Mine Closure 2011 — A.B. Fourie, M. Tibbett and A. Beersing (eds)

doi:10.36487/ACG_rep/1152_117_Wingrove

Former Clinton Creek asbestos mine

T.R. Wingrove *AECOM Canada Ltd., Canada*

G. Robinson *Dyregrov & Robinson, Inc., Canada*

R. Aslund *AECOM Canada Ltd., Canada*

B.W. Hartshorne *Yukon Government, Canada*

Abstract

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City in the Yukon. The site lies 9 km upstream of the confluence of Clinton Creek with the Forty Mile River. From 1968 until depletion of economic reserves in 1978, approximately 12 million tonnes of serpentine ore was extracted from the bedrock in three open pits. Over 60 million tonnes of waste rock from the open pits was deposited over the south slope of the Clinton Creek valley at what is referred to as the Clinton Creek waste rock dump. Over the same period of time, about 10 million tonnes of asbestos tailings from the milling operation were deposited over the west slope of the Wolverine Creek valley.

Since closure of the asbestos mine, concerns have been raised with respect to the physical conditions of the site, in particular downstream hazards associated with potential channel blockages resulting from landslides of the Clinton Creek waste rock dumps and Wolverine Creek tailings piles.

Qualitative assessment of risk scenarios and human and ecological exposure levels associated with the site conditions have been completed. The greatest risk at the site is the potential for loss of life immediately downstream of the mine site in the area potentially inundated by a breach of the waste rock pile, or within the Wolverine Creek valley in the event of a breach of a tailings blockage.

Channel stabilisation measures have been undertaken to better manage the outflow of water from Hudgeon Lake but continual creep movements of the waste rock threaten the long term integrity of these measures. Regular inspection, assessment and maintenance of the channel control structures are undertaken. All surface infrastructure has been demolished to remove some of the physical safety hazards. This paper will discuss the performance of the interim mitigation measures and present some of the closure actions that are being considered to provide a more permanent and higher level of protection against the identified risks at the site.

1 Background

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City, Yukon, 9 km upstream of the confluence of Clinton Creek with the Forty Mile River (Figure 1). The mine site is located within the unglaciated Yukon-Tanana Upland Region. Bedrock in the area consists of black argillite that was exposed to periglacial weathering. Near-surface material is heavily fractured and weathered. The serpentine ore body in the Porcupine Open Pit strikes NE and dips to the NW at approximately 45 degrees. Very little site-specific information exists with respect to permafrost conditions at the mine site. The mean annual temperature is –2.5°C, ranging on average from 15°C in the summer to –32°C during the winter. Previous research indicates the area consists of wide spread permafrost distribution up to 60 m thick and the active layer was reported to be 0.3 to 0.5 m thick.

Figure 1 Key plan (source – Google Maps)

The mine consisted of three open pits, two waste rock dumps and a tailings pile (Figure 3). From 1968 until depletion of economic reserves in 1978, the Cassiar Mining Corporation extracted approximately 12 million tonnes of serpentine ore from the bedrock. Over 60 million tonnes of waste rock from the open pits was deposited in the waste rock dumps. The ore was transported by an aerial tramway to the mill site located on a ridge along the west side of Wolverine Creek. Over the same period of time, about 10 million tonnes of asbestos tailings from the milling operation were deposited over the west slope of the Wolverine Creek valley.

2 Summary of site concerns

2.1 Clinton Creek waste rock dump

A significant slope failure of the waste rock dump into the Clinton Creek valley occurred in 1974 (Stapanek, 1992). Figure 2 shows the valley before the landslide. The resulting landslide dam blocked natural drainage through the valley creating a 74 ha lake (Hudgeon Lake) (Figure 3). Stability analysis indicates a weak foundation material is contributing to the continued creep movements of the waste rock dump. The loss of strength may be related to a number of geological conditions unique to the site including ice content, soil type and the relationship between the rate of thawing and dissipation of excess pore-water pressures. It is likely that disturbance to the thermal regime, in particular thawing of permafrost beneath the dump, has resulted from filling of the upstream reservoir (Hudgeon Lake).

