engineered cover to prevent the uncontrolled release of metals from the tailings. Other areas of the site were *not remediated*, including soils around the mill and tailings facility, and contaminated tailings that were deposited directly to Tagish Lake. These areas were the focus of recent environmental investigations aimed at identifying if humans or wildlife using the Site are at risk from exposure to contaminants and whether Tagish Lake near the Site is a healthy freshwater environment.

## Human Health

The Government of Canada recognized that contamination on Site may pose long-term health risks for people using the Site. Humans can be indirectly exposed to metals in soil by inhaling dust or incidentally ingesting soils on their hands, by drinking water with elevated metals, or through traditional use of

plants and animals that have accumulated metals in their tissues. Several metals are elevated in the soils, but other than signs warning people that there are high concentrations of metals on Site, human access is not restricted to the mill or tailings storage facility.

**Metals Contamination in Soils** – A soil sampling program was completed in 2016 and 2017 to determine how far metals contamination extends and the concentrations of various metals in the soil. Several metals, most notably arsenic, exceeded concentrations associated with risks to human health. Importantly, soils in the area are naturally high in metals which is often the case in mine settings. In the case of arsenic, the natural level exceeded the human health guideline.

A site-specific human health guideline was calculated based on quantitative human health risk assessment methods and taking into consideration different health endpoints, different routes of exposure and differences between adults and toddlers. The lowest Site-specific soil criterion for protecting human health was 300 mg/kg arsenic in soil. This guideline will help identify areas of the Site that require active remediation or management to protect human health. By remediating the soils, it is assumed that health risks to people using the Site for traditional purposes, such as collecting berries or traditional medicines, will also be reduced. Consuming water on the tailings or flowing from them was not considered a likely risk to human health.

**Metals Contamination in Sediments** – The other area of the Site that poses a potential risk to humans is the shoreline area of Tagish Lake downgradient from the tailings area. Sediment samples were collected



in 2018 to determine the spatial extent of metals-contaminated sediment along the shoreline at Venus. The results, which were primarily used in the ecological risk assessment for the slimy sculpin, also have relevance for human health. Elevated concentrations of arsenic, among other metals, were measured in sediment along the shoreline close to the outlet of Ditch Creek. Exposed sediments are only accessible when water levels are at their lowest after the ice comes off Windy Arm. For most of the year, the water level covers the fine sediments near the Site; nonetheless, the concentrations measured in the sediments may pose health risks to humans wading along the shoreline and incidentally ingesting contaminated sediment. Follow-up work is recommended to determine the extent of contaminated sediment extending out from the shoreline.

#### ***Human Health Risks***

*Processing ore at the Venus mill and tailings site resulted in high concentrations of arsenic and other metals in the soil. Measured concentrations of arsenic exceed concentrations that are safe for people using the site.*

## Ecological Health

Contaminated soil in the areas surrounding the mill site and tailings area will likely require remediation to protect human health. If these soils are cleaned up, then the ecological health of the area will also be protected. Plants growing on Site and the small mammals and birds that use it periodically will be protected. Larger mammals, such as moose, and birds that feed over wide geographical areas are unlikely to spend enough time at the Site to result in any health effects.

Recent investigations into the environmental health of Lake Tagish's shoreline have focused mostly on freshwater organisms that live close to the Site in Windy Arm. The investigations were conducted because water chemistry results showed increased concentrations of metals in Tagish Lake, indicating that Site runoff and groundwater from the tailings may be contributing factors. If tailings material is being deposited to Tagish Lake, metals concentrations in sediments off-shore from the Site would likely be elevated. The available data on the health of Tagish Lake's aquatic environment were mostly qualitative, and did not provide information about the possible effect(s) of metals on organisms living closer to shore.

### 2015 Investigation

**Background** – Recognizing the need to understand risks to the freshwater community in Windy Arm, a reconnaissance-level sampling program was completed in 2015. The program sought to determine if metals were accumulating in the freshwater food web along the shoreline at Venus compared to two reference areas on Windy Arm. It focused on analyzing metals in periphyton (algae growing on rocks), invertebrates that graze on periphyton (snails) and two different fish species that prey on invertebrates. Two fish species were chosen for collection, slimy sculpin — a small fish that lives between rocks and along the bottom of sediments and doesn't move around much — and juvenile lake trout that swim throughout the water column. The study design broadly represented the different communities of organisms present in Windy Arm.

**Results** – Results of the 2015 investigation showed that periphyton, snails, and slimy sculpin along the Venus shoreline were accumulating higher concentrations of metals than those in areas away from the Site in Windy Arm. Juvenile lake trout from Venus did not accumulate higher concentrations of metals than lake trout collected at the reference areas. Together, these results provided evidence that the periphyton and invertebrate communities that do not move much, and fish species that spend most of their life history near the Site are the most highly exposed freshwater organisms. Longer-lived fish species that forage over wider areas in Windy Arm were unlikely to accumulate enough metals to adversely affect the local population.



