Environment AECOM

Government of Yukon

Clinton Creek Technical Options Assessment

Prepared by:

AECOM
99 Commerce Drive 204 477 5381 tel
Winnipeg, MB, Canada R3P 0Y7 204 284 2040 fax
www.aecom.com

Project Number:

60191772 (402.19)

Date:

July, 2011

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AECOM
AECOM
99 Commerce Drive
Winnipeg, MB, Canada R3P 0Y7
www.aecom.com
204 477 5381 tel
204 284 2040 fax

July 7, 2011

Mr. Brett Hartshorne
Government of Yukon
Assessment and Abandoned Mines Branch
Department of Energy, Mines and Resources
4114 – 4th Avenue, Room 2C
Whitehorse, Yukon Y1A 1H9

Dear Sir:

Project No: **60191772 (402.19)**
Regarding: **Clinton Creek Options Assessment**

AECOM Canada Ltd. (AECOM) is pleased to submit our report on the above referenced project. If you have any questions regarding this report, please do not hesitate to contact Kendall Thiessen, P.Eng. of our office directly

Sincerely,
AECOM Canada Ltd.

Tom Wingrove, P.Eng.
Executive Vice-President,
Deputy Operations Director,
North America, Environment

KT:dh

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AECOM Signatures

PROFESSIONAL ENGINEER
YUKON TERRITORY
KENDALL THIESSEN
08/07/2011

Report Prepared By:

Kendall Thiessen, P.Eng.
Geotechnical Engineer

Report Prepared By:

Andrew Smith
Water Resources

Report Reviewed By:

Tom Wingrove, P.Eng.
Executive Vice-President,
Deputy Operations Director,
North America, Environment

Report Reviewed By:

Rolf Aslund
Manager, Water Resources

PERMIT TO PRACTICE
Signature
Date 8/7/11
PERMIT NUMBER: PP066
Association of Professional Engineers of Yukon

Summary

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City in the Yukon Territory. The mine consists of three open pits, two waste rock dumps, and a tailings pile. Over 60 million tonnes of waste rock from the open pits were 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 to 12 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 condition of the site, in particular downstream hazards associated with channel blockages resulting from landslides of the Clinton Creek waste rock dump and Wolverine Creek tailings piles.

This document provides an overview assessment of the closure options for Clinton Creek Channel, the Clinton Creek Waste Rock Dump, Hudgeon Lake, Wolverine Creek and the Wolverine Creek Tailings Pile at the Former Clinton Creek Asbestos Mine site. Several options have been considered for each element, with discussions addressing advantages, disadvantages, risks and uncertainty, and technical considerations for design. The options address the existing hazards and liabilities in various ways and to varying degrees.

Twelve options were discussed for the Clinton Creek Channel; three options for the Clinton Creek Waste Rock Dump; four options for Hudgeon Lake; six options for Wolverine Creek, and four options for the Wolverine Creek Tailing Pile. Leaving the site as-is or maintaining the status quo was considered as an option for each of the elements. The status quo also provides a baseline for comparison to other options.

The Clinton Creek Mine site has been the subject of numerous assessments and studies and various remedial measures have been implemented since mining operations ceased. The concepts presented in the report are generally not new concepts but are a compilation of the concepts that have been discussed in previous assessments. The objective is to provide one document that stakeholders can use to compare the benefits and disadvantages of the various concepts. In some cases, more details on the individual concepts may be available in the original referenced reports.

The options have been discussed by element in this report, but it is important to recognize that elements are not independent and therefore measures cannot necessarily be implemented to one element without considering the adjacent elements. For example, improvements to the Clinton Creek channel may affect the waste rock dump and/or Hudgeon Lake. These interactions have been identified in the text and are highlighted in a series of figures for Clinton Creek, Hudgeon Lake and the Waste Rock Dump.

The options have not been ranked in this report, and no recommendations have been provided by the authors. The summary table in Appendix B provides a qualitative assessment of the various options with respect to the primary objectives of the Government of Yukon and the technical challenges and liabilities associated with each of the closure options. Order of magnitude estimates of capital costs have been developed for the options and are exclusive of operations, maintenance and lifecycle costs. The range of costs vary from capital investment of zero if the status quo is chosen for all elements, to an estimated maximum of $144,000,000 if the Clinton Creek Valley is restored, the tailings are covered, and a rock drain is constructed at the toe of the tailings pile. The accuracy of the costs estimates are commensurate with the level of design for these concepts and should be considered as comparable to a Class D estimate. The cost estimates do allow for a financial comparison of the various options.

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Appendices

1. Introduction

1.1 Scope and Report Objectives

The scope of this report was established in the AECOM proposal, dated December 22, 2010, based on the terms of reference provided by the Government of Yukon, November 22, 2010. This report is an impartial technical piece that will support decision making to meet the broader site closure objectives at the Former Clinton Creek Asbestos Mine. There has been a significant amount of work done related to various issues at this site, but it is scattered through numerous documents. This report brings together the feasible options for remediating the various elements of the Clinton Creek Mine and discusses them in a succinct and fair manner to provide decision makers with enough information to make preliminary decisions for the path forward.

The terms of reference identified the following five major elements at the Former Clinton Creek Asbestos Mine Site to be considered in the report:

- Clinton Creek
- Waste rock pile
- Hudgeon Lake
- Wolverine Creek
- Tailings

This document will not present options or address issues specifically pertaining to other elements of the site such as Porcupine Creek, Porcupine Creek waste rock dump, open pits, mill site, crusher site, or other mine infrastructure.

In general, the assessments presented have been based on pre-existing information developed by AECOM during our history at the site, or from reports and data prepared by others. The scope and schedule of the current work precluded the development of significant amounts of new supporting data or technical analyses.

1.2 Background

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City in the Yukon Territory, 9 km upstream of the confluence of Clinton Creek and the Forty Mile River. The mine consists of three open pits (Porcupine, Creek and Snowshoe), two waste rock dumps (Porcupine Creek and Clinton Creek) along the south side of Clinton Creek, and a tailings pile on the west side of Wolverine Creek (Figure 01, Figure 02, Drawing 01).

From 1968 until depletion of economic reserves in 1978, the Cassiar Mining Corporation extracted approximately 12 million tonnes of serpentine ore from the bedrock. The ore was transported by an aerial tramway to the mill located on a ridge along the west side of Wolverine Creek, a tributary of Clinton Creek. Over 60 million tonnes of waste rock from the open pits were deposited over the south slope of the Clinton Creek valley at what is referred to as the Clinton Creek waste rock dump (Drawings 1 and 2). Over the same period of time, about 10 to 12 million tonnes of asbestos tailings from the milling operation were deposited over the west slope of the Wolverine Creek valley (Wolverine Creek tailings piles). Since closure of the asbestos mine, concerns have been raised with respect to the physical condition of the site, in particular downstream hazards associated with channel blockages resulting from landslides of the Clinton Creek waste rock dump and Wolverine Creek tailings piles (UMA, 2003a).

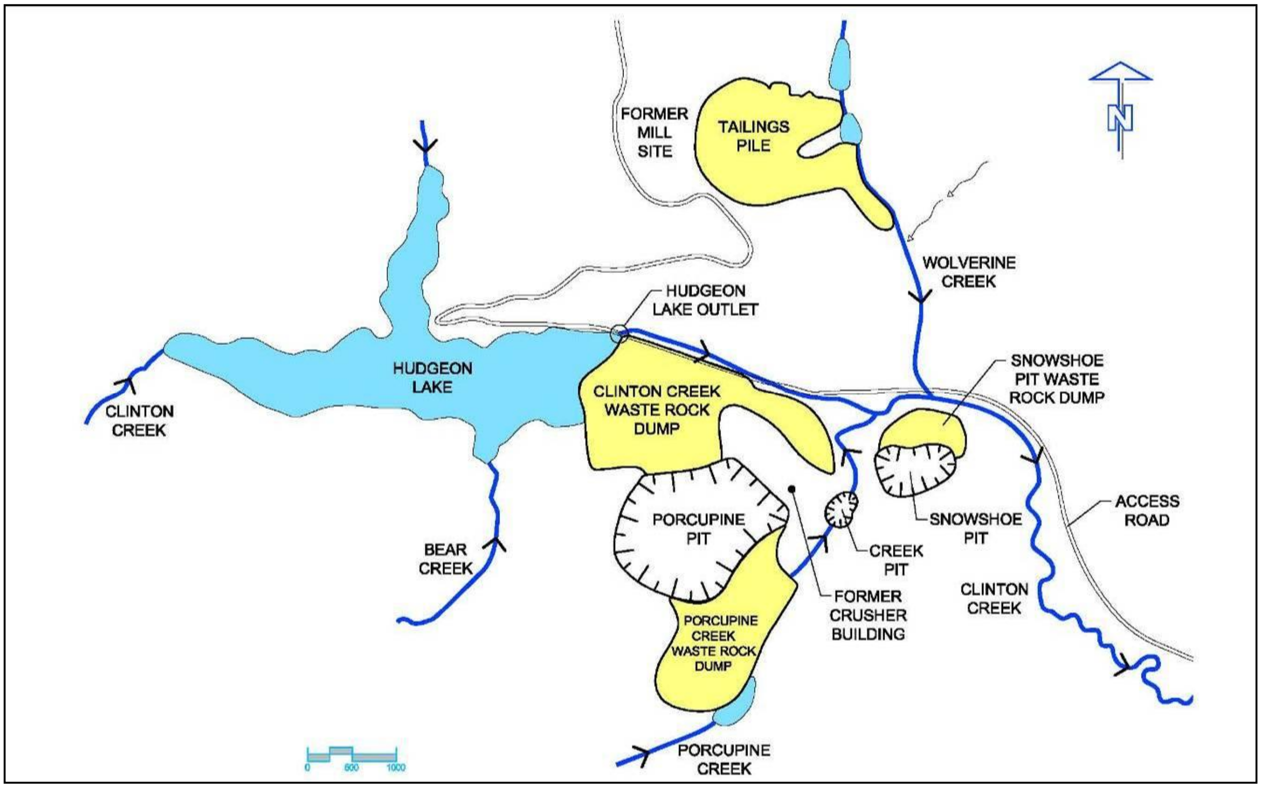

Figure 01. Site Layout (after Royal Road University 1999)

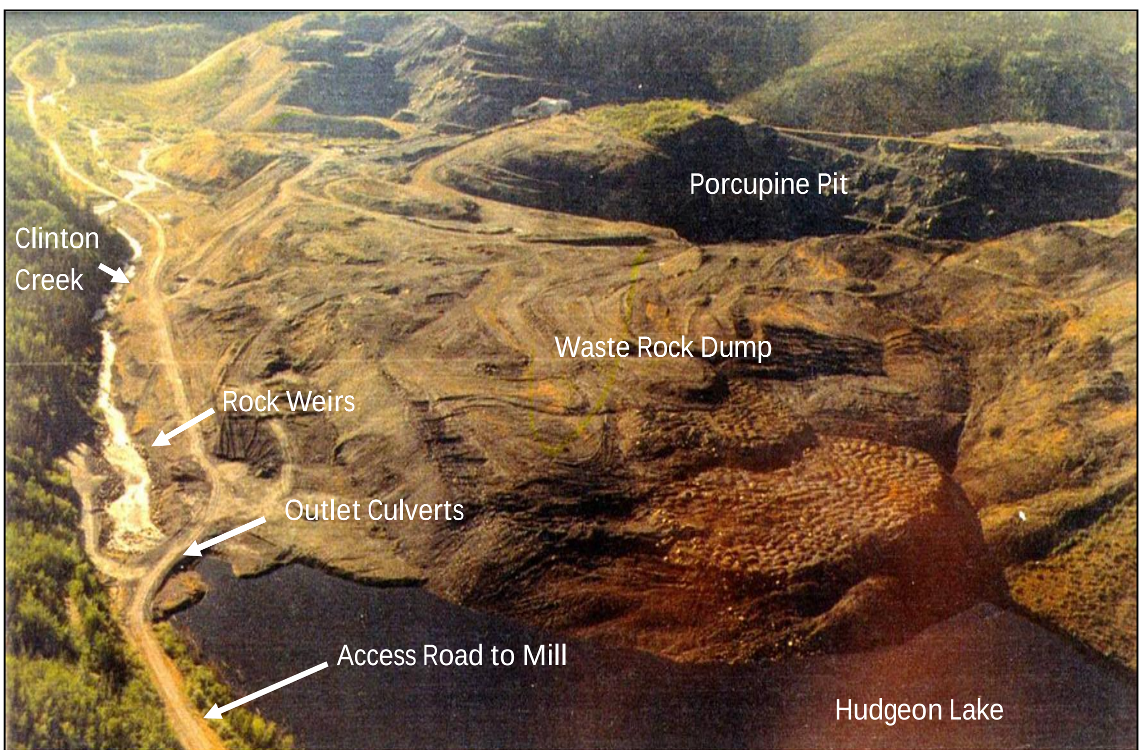

Figure 02. Clinton Creek waste rock dump (1985) (AECOM 2009b)

The risks and liabilities at the former Clinton Creek Mine Site have been well documented in several reports including:

- An Environmental Assessment of the Effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territory (Department of Environmental Protection Service 1979)
- Abandoned Clinton Creek Asbestos Mine Risk Assessment Report (UMA 2000)
- Abandoned Clinton Creek Asbestos Mine Environmental Liability Report (UMA 2003)
- Former Clinton Creek Asbestos Mine Hazard Assessment Report (2004)
- Former Clinton Creek Asbestos Mine – Summary of 2004 Hazard Mitigation Work, Monitoring, and a Screening Level Risk Assessment for Airborne Asbestos (UMA 2006)
- Former Clinton Creek Asbestos Mine Overview Report (AECOM 2009)
- Clinton Creek Mine Risk Review (SRK Consulting 2010)

The major (acute) risk to human health is a breach of the waste rock plug which forms Hudgeon Lake or a breach of the tailings dam which blocks Wolverine Creek. The natural environment would also be impacted by erosion and subsequent sedimentation of large amounts of material due to the high flow velocities. The Risk Assessment Study (UMA 2000A) estimated that a full breach of the waste rock blockage at the outlet of Hudgeon Lake would result in a peak discharge of approximately 500m^3/s and a maximum flow velocity of 3 to 4 m/s. A breach of the Hudgeon outlet would pose a significant hazard to humans in the vicinity of the outlet, or in downstream areas. The level of hazard along Clinton Creek, downstream of Hudgeon Lake has been ranked, and is illustrated in Figure 03.

A breach of the tailings blockages along Wolverine Creek would result in flows of 350 m^3/s, and for a much shorter duration compared to a breach of the Hudgeon Lake outlet.

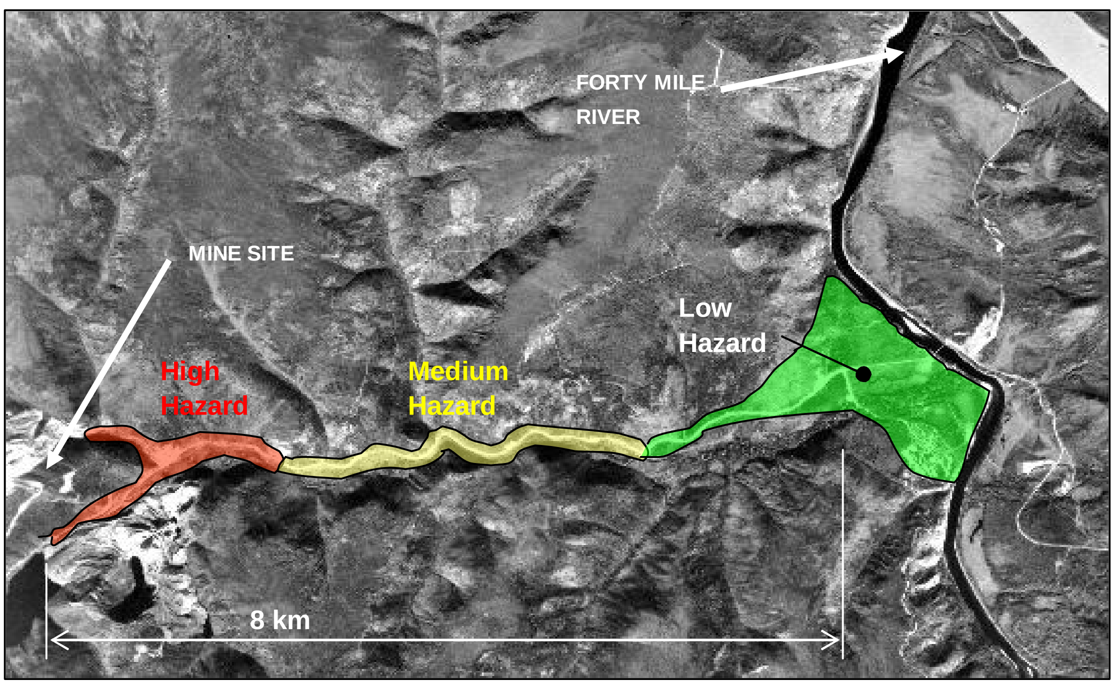

Figure 03. Downstream hazard map. (AECOM 2009)

Another potential risk to human health is that of airborne chrysotile asbestos. UMA Engineering Ltd. (2006) assessed the risks associated with exposure to airborne asbestos at the site. The report concluded that “for all but highly atypical individuals who may receive exposures not anticipated as part of this screening level assessment, it is expected that the cancer risks associated with airborne asbestos fibres is low.” The incremental lifetime cancer risk (ILCR) for an individual spending 3 months per year, 8 hrs per day, for ten years was estimated to be $1x10^{-5}$, which is considered to be negligible according to Health Canada. (UMA 2006). It should be noted that disturbance of the ground surface (especially of the tailings) may lead to increased concentrations of airborne asbestos, thus increasing the associated health risks for individuals in the area.