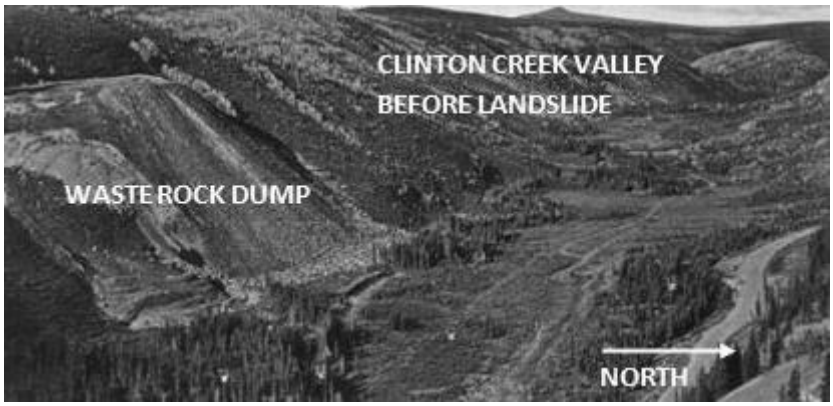

Figure 2 Clinton Creek valley before landslide

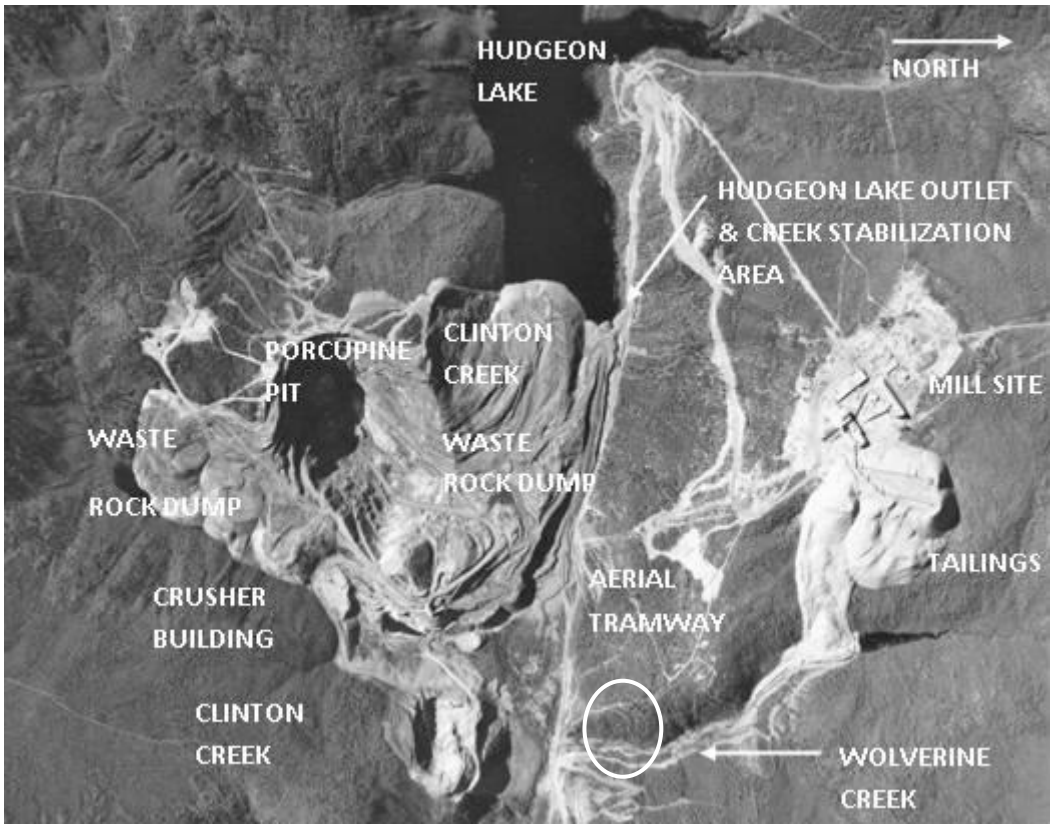

Figure 3 Mine site plan (1976)