## 2018 Investigation

Based on the chemistry results from the 2015 investigation, a progressive strategy was developed to evaluate the potential health effects for organisms living in Tagish Lake. The framework focused first on assessing the health of the freshwater community along the shoreline near Venus, because organisms in Windy Arm closest to Site are the most highly exposed to Site-related contamination and, therefore, are at greatest risk of effects. An added benefit of this approach is that the outcome of the shoreline investigations could help plan subsequent studies, if needed, on the potential effects on aquatic communities living in the deeper part of Tagish Lake.



*Slimy sculpin is a small fish species that lives between rocks in stream and lake environments. They are abundant throughout Tagish Lake and are a good species for assessing the health of freshwater environments.*

**Fish survey** – Following the progressive risk assessment strategy, a fish survey was completed in May/June 2018 to assess the health of slimy sculpin living close to the Site. The study design followed the Environmental Effects Monitoring guidance for evaluating the health of fish populations in lakes and streams that receive treated effluent from operational mine sites in Canada, which is well suited for contaminated sites investigations when using small-bodied fish species that do not move around much. The health of the slimy sculpin population was evaluated by collecting information on the survival, growth, condition (energy stores) and reproductive potential of slimy sculpin at Venus compared to two reference areas in Windy Arm. Two reference areas provided valuable information about the range in health measurements (e.g., the size of a fish at a given age), for the population of sculpin unaffected by contamination at Venus. Supporting sediment chemistry and fish tissue chemistry data were collected to evaluate spatial patterns in metals exposure and to help explain any negative effects on fish health.

**Sediment Chemistry** – Sediment samples collected from between the rocks along the shoreline at Venus were elevated in arsenic, cadmium, lead and zinc, relative to the reference areas. Arsenic was particularly elevated at Venus, with concentrations measuring between 38,000 and 57,000 mg/kg along approximately 100 m of shoreline downgradient from the tailings storage facility. The shoreline at Venus is predominantly rocky and fine sediments are limited to the spaces between rocks or deposit areas behind boulders.

**Results** – There was evidence of accumulation of some metals in slimy sculpin near Venus, but the spatial pattern of accumulation was confined to a few individuals collected from a relatively small area where sediment metals concentrations were the highest. There was also considerable within-area variability in accumulation of metals by slimy sculpin over a small area, suggesting sediment chemistry is

not a good predictor of accumulation in fish. Slimy sculpin are likely exposed to metals mainly through consumption of invertebrates and other diet items that are elevated in metals. Surface water is not considered a significant risk to the local population based on chemistry data collected near the shoreline and offshore at the Site. No porewater data are available for the shoreline area, and the surface water chemistry along the narrow mixing zone in Tagish Lake downgradient from the tailings generally met water quality guidelines for protecting aquatic life. A measure of certainty about low risk of exposure to metals from porewater was inferred from the fish survey results.

Overall, slimy sculpin from Venus showed similar health compared to fish collected from the reference areas in the 2018 investigation. Slimy sculpin was relatively abundant at Venus, with a mix of older fish (year 3+) and younger fish collected. Young slimy sculpin can be challenging to capture because of their small size, cryptic coloration, and tendency to live between rocks. Wind and wave action at Venus hampered collection of younger individuals relative to the reference areas, and any apparent difference in the size distribution at Venus compared to the reference areas was attributed to the collection efforts, not the Site. Measures of fish survival (age), growth (size-at-age), condition (i.e., how fat the fish are; liver size), and reproduction (e.g., gonad size and eggs/female) were within the range that is considered healthy, based on comparisons to the two populations of slimy sculpin at the reference areas.

#### ***Health of the Organisms in Tagish Lake***

*The slimy sculpin fish assessment indicated fish collected near Venus had similar measures of overall health compared to fish collected from reference areas in Tagish Lake.*

*Invertebrate and periphyton communities along the shore are functioning to provide prey for the slimy sculpin.*

The periphyton and invertebrate communities, which are critically important for the functional health of the aquatic environment, were indirectly evaluated in the slimy sculpin survey, on the assumption that if there are no effects on slimy sculpin at Venus, then the lower trophic levels they depend on must also be functionally healthy. The absence of any apparent effect on growth, condition, or reproduction in the slimy sculpin implied that the lower trophic level communities along the shoreline near Venus are functionally healthy and capable of supporting the relatively abundant and healthy slimy sculpin population observed at the Site.