1.3 Objectives of Remedial Works

The following broad objectives were provided by the client in the Terms of Reference for this work (November 2010) as appropriate guidelines for the assessment of the options:

- Protect human health and safety
- Protect the environment including land, air, water, fish and wildlife
- Return or retain the site in a state that allows original and traditional use
- Maximize local, Yukon and First Nations benefits from work generated at the site
- Manage, and where possible, reduce or eliminate risk and liability

The feasibility, constructability, costs, performance, maintenance, life cycle and design of the individual options have also been considered in the following evaluation.

2. Methodology

This report will generally consider alternatives that have been put forward in other reports, though there are some new concepts, and modifications to previously presented concepts. The objective of this work is to provide the Government of Yukon with a high level assessment of these options as input for a decision making process. The options are discussed at a conceptual level, and a limited amount of engineering effort has been invested in each option. The discussion is generally broken down into the specific areas, were applicable, including: hydraulics and structures, geotechnical and earthworks, environmental and human health and safety. No additional detailed investigations have been conducted as part of this current work. There are significant information gaps that remain for all options, and these gaps should be addressed as the option selection process and detailed design moves forward. The assessment of options is generally qualitative and considers objectives, risk, uncertainty, constructability and lifecycle. The drawings in Appendix A have been prepared to conceptually illustrate the options.

The options will be categorized by the main mine site features or elements, but the interactions between elements and options will also be considered. There are numerous options and combinations of options that would address the objectives to some degree. The interrelationships between the various options for the individual elements is a very important consideration; especially between Clinton Creek, the waste rock dump and Hudgeon Lake. For example, measures implemented to improve the conveyance of Clinton Creek flows may not be compatible or effective with options that address the stability of the waste rock, or with the options that affect Hudgeon Lake. The potential combinations of measures to address each element are illustrated in a series of flow-charts included in the discussions in Section 4. These flowcharts highlight the optimal combinations for the waste rock and Hudgeon Lake that are considered to be the most compatible with the specified option for Clinton Creek. This analysis has been focused around the Clinton Creek options because the conveyance of the water is a key technical challenge to be addressed at this site.

A summary table in Appendix B provides a qualitative rating of the options with respect to objectives and liabilities. This summary table does not provide a ranking of the alternatives as there has been no weighting applied to the individual parameters. This table will be useful for comparing the options with respect to constructability, risk, uncertainty and how well they address the objectives. All of the options in the Appendix B table are discussed in this document, but some of the options are not considered in as much detail, and cost estimates not provided, as they are considered to be impractical, unnecessary or have substantial shortcomings compared to similar options. These evaluations were discussed with the Yukon Government.

Quantity and cost estimates presented in Section 9 should be considered as Class D and are based on quantity calculations for the major line items. The cost estimates are provided for the purpose of comparing options, and not considered adequate for budgeting.

3. Existing Conditions

The following discussion of the existing conditions and remedial measures is based largely on previous investigations and reporting completed by AECOM (formerly UMA Engineering Ltd.) (for example AECOM 2009b, AECOM 2011b and UMA 2003a). In general, the conditions reported in these previous assessments still apply, with the noted exception of the impacts from the August 2010 precipitation event which caused significant erosion and damage to Drop Structure #4 (DS#4) and to sections of the Clinton Creek Channel. No specific site inspections were conducted for the development of this report.

3.1 Clinton Creek

3.1.1 Existing Remedial Measures and Performance

The existing creek channel across the toe of the waste rock dump is approximately 800 m long and up to 18 m below the existing mine access road (Drawing 3) located in the waste rock dump (on the south side of the creek channel). Figure 04 shows Clinton Creek from a number of perspectives. Side slopes of the waste rock that form the south creek bank are generally at, or steeper than 1H:1V. For the first 225 m downstream of the Hudgeon Lake outlet, the creek channel is flanked on the north and south sides by colluvium and waste rock material, respectively. It is in this zone that the four gabion basket drop structures are constructed (described below). Downstream of this point, the channel has cut into the argillite bedrock underlying the colluvium. As a result, the north and south channel banks consist of bedrock and waste rock, respectively. The channel bed consists of bedrock and boulders in this section. (UMA 2003a)

Four drop structures have been installed in Clinton Creek at the Hudgeon Lake outlet to mitigate the risk of a breach of the lake outlet. The four structures were constructed in three stages over a three year period (UMA 2003A, UMA2003b, UMA 2004, AECOM 2009). The structures convey flow from the lake over a vertical drop of approximately 8.5 metres.

In 2009, some damage was sustained to the drop structures during the spring freshet. The damage to the structures is presented in the 2009 Site Inspection Report (AECOM 2010b) and includes:

- Open baskets with staples removed;
- Large scour hole on the floor of DS#4.
- Damaged end sills.
- Large holes on some basket tops and sides due to broken wire mesh; and
- Partial or completely empty baskets.

The empty baskets were a result of either smaller diameter material within the baskets washing out or broken mesh that had allowed larger diameter material to wash out. All the damage was repairable, and despite the damage, the gabions were still generally functioning. DS#2 and #4 had the most damage.

Repairs to the structures included (AECOM 2010a):

- Removal of debris including large logs from the structures;
- Replacement of gabion fill material within the empty baskets;
- Repair of the gabion baskets;
- Hand stitching the downstream top edge of each basket at the drops;
- Replace damaged end sills; and
- Fill in large scour hole, place and secure mesh top, and cover with 5 m long, 0.5 m tall gabion baskets.

In the summer of 2010 a significant precipitation event occurred resulting in high flows in Clinton Creek and severe erosion downstream of DS #4. Erosion progressed to the point where the downstream floor of the fourth drop structure was lost and the remaining section now is almost completely vertical as of October 2010. An effort was made to place material immediately downstream of the fourth structure for stability but was unsuccessful as the contractor did not have enough time or resources to place the material in the creek prior to the end of the construction season.

The impact of slope movements on the drop structures is also a concern. The ongoing movement of the waste rock across the valley is squeezing the gabion structures. Movement monitors have been installed at each structure to monitor closure of the channel. The top edges of the gabion structures were moving towards each (ie. narrowing the section) other at rates ranging from 3 cm/year to 10 cm/year, measured between 2008 and 2010 (AECOM 2011a).

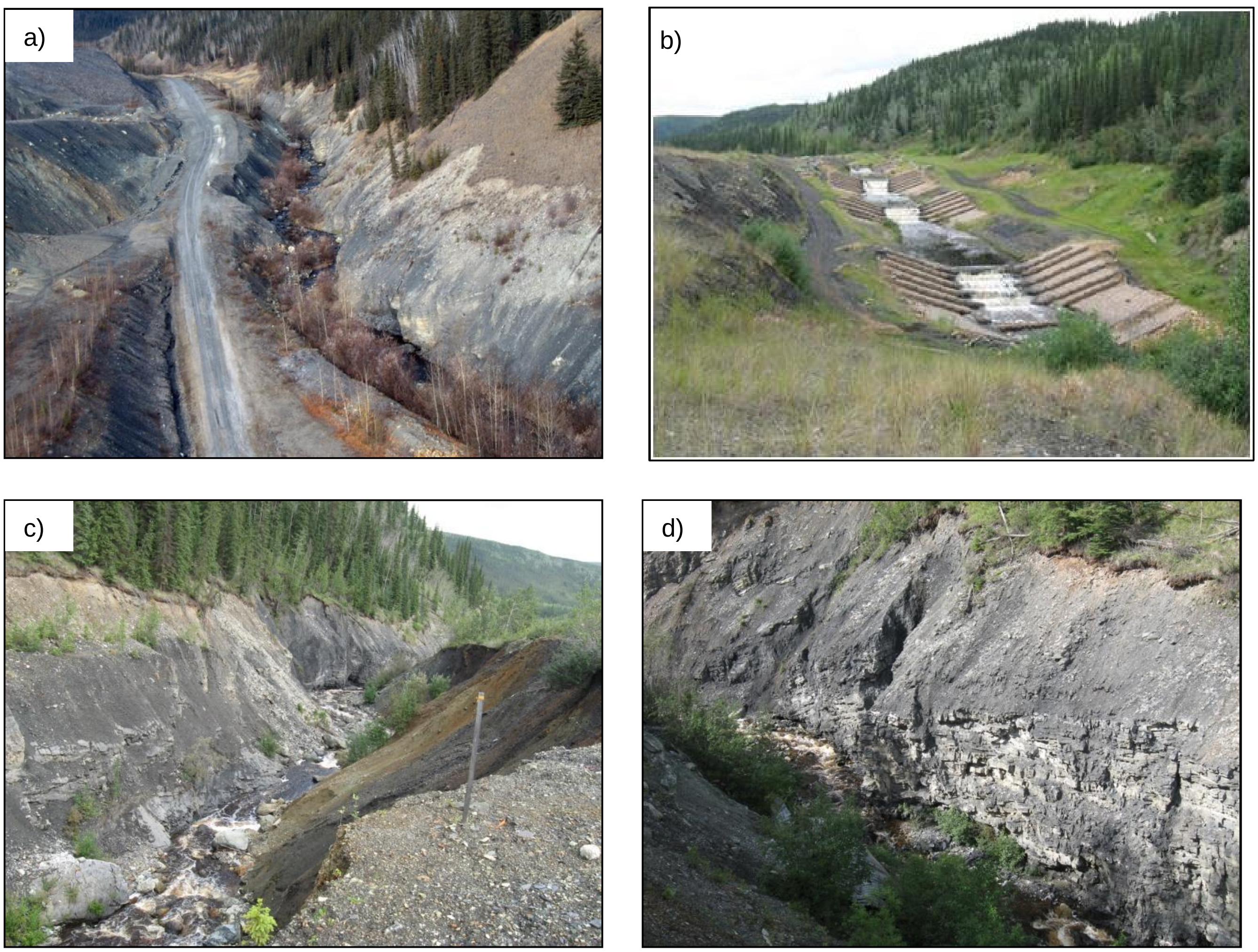

Figure 04: a) Clinton Creek channel (2007) facing upstream b) drop structures (July 2010) c) channel at toe of waste rock facing downstream d) north bank of channel showing weathered and unweathered argillite bedrock.

3.1.2 Uncertainty and Residual Risk

The primary risks associated with Clinton Creek are related to a breach of the Hudgeon Lake outlet, and the subsequent rapid release of a large volume of water into the Creek. The major concerns are (UMA 2008):

- re-distribution of sediments and mine waste farther downstream in the Clinton Creek, Fortymile River, Yukon River system along with an associated alteration of aquatic habitat;
- massive changes in hydrology associated with downstream flooding and the subsequent erosion of fish habitat (banks, sand and gravel bars, spawning gravels); and
- endangerment to human life and property within the floodplain and possibly higher areas downstream in association with the flood event.

As noted in the previous paragraphs, the risk of a breach has been mitigated by the installation, maintenance and performance monitoring of the gabion drop structures. The performance of the drop structures has been adequate to this point, but the events of 2009 and 2010 have shown that they are susceptible to damage under high flow conditions. The gabion structures were intended to be temporary measures; to be a long term solution, the gabions would need regular monitoring and maintenance and periodic replacement. The gabions are subject to wear and tear, but are also stressed by ongoing lateral creep movements of the waste rock.

The following discussions will focus on the upgrades to the channel itself, but it is also important to consider strategies that would reduce the risk to downstream fish habitat. One measure that would be applicable to all scenarios would be to maintain and enhance the relatively quiescent areas of Clinton Creek close to the former mine site (ie. immediately downstream from the Clinton Creek/Wolverine Creek confluence) to accommodate the sedimentation of suspended solids in a wetland area.

3.2 Waste Rock Dump

Overburden (ie. waste rock) from the three open pits and crusher was deposited in either the Clinton Creek and Snowshoe Pit waste rock dumps on the south side of the Clinton Creek valley or the Porcupine Creek waste rock dump in the Porcupine Creek valley (Drawing 01). The total mass of waste rock is estimated to be 60 million tonnes (Roach 1998). The waste rock typically consists of argillite, phyllite, platey limestone and micaceous quartzite (Stepanek and McAlpine 1992). Asbestos fibres are occasionally found within the waste rock (Royal Roads University 1999).

Shortly after dumping of waste rock onto the Clinton Creek valley slopes commenced, failures of the waste rock face occurred and the waste rock spread across the valley as more material was added. The current waste rock dump is shown in Figure 05 and Drawing 02. The failure history is not well documented, however, continued dumping and movement of the waste rock across the valley resulted in the eventual blockage of Clinton Creek and the formation of Hudgeon Lak. The mechanics of the failure, and current stability of the waste rock dump have been studied by several investigators (Stepanek and McAlpine 1992, UMA 2002, AECOM 2009b). Figure 06 shows the complex translational/spreading type of mechanism interpreted by Stepanek and McAlpine (1992).

Figure 05. The waste rock dump with the east end of Hudgeon Lake on the right. (2009)

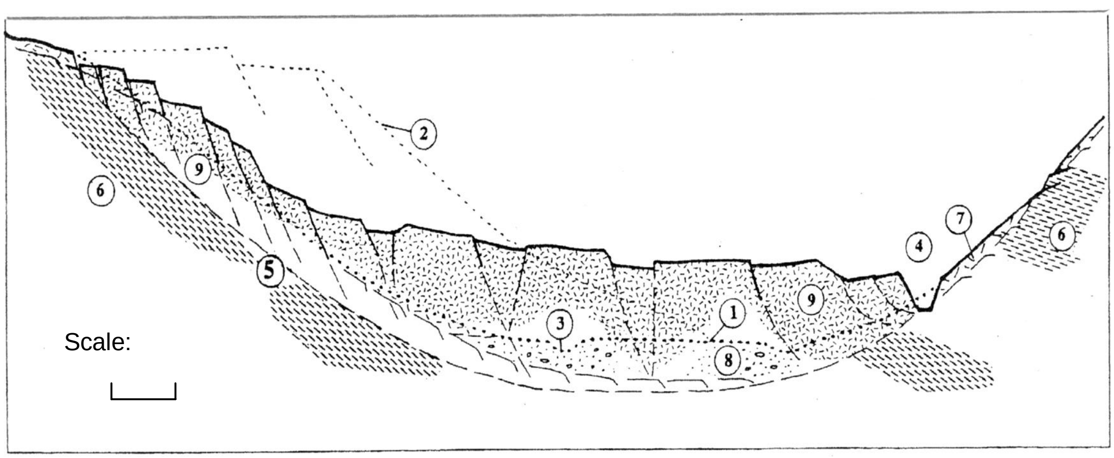

Figure 06. Cross section of waste rock slide looking upstream (Stepanek and McAlpine 1992)

3.2.1 Existing Remedial Measures and Performance

Waste rock movement monitoring carried out since reactivation of the monitoring program in 1999 has confirmed that creep movements of the waste rock dump are continuing. The average horizontal movements for the monitoring interval from 2008 to 2010 range from 0 to 6 cm/yr which is about the same as measured in the previous monitoring period (2004 to 2006). This is a marked decrease in the movement rates observed earlier in the monitoring program as shown in Table 3.1 . There does not appear to be any significant difference between the movement rates in the upper, mid and lower portions of the waste rock dump, a behaviour indicative of a mass movement rather than individual blocks moving independently within the waste rock. Vertical settlement of the waste rock is also continuing at average rates of 1 cm/yr in the lower portion of the waste rock dump and 2 cm/yr in the mid-slope area (AECOM 2011a).

Table 3.1. Average horizontal movement rates of waste rock (AECOM 2011a)

Date	Upper Slope (cm/year)	Mid Slope (cm/year)	Lower Slope (cm/year)
1999-2001	6	8	7
2001-2003	5	5	4
2003-2004	4	5	4
2004-2006	2	3	2
2006-2008	2	3	2
2008-2010	2	2	2

The movement magnitudes over the last few years have not resulted in any significant change in the physical condition of the dump. The majority of the major landslide features visible across the dump are associated with the large movements experienced during active mining and for a number of years thereafter. Since about the mid 1990's it appears that these movements have gradually tapered off to the rates now being observed. Vegetation of the dump is sparse although is slowly becoming established in sheltered areas on flatter portions of the dump and along the edges of the roads on the dump. Initial seeding trials have been undertaken by GY since completion of the gabion drop structures in 2004 in an attempt to establish some vegetation on the waste rock pile. These trials have not been widely successful, most likely due to the waste rock being a poor growth medium. In 2008, a different trial approach to re-vegetation was undertaken that included willow staking and transplanting of native vegetation taken from along the mine access road. The success of these methods will be assessed in coming years. (AECOM 2009b)

The stability of the waste rock pile was considered in the Conceptual Design Report (UMA 2002). The report concluded that unique geological conditions, in particular a very weak foundation layer and high porewater pressure conditions, are responsible for continued movement of the waste rock. Almost certainly, degredation of the permafrost resulting from the filling of the Hudgeon Lake reservoir has been a contributing factor, and may continue to be a factor in the future. No additional stability analysis has been performed for the development of this report.

3.2.2 Uncertainty and Residual Risk

The ongoing creep movement of the waste rock is not considered to be a considerable hazard on its own. The greater concern is how the movements of the waste rock will affect the performance of any improvements to the Clinton Creek channel. Cross-section surveys have been included in the Long Term Performance Monitoring Program to help detect deformations and movement monitors have been installed at the corners of each drop structure to help measure closure of the structures. The channel widths have decreased (ie. the outside edges moved together) an average of 6 cm/year since 2008, however the shape of the drop structures does not appear to have been affected(AECOM 2011a).