2.2 Breach potential of the Hudgeon Lake outlet

Progressive erosion of the Clinton Creek channel immediately downstream of and towards the Hudgeon Lake outlet increased the likelihood of the development of a breach of the landslide dam (UMA, 2000). Following the spring 1997 flood event when the original erosion control works were effectively destroyed, a breach at the lake outlet could have been triggered at any time and was not considered susceptible to any particular precipitation event, i.e. a relatively minor inflow could trigger the failure mechanism necessary to initiate a breach.

The U.S. National Weather Service (NWS) FLDWAV model was used for the waste rock pile dam breach analysis. It was determined that a breach of the waste rock blockage at the Hudgeon Lake outlet would result in a peak discharge of approximately 500 m^3/s and a maximum flow velocity of about 4 m/s. The flood peak quickly attenuates however, reaching a base flow level at the valley constriction downstream of Wolverine Creek.

2.3 Public safety related to dam breach

In terms of public safety, the level of risk downstream of the mine site was categorised as high, medium or low based on the severity of flooding in each zone (Figure 4).

- *High Hazard Zone:* Potential injury, loss of life and destruction of property.
- *Medium Hazard Zone:* Risk to human life considered low. Sufficient warning period is likely and high ground readily available. Possible loss of property or access road in low lying areas.
- *Low Hazard Zone:* No anticipated injury, loss of life or property loss.

The inherent risk to humans and the potential for loss-of-life is dependent upon the likelihood of exposure (occupancy) within these zones. The potential for loss-of-life is greatest immediately downstream of the mine site in the area potentially inundated by a breach of the Hudgeon Lake outlet. Farther downstream along Clinton Creek, the risks are reduced, as the high water levels will be confined to the creek valley below

the mine access road where human exposure is less likely. The risk is considered low at the next most likely downstream area of occupancy in the vicinity of the former Clinton Creek town site where the valley widens considerably.