## **Site Management Considerations**

The human health and ecological risk assessment, along with ongoing site investigation work, has provided a great deal of clarity about the sources of contamination to the terrestrial and aquatic environment and the potential health risks to humans, wildlife and aquatic life in Tagish Lake. Remedial efforts that are needed to address unacceptable risks to human health from contaminated soil are expected to address any unacceptable risks to plants and animals, and to mitigate metals loading to

Tagish Lake from surface runoff. There are uncertainties that may require further investigation, including:

1. Future Site conditions in the littoral aquatic receiving environment: on-going monitoring is recommended to address uncertainty about current vs future conditions in Tagish Lake under the preferred risk management option for contaminated soil.
2. The extent and magnitude of potential Site-related contamination and associated biological impacts in the profundal zone of Tagish Lake. Reconnaissance-level sediment sampling is recommended to address this uncertainty.
3. Assessment of potential health risks from people consuming lake trout from Windy Arm or from consuming plants from the Site as food (berries) or traditional medicine.
4. Additional sediment sampling and a quantitative HHRA may be necessary to define the extent of sediment in the mud bench that requires risk management.



## **Venus Tailings and Former Mill Site**

### **Data Compilation for the Venus Site – 2019**

FINAL

April 2020

Carcross Tagish Energy Corporation



**Venus Tailings and Former Mill Site**

Project No: CE761000.A.CS.EV.7-1-1  
Document Title: Data Compilation for the Venus Site – 2019  
Document No.: FES0124201521VBC  
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Client Name: Carcross Tagish Energy Corporation  
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**Document History and Status**

Revision	Date	Description	By	Review	Approved

## Executive Summary

The original Venus Tailings and Former Mill Site (the Site) was built in 1908 and operated intermittently until 1920 when it ceased production. This first mill used belt-driven machinery to crush and grind ore into a powder, after which mineral concentrate extracted from the crushed rock by chemical means was dried, bagged, and shipped to Carcross, Yukon. In the mid-1960s, mining activity resumed, and a second mill was constructed (capable of producing 272 metric tonnes of ore per day). Tailings produced from this short-lived milling operation were placed in a small natural depression at the edge of Tagish Lake.

The former mill and the adjacent Tailings Storage Facility (TSF) are located between the Klondike Highway and Tagish Lake. Exposed bedrock of Montana Mountain rises west of the highway with the tailings located east of the highway. The tailings were reported to be confined by ground and bedrock exposures to the north and west, and at the northern end of the east side. A perimeter dike was constructed for the tailings area on the east side, to confine the tailings solids (but not retain water).

In 1994, a report was prepared that summarized costs versus efficacy of various closure options. The selected remediation option was a low permeability cover system with a groundwater cutoff wall. The design implemented includes an impermeable sheet pile wall located down-gradient of the tailings, different from the groundwater diversion presented in the evaluation of options.

In 2019, Jacobs installed drive points, drilled boreholes, and installed monitoring wells at each drill location. Some of the wells were nested wells (either two wells drilled within close proximity to one another, or a second well added to an existing well location). The intention of nesting wells was to obtain groundwater and soil information from different depths (and potentially different geological or hydrogeological units) at the same location. In the case of wells nested beside existing wells, the wells were installed to determine the vertical extent of contamination.

The closure activities included installing a sheet pile wall, plugging the decant pipe, excavating and consolidating tailings, and installing a cap on the tailings. Following installation of the sheet pile wall, further investigations and assessments were completed. Following the 1998 Site visit, SRK designed a buttress to support the sheet pile wall and made recommendations regarding ponded water. A report dated May 1999 by EBA Engineering Consultants Ltd. documented repairs made to the access road, buttress construction, and the addition of more geotextile and drain rock to the TSF surface to manage standing water.

In 2013, Hemmera reviewed a decade of post-closure water monitoring at Venus. Based on the findings in the 2013 Hemera report, it is evident that increased concentrations of dissolved metals associated with acid rock drainage are present in both groundwater and surface water at the Site, suggesting that the TSF is not functioning as designed.

This data report summarizing field work completed is the sole deliverable for 2020 work at the Site. The 2019 scope did not include interpretation of the data, and as such, no conclusions or recommendations were made as a result of the investigations completed.

April 30, 2020

Crown-Indigenous Relations and Northern Affairs Canada  
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ISSUED FOR USE  
FILE: ENW.EENW03031-10  
Via Email: ron.gee@canada.ca

**Attention:** Ron Gee, P.Eng. – Senior Engineer (CIRNAC)  
Cc: Michael Bernardin – Project Manager (PSPC)

**Subject:** Results of 2019 Drilling Program and Dam Stability Update  
Venus Tailings Storage Facility, Yukon

## 1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the Government of Canada (Canada) to carry out a geotechnical drilling program and an updated evaluation of dam stability at the Venus Tailings Storage Facility (TSF), located south of Carcross, Yukon, at about km 86.5 on the South Klondike Highway (Yukon Highway No. 2).

The work was procured by Public Services and Procurement Canada (PSPC) via Standing Offer Agreement (SOA) EW699-170520/004/NCS, on behalf of Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC).