3.3 Hudgeon Lake

Hudgeon Lake was formed in the mid 1970's when the Clinton Creek Waste Rock Dump failed resulting in a blockage of the valley. Continued movements of the waste rock dump resulted in the current configuration. Drawings 04 and 05 show Hudgeon Lake in plan and section, respectively.

Hudgeon Lake is approximately 2100 m long, with a width of up to 600 m. Bathymetry data measured in 2010 shows a maximum lake depth of approximately 29 metres and a lake volume estimated at 10 million cubic metres. The lake area at the time of the survey was 72 ha, at a water surface elevation is 411.6 m. The depth of the lake increases from west to east with the original valley slope. The deepest part of the lake is directly west of the Clinton Creek Waste Rock Dump. A stage volume curve of Hudgeon Lake is shown below in Figure 7.

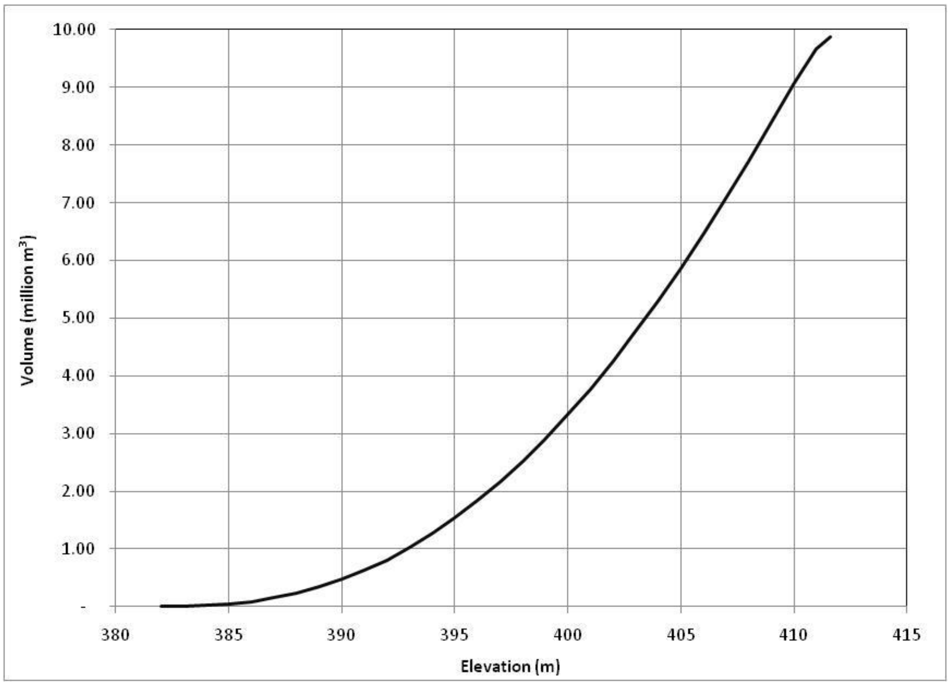

Figure 07: Stage-volume curve for Hudgeon Lake

Hudgeon Lake is anoxic (low oxygen levels) below a depth of 5 m in periods of open water (AECOM 2009b) based on data collected by Werner Liebau (INAC) The lakebed consists of former terrestrial vegetated areas that were inundated following the blockage of the Clinton Creek valley by mine waste rock. As such, Hudgeon Lake contains large amounts of woody debris and other organic materials that can decompose on the lake bottom in the presence of elevated sulfate levels (believed to be naturally occurring) and in a limited oxygen supply thought to be due to the limited capacity of inflowing water to replenish oxygen at depth in the lake. The low oxygen conditions during both summer and winter (under ice) are not suitable for over-wintering survival of fish.

3.3.1 Uncertainty and Residual Risk

Similar to Clinton Creek, the associated risks with Hudgeon Lake are related to a breach at the lake outlet and the subsequent rapid release of a large volume of water. Measures to reduce this risk have been the installation and maintenance of the gabion drop structures. Due to the events of 2010, the risk of a breach of the lake outlet has increased with the undermining of the toe of the most downstream drop structure. There is the potential that Gabion

Structure #4, the most downstream structure, may fail and trigger a further progression of channel erosion upstream to the lake outlet.

3.4 Wolverine Creek

Wolverine Creek is a tributary of Clinton Creek that drains an area approximately 29 km² (UMA 2003). The flood flows have been estimated at the outlet of Wolverine Creek and are presented in the table below.

Table 3.2. Estimated flows in Wolverine Creek

Return Period	Discharge (m^3/s)
25-Year	10.0
50-Year	12.2
100-Year	14.9
200-Year	17.3

The tailings are located in a section of the Wolverine Creek Valley that is deeply eroded. The creek flows along the base of the north and south tailings lobes, as discussed in Section 3.5. Slope failures have occurred at both lobes and the tailings have moved across the valley floor, forming two landslide dams across Wolverine Creek and creating two water impoundments. A plan and profile of Wolverine Creek are illustrated in Drawings 6 and 7, respectively.

The tailings, forming the west or right hand side of the creek bed, continue to erode and be transported downstream by Wolverine Creek almost as quickly as the tailings lobes advance into the valley bottom. As illustrated in Drawing 7, the south and north lobes cover approximately a 750 m length of the creek alignment to a depth up to 14 m above the original creek bed. The north and south lobes are shown in Figure 08. Figure 09 shows the creek from several other perspectives.

An armoured section of the Wolverine Creek channel is located on the downstream (south) end of the south tailings lobe. It consists of a rock lined channel with a series of rock weirs constructed over about 5 to 10 m of tailings. Although normal summer flows through the channel are small, the spring freshet produces relatively higher albeit short term flows. The rock lined channel provides a transition across the tailings downstream of the south lobe to the natural Wolverine Creek channel.

Figure 08: View of Wolverine Creek and lower portion of tailings lobes. (2010)

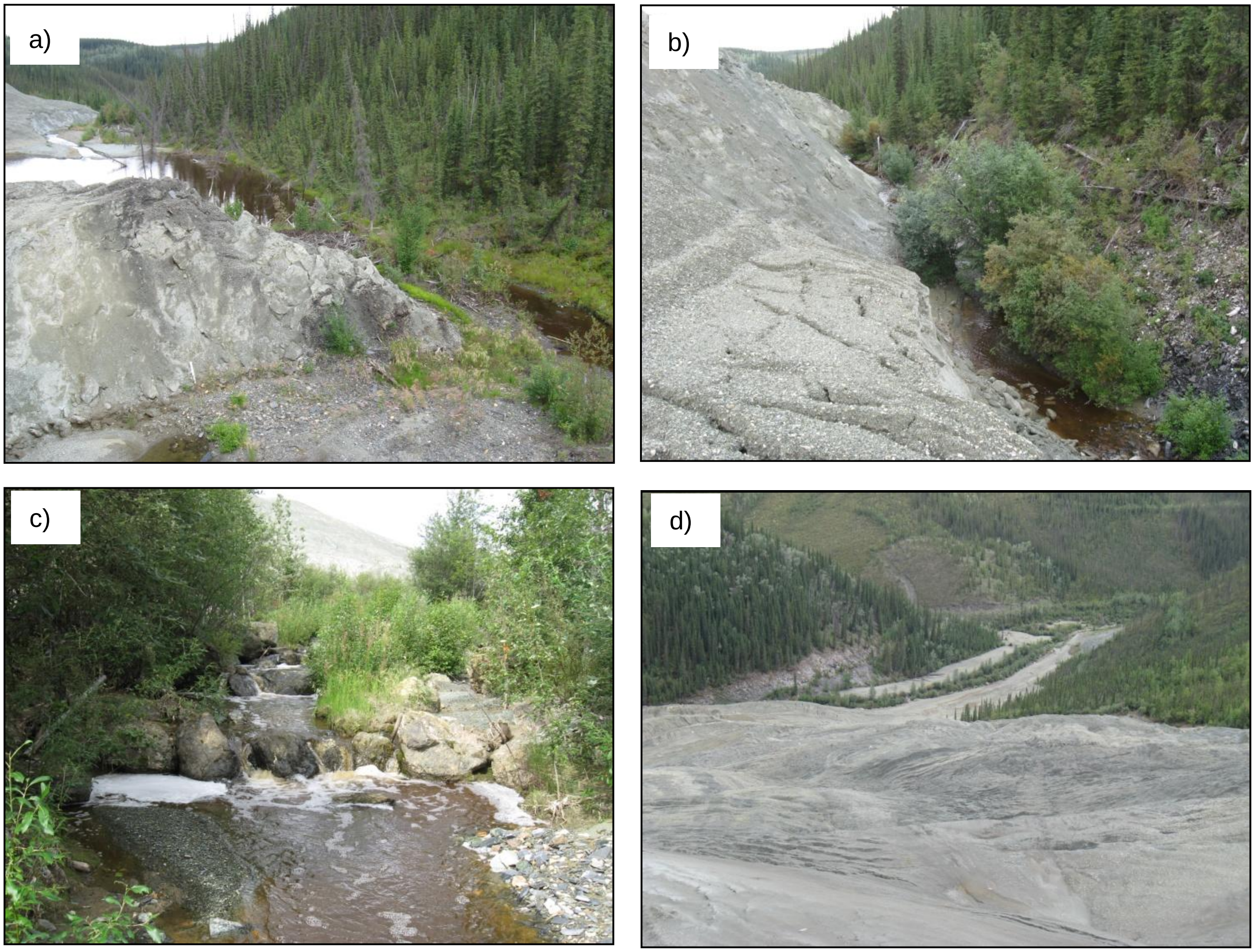

Figure 09a) pond between North and South lobes, looking North; b) view upstream along Wolverine Creek at downstream at base channel looking north-west, with south edge of south lobe in the foreground; c) armored drop structures along Wolverine Creek; d) view south towards from south tailings lobe to confluence of Wolverine Creek and Clinton Creek (July 2010)

3.4.1 Existing Remedial Measures and Performance

The following comments were taken from the "Former Clinton Creek Asbestos Mine 2009 Inspection" Report (AECOM 2009c). The report describes the observed site conditions of the creek channel from station 0+800 to 1+500 (Drawing 07) which includes the armoured channel section (rock weirs) and the section of the creek that is coincident to the tailings.

A comparison was made of the armoured section of the channel in 2005, 2007 and 2009 (AECOM 2009a). The comparison showed no significant changes in the condition of the channel from 2005 to 2009 although vegetation, including trees, is gradually encroaching on the channel after brushing work was carried out in 2007. Brush clearing work was limited to the removal of the trees and brush from the bottom of the channel only and not the channel banks. The rock weirs are in good condition and there is minimal erosion along the bottom and sides of the channel.

The performance monitoring results from September 2010, after the large precipitation event, do show some inconsistencies in the creek profile, but these have not yet been followed up by a visual inspection (AECOM 2011a)

For the creek channel section over the tailings, there does not appear to have been any significant change in the physical features of the tailings or channel (AECOM 2011a and 2011b). Within the channel across the south lobe, there does not appear to have been any significant changes since 2007, with trees and vegetation apparently undisturbed. The leading edge of the lobe however, consists of freshly exposed tailings with numerous slumps confirming that there is ongoing erosion of the tailings and deposition of this material downstream.

3.4.2 Uncertainty and Residual Risk

The primary risks associated with Wolverine Creek include the chronic redistribution of asbestos laden tailings and high flows from a potential failure of the channel blockages (UMA 2000A).

The downstream consequences of a breach of the tailings piles are associated with human occupancy within the Wolverine Creek valley. Since the peak flow is quickly attenuated once the outflow enters the Clinton Creek channel, the risk to human life within the Clinton Creek valley downstream of Wolverine Creek is considered low.

Although sediment deposition does not pose any direct threat to human life or property downstream of the mine site, some risk to riverine habitats and species may exist if slumping and erosion contribute to excessive sediment loads (RRU, 1999). The potential for deleterious effects on fish species and habitats from the chronic transport of sediment from the tailings largely depends on the timing of release and downstream extent of sedimentation.

3.5 Tailings

About 12 million tonnes of mill tailings were deposited over the west valley slope of the Wolverine Creek valley. The tailings are composed primarily of sand and gravel sized crushed serpentinite rock and fine asbestos fibres (Golder 1978). The original tailings deposit, now referred to as the south lobe, failed in 1974 resulting in displacement of tailings to the floor of the valley where flow in Wolverine Creek became blocked. This initial landslide blockage was almost immediately breached dispersing tailings as far as 2 km downstream (Stepanek and McAlpine, 1992). Remedial works, including the removal of some tailings was undertaken soon after the breach occurred. Following the 1974 failure, downslope movements of the south lobe continued resulting in occasional channel blockages. Cassiar constructed a series of rock weirs in 1978 to convey water over the south tailings lobe down to the natural creek channel.

Following the failure of the south lobe, tailings were placed farther to the north in the north lobe. However, downslope movements of the north lobe began almost immediately and tailings were then placed farther to the northwest on flatter ground until mining operations ceased. In 1978, Cassiar unsuccessfully attempted to stabilize both tailings pile lobes by partial regrading and terracing. By 1986, the north lobe had reached the east valley slope forming a second pond. Significant heaving of the valley floor also occurred along the north side of the lobes, resulting in a narrowing of the upstream section of the creek channel and contributing to the formation of the two ponds. As the lobes advanced over the years, the leading edge was being eroded and the tailings transported downstream. It is believed however, that the tailings advanced faster than they were being eroded as evidenced by mounding and lateral spreading at the toe.

The photographs in Figure 08 and Figure 10 were taken in 2010 and document the current condition of the tailings pile.

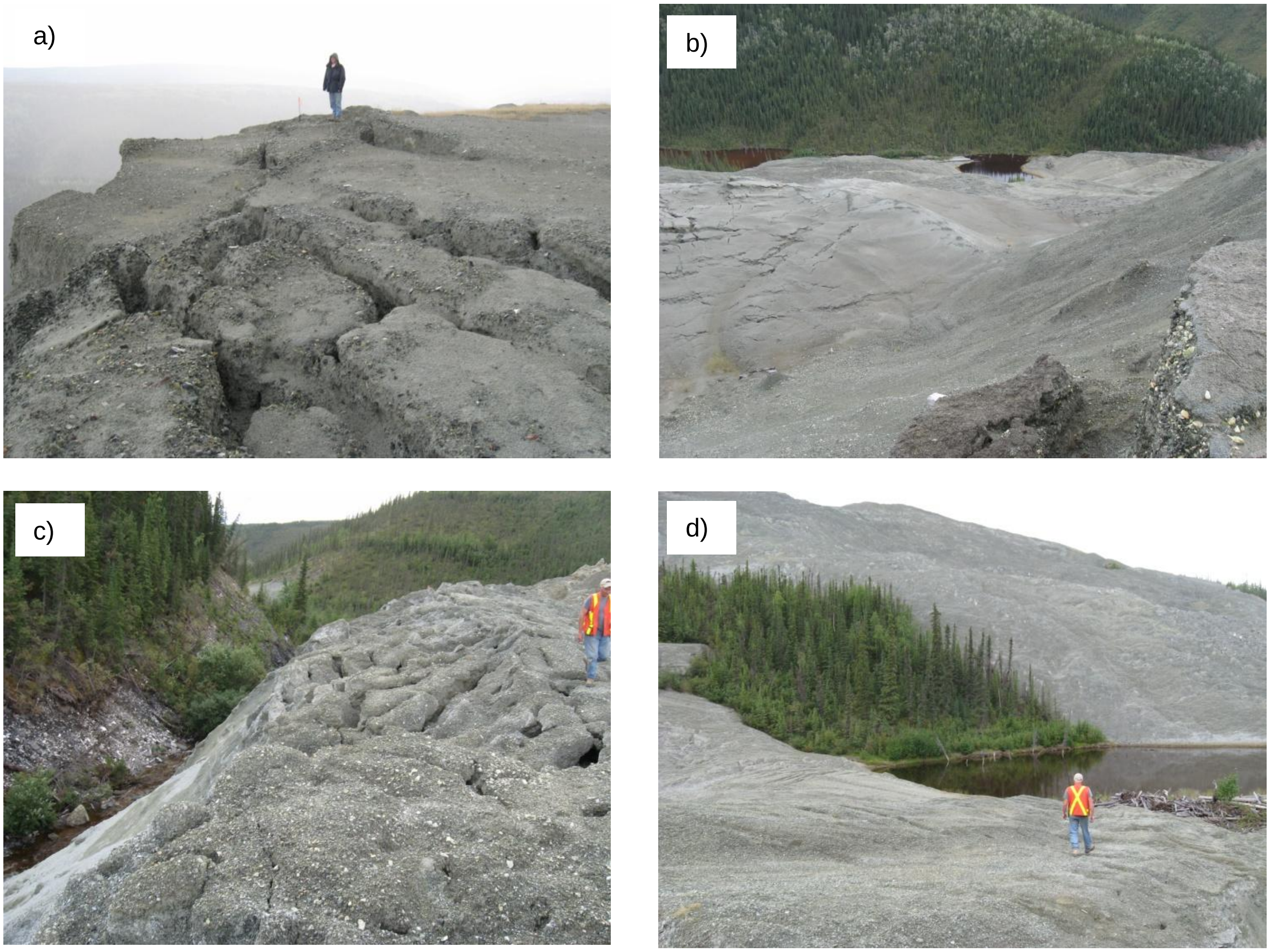

Figure 10 a) Tension cracks at top of tailings pile; b) Tailings and ponds at toe of tailing viewed from top of tailings; c) North edge of south tailings lobe; d) Pond between tailings lobes, looking north

3.5.1 Existing Remedial Measures and Performance

The tailings are continuing to advance downslope although at slower rates that previously observed (AECOM 2011a). It has also been confirmed that significant mounding and spreading of the tailings is occurring as the passive resistance to sliding develops. The leading edge of the tailings is very steep and material frequently slumps into the creek channel. The result is a continual process of tailings being eroded along the leading edge of the lobes and gradual advancement of the tailings mass. Evidence of movements extends to the top of the tailings pile. A crust formed on the surface of the tailings has greatly reduced air-borne asbestos. Seeding trials on the tailings have not proved very successful, likely due to the poor growth medium (AECOM 2009b)

When the original monitoring program ended in 1984 the north and south lobes were moving at rates up to 25 m and 7 m per year, respectively (UMA 2003). The higher movement rate for the north lobe was a consequence of the tailings having not yet reached the valley bottom and therefore had minimal toe support to resist the movements. These rates have decreased drastically, and continue to decrease as shown in Table 3.3; however the movements are still significant. As would be expected, the unstable tailings pile is slowly evolving to a more stable state through natural processes. In effect, the natural movements are forming the equivalent of a toe buttress while reducing the upslope driving mass. Without a significant change in the other variables in the system, it would be expected that the rates of movement would continue to slow with time, though movements are expected for the foreseeable future.