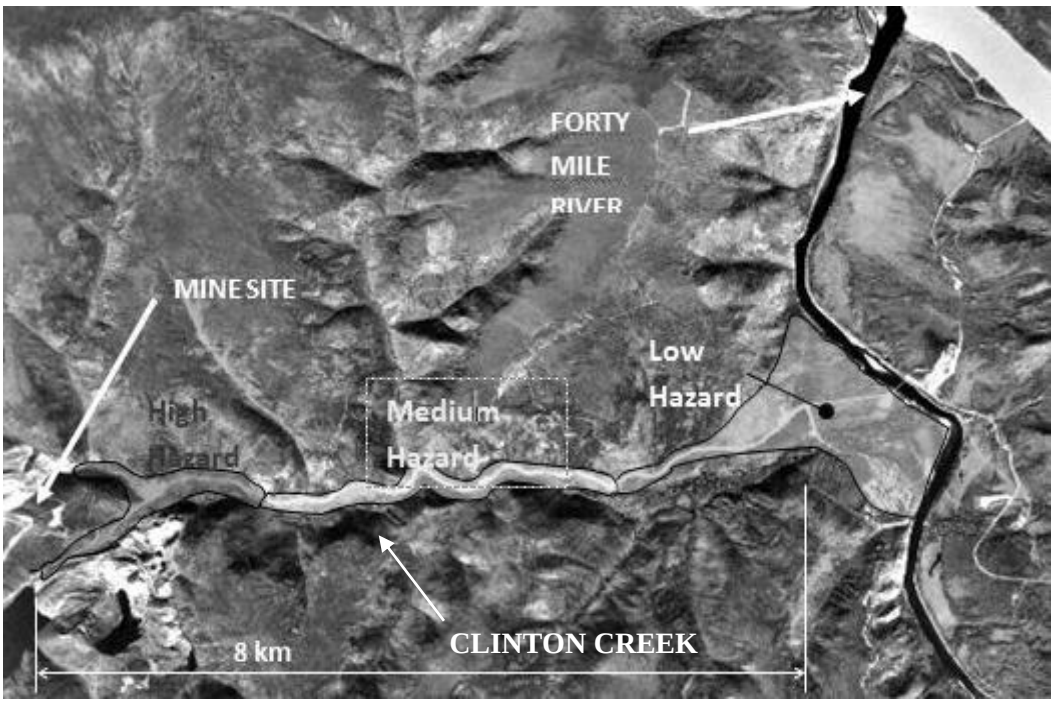

Figure 4 Downstream hazard mapping

2.4 Ecological and health risks

The Clinton Creek Mine was shut down without any appreciable detailed closure planning. In addition to concerns associated with the failure of the waste rock dump and blockage of the former Clinton Creek valley, important residual mine site features included three, steep-walled open pits, a waste rock deposit in the Porcupine Creek valley, the asbestos tailings deposit (made up largely of fibres plus crushed host rock that were shorter than desired for subsequent manufactured materials), a large mill, and industrial complex.

Major issues of concern fall into two major categories: (i) physical hazards; and (ii) chemical/toxicological hazards. Concerns regarding chemical / toxicological hazards at the site arise from two site characteristics.

The extent of historical mine workings and deposits could affect Clinton Creek and two major tributaries: Wolverine Creek, the channel of which intersects the toe of the tailings deposit; and Porcupine Creek, which is potentially affected by two open pits and a waste rock dump. Several studies of fish and invertebrate life in the Clinton Creek system have been completed since 1998. The overall results to date (RRU, 1999; UMA, 2004) indicate that the aforementioned metals/metalloids are poorly soluble, and are not found in water courses at concentrations in excess of Canadian water quality guidelines for freshwater life protection. Nor are the metals/metalloids of concern found in elevated concentrations in fish tissues in comparison with reference samples from lower reaches of the Forty Mile Creek.

An assessment of human health risks associated with asbestiforme fibres in surface soils was completed in 2003–2005 based especially on an air monitoring program. Data on airborne fibre characteristics (type and fibre length distributions) and concentrations were gathered for: (i) heavy equipment operators and workers involved in reconfigurations to waste rock, in construction of the gabion drop structures at the Hudgeon Lake outlet, and in mill infrastructure and other demolition work; (ii) site investigators walking around various areas of the site (representative of a casual, recreational site visitor); and (iii) personnel moving around the site using all-terrain vehicles (ATVs). The expected inhalation exposures were quantified for these three higher risk activities using personal air samplers set at a flow rate of 2.5 L/min. In addition, stationary air samplers (Q = 2.5 l/min) were set up at various Site locations. More than sixty air samples were collected (UMA, 2006). Using the average observed airborne concentration measured during the air sampling

programme, and assuming an individual would be exposed for up to 20 years, for three months per year (i.e. during the snow free summer-time period) for 8 h/d, the estimated incremental lifetime cancer risk was estimated to be 2 x 10-5. Overall, it was concluded that human health risks associated with asbestos inhalation would be negligible for a non-residential type exposure.

3 Creek stabilisation measures

Based on evidence of ongoing deterioration of the Clinton Creek Channel downstream of the Hudgeon Lake outlet, the implementation of remedial measures, i.e. creek stabilisation, was considered necessary. Because the waste rock is still undergoing creep movements, and may do so for many more years, the channel stabilisation measures had to be able to accommodate some movements of the waste rock pile and remain functional. This design requirement was met through the use of gabion drop structures that serve as grade control points connecting nearly flat channel sections (UMA, 2003). The waste rock movements are being monitored along with the measurements of the gabion drop structures to determine if the channel stabilisation works are being impacted.

In 1999, the movement monitoring programme for the Clinton Creek waste rock dump was re-established and the results confirmed observations made shortly after mine closure that the movement rates of the waste rock dump were decreasing over time. Subsequent monitoring events reveal that the waste rock is creeping in a northward direction at rates of about 5 to 7 cm per year.