This letter presents the results of the fieldwork completed at the site in November 2019 and an updated slope stability assessment of the dam embankment.

## 2.0 BACKGROUND

Tetra Tech was retained by CIRNAC to carry out an assessment of the Venus TSF in 2018-19, which consisted of a technical review of geotechnical, hydrotechnical and environmental aspects of the dam design using existing information, in order to evaluate the TSF with respect to applicable guidelines provided by the Canadian Dam Association (CDA 2013, CDA 2014). Tetra Tech's Dam Assessment Report was Issued For Use to CIRNAC in April 2019 (Tetra Tech 2019).

The report included a geotechnical assessment of the TSF, which focused on the stability of the tailings dam and included a program of slope stability modeling using subsurface geotechnical information that was available in historical reports pertaining to the site.

The results of the slope stability modeling suggested that the dam meets applicable CDA criteria for slope stability under regular operating conditions but did not meet CDA criteria for seismic conditions. Significant uncertainty was noted with respect to practically all input parameters used in the slope stability modeling, including the subsurface stratigraphy of the native soils and geometry of the dam embankment at the site, material parameters of the various subsurface strata, and groundwater elevations throughout the site.

As a result, the dam assessment report recommended carrying out a geotechnical field program including geotechnical drilling, Cone Penetration Testing (CPT), laboratory testing, and installation of piezometers in order to resolve data gaps and facilitate an updated slope stability assessment with less uncertainty.

## 3.0 GEOTECHNICAL FIELD PROGRAM

### 3.1 Fieldwork

A geotechnical field program was carried out at the site between November 7 and November 14, 2019, in conjunction with other drilling work (by others) to install new monitoring wells at the Venus and Arctic Gold and Silver tailings sites. No work was done on some days during the field program due to equipment damage and breakdowns.

The geotechnical field program included drilling of boreholes using a sonic drilling rig operated by Metro Drilling (Metro) of Carcross, Yukon, and CPT soundings conducted by Gregg Drilling (Gregg) of Prince George, BC. CPTs were advanced using a hydraulic ram mounted on the sonic drilling rig. Metro and Gregg were retained by the Carcross/Tagish Energy Corporation (C/TEC), on behalf of CIRNAC.

Underhill Geomatics Ltd. (Underhill) of Whitehorse was retained by Tetra Tech to lay out the proposed borehole and CPT locations in the field, which are shown on Figure 1, attached.

Sonic boreholes were logged in the field by a geotechnical engineer from Tetra Tech's Whitehorse office, and representative disturbed samples were collected from the sonic core and by Standard Penetration Testing (SPT) and returned to Tetra Tech's Whitehorse laboratory for geotechnical index testing. It was noted in the field that SPTs were conducted with the SPT drop hammer suspended from a winch line on the sonic drill, which was difficult to keep plumb while conducting SPTs, and therefore the resulting SPT N-values (blow counts measuring penetration resistance) may be of limited use. Vibrating Wire Piezometers (VWPs) were installed and grouted into place in selected boreholes (see Figure 1) to provide ongoing measurements of porewater pressure in the ground.

Tetra Tech's field representative was also present during all of the CPT soundings, to monitor progress and to identify suitable depths to conduct porewater dissipation testing. Seismic shear wave velocity was measured in selected CPT soundings (see Figure 1).

It was not possible to complete the full scope of the proposed field program due to scheduling and budget constraints, as summarized below and illustrated on Figure 1. Elements of the field program that were not completed included the following:

- CPT19-01 encountered premature refusal at or near the base of the tailings and was not drilled out and re-attempted.
- Proposed sonic borehole BH19-02 was not drilled.
- Proposed sonic borehole BH19-03 was not drilled.
- Proposed sonic borehole BH19-04 was not drilled, which would have had two VWPs installed.
- Proposed sonic borehole BH19-05 was not drilled, which would have had one VWP installed.

The results of the drilling program are presented on the borehole logs and laboratory test results from the sonic drilling program, which are attached in Appendix B, and in Gregg's Cone Penetration Testing Report, which is attached in Appendix C.



# Interim Site Risk Management Human Health Risk Assessment

Venus Tailings Site

Final

Prepared for:

Carcross/Tagish Energy Corporation  
Suite #15 – 1114 Front Street  
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May 2020



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**Report Version Log**

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Draft (Rev 0)	April 29, 2020	e-copy to CTEC and CIRNAC
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## EXECUTIVE SUMMARY

Azimuth Consulting Group Partnership (Azimuth) has been working on behalf of the Carcross Tagish Energy Corporation (CTEC) to if environmental contamination associated with the former Venus mill and tailings storage facility (the Site) poses risks to human health and/or to the environment. The previous human health risk assessment for the Site, which is located 20 km south of Carcross, reported that concentrations of metals in soil pose unacceptable health risks based on long-term (chronic) exposure for people using the Site. Remedial options to address long-term health risks are in development. The timeline for remediation of the Site to conditions that are safe for human land use is likely several years away.