Table 3.3 Average annual rates of movement for tailings lobes. (AECOM 2011a)

Date	Upper Slope (cm/year)		Mid Slope (cm/year)		Lower Slope (cm/year)	
	North Lobe	South Lobe	North Lobe	South Lobe	North Lobe	South Lobe
2003-2004	4	15	21	87	11	46
2004-2005	7	13	18	76	13	45
2005-2006	6	10	13	59	9	35
2006-2008	3	7	10	45	7	28
2008-2010	3	4	6	36	5	23

There have been several studies investigating the behaviour and potential remedial measures for the tailings including Hardy (1978, 1980, 1984), Klohn Leonoff (1986) Golder (1978) and UMA (2003a).

Wolverine Creek does continue to erode and transport tailings away from the base of the tailings lobes, but at a rate that is slow enough that it is not undermining the stability of the entire mass. Based on the recent movement rates measured and the height and length of tailings along Wolverine creek, the volume of tailings eroded annually was estimated to be in the order of 1,500 m^3 per year (AECOM 2009b) compared to previous estimates of 7,500 to 15,000 m^3/yr (UMA, 2000a).

Of particular concern with respect to tailings pile stability is the potential for channel downcutting where Wolverine Creek passes over the toe of the tailings. In this regard, maintaining the integrity of the rock-lined channel downstream of the tailings is considered to be essential to reducing the likelihood of mass tailings movements.

3.5.2 Uncertainty and Residual Risk

The north and south lobes continue to creep downslope, but the rates of movement have generally decreased with time, though there was an increase in the calculated rate of movement over the period between July and September 2010. This increase in movement is attributed to heavy rains during this period, and the fact that the monitoring interval only spanned two summer months. The long term effects of the precipitation event won't be known until additional monitoring can be completed. It is expected that movements will continue for several decades or longer. Wolverine Creek appears to have the capacity to remove tailings at a sufficient rate to keep up with the current rates of downslope movements of the north and south lobes as evidenced by active erosion of the leading edge of the north and south lobes.

Hazards associated with the current physical condition of the tailings piles include a potential breach of tailings blocking the channel, the presence of airborne asbestos fibres and the chronic redistribution of tailings material including asbestos fibres into the downstream environment. The risks to humans and property associated with a breach of the tailings are discussed in UMA's Risk Assessment Report (UMA 2000a). A sudden blockage of the existing creek channel could result in more water being ponded behind the blockage and a subsequent breach of the blockage could occur. The sudden blockage could occur due to sudden gross movement of the tailings pile or a localized failure at the toe of the tailings. A localized failure is most likely to occur. Once the blockage is breached there will be a sudden release of water that could cause localized flash floods and erosion of the tailings. If there is a sudden release of water then there is a possibility it could be diverted away from the entrance to the rock lined channel or overflow the banks of the channel. If this were to occur then the creek would be flowing directly over tailings material and possibly forming a new channel.

The consequences of a breach of the tailings are considered less severe than a breach of the Hudgeon Lake outlet because the volume of water stored upstream of the tailings is small in comparison to the waste rock dump. Also, the rock-lined channel and rock weirs downstream of the south lobe, installed in 1978, help reduce the likelihood of a large scale breach. Although the rock lined channel has performed reasonably well over the years, continued care and maintenance will be required to maintain its serviceability.

A thin crust has formed over time on much of the tailings mass and appears to have significantly reduced the release of fugitive asbestos fibres compared to conditions during active milling operations. However, air samples collected during site investigation activities suggest that the potential remains for asbestos fibres to become airborne either by human activities, movements of tailings from instabilities of the pile(s), or environmental effects such as erosion from wind or surface water run-off (UMA 2005).

A remaining uncertainty at the present time is the potential impact on the health of fish, associated with waterborne asbestos fibres. Ongoing research (by the Department of Fisheries and Oceans) is expected to provide some conclusions and recommendations regarding this issue.

Personal injury can occur to those traversing the tailings due to the physical condition of the tailings pile which includes steep slopes, uneven surface and numerous tension cracks that are about 100 to 200 mm wide

4. Clinton Creek Options: Description and Assessment

Twelve options are presented for addressing Clinton Creek. Through an informal screening process, involving the Government of Yukon, Options CC-1 to CC-6 have been selected for more detailed consideration. They generally meet the project objectives and are considered to be feasible and constructible. Options CC-7 to CC-12 are not considered in detail as they fall substantially short of addressing the objectives or are technically impractical and therefore do not warrant further investigation as mutually agreed upon by AECOM and the Government of Yukon.

4.1 Option CC-1: Status Quo – Maintain and Monitor Gabion Drop Structures

4.1.1 Description

Section 3.1 describes remedial measures implemented along the Clinton Creek Channel, specifically the four gabion drop structures. An integral part of the current program for managing risk at the site includes bi-annual inspections and a bi-annual performance monitoring program. The specific aspects of the *Status Quo* are described in the following sections.

Hydraulics and Structures

Option CC-1 would require the ongoing maintenance, performance monitoring and inspections of the four existing drop structures. If the drop structures are maintained on a regular basis, the likelihood of a catastrophic breach occurring along the channel alignment is low. The design concept for the current measures including the four gabion drop structures was presented in the "Abandoned Clinton Creek Asbestos Mine Environmental Liability Report" (UMA 2003a). The details of the drop structure construction are summarized in UMA 2003b, UMA 2003c, and UMA 2005. Repairs to the drop structures were completed in 2009 and 2010 as described in Section 3.1 and regular repairs should be anticipated in the future. Ongoing movements of the waste rock may necessitate the replacement of the drop structures at some point in the future.

Geotechnical and Earthworks

This option requires little in the way of additional geotechnical and earthworks considerations. It is believed that some of the rockfill is escaping through the wire mesh of the gabion baskets because the gradation was too fine, or the particle sizes have been further reduced by weathering. Finding a more durable source of rock would improve the performance of the baskets.

The Clinton Creek Channel downstream of the drop structures would be left as is without protection from natural processes. Further downcutting of the channel, sloughing of the slopes, and erosion of the banks should be expected.

Environmental and Human Health and Safety

Regular monitoring and maintenance and periodic replacement are essential to ensuring that the gabion structures are able to effectively mitigate the risk of a breach at the Hudgeon Lake outlet. In general, this option is not expected to result in any significant net changes to the environment or changes to human health risks in the long term. The current risks were most recently assessed in a report prepared by SRK Consulting (2010)

4.1.2 Discussion

Interaction with other options

The waste rock would not need to be stabilized or regraded to implement this option, but increasing the stability of the waste rock slopes would improve the long-term performance of the gabion drop structures. The monitoring of the drop structures (for example AECOM 2009A) has shown that the waste rock movements are reducing the top width of the gabion structures as the waste rock moves northward perpendicular to the creek channel. The stability of the waste rock could be improved by selectively relocating some of the waste rock from driving zones (south side of the waste rock pile) into the Porcupine pit, Hudgeon Lake or possibly some other stable location. This is discussed in more detail in Section 5 (Waste Rock Dump Options). Figure 11 shows what measures can be implemented in the waste rock dump or Hudgeon Lake, if Option CC-1 is implemented. Under CC-1, Hudgeon Lake would be maintained at its current elevation, controlled by DS #1.

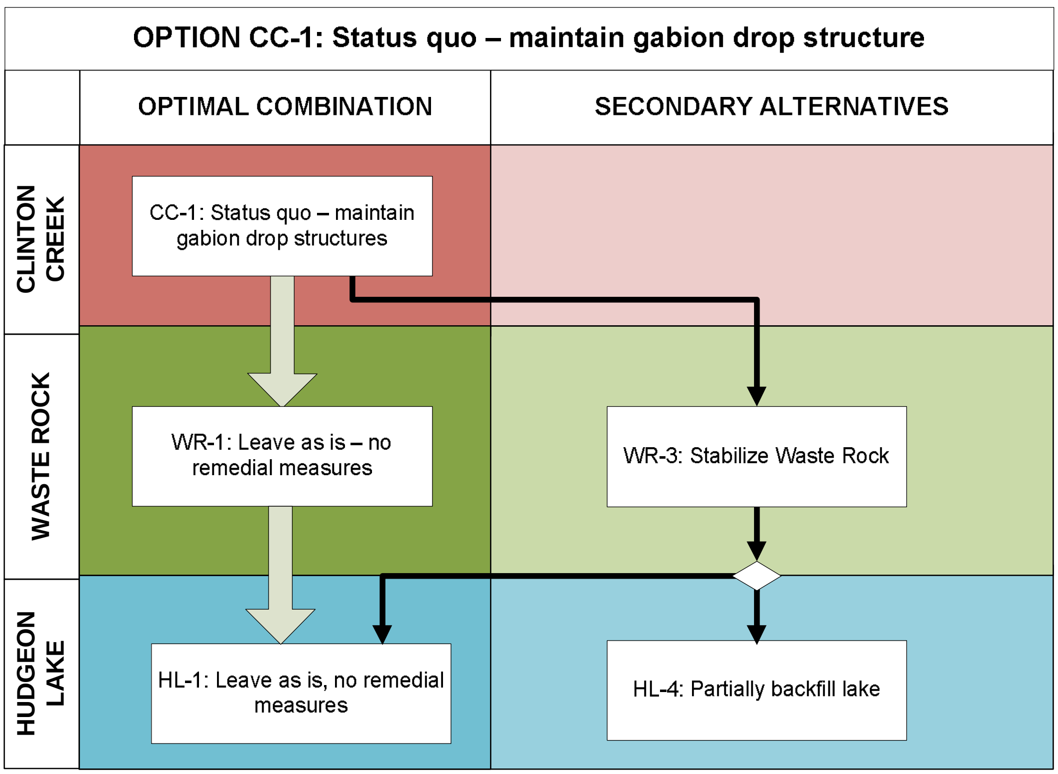

Figure 11. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-1.

Advantages

- Simple, available and relatively inexpensive technology.
- Drop structures are already constructed (ie. no capital expenditures are required).
- Gabions are providing aeration of the water flowing out of Hudgeon Lake.
- Mitigates the risk of a breach of the Hudgeon Lake Outlet if maintained.

Disadvantages

- Monitoring and maintenance will be required.
- Gabions are susceptible to undercutting if the creek channel erodes significantly,
- Does not protect channel downstream of the drop structures.
- Waste rock may need to be stabilized in the future to avoid having to rebuild the drop structures due to the effects of ongoing waste rock movement.

Risks and Uncertainty

- Extreme precipitation events, such as the storm in August 2010, can result in very high creek flows which can cause significant erosion of the creek. This can (and has) undermine the last drop structure.
- The gabions are squeezing together with time due to the ongoing movements of the waste rock pile and may reduce capacity over time due to a reduced cross-sectional area.

Technical Considerations for Detailed Design

- More durable rockfill should be found if possible to help improve long term performance of the gabions.
- Consider stabilization of waste rock dump to reduce the ongoing squeezing of the structures.

4.2 Option CC-2: Armoured Channel over Waste Rock

4.2.1 Description

Option CC-2 involves relocating the Clinton Creek Channel to an alignment over top of the waste rock dump. The flow would pass over a series of drop structures at the East end of the waste rock pile as it descends to the valley floor, and to the current creek channel alignment. This option is illustrated on Drawings 08 and 09. Relocating the channel would allow for stabilization of the toe of the waste rock, and further reduce the risk of a catastrophic breach of the Hudgeon Lake outlet. This option was initially presented in the Conceptual Design Report (UMA 2002). In general, the concept discussed here has not changed substantially from that report.

Hydraulics and Structures

Previous reports have indicated that any option that conveys water over the waste rock dump must include channel stabilization measures due to the erodible nature of the waste rock (UMA 2002). Onsite experience with the drop structures has shown that channel stabilization can be achieved over the waste rock without eroding the channel (the erosion that occurred in August 2010 happened downstream of the drop structures). The stabilization measures for Option CC-2 are based on the remediation alternative presented in the 2002 Conceptual Design Report and are summarized below. Stabilization measures consist of lining the channel with erosion resistant material while using drop structures to reduce the slope of the channel sections between each pair of drop structures.

The channel will convey flow from the lake, across the waste rock to a series of drop structures. The drop structures will convey flow down the northeast face of the waste rock pile to the existing Clinton Creek channel. The channel profile is shown on Drawing 09 in Appendix A. The drop in elevation from the Hudgeon Lake Outlet and the tie-in to Clinton Creek is approximately 35 m. Approximate channel length, including the drop structures is estimated at ±725 m.

The existing drop structures were designed using an estimated 25 year design flow (28.9 m^3/s). The channel section for this flow is about 2 m deep and 7 m wide at the bottom with side slopes of 3H:1V (UMA 2003A). If the design discharge for the new structures was increased to the 100 (39.0 m^3/s) or 200-Year (44.5 m^3/s) flood, the bottom width would increase. It should be noted that these discharges have been calculated based on a limited understanding of the watershed and environmental conditions at this site.

The potential for erosion of the channel sections upstream of, and between the drop structures would be reduced by flattening the longitudinal slope and lining the channel with material sufficient to resist anticipated flow velocities. The longitudinal slope between the drop structures can be maintained by adjusting the number, height and location of the drop structures.

Based on experience at the site, constraints associated with this option include:

- Continued creep movements of the waste rock could deform structures in the constructed channel.
- Floating debris from Hudgeon Lake such as logs and ice that may impede flow, or cause damage to in-channel structures

The new channel alignment could be constructed in the dry while maintaining flows in the existing creek channel. Once the new channel and drop structures have been constructed, flow would be diverted to the new channel. The existing channel could be used as an emergency overflow spillway or filled in to provide toe stabilization for the waste rock pile. If the existing channel was to be filled, a portion of the waste rock from the new channel would be stockpiled adjacent the existing channel during excavation for subsequent infilling.

Geotechnical and Earthworks

The channel alignment would most likely be located near the middle of the waste rock pile (in plan view) as shown in Drawing 08, to allow for continued use of the existing creek channel during the construction of the new channel and structures. The alignment will take into consideration the hydraulic design, while minimizing the amount of earthwork required to construct the channel and stabilize the waste rock.

The alignment shown in Drawing 08 would require the excavation of approximately 1,500,000 m^3 of waste rock (UMA 2002). Approximately 1,000,000 m^3 of the excavated material would be used to backfill the existing channel, and the remainder could be placed into the Porcupine Pit or Hudgeon Lake.

Approximately 6000 m^3 of armouring material would be required to line the channel with a 0.3 m thick layer, and construct the drop structures. This volume of competent rock may not be readily available at the site. Alternatively, if quarrying a suitable material is not feasible, the channel could possibly be lined with concrete, a corrugated steel half-pipe, or other manufactured armouring (Options CC-9 to CC-12). A rigid channel lining (ie. concrete) is not expected to perform as well over the long term.

Environmental and Human Health and Safety

Option CC-2 decreases the risk of a downstream flood event resulting from a breach of the Hudgeon Lake outlet by locating the drop structures over 400 m from the edge of the lake. The banks of the channel would be sloped to eliminate the current problems of waste rock sloughing into the channel.

The length of Clinton Creek habitable by fish is decreased by approximately 500 m, over the status quo, because the gabion structures will be re-located further downstream at the east end of the waste rock. It is unlikely that fish will be able to travel upstream past the gabions, without the aid of a fish ladder. This has not been considered in the current assessment.