Gabion drop structures (i.e. grade control structures) were selected over rigid structures (e.g. concrete) because they are flexible enough to allow some deformation while remaining structurally sound and fully functional, an important consideration given the observed creep movements of the waste rock (Figure 5).

Figure 5 Completed channel stabilisation works (2004)

4 Site inspection

The site is regularly inspected to:

- Visually inspect the gabion drop structures at the Hudgeon Lake outlet and the downstream reaches of the Clinton Creek Channel.
- Measure the horizontal distances across each drop structure.
- Inspect the former Mill site for signs of subsided backfill placed during the demolition work in 2004.
- Visually inspect the rock lined channel on Wolverine Creek.

- Inspect the portion of the tailings pile lobes along Wolverine Creek.
- As time permits, inspect the Porcupine Creek open pit and waste rock dump.

In August of 2010 there was a period of intense rainfall that produced extraordinary flows in Clinton Creek. Extensive erosion and channel downcutting occurred. Drop Structure 4 (DS#4) was partially damaged (Figures 6 and 7) and will be repaired. This event reinforced the effectiveness of the four drop structures in protecting against a breach of the Hudgeon Lake Outlet (AECOM, 2011b).

Figure 6 Clinton Creek Channel d/s of DS#4 on August 23, 2010

Figure 7 Clinton Creek Channel – DS#4 on August 23, 2010

5 Performance monitoring

The monitoring work (AECOM, 2011a) consists of surveying the movement monitors on the Clinton Creek waste rock dump, at the drop structures and on the Wolverine Creek tailings pile, surveying channel profiles of Clinton Creek and Wolverine Creek and surveying cross-sections at two locations on each drop structure. Horizontal measurements across each drop structure are also collected.

5.1 Waste rock movements

The Clinton Creek waste rock dump continues to undergo creep movements ranging from nil up to 0.08 m per year. In general, the movements measured for the 2 year period ending in July 2010 are the same or slightly higher than the previous monitoring period (2006 to 2008). The results from the 2 month monitoring period from July to September 2010 suggest that the August precipitation event and associated erosion along the toe of the waste rock resulted in additional movements of the waste rock pile. Figure 8 illustrates the direction and magnitude of waste rock movements.

In general, the monitoring data suggest the western area of the waste rock dump nearest to Hudgeon Lake is moving in a westerly direction towards the lake and the main mass of the waste rock dump is moving in a northerly direction across Clinton Creek.

The waste rock continues to close in on the stabilised section of the creek channel at a rate of about 0.05 m/yr. While movement rates to the end of July 2010 are similar to those previously reported, it is expected that the integrity of the gabion drop structures will eventually be compromised unless stabilisation measures for the waste rock dump are implemented. Alternatively, the gabion structures can be replaced or repaired as required in the future to restore their functionality. While movements of the mid and lower slope areas of the waste rock pile downstream of the gabion drop structures are erratic, they are of no consequence to the drop structures.