At the request of the Carcross/Tagish First Nation (C/TFN), Azimuth was tasked with determining if current Site conditions pose acute public health risks between now and when the Site is remediated. If conditions do pose a risk to the health of people accessing the Site during the interim period, additional risk management measures will be required to prevent unauthorized access to areas at Venus where contaminant concentrations pose unacceptable risks to human health.

### ***Acute Public Health Risk***

*If conditions pose an acute public health risk, additional risk management measures will be required.*

*Note: Acute exposure is defined as being exposed only once or being exposed repeatedly over a period no longer than 14 days.*

### **Current Risk Management Measures**

The Site is located adjacent to the Klondike Highway, which connects Skagway, Alaska with Carcross. Venus is one of the few places between Carcross and the BC border where vehicles can safely pull over, and the Site is a popular location for tourists to stop and take photographs of Tagish Lake and the surrounding scenery. Signs are located close to the highway and the edge of the tailings impoundment alerting the public that concentrations of arsenic in soil pose health risks. The signs have, on multiple occasions, been removed or torn down.

A temporary fence was constructed by the CTEC Land Stewards in 2019 to deter public access while also allowing wildlife to freely migrate between the upland area west of the Site and Tagish Lake. The fence does not reasonably restrict people from accessing areas at Venus by foot. Vehicle access to the tailings impoundment is further restricted by a concrete barricade on the gravel trail leading from the highway to the northern edge of the tailings impoundment.

The location of Venus on the shoreline of Tagish Lake means people can, and have, accessed the Site by boat. There are currently no signs located along the shoreline warning visitors arriving by boat or canoe that concentrations of metals on Site pose risks to human health.



### Site Use

Members of the C/TFN were surveyed in November 2019 regarding their past and present use of the Site. This information, along with other anecdotal evidence of public use of the area surrounding Venus, was used to develop exposure scenarios for assessing acute risks from site-related contaminants. The scenarios were broadly classified as either *unauthorized public access* or *authorized visits*.

*Unauthorized public access* was the catch-all term for any member of the C/TFN or general public accessing the Site without formal consent of the C/TFN. Members of the C/TFN that participated in the Site Use Survey indicated that Venus is located in an area that is culturally important.

Among the activities included in the questionnaire, berry picking, exploring, and boating were the most commonly-listed activities that respondents engage in at Venus. Adults and older teen-aged children were the age groups listed as most likely to visit the Site, but young children (under the age of 5) and infants were listed as likely to accompany adults on boating excursions to Site, wildlife viewing/hiking, and winter activities. Knowing that young children are potentially accompanying adults is important for the Interim Site Risk Management HHRA because children are, on average, more highly exposed to contaminants in the environment by virtue of their behaviour (in close contact with the ground) and their comparatively high rate of food and water ingestion relative to their body size.

#### ***Unauthorized Public Access vs Invited Public Visits***

*Unauthorized public access refers to people accessing the Site without consent from the C/TFN. Unauthorized public access includes all age groups, including young children.*

*Invited public access refers to people participating in Site visits for cultural or educational purposes under the direction of the C/TFN or CTEC. Authorized visits do not include young children because they are the age group most at-risk from being exposed to contaminants in soil.*

For the unauthorized public access exposure scenario, the critical receptors (most at risk) are children less than five years old.

*Invited guest visits* was included as an exposure scenario in the Interim Site Risk Management HHRA to provide the C/TFN with information on the potential risks to people who visit the Site for cultural and education purposes. Under this exposure scenario, we assumed that member(s) of the CTEC or C/TFN would be responsible for providing access and supervision while invited public are on Site, and that children less than 5 years old would not be included.

## Acute Health Risks and Recommended Interim Risk Management Measures

### *Approach*

Previous investigations at Venus showed arsenic is both the most wide-spread contaminant of concern in soils and that it is the contaminant that exceeds soil quality guidelines for protecting human health more than any other Site-related metals. Therefore, *assessing risks from exposure to arsenic* was used to assess whether current Site conditions pose acute health risks.

Implementing interim risk management actions based on risks from exposure to arsenic means that outstanding risks from other contaminants of potential concern (COPCs) will also be addressed.

### *Incidental Soil Ingestion*

Based on the available toxicological data, soil arsenic concentrations higher than 450 µg/g are enough to pose acute (short-term) health risks to children younger than 5 years old. The highest concentrations of arsenic are found in soils around the periphery of the former mill, soils near the tailings impoundment, and in sediment from the mud bench along the shoreline near Ditch Creek. Additional fencing is recommended to prevent unauthorized public access to areas where soil arsenic concentrations exceeded 380 µg/g.