4.2.2 Discussion

Interaction with other options

Conveying the flows from Hudgeon Lake over top of the waste rock is compatible with several of the alternatives that deal with both waste rock and Hudgeon Lake, as shown in Figure 12

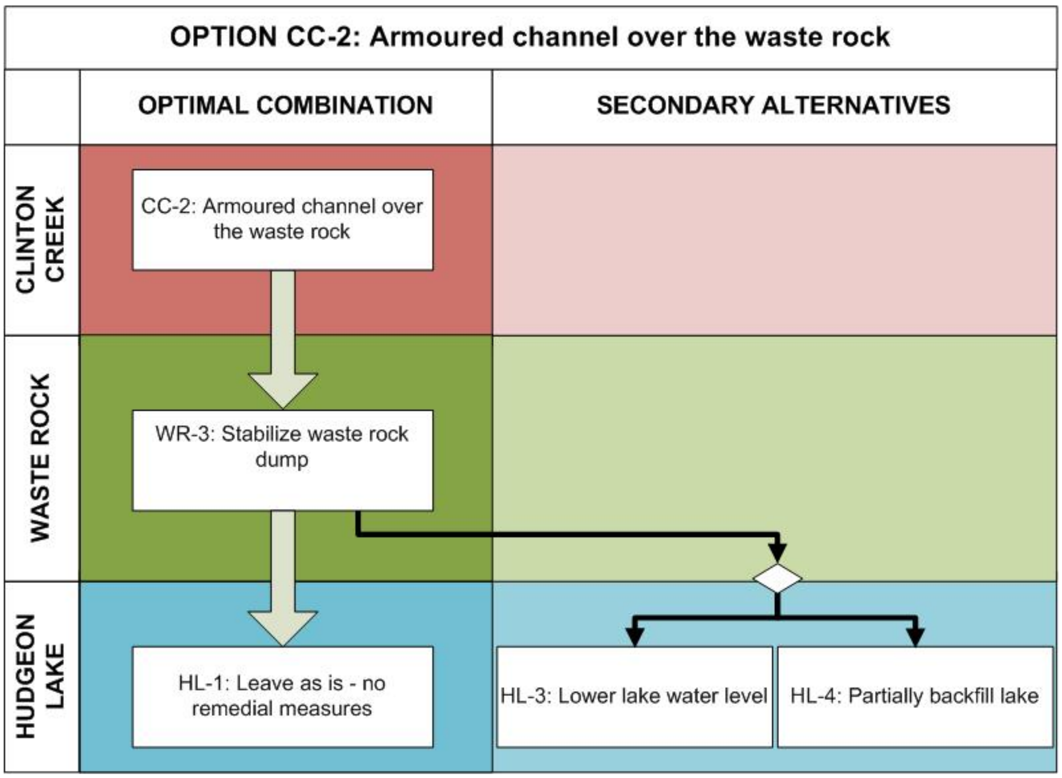

Figure 12. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-2.

Constructing a new channel would provide a good opportunity to reduce the levels of Hudgeon Lake by lowering the invert of the channel inlet. Lowering the lake level would require some additional earthworks compared to maintaining the lake level at the current elevation. Cost estimates have assumed that the water levels in Hudgeon Lake will be maintained at the current elevation.

The existing channel could be backfilled with some of the material excavated from the proposed channel, providing toe support to the waste rock pile. Additional re-grading of the waste rock pile, as illustrated in Drawing 09, could further improve the stability of the waste rock.

Advantages

- Construction would be relatively basic, and could be carried out by local contractors,
- This option is compatible with lowering the level of Hudgeon Lake, which reduces the risks associated with a catastrophic breach of the lake outlet,
- The channel could accommodate some ongoing movements of the waste rock,

- An extreme flood event would be less likely to cause a breach of the lake outlet (ie. landslide dam), compared to the current configuration (Option CC-2).

Disadvantages

- Regular inspection, monitoring and maintenance of the channel (ie. drop structures and armouring) would be required,
- The waste rock would erode rapidly in the event that the armouring was overtopped or compromised,
- Hudgeon Lake would remain,
- A large amount of earth-work would be required,
- Eliminates approximately 500 m of fish habitat.

Risks and Uncertainty

- Local availability of competent rock for armouring and construction of drop structures is limited or not yet identified,
- Channel downcutting may occur if flows breach the armoured portion of the channel.

Technical Considerations for Detailed Design

- Final channel alignment,
- Design of the drop structures,
- Construction sequencing and temporary structures required, especially if the level of Hudgeon Lake is to be lowered,
- Optimization of cuts and fills to minimize the quantity of earthwork while maximizing the stability of the waste rock,
- A fish ladder, if required.
- The placement locations for the large volume of excavated material have to be identified; the Porcupine Pit and the southeast corner of Hudgeon Lake are potential locations.
- The need for maintaining the road across Clinton Creek,near Hudgeon Lake, has to be reviewed. If there is a need for maintaining this road, a new road and creek crossing will be incorporated into the design.

4.3 Option CC-3: Tunnel Through Bedrock

4.3.1 Description

The concept of diverting the flows of Clinton Creek through a tunnel, thus circumventing the waste rock pile, and existing channel, was proposed by UMA (2000a). The proposed alignment has been altered from the UMA (2000a) report to shorten the tunnel length. The alignment is shown on Drawing 10. The total distance for this alignment is approximately 1700 m. Tunneling through the waste rock or bedrock on the south side of the valley is not considered feasible given the unstable ground and required tunnel length.

The inlet elevation could be set to maintain the current lake level, or it may be desirable to set the inlet at a lower elevation to reduce the volume and footprint of Hudgeon Lake, and decrease the gradient of the tunnel. The lake level would be artificially lowered with pumps or siphons, or the inlet isolated by a cofferdam during construction to accommodate construction below the current lake level. To allow isolation of the tunnel for inspection and maintenance, a low-head sluice gate would be installed at the inlet.

No work would be necessary on the existing waste rock pile or channel. The existing Clinton Creek Channel could remain and act as an emergency spillway.

Hydraulics and Structures

The full supply level (FSL) of Hudgeon Lake would be set at Elevation 411 m, which is approximately the current lake level. The obvert of the tunnel inlet would be set equal to the FSL. The invert at the tunnel outlet would be set to match the topographic elevation at the outlet that is in the range of 365 to 370 m.

The tunnel system includes three major components: inlet structure, tunnel reach and outlet structure. The key features of the different components are described in more detail below.

- The tunnel inlet would include a concrete portal with a low-head sluice gate. The provision of a sluice gate allows for the isolation of the tunnel for inspections and maintenance.
- The tunnel reach would have a diameter of 2.6 m or larger and a length of approximately 1,700 m. With the tunnel placed at a slope of 0.023 m/m, the invert of the tunnel would drop from Elev. 407.4 m at the inlet to Elev. 368.3 m at the outlet. At a discharge of 43 m^3/s (the estimated 200-year flood), the flow velocity in the tunnel would be 9.9 m/s at normal depth. The required tunnel diameter varies with the slope of the tunnel and would be re-assessed during detailed design, if this alternative is selected.
- An energy dissipation structure is required at the tunnel outlet, near the Clinton Creek/Wolverine Creek confluence, to dissipate the energy of the outflow before discharging into the creek.

Geotechnical and Earthworks

The method used to advance the tunnel, and materials used to line the tunnel would be determined in detailed design phases to suit the ground conditions along the proposed alignment. An extensive subsurface investigation would be required along the possible alignments. A specialty contractor with appropriate tunnelling equipment and experience would be required for this work.

The existing channel could either be partially backfilled or left as it is. If it is left as is, it should be expected that ongoing movement of the waste rock, aided by other processes, would eventually result in some partial closure of the channel. Other maintenance requirements along the existing channel would be minimal because the channel would only be used as an emergency spillway to convey flows in the event that the tunnel is blocked or its capacity is exceeded.

Environmental and Human Health and Safety

The risk of a breach of the Hudgeon Lake outlet would be greatly reduced by conveying the Clinton Creek flows through a tunnel. Appropriate physical barriers would need to be constructed to prevent humans or wildlife from entering the tunnel from either the upstream or downstream ends.

A tunnel would not allow for fish passage. There would also be some loss of natural fish habitat along the existing Clinton Creek channel unless a riparian flow is maintained.

4.3.2 Discussion

Interaction with other options

By conveying the flows of Clinton Creek around the waste rock pile, ongoing movements of the waste rock are inconsequential. As described previously, the tunnel could be constructed to lower the elevation of Hudgeon Lake if desired, but no other interaction is envisaged at this time. The potential relationships between the options for the three elements are shown in Figure 13.

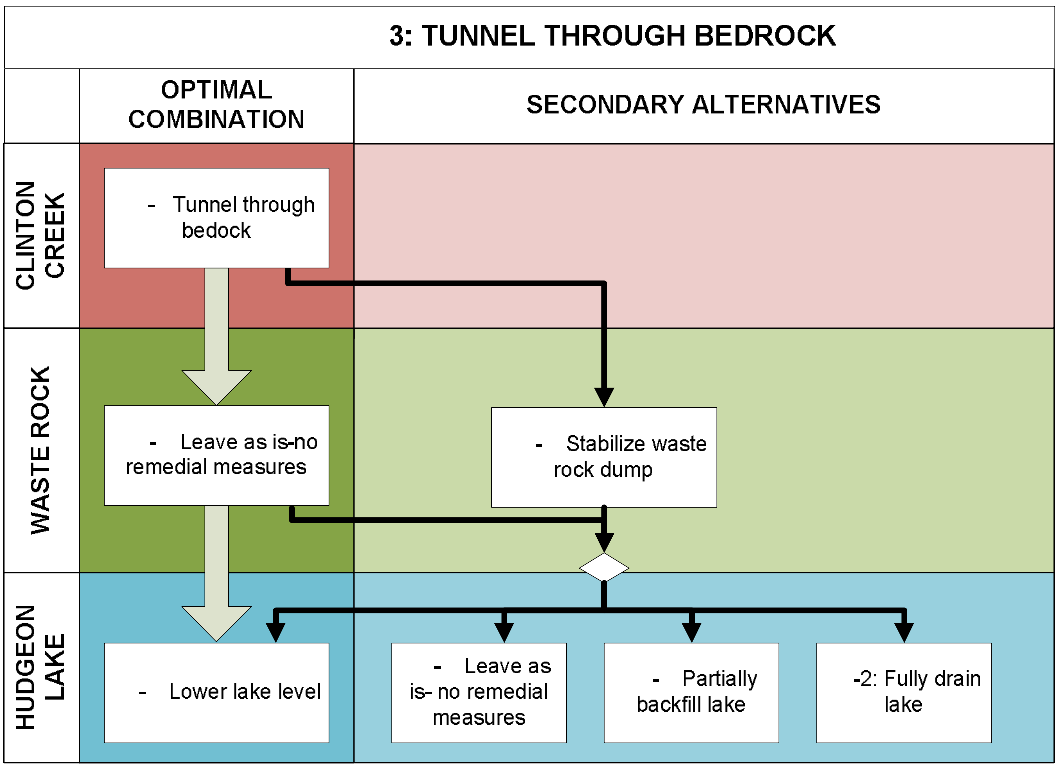

Figure 13. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-3.

Advantages

- Ongoing waste rock movements are inconsequential to the tunnel,
- Opportunity to lower lake level.
- Existing channel could be utilized during construction and also post-construction where it would serve as an emergency spillway.
- Reduces the risk of a breach of the Hudgeon Lake outlet by diverting Clinton Creek flows through a tunnel

Disadvantages

- Though the primary flows are diverted around the waste rock, a functional emergency spillway would still be required, in the event the tunnel or tunnel inlet is blocked,
    - o Spillway must be able to withstand ongoing slope movements,
- Construction and maintenance would require a specialist contractor,
- Eliminates approximately 500 m of fish habitat,

- Debris screening at tunnel inlet requires regular inspection and maintenance,
- The lifespan of a tunnel is finite and repair and replacement would be expensive,

Risks and Uncertainty

- The feasibility, design, cost and construction of the tunnel are dependent on the bedrock conditions,
    - The bedrock conditions at depth along the proposed alignment are unknown,
- A blockage or collapse of the tunnel would force the spillway into service.

Technical Considerations for Detailed Design

- Extensive site investigation, in difficult drilling conditions, to assess the feasibility and practically of constructing a tunnel is needed,
- Inlet and outlet structure designs are required that prevent blockage, while keeping humans, wildlife and debris out of the tunnel,
- Considerations for ice and winter operating conditions,
- Spillway design.

4.4 Option CC-4: Armour Existing Channel

4.4.1 Description

Option CC-4 is similar to the concept presented in “Abandoned Clinton Creek Asbestos Mine Environmental Liability Report” (AECOM 2003), and involves improving the existing channel by installing a series of drop structures along the entire length through the waste rock. This Option is illustrated on Drawing 11. The drop structures would be constructed of rock filled gabion baskets, similar to those currently in place between Station 0+000 and 0+150 downstream of the Hudgeon Lake outlet. The gabion baskets are placed as steps, ranging in height from 0.5 to 1 m, which provide energy dissipation between each step as the water travels through and over the drop structures.

There are other armouring methods that could be implemented along the existing channel. Options CC-9 to CC-12 could all be implemented along the existing channel with varying levels of practicality and performance. Those options will be briefly discussed in following sections.

Hydraulics and Structures

The length of the existing channel section to be stabilized downstream from the Hudgeon Lake outlet is approximately 800 m long. Of the 800m, just over 200 m had previously been stabilized with existing gabion drop structures.

The existing structures were designed for an estimated 25-Year flood discharge of 28.9 m^3/s. If the 25-Year discharge was used for the new structures the geometry would be similar to the existing structures with a bottom width of 7.0 m and side slopes of 3H:1V, though the geometry may need to be altered to accommodate the existing channel geometry. If the design discharge for the new structures was increased to the 100 (39.0 m^3/s) or 200-Year (44.5 m^3/s) flood the bottom width would increase. The existing gabion drop structures would have to be modified to handle the increased design discharge.

Erosion of the channel sections between the drop structures would be reduced by flattening the longitudinal slope and lining the channel with material sufficient to resist anticipated flow velocities. The longitudinal slope between the drop structures can be maintained by adjusting the number, height and location of the drop structures.

Based on experience at the site, constraints associated with this option include:

- Continued creep movements of the waste rock will likely deform any built structures in the creek channel
- Floating debris from Hudgeon Lake such as logs and ice that may impede flow, or cause damage to structures in the creek channel
- The requirement to direct some flow from Hudgeon Lake around the construction area in the creek channel to maintain fish habitat downstream of the construction area

Geotechnical and Earthworks

Installing gabions at the base the current Clinton Creek alignment would be challenging because of the very restricted space in the narrow and deep channel. Working in the channel bottom is a safety concern because there is a potential for slope instabilities or rockfalls along the channel. To improve the stability of the waste rock, material would need to be removed from the upslope portions of the waste rock pile. The stability of the bedrock is also a concern in some areas.

As an alternative, the base of the upstream portion of the channel could be built up prior to armouring , thereby concentrating the head loss (via the drop structures) near the downstream end of the waste rock. The creek profile would be similar to the profile of the creek aligned over top of the waste rock (Option CC-2). The benefits of raising the base of the channel include improved stability due to toe support and a reduced risk of a breach of the Hudgeon Lake outlet. This alternative was presented by AECOM (2003a), but will not be discussed in detail here.

Environmental and Human Health and Safety

This option may reduce the length of Clinton Creek habitable by fish by approximately 500 m, over the status quo, because gabion structures will be situated along the entire length of the waste rock. It is unlikely that fish will be able to travel upstream past the gabions, without aids (ie. fish ladder).

As noted above, working in the deep channel areas is a health and safety concern.

4.4.2 Discussion

Interaction with other options

Figure 14 shows what measures can be implemented in the waste rock dump or Hudgeon Lake, if Option CC-4 is implemented. Stabilization of the waste rock is not an immediate necessity, but would be desirable for maintaining the long term performance of the armoured channel, especially considering the investment in upgrading the channel. Without additional stabilization measures, it is expected that the channel would continue to be squeezed by ongoing waste rock movements, and occasional localized slumping would cause temporary blockages of the channel.

As with Option CC-2, it would be possible, but challenging, to lower the level of Hudgeon Lake by removing one or more of the upstream gabion structures. The ground conditions upstream of DS #1 are challenging to work in due to the frequent boulders, the soft soils and high water levels.

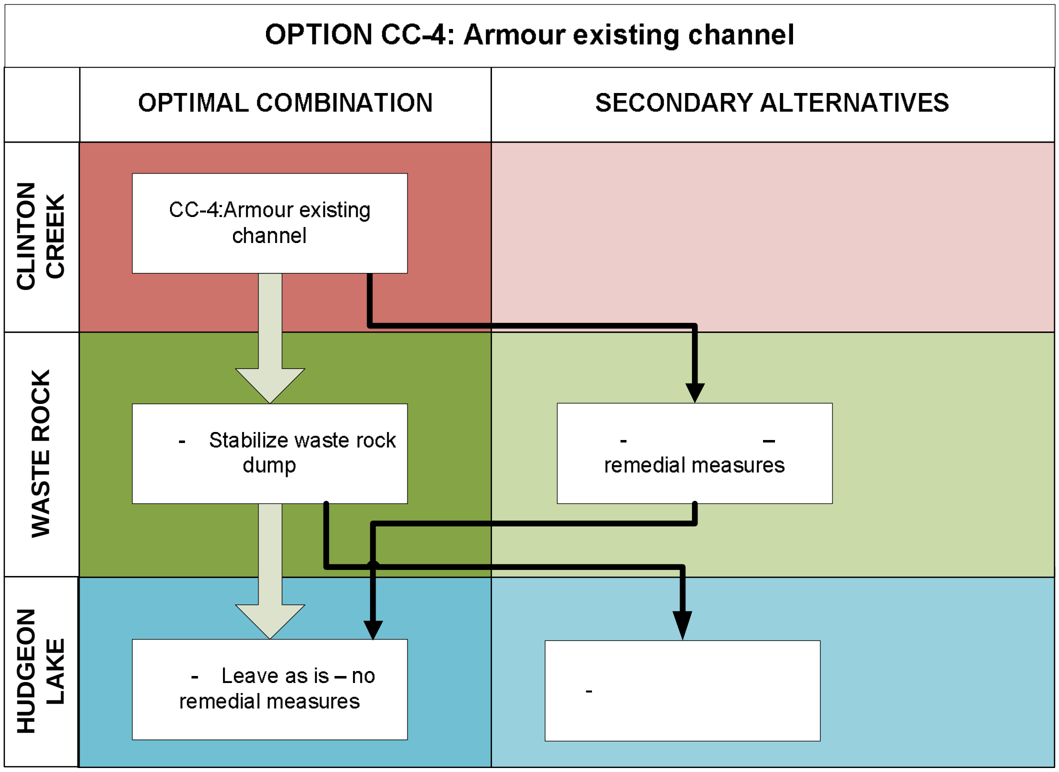

Figure 14. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-4.