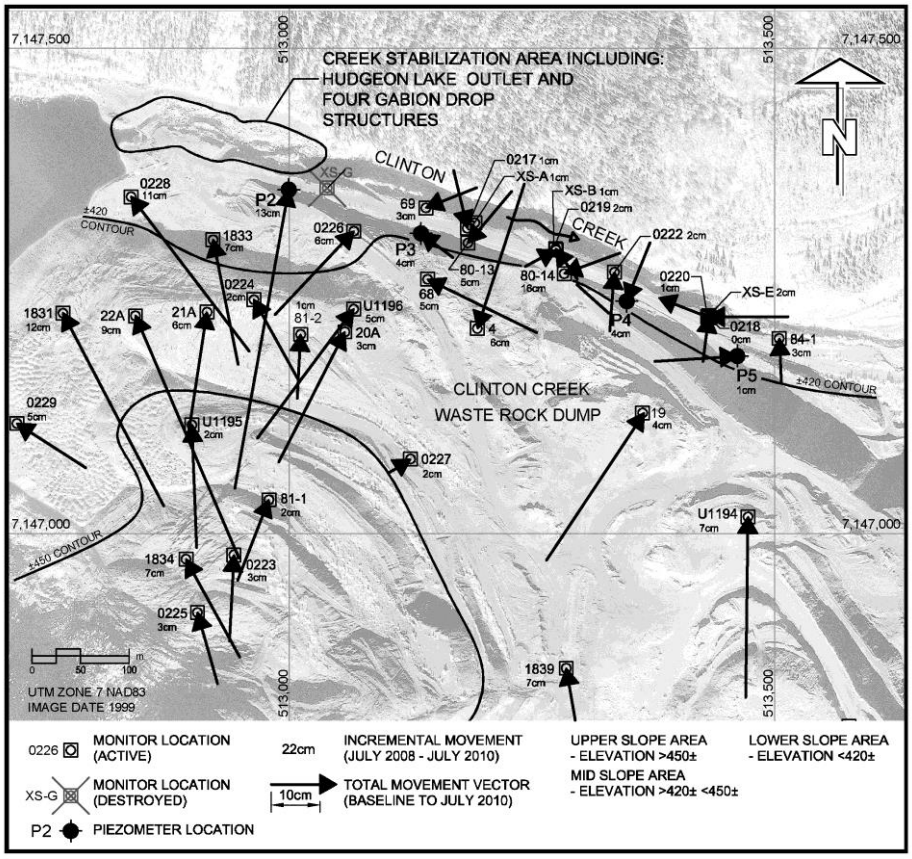

Figure 8 Clinton Creek waste rock dump – July 2008 to July 2010 movement monitoring

5.2 Gabion drop structures

The changes in the horizontal measurements taken at the gabion drop structures are at least partially a result of continued waste rock movements. In general, the side slope angle has not been impacted by the waste rock movements and is still well below the trigger level of 2H:1V sideslopes and the 2.01 m flow depth is still within the channel cross-section.

5.3 Tailings movement

The small movement rates on the upper slope area of the South Lobe are not unexpected because the original landslide did not encompass much of this area, which may be due to a decrease in the inclination of the underlying valley slope above elevation 530 m. The flatter valley slope feature is visible on aerial photographs taken before mine site development (UMA, 2003). The mid and lower slopes are most active since these areas are coincident with the main area of the original landslide which occurred in 1974 (UMA, 2003). As the tailings mound up in the valley bottom (i.e. lower slope area), the movement rates in the mid-slope area may continue to decrease as toe support due to mounding increases (Figure 9).

Figure 9 View of Wolverine Creek and lower portion of tailings lobes

The movement rates for the North lobe are less than those measured for the South lobe. The average horizontal movement rates for the upper, mid and lower slope areas of the North Lobe for the monitoring period (July 2008 to July 2010) are 0.03, 0.06 and 0.05 m/yr, respectively. The rates are the same or less than those for the previous monitoring period (2005 to 2006) by about 0.0, 0.04 and 0.02 m/yr, respectively. The upper slope is the least active area, consistent with previous monitoring data, with movement rates ranging from 0.01 to 0.10 m/yr.

6 Long term options

The extreme precipitation event in August of 2010 was a reminder that the works completed at Clinton Creek are very much interim in nature. It was requested that a review of options to provide a more permanent closure of the site be undertaken including identification of advantages, disadvantages, risks, uncertainties and costs to enable decision makers to consider if additional efforts should be expended at the site. This work focused on Clinton Creek, the waste rock pile, Wolverine Creek and the tailings – recognising that actions at one site feature may well be inter-dependent with adjacent features. An initial list was developed and then shortened to prioritise those options which seemed to be the most appropriate.