Adults and older children visiting Venus as authorized guests for cultural, educational, or other C/TFN sanctioned events are at low risk of acute health effects from incidental soil ingestion. We recommend authorized group visits exclude children less than 5 years old because they are more likely to be in contact with soil and are more prone to frequent hand-to-mouth contact.

### *Dust Inhalation*

Acute health risks from dust inhalation were evaluated using 1-hour and 24-hour exposure scenarios assuming dusty conditions on Site, defined as the concentration of respirable particulate matter (PM<sub>10</sub>) equal to 250 µg/m<sup>3</sup>. The soil screening value for the acute dust inhalation pathway was calculated by dividing the air quality screening value for arsenic (0.2 µg As/m<sup>3</sup>) by the concentration of respirable dust under dusty conditions (250 µg/m<sup>3</sup>). The lowest soil arsenic air quality screening value was 800 µg/g (or parts per million) for 1-hour exposure.

Dust originating from areas on Site where arsenic concentrations are greater than 800 µg/g could pose health risks to people under dusty conditions if the duration of exposure is 1 hour or longer. Research on dust dispersion suggests people could be exposed to up to 250 µg/m<sup>3</sup> of dust as far away as 200 m from the source depending on the wind speed and direction.

We recommend that authorized group tours to the Site be avoided when conditions on Site are visibly dusty. The terrain at Venus is not conducive to vehicle use, but if ATVs are used for site tours, we recommend driving cautiously to avoid creating dust, particularly on the trail around the mill and the pathway leading from the highway to the tailings impoundment. The tailings impoundment cover was constructed with coarse rock and is not a significant source of fine particulate material that could become airborne during windy conditions.

Preventing people from continuous exposure to dust originating from the Site for 1 hour or more is the primary objective of risk management measures to protect the public against acute health effects caused by dust inhalation. General public exposed to dust for a few minutes while driving past the Site or stopping to take photographs are not at risk of acute health effects.

People living at the private property located north of the Site may be intermittently exposed to dust originating from areas on Site with high arsenic concentrations during windy conditions. The duration of exposure, and ensuing health risks, are likely low. However, in the absence of site-specific data regarding the extent and magnitude of off-site dust migration at Venus, potential health risks to people on the property cannot be ruled out.

#### *Vegetation for Country Foods and Traditional Medicines*

Arsenic concentrations measured in raspberry samples from the periphery of the tailings impoundment are high enough to pose acute health risks if adults consume more than 150 g of berries in one day. Children under the age of 5 may be at risk if they eat more than 35 g of berries in a single day. We advised against harvesting berries and other plants for consumption as country foods or traditional medicines from anywhere at Venus until the distribution and concentration of arsenic (and other metals) in vegetation consumed as country foods or used for traditional medicines is better understood.

Installing additional fencing to restrict public access to areas where soil arsenic is greater than 380 µg/g will also limit access to areas of the Site for collecting berries and other country foods/traditional medicines (e.g., *Equisetum*; see photo).





### *Drinking Water Consumption*

Water quality guidelines that address acute risks from inorganic substances in the short term are not well developed. To our knowledge, only nitrate, nitrite, and copper have guidelines meant to protect against potential effects from short-term exposure. Surface water collected from Tagish Lake is safe to drink, as concentrations of metals are typically below chronic (long-term) guidelines

for the protection of human health. There are, however, potential health risks associated with people drinking water from Ditch Creek, which is partly made up of runoff from the tailings impoundment (see photo). We recommend installing warning signs near Ditch Creek advising people to avoid drinking water originating from sources flowing on Site.

### *Summary*

Venus will eventually be remediated to ensure that human exposure to residual environmental contamination will not present a public health risk. In the interim period, it's imperative that unauthorized access to the Site be restricted to prevent potential health risks from acute exposure to contaminants:

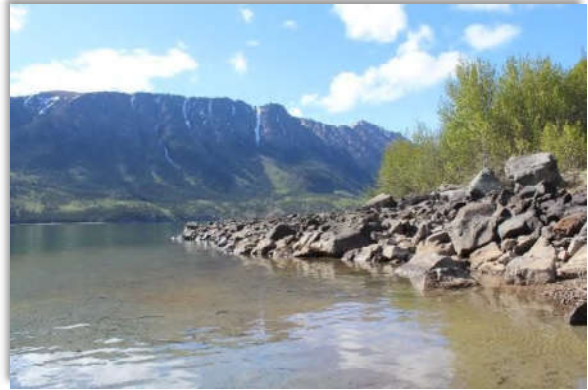
- Children less than five years old must be prevented from contacting arsenic-contaminated soil or sediment at the Site in excess of 380 µg/g, even for very brief periods of time.
- Children and adults must be prevented from inhaling airborne dust from arsenic-contaminated soil at the Site in excess of 800 µg/g for durations of 1 hour or longer.