Advantages

- Local contractors have experience with installing gabion structures,
- Simple technology that does not need a lot of imported materials.

Disadvantages

- Locally available competent rock for gabions is limited (based on currently identified borrow sources),
- Regular inspection, monitoring and maintenance will be required for gabion structures,
- Requires stabilization of waste rock to be effective in the medium to long term,
- Eliminates approximately 500 m of fish habitat,

Risks and Uncertainty

- Working in existing channel may not be safe.
- Option is dependent on finding a viable source of rockfill.

Technical Considerations for Detailed Design

- Trade-offs between raising channel bottom or maintaining current profile,
- Stabilization of waste rock to improve long term performance,
- Hydraulic design.

4.5 Option CC-5: Lower Existing Channel to Bedrock

4.5.1 Description

The objective with this option was to generate an option that (a) has no structures that require annual inspection, monitoring and maintenance and (b) reduces the risk of Hudgeon Lake breaching through the waste rock pile. The layout of this option is shown in Drawing 12.

The current channel alignment across the waste rock pile would be maintained but the constructed channel bed would be lowered so that the downstream end of the lowered reach would be in contact with the bedrock surface, immediately downstream of the existing Drop Structure #4. The bedrock is less erodible than the waste rock and therefore the channel would be more stable and the potential for a breach of the Hudgeon Lake outlet would be reduced. The level of Hudgeon Lake would also be lowered 13 m to approximately Elevation 398 m, which is approximately 5 m below the design elevation of the downstream apron of Drop Structure #4.

At its current water level (approximately Elevation 411.2 m) Hudgeon Lake is approximately 29 m deep and holds approximately 9.5 million cubic metres of water, based on the 2010 bathymetry. With the lake water level lowered to Elevation 398 m, the depth of Hudgeon Lake would be approximately 16 m and the lake water volume would be approximately 2.5 million cubic metres.

This option would require re-grading of the waste rock pile surface to reduce or eliminate the cross-valley movement of the waste rock pile.

Hydraulics and Structures

The channel would have a bed width of 7 m, 3H:1V side slopes on the south waste rock side, 2H:1V side slopes on the north hill side and a grade of 0.0005 m/m. This geometry is similar to the current channel geometry and therefore the flow velocity should be sufficiently low to reduce the channel armouring requirements. The channel geometry and grade would be re-assessed during the preliminary design, if this option was carried forward.

Overall the mean channel grade would be decreased because of the lowered Hudgeon Lake outlet, though it would still be steeper than the natural gradient of the Creek prior to mine development. As a result, it is likely that the channel will continue to slowly degrade over time.

Geotechnical and Earthworks

The challenges of working along the channel would be similar to those identified for Option CC-4, though less armouring would be required.

The stability of the waste rock would need to be evaluated before detailed design could be undertaken. Stability analysis is beyond the scope of the current assignment. It would be reasonable to expect that the volume of regraded material would be 20% greater than for Option CC-4.

Environmental and Human Health and Safety

The lowering of the lake level could cause instability of valley slopes and submerged waste rock around the lake as previously submerged surfaces become exposed to the air. Some slumping may occur during the draw-down process.

4.5.2 Discussion

Interaction with other options

The lowering of the Hudgeon Lake outlet interacts with the following options (Figure 15):

- WR-3 – Stabilize by removing upslope material and
- WR-4 – Partially backfill Hudgeon Lake

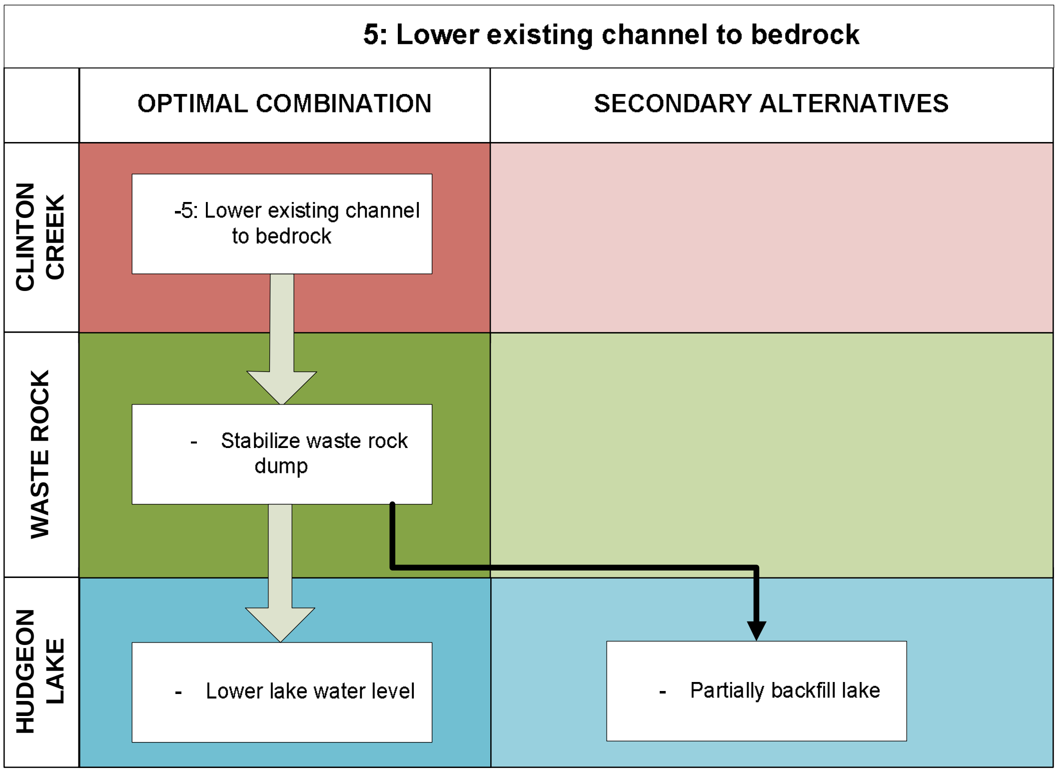

Figure 15. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-5.

Advantages

- No structures are required, which eliminates the cost of inspections, monitoring and maintenance.
- The flat side slope towards the south will allow sunlight to reach the full width of the channel and likely reduce the ice build-up on one side of the channel, which has affected the flow in the current channel during spring runoff.
- The creek channel is left to evolve naturally, which is best for fish and wildlife.
- Uninterrupted fish movement into and out of Hudegon Lake through a naturally evolving channel.
- A part of Hudgeon Lake is maintained, which allows for the heating of the creek water that in turn appears to be beneficial for the fish in Clinton Creek.
- The reduced lake depth and increased height to the top of the waste rock pile significantly reduces the risk of a catastrophic breach of the waste rock pile.
- If a catastrophic breach occured, the severity of the downstream impact will be greatly reduced compared to a breach with the lake at the current level.
- The 3H:1V channel side slope on the south waste rock side allows some lateral movement of the channel towards the waste rock pile as a result of the bedrock dip angle (due to erosion).

Disadvantages

- A large volume of waste rock material has to be excavated and placed at one or more suitable locations.
- The work will span a number of years, to provide a gradual draw-down of Hudgeon Lake and thereby reduce the risk of rapid draw-down failures of the slopes around the lake.
- Some channel erosion will occur in the channel during extreme events, as part of the natural channel self-armouring processes during which finer bed materials are moved downstream while leaving coarser material in place.
- Need to divert flows around site during construction.

Risks and Uncertainty

- The risk of a breach of the waste rock pile will remain but the consequence of a breach will be significantly reduced, due to the reduced depth and water volume in Hudgeon Lake.
- The total quantity of waste rock material that has to be excavated from the channel and moved to increase the stability of the waste rock pile is uncertain at this time.
- The risk to the public using the waste rock pile for recreational purposes is reduced by flattening the side slopes of the Clinton Creek channel.

Technical Considerations for Detailed Design

- Stabilization of the waste rock pile.
- The water levels should be lowered at a rate that does not cause instabilities due to rapid drawdown.
- Determine best allocation of waste rock fill between potential receiving sites.
- The need for maintaining the road across Clinton Creek,near Hudgeon Lake, has to be reviewed. If there is a need for maintaining this road, a new road and creek crossing will be incorporated into the design.
- A large part of the earth moving can be done at any time above the Hudgeon Lake stockpile area as the work would not be classified as work in or adjacent to streams.
- The lowering of the lake could be done in increments by sequentially removing the highest row of gabions after pre-excavating the upstream channel to the same depth or more. The next row of gabions would not be removed until the lake has stabilized at the new lower level.

4.6 Option CC-6: Restore Clinton Creek to Original Valley Bottom

4.6.1 Description

This option would involve draining Hudgeon Lake and removal of enough waste rock to reinstate Clinton Creek to the natural valley bottom, thereby eliminating the risks associated with a breach of the Hudgeon Lake outlet. This concept is illustrated in Drawings 13 and 14. The option of restoring the valley was discussed in the UMA (2002) Conceptual Design Report.

Hydraulics and Structures

Once the creek is flowing along the valley bottom, no hydraulic structure would be required to provide energy dissipation. The lake would be drained in stages as excavation of the waste rock proceeded and would likely require two or more years of construction. A section of the valley bottom below the waste rock dump would be restored and Clinton Creek reconnected through the lake and excavated portion of the waste rock footprint. A minimum valley width of 100 m would be required to provide for a meander pattern typical to the Clinton Creek Channel.

A creek training channel would be established through the newly exposed valley floor, but after some initial maintenance, the creek would be allowed to determine its own course with time. The creek may at some point meander in a way that would lead to erosion of the base of the waste rock, but it is considered that this erosion would have minimal negative impact on the environment because the rate of erosion would be relatively slow. The original valley bottom buried beneath the waste rock is wide and relatively flat based on bathymetric surveys of Hudgeon Lake, the downstream topography and photos of the site before the landslide dam was formed.

Geotechnical and Earthworks

The geotechnical and earthworks aspects of this option are discussed in Section 5.2 (Option WR-2: Remove Waste Rock to Expose Valley Floor).

Environmental and Human Health and Safety

This option, more than any other presented here, would restore the Clinton Creek Valley toward its natural form and function. This option should reinstate the natural fish habitat of the upstream portions of Clinton Creek. Under the existing conditions, fish are unable to negotiate the existing gabion drop structures and Hudgeon Lake provides minimal fish habitat due to low oxygen levels. Hudgeon Lake would be eliminated, but because it is not a naturally occurring feature, it is not considered to be a critical part of the natural environment.

The valley floor would be revegetated with native species along the wetted perimeter of the current Hudgeon Lake, and beneath the waste rock, where the valley bottom is exposed. The remaining waste rock piles are not expected to be able to support vegetation without some amendments.

4.6.2 Discussion

Interaction with other options

Restoring Clinton Creek would require the relocation of much of the waste rock and Hudgeon Lake would be completely drained (Figure 16). The remaining waste rock would be re-shaped to ensure long term stability. It goes without saying that Hudgeon Lake would be completely drained in this scenario, and there would be no potential for the existing condition to re-develop (i.e. where a deep lake has been formed by a landslide dam).

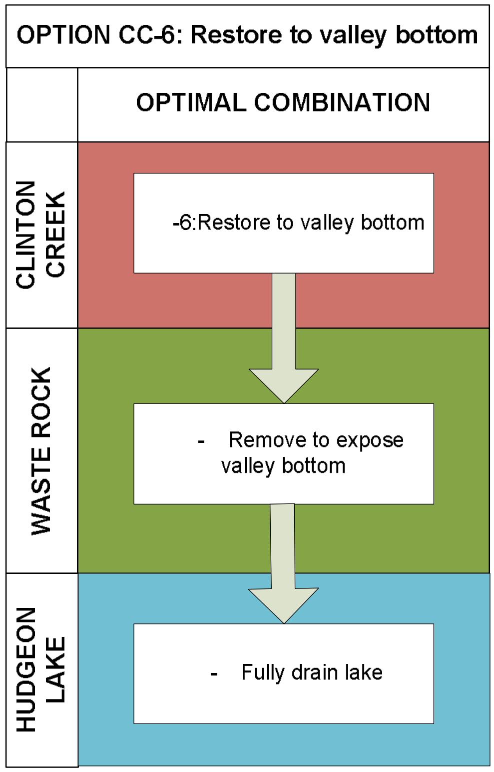

Figure 16. Alternatives for the waste rock and Hudgeon Lake that are compatible with Option CC-6.

Advantages

- The creek channel would be left to evolve naturally, which is best for fish and wildlife.
- Uninterrupted fish movement along Clinton Creek through a naturally evolving channel.
- Hudgeon Lake and the associated risks are eliminated.
- The remaining waste rock in the valley would be shaped to provide long term stability (i.e. no risk of a landslide dam forming).
- The open pits could be backfilled (though this may not be the most efficient option.
- The options would very nearly be a walk-away solution for Clinton Creek, the waste-rock dump and Hudgeon Lake, as the lake, and risks associated with a breach are eliminated.

Disadvantages

- A very large amount of earthwork would be required, over several years of construction
- A large quantity of waste rock would need to be relocated to either the pit, or other portions of the Clinton Creek Valley.
- The work will span a number of years, to provide a gradual draw-down of Hudgeon Lake and thereby reduce the risk of rapid draw-down failures of the slopes around the lake.

Risks and Uncertainty

- The stability of the natural slopes along Hudgeon Lake and the waste rock dump may be low due to thawing of permafrost.

  - o The warm water of Hudgeon Lake may have thawed permafrost in the natural slopes with time, thereby reducing the strength of the colluviums.
- The performance of vegetation restoration and the adaptation of wildlife to the new environment may not meet expectations.
  - o May take more time, effort and money then expected.
- Generation of air-borne asbestos associated with the moving of the waste rock.

Technical Considerations for Detailed Design

- A safe method for draining Hudgeon Lake in the early stages of construction must be developed.
- The water levels should be lowered at a rate that does not cause instabilities due to rapid drawdown.
- Stability analysis would be required to determine appropriate geometries of remaining waste rock to provide long term stability.
- Optimization of cuts, and fills considering natural topography, equipment and staging.
- Determine best allocation of waste rock fill between potential receiving sites.
- Detailed cost benefit analysis would be necessary to determine the viability of this option.
- Extensive geotechnical and environmental site investigations would be required as part of detailed design.

4.7 Option CC-7: Leave As Is – No Annual Maintenance

One option that had been discussed previously is to discontinue maintenance, inspections and long term performance monitoring, including any repair to damaged drop structures. This would eliminate the costs associated with maintenance. If no maintenance is completed, the drop structures will gradually degrade and their effectiveness in mitigating the potential for a breach will be compromised. It would be expected that debris would accumulate in the channel. Some gabion baskets may be damaged by the debris with some gabion fill material being lost through the damaged baskets, thus affecting the overall performance.

As observed in the summer of 2010, erosion of unprotected channel sections has undermined the lower tier (i.e. floor) at drop structure #4. The floor rotated down to a nearly vertical orientation due to the erosion. If not repaired, it is likely that erosion will continue to undermine the rest of Drop Structure #4. Erosion and subsequent failure of the structures would then proceed in an upstream direction towards Drop Structure #1 and the gabion mat installed just upstream of the structure.

If the structures are lost, the only erosion control that would remain are the boulders below the channel, directly upstream of DS#1. It is not known how quickly the channel will degrade.

Consequences of proceeding with this option include:

- Failure of the drop structures
- Uncontrolled release of water from Hudgeon Lake
- Large amount of waste rock material being carried downstream of the waste rock pile

This option does not proactively address any of the identified risks and liabilities. In fact the risks and liabilities will be greater. It has already been established by previous studies (UMA 2000a) that the risk of a sudden breach of the Hudgeon Lake outlet should be mitigated, and the risk of a breach has been greatly reduced by the work done to date (ie. status quo). By this reasoning, proposing an option which does not at least maintain the current level of protection is not justified, unless additional studies show that the risk factors have changed.

Advantages

- No capital or maintenance costs.

Disadvantages

- Does not address any of the identified risks and liabilities.
- Stability of the waste rock may decrease with time, as erosion of the Clinton Creek channel advances.
- The risk of a breach will increase with time, and will likely occur at some point in the future.

Risks and Uncertainty

- Without a doubt, the channel alignment and profile will change with time, but the acute and chronic impacts are uncertain, and uncontrolled.
- Length of time before a breach scenario develops.

4.8 Option CC-8: Tunnel Through Waste Rock

A tunnel through the waste rock would perform the same function as a tunnel through the bedrock (Option CC-3). Because the waste rock is not stable, the performance of a tunnel through the waste rock could be affected by future slope movements. Differential movements in the waste rock would likely shear a tunnel.

A cut and cover tunnel may be technically feasible, but for a similar level of effort, several other options provide more advantages, and less uncertainty.

Advantages

- Existing channel could be utilized during construction and also post-construction where it would serve as an emergency spillway.

Disadvantages

- Though the primary flows are diverted through the tunnel, a functional emergency spillway would still be required, in the event the tunnel or tunnel inlet is blocked by debris.
    - o Spillway must be able to withstand ongoing slope movements,
- Construction and maintenance would require a specialist contractor
- Eliminates approximately 500 m of fish habitat, unless a riparian flow can be maintained in the existing channel.
- Debris screening at tunnel inlet requires regular inspection and maintenance.