Table 1 Qualitative assessment of options

Option	Description	Protect Human Health and Safety		Primary Objectives			Technical Challenges and Liabilities				
		On-site	Down-stream	Enables Original and Traditional Use of Land	Maximises local, Yukon and FN Benefits from Work	Manage, Reduce or Eliminate Risk and Liability	Construct-ability Challenges	Design Issues	Uncertainty	Long-Term Maintenance	Lifecycle Costs and Effort
CC-1	Status quo-maintain gabion drop structure	Med	Med	Low	Low	Med	Minor	Minor	Mod	Sig	Sig
CC-2	Armoured channel over the waste rock	Med	Med	Low	High	Med	Minor	Minor	Sig	Sig	Sig
CC-3	Tunnel through bedrock	Low	Med	Low	Low	Med	Sig	Sig	Sig	Mod	Mod
CC-4	Armour existing channel	Med	Med	Low	Med	Med	Sig	Minor	Mod	Sig	Sig
CC-5	Lower existing channel to bedrock	Med	Med	Med	Med	High	Mod	Mod	Mod	Minor	Minor
CC-6	Restore to valley bottom	High	High	High	High	High	Sig	Sig	Mod	Minor	Minor
CC-7	Leave as is - no annual maintenance	Low	Low	Low	Low	Low	Minor	Minor	Sig	Minor	Minor
CC-8	Rock trench with overflow channel	Med	Med	Low	High	Med	Sig	Sig	Sig	Mod	Mod

Ratings:

High: Satisfies primary objective.
Medium (Med): Partially satisfies primary objective.
Low: Does not meet primary objective.

Significant (Sig): Option has major challenges or significant cost.
Moderate (Mod): Option has moderate challenges that can be addressed.
Minor: Option has challenges that are easily addressed.

Table 1 is an illustration of the approach to presenting a list of potential options to address the flows in Clinton Creek and assessing each option against objectives, with the most important objective being the protection of human health and safety. Design and construction challenges were scored on a relative scale. Uncertainties were evaluated and costs estimated.

Figure 10 illustrates how the interaction between adjacent features was presented for maintaining the status quo of the gabion drop structures in Clinton Creek.

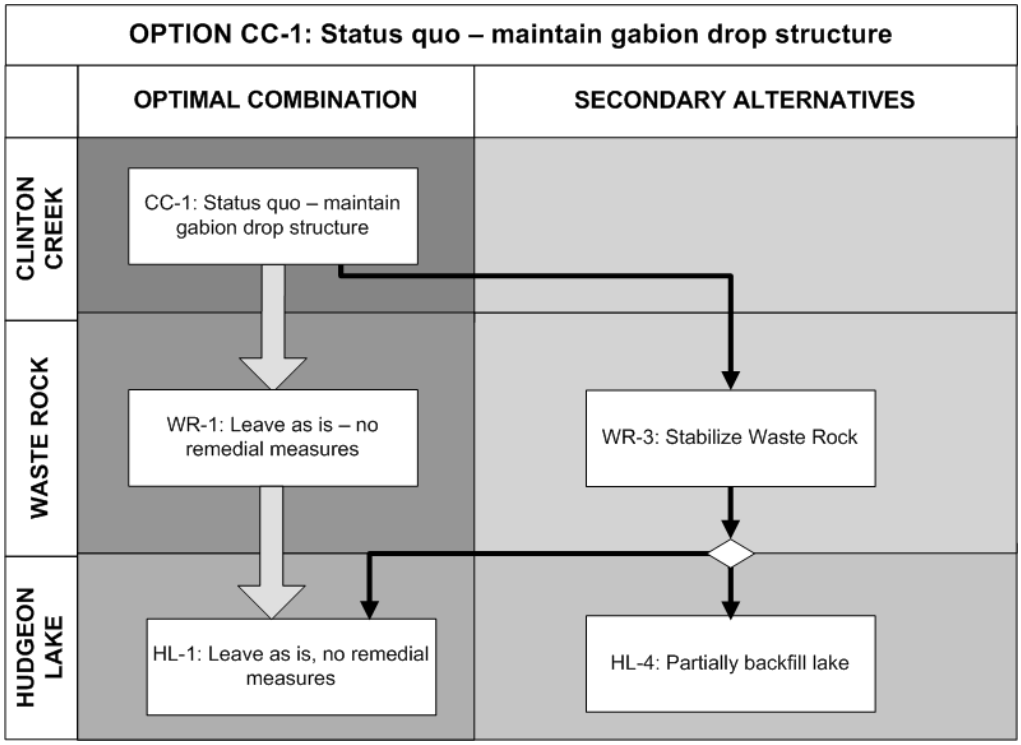

Figure 10 Alternatives for waste rock and Hudgeon Lake that are compatible with Option CC-1