It is ultimately up to C/TFN and CTEC, in consultation with Federal and Territorial agencies, to determine the most suitable risk management actions to restrict public access to Venus and prevent exposure to contamination that poses plausible acute health risks. Such risk management actions may include:

- Installing a secure fence and gate to prevent the public from accessing arsenic-contaminated soil and sediment at the Site
- Implementing policies and procedures to prevent children less than five years old from visiting the Site and to prevent invited older children and adults from being exposed to dusty conditions at the Site



- Installing warning signs at areas where people are likely to access the Site by boat, in particular the mud bench area (see photo) near the outlet of Ditch Creek
- Installing pilings or other physical structures to prevent or dissuade people from landing a boat at the mud bench area near the outlet of Ditch Creek





# Annual Environmental Monitoring Summary Report (April 2021 to March 2022) Venus Mine, Carcross, Yukon

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Appendix E	Monitoring Plan

## LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
ARD	Acidic Rock Drainage
ASTM	American Society for Testing and Materials
AW	Aquatic life water use
CCME	Canadian Council of Ministers of the Environment
CIRNAC	Crown Indigenous Relations and Northern Affairs Canada
COC	chain of custody
COPC	contaminants of potential concern
C/TFN	Carcross Tagish First Nation
C/TMC	Carcross/Tagish Management Corporation
DO	dissolved oxygen
DP	Drive points
DW	Drinking water use
FAL	Freshwater aquatic water use
FIGQG	Federal Interim Groundwater Quality Guidelines
HASP	Health and Safety Plan
kPa	Kilopascal
L	Litre
LDL	Laboratory detection limit
L/s	Litres per second
m	Metres
m bgs	metres below ground surface
masl	metres above sea level
NM	Not measured
ORP	oxidation-reduction potential
PPE	Personal Protective Equipment
Q	Discharge
QA/QC	Quality Assurance/Quality Control
RPD	relative percent difference
Salt	Sodium and chloride
SPC	Specific conductivity
TDS	Total dissolved solids
TSS	Total suspended solids
TWA	Time weighted average
VWP	Vibrating wire piezometer
YCSR	Yukon Contaminated Sites Regulations

## 1.0 INTRODUCTION

Hemmera was retained by Crown Indigenous Relations and Northern Affairs Canada (CIRNAC) to complete the 2020-2022 monthly environmental and geotechnical monitoring programs at Arctic Gold and Silver (AGS) and Venus abandoned mine sites. Both mines are in their closure phases, and the associated monitoring and maintenance requirements are managed by CIRNAC. This report summarizes the objectives, scope, deliverables, and methodologies that were used to carry out the program between April 2021 and March 2022 at the Venus mine in Carcross, Yukon (the Site). An evaluation of temporal and spatial trends in groundwater and surface water quality is also provided.

The Venus mine is in the traditional territory of the Carcross Tagish First Nation. The Site is located at Zone 8N, 6656042 North and 522574 East, approximately 22 km south of Carcross, Yukon, on the east side of the South Klondike Highway and adjacent to the edge of Windy Arm, Tagish Lake (Windy Arm). The general Site layout is shown in **Figure 1**. Photographs from the monitoring events are provided in **Appendix A**.

Mining-related activity at the Venus mine commenced around 1904. Several punctuated stanzas of mining occurred (1904-1912; 1916-1920; 1966-1971; 1979-1981) and the mine produced silver and gold, with minor amounts of lead, zinc and cadmium. The major portion of mine tailings that occur on site were from milling activities in the last operational period. The mill was dismantled during the late 1980s and early 1990s. The major residual feature of the mine site is the tailings deposit.

Mineralization around Venus mine includes irregular bands and pods of pyrite, arsenopyrite, galena and sphalerite, with minor amounts of tetrahedrite and chalcopyrite. The deposits are typical of polymetallic sulphide mineralization, and the Venus mine tailings have been found to be net acid generating. Analysis of the Venus tailings showed that they contain very high levels of sulfide minerals (3 to 20%), very high arsenic concentrations (2.5 to 7% of solids by mass) and various metals that may be important in the context of water quality - such as cadmium, lead and zinc, and to a lesser degree cobalt and nickel. It has been estimated that approximately 54,000 tonnes of tailings are being risk-managed on-site.

In 1995, the rehabilitation of the Venus mine tailings was initiated with the major works comprising the in-place containment of the tailings. The 1.5 ha containment cell consists of a sealed Waterloo Barrier Sheet Pile Wall on the downgradient side of the tailings deposit toward the lake, and a cap constructed over the top of the deposit. The cap consists of a geotextile membrane over top of the tailings, capillary break material, and a silty-clay cap. To control the surface runoff within and above the capping material, a drainage discharge system was installed.