Risks and Uncertainty

- The feasibility, design, cost and construction of the tunnel are dependent on the waste rock conditions.
    - o The loose, non-uniform waste rock may not be suitable for tunnel boring.
- A blockage or collapse of the tunnel would force the spillway into service
- Ongoing movements of the waste rock may damage the tunnel, leading to
    - o collapse of the conduit,
    - o erosion of waste rock around the pipe.

4.9 Option CC-9: Gabion Chute Along Existing Channel

A gabion chute could be constructed along the existing channel alignment to convey the flows from Hudgeon Lake across the waste rock. This option though technically feasible, would not provide significant benefit over options CC-4 or CC-5, while costing substantially more. A gabion chute would be able to withstand higher flow velocities than gabion drop structures. For this reason, the channel dimensions could be smaller. A gabion chute would also be impacted by waste rock movements and landslides at the waste rock toe.

4.10 Option CC-10: Concrete Along Existing Channel

A concrete lining along the existing channel would be able to withstand high flow velocities, therefore drop structures would not be required, though a stilling basin would be required at the end of the concrete channel. This option will not be considered in more detail because the costs of constructing a long concrete channel in a remote location are expected to be much higher than for some of the other feasible options. Concrete is also a brittle material, and may not be able to withstand the stresses of the ongoing creep movements of the waste rock.

4.11 Option CC-11: Pressure Grouting Along Existing Channel

This option would involve pressure grouting radially around the creek bed at stations along the creek alignment. The grout would cement the granular materials and fill the voids and cement the fractures in the bedrock. The channel would retain a natural look, but would be more durable. The grouted sections would essentially act as weirs along the alignment, allowing for some natural erosion to occur between the grouted segments.

Because the cost of grouting along the existing channel is expected to be high, this option has not been considered further.

4.12 Option CC-12: CSP Half-Round Chute

The benefits of a corrugated steel pipe (CSP) half-round chute would be similar to the benefits identified for a concrete or gabion chute (Options CC-9 and CC-10). It would less expensive to construct than a concrete chute, but would still rely on imported materials. A benefit over a concrete or gabion chute is that a highly durable aggregate source is not required. A CSP chute would not blend into the natural surroundings, and would not allow for passage of fish upstream. A CSP chute is not as flexible as gabions, and would be susceptible to damage from waste rock movements. Water flow or seepage along the base and sides of the CSP chute may cause erosion, thus destabilizing and damaging the pipe. Aligning and preparing bedding for a CSP pipe would also be challenging in the existing channel

5. Waste Rock Dump Options: Description and Assessment

The critical risks in this area of the mine site are related to the performance of the drop structures and the conveyance of the flows of Clinton Creek. Although the failure of the waste rock dump led to the formation of Hudgeon Lake, further stabilizing the waste rock without implementing improvements to the Clinton Creek Channel would only marginally reduce the risks at the mine site. The rates of movement have generally been decreasing with time, and this trend is expected to continue. Additional melting of the permafrost beneath the waste rock, or erosion at the toe of the waste rock by Clinton Creek, could contribute to continued slope movements.

5.1 Option WR-1: Leave As Is – No Remedial Measures

The Option would involve no remedial works to the waste rock dump. The current bi-annual performance monitoring program could be maintained to identify changes in the behaviour of the waste rock. If no improvement in stability of the waste rock dump is made, the drop structures, or any other measures implemented on the waste rock or along the existing creek alignment, will continue to be impacted by the movements of the waste rock dump.

5.1.1 Discussion

Advantages

- No new capital or maintenance costs. The current expenditures are for monitoring and inspections.
- The existing Long Term Monitoring program is already established, and would be relatively easy to continue.

Disadvantages

- The waste rock will continue to move northward across the Clinton Creek Valley, which will lead to additional constriction of the channel and gabion structures.

Risks and Uncertainty

- The flows in Clinton Creek will continue to erode the toe of the over-steeped waste rock pile unless otherwise mitigated.
    - Toe erosion will destabilize the lower slope of the waste rock leading to localized slumping.
    - Toe erosion may lead to increased movements of the entire failed waste rock dump.
- Additional thawing of permafrost may lead to an increase in movement rates.

Technical Considerations for Detailed Design

- Regular (ie. bi-annual) monitoring of waste rock movements should be considered. Remote sensing technology could be considered to provide supporting measurement, and reduce long term labour costs.

5.2 Option WR-2: Remove to expose valley floor

5.2.1 Description

Option WR-2 would be implemented along with Option CC-6 *Restore Clinton Creek to Original Valley Bottom* and Option HL-2 *Fully Drain Hudgeon Lake*. If this option were implemented, Clinton Creek would be restored to the natural valley bottom, and therefore Hudgeon Lake would be eliminated. To accomplish this, approximately

10,000,000 m^3 of waste rock would be relocated to several potential receiving areas. Approximately 300,000 m^3 of waste rock would be used to backfill the existing channel, where it has cut into the north valley slope, while the rest could be relocated back into one of the pits or placed along the south slope of the valley, within the current footprint of Hudgeon Lake. The quantities relocated to each of the potential disposal areas would be determined during future design phases. An additional 1,000,000 m^3 of regrading may be required to stabilize the waste rock on the south side of the valley based on the preliminary stability analysis by UMA (2002). It is expected that implementing this option, including draining the lake, and establishing a new alignment for Clinton Creek, would take several years to complete due to the technical challenges, large earthwork volumes and construction staging.

Other details related to this option are described in Section 4.6 (Option CC-6) and 6.2 (Option HL-2) as these three options are integral to each other. As shown on Drawing 13, the creek would be re-aligned along the north side of the former valley bottom. It would not be necessary to remove all the waste rock from the valley, but the remaining waste rock along the south slope would be shaped to provide long term stability.

Implementing this option would require very little processed material (ie. blast rock, geotextile etc) assuming that placing the waste rock as-is into the pits and upstream in the valley would be acceptable. The Porcupine and Creek open pits have ponded water in them. This water would be displaced if the pits were backfilled. The water quality should be considered prior to backfilling the pits since some or all of the water would be removed or displaced to facilitate backfilling. Any discharge to receiving streams will need to meet appropriate water quality guidelines.

5.2.2 Discussion

The excavation of the waste rock may cause asbestos fibres to become airborne if the excavated material is dry. Air sampling completed during previous site work has shown that the airborne asbestos concentration is typically low and usually below the allowable limit. Protective safe work practices can be implemented that would reduce exposure to an acceptable level to allow construction to proceed without risk to workers, should monitoring determine this is required. Prohibiting access to the general public during construction would prevent accidental exposure to non-workers.

Advantages

- Concerns about the stability of the Clinton Creek Waste Rock Dump are eliminated
- The risk of a breach of the Hudgeon Lake outlet is eliminated (See also Option CC-5 and HL-2)
- Open pits could be partially backfilled with waste rock thereby reducing or eliminating hazards associated with the existing open pits.

Disadvantages

- Would require a large fleet of equipment to accomplish this task in a reasonable time period.
- Valley bottom would require restoration.
- Construction staging would be required to draw down lake gradually and safely.

Risks and Uncertainty

- The stability of the natural slopes along Hudgeon Lake may be low due to permafrost degradation and saturated ground conditions.
- See also comments in Sections 4.6 and 6.2, Option CC-6: Restore Clinton Creek to valley bottom and Option HL-2:Fully drain Hudgeon Lake respectively.

- Restoration of the valley slopes and bottom may be challenging depending on the ground conditions on site, once the lake is drained, and the waste rock is removed.
- Backfilling of the Creek pit may not be feasible due to water flow from Porcupine Creek.

Technical Considerations for Detailed Design

- Remaining waste rock piles must be shaped to provide long term stability.
- Best receiving areas for waste rock must be determined and balanced against costs.
- Lowering lake level must be staged to not induce valley slope failures due to rapid drawdown effects.
- Restoration plan for valley would be required.

5.3 Option WR-3: Stabilize Waste Rock Dump

No new stability analysis of the waste rock dump was completed for this report, and the options for improving the stability have been taken from previous work , for example the UMA Conceptual Design Report (2002). The stability of the waste rock dump and improvement measures has been undertaken on several occasions in the past including by Golder Associates (1978) and UMA (2002). The conceptual design analysis by UMA (2002) targeted a minimum overall FS of 1.25 for stability improvements. In general, this would be accomplished by regrading the waste rock and off-loading material from the upper portion of the waste rock dump to reduce the driving forces on the slide mass as shown on Drawing 9. Two unloading scenarios were evaluated; with the channel along its existing alignment (Option CC-4, not illustrated on Drawing 9) and an alternative alignment through the middle of the dump (Option CC-2).

Approximately 600,000 m^3 of waste rock would be excavated to achieve a stable waste rock geometry. Approximately half of this volume (300,000 m^3) would be used to fill the existing channel. The remainder (300,000 m^3) would be used for re-grading the mid to lower sections of the dump or be disposed of in the open pit area. To carry out the construction work, discharge from the lake would have to be controlled. This could be accomplished by drawing down the lake level prior to construction and/or using the existing channel during construction, which would then be backfilled once the new channel is flowing.

Placement of 300,000 m^3 of material to in-fill the channel would take approximately 60 days, assuming an average placement rate of 5,000 m^3/day. Regrading on the upper portion of the waste rock dump could continue during the channel stabilization work. This earth moving operation, however is not highly weather dependent and construction could proceed into the winter months if required.

5.3.1 Discussion

Advantages

- The waste rock movement would be abated or stopped, and presumably the gabion baskets would no longer be subjected to deformations.
- Requires less than one tenth the volume of earthwork required compared to Option WR-2.

Disadvantages

- Stabilizing the waste rock does little to reduce risk and liability on its own without addressing the risk of a breach of the Hudgeon Lake outlet by maintaining the drop structures or implementing one of the other options for the Clinton Creek channel discussed in Section 3.

Risks and Uncertainty

- The physical mechanisms driving the creep movements of the Waste Rock Dump are poorly understood.

Technical Considerations for Detailed Design

- The geometry of the regraded waste rock must be tailored to any improvements to the Clinton Creek Channel that may be considered.
- The stability analysis must be updated, considering and incorporating .
  - Current geometry of waste rock and Clinton Creek Channel.
  - Design of measures for Clinton Creek if considered.
  - Level of acceptable risk.
  - More advanced analysis methods.
  - Additional soils testing, including confirmation of permafrost, measuring groundwater levels, slope inclinometer monitoring, and strength testing.

6. Hudgeon Lake Options: Description and Assessment

In general there are four options for Hudgeon Lake:

1. Leave Hudgeon Lake as it is (Option HL-1)
2. Fully drain Hudgeon Lake (Option HL-2)
3. Partially drain Hudegeon Lake by lowering the outlet level (Option HL-3)
4. Partially backfill Hudgeon Lake with waste rock (Option HL-4)

The discussions on Clinton Creek in Section 4 included comments on the feasible and preferred alternatives for Hudgeon Lake for each scenario. It is clear that the existence of Hudgeon Lake is due to the failure of the waste rock in the1970's, and the level of Hudgeon Lake is controlled by the outlet into Clinton Creek. The following discussions will focus on the considerations specific to Hudgeon Lake for each of the above options. UMA Engineering Ltd. (2008) reviewed several options for improvements to Hudgeon Lake.

The following discussions do not consider the health of Hudgeon Lake, except where remedial actions will have a readily apparent impact on the water quality or fish habitat. The environmental impact of implementing one of the following options should be assessed as part of future design stages.

6.1 Option HL-1: Leave As Is – No Remedial Measures

The level of Hudgeon Lake would be maintained at its current elevation by maintaining the outlet at the current elevation. For the purpose of this discussion, it is assumed that the health of the lake would remain relatively unchanged into the future. That is, the lake will not be able to support fish because of the low oxygen levels, nor would fish be able to access the lake because of the existing drop structures or tunnel isolating the lake from the lower reaches of Clinton Creek.

Advantages

- The state of relative equilibrium would be maintained,
- It would not require any earthwork.
- The lake provides flood attenuation effects.

Disadvantages

- The consequences of a breach of the waste rock dam (ie. the lake outlet) remain unchanged.
- This option does not reinstate any fish habitat.

Risks and Uncertainty

- The body of water will continue to contribute to permafrost degradation, if permafrost is still present, with undetermined consequences
- Hudgeon Lake is still relatively young, and is still evolving. The water quality in the lake is expected to continue to change with time.
- Consequences of a tidal wave caused by a massive landslide into the lake are undetermined, but potentially severe. Small landslides have occurred into the lake with no noticeable effects.

Technical Considerations for Detailed Design

- Not applicable.

6.2 Option HL-2: Fully Drain Hudgeon Lake

Fully draining Hudgeon Lake would require that Clinton Creek be re-established along the base of the valley by removing a significant portion of the waste rock dump (Option CC-6 and WR-2). Implementing this option would be technically challenging.

Drawdown would have to be carefully staged and controlled to minimize instabilities of the slopes around Hudgeon Lake. Assuming an average lake discharge of about 0.6 m^3/sec (20 cfs) during the summer, a pumping capacity of 75 m^3/min (20,000 gpm) over approximately one month would be required to draw down the lake level by approximately 2m.

Depending on the final location and configuration of a new channel, stability of the valley side slopes on the north side of the existing creek channel may need to be checked. Stability of the valley side slopes below the existing lake level in Hudgeon Lake would also need to be considered. Before Hudgeon Lake formed, the stability of the valley slopes was likely influenced by permafrost which is known to be prevalent in the area (Golder 1978). The permafrost below the lake level will have degraded significantly since the lake formed in the early 1970's and draw down of the lake level could trigger some landslides due to saturated ground conditions. There are a few locations around the lake (e.g. near Bear Creek) where at least one slope failure has already occurred, just above the waterline, possibly due to degradation of permafrost.

Advantages

- Valley could be restored.
- No potential for breach, and therefore hazard is eliminated.

Disadvantages

- Long period of time required to lower lake.
- Water temperature in Clinton Creek may decrease which would affect fish habitat.
- Flood attenuation effects of lake would be eliminated.

Risks and Uncertainty

- The permafrost in the valley slopes has been degraded, and instabilities may develop after water has been drawn down.
- Restoration of the valley would take a long time to mature with uncertain performance and effectiveness.
- Potential impacts on the fish population.

Technical Considerations for Detailed Design

- The methods and staging for lowering the lake must be considered.
- The valley slopes may be unstable due to degredation of permafrost and the saturated soils.

6.3 Option HL-3: Lower Hudgeon Lake Water Level

UMA Engineering Ltd. 2008 provided a comprehensive analysis of the issues around lowering Hudgeon Lake. Permanently lowering the water level in Hudgeon Lake has been suggested previously by others as a possible means to improve the water quality in the lake to support fish habitat. The premise is the reduction in lake level will allow the lake to turn over more completely on a regular basis to allow the lake to switch over to an aerobic state. This concept was largely dismissed in UMA Engineering LTD., 2008, because the surface area and wind exposure would both be decreased.

It has been suggested that all the gabion drop structures be removed since the creek channel downstream of the drop structures is on bedrock and the gabion drop structures are a barrier to fish passage in to Hudgeon Lake. Removal of the drop structures is expected to be beneficial to fish passage (Option CC-5). Lowering the lake level would also decrease the hydraulic gradient between the outlet (Station 0+000) and the natural Clinton Creek Channel (around station 0+700). The probability and consequences of a dam breach would be decreased if the lake level was lowered.

The discussion in Section 4.5 (Option CC-5: Lower existing channel to bedrock) addresses the geometric and volume changes of a lowered Hudgeon Lake. The bathymetry of Hudgeon Lake shown on Drawings 04 and 05, is useful for conceptualizing the changes to the lake as a result of lowering the water level. Figure 07 shows the stage-volume curve for Hudgeon Lake.

The issues related to slope stability due to drawdown rates addressed in Section 6.2 also apply to partial lowering of Hudgeon Lake.

Advantages

- The impact of a breach would be reduced because
  - The average gradient along the channel between station 0+000 and 0+600 would be decreased
  - The volume of water available to be released would be reduced
- May allow fish passage into Hudgeon Lake, depending on the improvements made to the Clinton Creek channel (Option CC-5).

Disadvantages

- Channel through waste rock would be deeper, unless waste rock was re-graded to improve local stability.
- May decrease oxygen content in lake water and also downstream in Clinton Creek.

Risks and Uncertainty

- Positive and/or negative impacts on fish population.
  - The lowering of the water level may affect water temperatures and water quality with some impact on downstream fish populations.

Technical Considerations for Detailed Design

- Probability and consequence of a breach under design conditions.
- Waste rock should re-graded to provide stable slopes along the deeper Clinton Creek channel.
- The existing stability of the waste rock dump and existing valley slopes around Hudgeon Lake, and how stability would be affected by water level of the lake.

- Construction methods and staging for lowering the lake.
- Appropriate restoration of vegetation along the exposed shoreline.

6.4 Option HL-4: Partial Infilling of Hudgeon Lake

The UMA (2008) report also investigated the concept of partially infilling Hudgeon Lake with waste rock. Infilling of Hudgeon Lake with waste rock material has been suggested as a possible means to improve the water quality to support fish habitat. The premise is that anaerobic decomposition of the organic matter in the lake bottom would reduce / stop if the lake bottom is covered and that a reduction in lake depth will allow the lake to turn over on a regular basis, which would also aid in the transition to an aerobic condition. It was stated in UMA (2008) that:

> Overall, it cannot be confidently predicted that infilling would increase fish over-winter survival potential without conducting a much more detailed study. A study of this nature is expected to be very costly and difficult to justify based on the minimal (negligible) expected benefit associated with the goal of enhancing Chinook productivity.