Discussion of Option CC-1 status quo – maintain gabion drop structure:

Hudgeon Lake would be maintained at its current elevation if no other changes are made because the lake level is controlled by Drop Structure #1. The lake level could be lowered by removing individual steps or entire drop structures proceeding downstream from the Hudgeon Lake outlet.

Advantages:

- Proven, simple, available and relatively inexpensive technology.
- Drop structures are already constructed, i.e. no capital expenditures are required.

Disadvantages:

- The existing gabion structures have required significant maintenance twice in the seven years of operation. Similar maintenance requirements should be anticipated in the future.
- Gabions are susceptible to undercutting due to downstream erosion.
- Does not prevent further downcutting of channel downstream of existing drop structures.

Risks and uncertainty:

- Flows from Hudgeon Lake due to extreme weather events, such as the storm in August 2010, can cause significant damage to gabion structures.
- The gabions are squeezing together with time due to waste rock creep movements which is expected to gradually decrease the capacity of the channel.

Technical considerations for detailed design:

- Durable rockfill should be chosen to improve long term performance of the gabions.
- Consider lowering Hudgeon Lake to reduce the number and drop across the gabion structures.
- Waste rock dump should be stabilised to reduce the ongoing squeezing of the structures.

7 Closure

The legacy of the operation of the former Clinton Creek Asbestos Mine is that it left a mix of challenging site conditions that represent a real risk to human health and safety as well as the ecological environment and for which there is no responsible party. Studies commissioned by Government lead to the construction of interim creek stabilisation measures to guard against a sudden and catastrophic breach of Hudgeon Lake. Events of 2010 demonstrated the value of these works but also reinforced the vulnerability of the site to extreme weather events. Routine performance monitoring also demonstrates that movements of the waste rock and tailings continue. At a minimum, creep of the waste rock will continue to squeeze the gabion structures creating a need for repairs and possibly replacement. There is a desire to seriously consider all options that might virtually eliminate the risk to human health and at least reduce the future requirement for regular maintenance and inspection. These actions have been evaluated against a broad set of objectives for any actions from maintaining the status quo to stabilising the waste rock. This options assessment is intended to allow Government and stakeholders to make decisions on the future of the former Clinton Creek Asbestos Mine site.

References

AECOM Canada Ltd. (2011a) Former Clinton Creek Asbestos Mine: Long Term Performance Monitoring – 2010. April 2011.

AECOM Canada Ltd. (2011b) Former Clinton Creek Asbestos Mine: 2010 Site Inspection. April 2011.

RRU (1999) Royal Roads University – Applied Research Division. An Environmental Review of the Clinton Creek Abandoned Asbestos Mine.

Stapanek, M. and McAlpine, H.F. (1992) Landslide Dams at Clinton Creek. In Geotechnique and Natural Hazards, Bitech Publishers, Vancouver, BC, pp. 291–298.

UMA Engineering Ltd. (2000) Abandoned Clinton Creek Asbestos Mine Risk Assessment Report.

UMA Engineering Ltd. (2003) Abandoned Clinton Creek Asbestos Mine Environmental Liability Report. June, 2003.

UMA Engineering Ltd. (2004) Government of Yukon, Former Clinton Creek Asbestos Mine – Hazard Assessment Report - June 2004.

UMA Engineering Ltd. (2006) Government of Yukon, Former Clinton Creek Asbestos Mine – Summary of 2004 Hazard Mitigation Work, Monitoring and a Screening Level Risk Assessment for Airborne Asbestos – March 2006.