This report is the latest in a series of post-rehabilitation monitoring reports.

This Work was performed in accordance with Contract number 4500413475 between Hemmera Envirochem Inc. (Hemmera), a wholly owned subsidiary of Ausenco Engineering Canada Inc. (Ausenco), and Crown Indigenous Relations and Northern Affairs Canada (Client), dated July 17, 2020 (Contract). This Report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for sole benefit and use by Crown Indigenous Relations and Northern Affairs Canada. In performing this Work, Hemmera has relied in good faith on information provided by others and has assumed that the information provided by those individuals is both complete and accurate. This Work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings

presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the Report was produced. The conclusions and recommendations contained in this Report are based upon the applicable guidelines, regulations, and legislation existing at the time the Report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

## 1.1 Objectives

Hemmera was retained by CIRNAC to conduct a monthly monitoring and sampling program for surface water and groundwater quality, air quality and geohazard/geotechnical monitoring at the Site from August 2020 to March 2022. The purpose of the monitoring and sampling program is to monitor water quality (surface and groundwater), groundwater levels, surface water flow, air quality and geohazard/geotechnical conditions at the Site. This report summarizes the results of the monitoring program from April 2021 to March 2022.

## 1.2 Scope of Environmental Monitoring

The Site monitoring tasks and methods used are described in detail in the 2020/21 Monitoring Plan developed by Hemmera in August 2020 (Hemmera, 2020; attached in **Appendix E**). Departures from the scope of work are outlined in **Section 3.3.8**. The following activities were carried out during the April 2021 to March 2022 portion of the sampling program.

### Groundwater monitoring:

- Measuring groundwater levels in wells and drive points.
- Inspection of monitoring wells for damage/assessing needed repairs.
- Purging and sampling of monitoring wells and drive points.
- Measuring and recording field parameters (water temperature, pH, conductivity, oxidation-reduction potential [ORP] and dissolved oxygen [DO]).
- Collecting groundwater samples from each location for laboratory analysis.
- Downloading data from data loggers and processing data for plotting of groundwater levels.

### Surface water monitoring:

- At drive point locations installed in surface water, measuring the depth to surface water on the outside of the drive point.
- Measuring field parameters (water temperature, pH, conductivity, ORP, turbidity and DO).
- Collecting surface water samples from each location for laboratory analysis.
- Obtaining flow measurements at the diversion pipe outlet to Ditch Creek.

### Groundwater seeps:

The scope of work for the groundwater seep survey included a visual survey of the groundwater discharge area along the shoreline of Windy Arm. Where possible, the following were obtained:

- Field parameters (water temperature, pH, conductivity, ORP and DO).
- Visually estimated flow rate.
- GPS coordinates.
- Representative photographs.

### **Air quality:**

The scope of work for air quality monitoring included a minimum of one personal air quality monitoring device collecting real-time particulate matter concentrations to determine the need for an enhanced Personal Protective Equipment (PPE) program. Air quality monitoring was not performed when the Site was covered with snow or when it was raining, as it is assumed to be a very low potential for workers to be exposed to airborne particulates under such conditions.

### **Geotechnical considerations:**

Visual geohazard/geotechnical inspections were conducted during each monitoring event. The inspections were completed by field staff under the direction of a senior geotechnical engineer. Field staff documented any critical observations, and the results were reviewed by a senior geotechnical engineer.

The scope of work for geotechnical borehole monitoring included utilizing an RST VW2106 vibrating wire readout device and recording the vibrating wire piezometers (VWPs).

## **2.0 MONITORING STATIONS**

Observations and sampling (where and when feasible) were conducted on 17 groundwater monitoring wells, 9 drive points (DP), and 11 surface water monitoring stations. Two geotechnical boreholes were visited as part of the program. A list of the monitoring stations with a description and geographic coordinates are provided **Appendix B** (Tables B1 to B4). Monitoring stations are shown in **Figure 1**.

## **3.0 METHODS**

The methods used to carry out the monitoring program during the April 2021 to March 2022 period are described in the following subsections.

### **3.1 Health and Safety**

Hemmera developed a site-specific Health and Safety Plan (HASP) for the monitoring program prior to completing any monitoring events. At the beginning of each field day, a tailgate meeting was carried out to review the scope for the day and any health and safety concerns specific to the program. No health and safety incidents occurred at the Venus mine during the April 2021 to March 2022 monitoring period:

### **3.2 Field Schedules and Staff**

Monitoring events were carried out monthly between April 2021 to November 2021, and in January and March 2022 by Hemmera and Carcross/Tagish Management Corporation (C/TMC) staff at the Venus mine as shown in **Table A**.

The following scope of work was completed for each monitoring event:

- Sampling of all groundwater and surface water sites that had sufficient volumes of water and were not frozen.
- Completion of geotechnical inspections.