The waste rock material most readily available for deposition into Hudgeon Lake is located above elevation 415 m of the waste rock dump. The waste rock backfill material would be sourced selectively to improve the stability of the waste rock dump as part of overall stabilization work (See also the discussion on Option WR-3: Stabilize Waste Rock Dump). A preliminary estimate suggests that there is about 3 million m^3 of waste rock available. If a 10 m thick layer was to be placed in the bottom of the lake then the lake area that could be covered is about 300,000 m^2. This option was generally dismissed as not being cost effective and because of constructability challenges (UMA 2008).

Alternatively, if the benefits of covering the bottom of the lake were found to be minimal, the backfilling could be concentrated along the south-east shore of the lake, where the waste rock can be pushed out from land. The material would be placed against the east slope of the waste rock, and the south slope of the Clinton Creek valley (ie south shore of Hudgeon Lake) as shown on Drawing 13.

Advantages

- Volume of lake is decreased.
- May decrease the anaerobic decomposition of organic matter on the lake bottom.
- Pushing waste rock into the lake would be an efficient way of unloading waste rock pile.

Disadvantages

- The ability of the lake to buffer major hydrological events would be slightly decreased
- Work on or under water is difficult and costly to perform, monitor and control.
- Sedimentation will occur, and must be controlled.
- Local contractors may not have suitable equipment or experience.

Risks and Uncertainty

- Condition and stability of submerged waste rock and/or valley slopes is uncertain, and additional loading may cause instabilities

Technical Considerations for Detailed Design

- Effects on decomposition of organic material on lake bottom
- Determine the areas of the lake that would benefit most
  - o Pushing material out from shore would be the most economical approach, but would not provide much coverage of the lake bottom
- Transportation and placement methods for lake infilling
- Sediment control for suspended solids.
- Effect on waste rock dump stability, both during and post-construction
- Effectiveness of covering lake bottom to improve lake water quality.

7. Wolverine Creek Options: Description and Assessment

To assess the conditions along Wolverine Creek, the length of the creek can be divided into four sub-reaches:

(1) The reach upstream of the tailings
(2) The reach past the north and south lobes
(3) The rock lined channel downstream of the south lobe.
(4) The reach downstream of the rock lined channel.

The reach upstream of the tailings is undisturbed and the creek is evolving naturally. As a result, this upstream reach of Wolverine Creek is not assessed further and no modification or maintenance is proposed in any of the considered options.

Along the reach that flows along the toe of the north and south lobes, the creek flow is first constricted by the north lobe before it discharges into the small lake between the north and south lobes and it is then again constricted by the south lobe before leaving the reach. Along this reach, the flow through the small lake between the north and south lobes needs no further assessment and can be left as is. The flow past the constrictions caused by the north and south lobes are two areas where the channel is actively changing and maintenance or modifications may be considered.

Downstream of the south lobe, Wolverine Creek flows over the rock lined channel which protects the underlying tailings from eroding further. Following the 1974 breach, the Wolverine Creek channel on top of the tailings was armoured with riprap and several riprap rock sills were constructed across the channel to stabilize it. The channel is steep and fairly shallow and at one point in time, the creek flow overtopped the low bank and cut a new channel in the lower part of the valley and north of the current creek alignment. Along this reach, the creek channel is well vegetated and maintenance has been done recently in the form of removing trees from the creek bed, to improve the discharge capacity, while leaving smaller willows in the channel to bond the creek bed.

7.1 Option WC-1: Leave As Is – No Annual Maintenance

Under this option, it is proposed to leave the creek as it is and not carry out any annual maintenance in the future. In the past, the site-specific work along Wolverine Creek has been limited to construction of the rock lined channel downstream of the south lobe and one channel restoration after the creek once cut through the left bank of the creek channel.

If no maintenance is done, the vegetation in the Wolverine Creek channel downstream of the tailings may become too dense, which will increase the flow depth in the shallow creek channel and in turn may cause the creek to overflow the lined channel. If this were to occur, the creek would be flowing directly over the exposed tailings.

The north and south tailings lobes are slowly but constantly moving across the creek valley and constricting the flow. The constrictions narrow the channel width and the flow velocities are increased at these locations, which leads to accelerated erosion rates. In addition, as erosion occurs along the toe of the tailings, the steep tailings slump into the channel, thus blocking and/or narrowing the channel which increases the water depth and flow velocity and erodes and transports the slumped material farther downstream.

Advantages

- No maintenance required.

Disadvantages

- Erosion of the tailings leads to the release of asbestos fibres into the Wolverine Creek flow on an on-going basis.
- The rock lined channel will slowly deteriorate to the point that it no longer functions. Over time, the Wolverine Creek channel may break out from the current channel and cut a new channel in or alongside the tailings.

Risks and Uncertainty

- If the presence of asbestos fibres in the stream flow is found to be harmful to fish, then there is an elevated risk of this option causing harm to fish by not stabilizing the slumping tailing fronts of the north and south lobes.
- The densification of vegetation in the creek channel increases the risk of the creek breaking out of the current shallow creek channel.

Technical Considerations for Detailed Design

- Not applicable.

7.2 Option WC-2: Status Quo – Maintain Armoured Channel

Under this option, it is proposed to maintain the rock lined channel downstream of the south lobe, but without implementing any measures to the creek channel along the north `and south lobes. This would be similar to the practice over the past few years on Wolverine Creek where only minor maintenance such as clearing of trees in the creek channel is performed. The tailing lobes would be allowed to continue to erode and slump into Wolverine Creek as the result of erosion.

By removing trees and brush from the rock-lined channel, the discharge capacity of the creek channel is maintained. If the flow depth increases due to dense vegetation, the flow may break out where the tailings are exposed and cut a new channel outside the existing armoured channel.

Advantages

- The discharge capacity of the Wolverine Creek channel is maintained.
- Relatively low maintenance cost for vegetation clearing using hand-tools. Cleared woody debris will be placed on top of the tailings outside the existing and thereby contribute to the establishment of vegetation outside the channel.

Disadvantages

- Tailings, including asbestos fibres are released into the Wolverine Creek flow on an on-going basis.
- Regular but not necessarily annual inspections and maintenance has to be done.
- Some repairs to the rock lined channel may be required in the future.

Risks and Uncertainty

- If the presence of asbestos fibres in the stream flow, due to the erosion of the tailings lobes, is found to be harmful to fish, then there is an elevated risk of this option causing harm to fish.

- By maintaining the rock lined channel, the creek channel capacity will be maintained and thereby reduce the risk of the creek breaking out of the current armoured channel section.

Technical Considerations for Detailed Design

- None.

7.3 Option WC-3: Rock Drain Along Toe of Tailings Lobe(s)

Under this option, it is proposed to infill the existing channel section between the face of the south lobe (and possibly the north lobe) and the valley slope with coarse rock, to form a rock drain. The rock drain will allow the creek to flow through the rock while protecting the tailings from further erosion. The rockfill may also help to provide additional toe support to the tailings mass.

Advantages

- The amount of tailings released into the Wolverine Creek flow is reduced.
- The stability of the tailings may be improved.

Disadvantages

- A construction access road has to be constructed from Clinton Creek and up to the north lobe, to provide access for large construction equipment and hauling trucks.
- The functionality of the rock drains are difficult to assess during regular inspections in the future.
- Access road has to be maintained to the north lobe, to provide access for construction equipment for repairs, if required.

Risks and Uncertainty.

- There is a risk that the rock drain becomes plugged by debris. If plugged, water would pond upstream of the blocked rock drain and eventually overtop the easily erodible tailings material and cut a new channel. An emergency overflow would be required.
- The cross-valley movement of the tailings may deform the rock drain

Technical Considerations for Detailed Design

- Construction access.
- Identify a source for suitable rock material that will not break down over time.
- Effects of continued tailings movement on rock drain.
- Suitable gradation of the rock drain material.
- Emergency overflow.
- Transition into the rock lined channel.
- Effects of winter conditions (icing or glaciations) along the channel and at the inlets and outlets.

7.4 Option WC-4: Culvert Along Toe of Each Lobe

Under this option, it is proposed to construct culverts at the fronts of the north and south lobes, to convey the Wolverine Creek flow through the culverts and thereby reduce the erosion of asbestos fibres into the Wolverine Creek flow.

Advantages

- The amount of asbestos fibres released into the Wolverine Creek flow is reduced.

Disadvantages

- A haul road has to be constructed from Clinton Creek and up to the north lobe, to provide access for construction equipment.
- The culverts are easily damaged by deformations, and will corrode with time.
- The culverts would be susceptible to damage due to ongoing movements unless the tailings were stabilized.

Risks and Uncertainty

- There is a risk that a culvert becomes plugged by debris. If plugged, water would pond upstream of the blocked rock drain and eventually overtop the easily erodible tailings material and cut a new channel.
- The cross-valley movement of the tailings may generate non-uniform loads on the culvert that will damage the culvert requiring repair or replacement.

Technical Considerations for Detailed Design

- An emergency overflow would be required, with a transition into the rock-lined channel.
- Construction access.

7.5 Option WC-5: Armoured Channel Over Tailings

Under this option, it is proposed to construct an armoured channel over the tailings and infill the existing channel, to avoid the ongoing erosion of the north and south lobes and thereby reduce the release of tailings (including asbestos fibres) into Wolverine Creek.

Advantages

- The amount of asbestos fibres released into the Wolverine Creek flow is reduced.
- Infilling of existing channel may help to stabilize tailings pile.

Disadvantages

- The introduction of an additional armoured channel increases the requirement for regular inspections, maintenance and repairs.
- Drop structures will be required on the downstream sides of the lobes, which increases the need for regular inspections, maintenance and repairs.
- A haul road has to be constructed from Clinton Creek and up to the north lobe, to provide access for large construction equipment and hauling trucks. After construction of the armoured channel across the lobes, the haul road has to be left in place for future maintenance and repair work.
- The channel will be built over the unstable tailings (unless tailings are also stabilized.
- More impounded water if channel is established over top of the lobes (larger breach event).

Risks and Uncertainty

- It is uncertain if the bearing capacity of the tailings is sufficient to allow passage by loaded wheel-mounted haul trucks.
- There is no guarantee that the flow will stay within the new armoured channel across the tailings in the long term.
- The potential for seepage through the channel bed needs to be assessed.
- By intentionally raising the water level in the lake between the north and south lobes, the risk for a significant sudden breach of the south lobe is increased.

Technical Considerations for Detailed Design

- Check if the bearing capacity of tailings is sufficient to handle loaded wheel-mounted haul trucks.
- The construction of a haul road between the north and south lobes will have to follow either (a) the east treed valley side or (b) the west (mill) side of the valley. The west (mill) side route will be longer and requires construction across the unstable tailings. The route along the east (treed) valley side will be shorter but, due to the steepness of the valley side, it may be difficult to cut a stable road in the hillside, especially along the lake shore. Along the lake, the road may have to be built into the lake, which is relatively deep.
- The channel over the tailings has to be well armoured with revetment along its entire length, as the tailings are easily erodible.
- Drop structures must be flexible enough to bend in response to the cross-valley movement of the lobes.
- Would require a source of rock for armouring.

7.6 Option WC-6: Armoured Channel Around Tailings

Under this option, it is proposed to construct an armoured channel around the tailings, to avoid the slumping fronts of the north and south lobes and thereby reduce the release of asbestos fibres into the Wolverine Creek flow. As there is no realistic route for Wolverine Creek around the tailings, this option was not assessed any further.

8. Tailings Options: Description and Assessment

Four options for the Clinton Creek Tailings Pile are discussed in the following sections. As discussed in Section 3.5, ongoing monitoring of the tailings piles have shown the piles continue to move. As well, Wolverine Creek continues to flow at the base of the north and south lobes of the tailings pile, causing some erosion. The following options address some of the issues identified in Section 3.5

8.1 Option T-1: Status Quo– No Remedial Measures

8.1.1 Description

Under this option, no remedial or maintenance work would be undertaken. However, the bi-annual performance monitoring program would be continued as a means of identifying changes in the behaviour of the tailings. It is expected that creep movements would continue to slow with time, as the mass of tailings move dowslope to a more physically stable state, unless the equilibrium is affected by factors such as thawing permafrost or erosion. Erosion of the tailings face along Wolverine Creek is expected to continue.

There would be some benefits to implementing upgrades to the Wolverine Creek Channel (Options WC-3 to WC-5), as these options would reduce the erosion at the base of the tailings, and provide a durable channel to pass the flows from the Wolverine Creek drainage basin.

8.1.2 Discussion

Advantages

- No capital costs and low maintenance costs.
- Does not require work on the tailings. This is an important consideration as moving or working on the tailings would disturb the natural crust and mobilize asbestos fibres.

Disadvantages

- Slope movements will continue for the foreseeable future.
- Ongoing slumping at the toe of the tailings pile will cause intermittent blockages of Wolverine Creek. It is believed that these have been small, localized blockages that have been quickly washed away by creek flows.
- The surface of the tailings pile will remain exposed. Visitors to the tailings pile will be exposed to airborne asbestos fibres, especially if the surface of the tailings pile is disturbed (e.g. walking, atv's etc).

Risks and Uncertainty

- The long term behaviour of the slope is unknown. Climate changes may lead to additional thawing of the permafrost underlying the tailings and may lead to changes in the nature of slope movements.
- The potential for a breach of the tailings lobes would remain. A breach would result in the rapid release of water which would pose a risk to individuals in the vicinity of Wolverine Creek between the tailings piles and the confluence with Clinton Creek.

Technical Considerations for Detailed Design

- Not applicable.

8.2 Option T-2: Stabilize Tailings

8.2.1 Description

As described in Section 3.5, there have been several attempts at stabilizing the tailings, including removing some material, and benching the tailings lobes. Though benching the tailings did result in a slowing of the movements, neither measure was effective in the long term.

Due to the large scale of the tailings pile, the most feasible method of stabilization is by offloading and/or regrading the tailings pile. Unloading the middle and upper areas of the tailings pile would reduce the forces that are driving slope movements, and placing material at the toe area of the tailings pile would increase the forces resisting slope movements.

No stability analysis has been conducted as part of the current work, but several stability assessments have been done previously, including UMA (2003a). Drawings 16 and 17 illustrate a re-grading concept for the tailings pile to improve stability. A cut volume of approximately 2,700,000 m^3 would be required, of which 2,250,000 m^3 would be used to regrade the lower slope of the tailings lobes and fill the existing Wolverine Creek channel and ponds. The remaining 450,000 m^3 could be placed in the vicinity of the former mill site (UMA 2003a). In this example, a new channel for Wolverine Creek would be constructed across the tailings.

8.2.2 Discussion

Advantages

- Slope movements would be greatly decreased or stopped entirely.
- The risk of a breach scenario is greatly reduced.

Disadvantages

- Would require a large amount of earthwork in challenging terrain.
- Disturbing the tailings will likely result in high concentrations of airborne asbestos fibres. Asbestos abatement and worker protection programs will be required. The public would be banned from the site during construction.
- Wolverine Creek would have to be re-aligned over or through the tailings (refer to Section 7).
- Does not address concerns about airborne asbestos.

Risks and Uncertainty

- The current crust over the tailings would be destroyed, and it may take several years for this protective crust to re-establish. Alternatively, an engineered or biotechnical solution (Option T-3) could be implemented to control wind erosion of the tailings.
- The subsurface conditions beneath the tailings.

Technical Considerations for Detailed Design

- Moving the tailings would be challenging
    - Difficult to push up-slope, but easier to push downslope or sideways
    - Need a suitable location for excess cut material.

- The flows in Wolverine Creek would be diverted around, over, or through the tailings pile both during construction and permanently.
- The re-grading should be optimized to minimize volumes to be moved to achieve a stable slope. Optimization would be aided by a geotechnical investigation to help understand the current mechanisms of waste rock movement. Slope inclinometer installations would provide a full depth profile of slope movements. Piezometers and thermistors would also be helpful for characterizing piezometric and thermal conditions respectively.
- Human and environmental health related to airborne asbestos during construction activities.

8.3 Option T-3: Provide Cover and Armouring

8.3.1 Description

A cover would be provided over the tailings to prevent erosion by wind and surface runoff. Along the Wolverine Creek channel, the cover would be complimented by armouring to prevent erosion. This option would reduce the potential for asbestos fibres to enter the atmospheric and aquatic environments.

This option would best be implemented after the tailings have been stabilized. Without a stable tailings pile, it is expected that any cover would get distorted or separated along tension cracks and shear zones in the tailings, thus re-exposing some tailings to the erosional processes.

The surface area of the tailings, assuming that they are re-graded to improve stability, would be approximately 41 hectares. It is beyond the scope of this report to consider cover options in detail. In general, a soil cover, held in place by robust vegetation would provide the best combination of relatively low costs, low maintenance and flexibility. However, seeding trials on the tailings have not proved very successful, likely due to the poor growth medium (AECOM 2009b).

8.3.2 Discussion

Advantages

- Reduces the erosion of the tailings by wind and water and mitigates the environmental risks to both humans and wildlife.

Disadvantages

- Would require regular and expensive maintenance. The maintenance requirements would be more substantive if the tailings are not stabilized.
- Tailings should be stabilized before installation of a cover.

Risks and Uncertainty

- It is unlikely that the cover would perform satisfactorily without stabilizing the tailings, considering the tailings continue to move at rates of 0.5 m per year or greater in some areas.
- Under the current conditions the cancer risk associated with airborne asbestos fibres is believed to be low to negligible (UMA 2006). Therefore the improved benefits to human health are low.
- Ongoing studies by the Department of Fisheries and Oceans (DFO) are investigating the impacts of waterborne asbestos on aquatic species. The benefits of this options are closely linked to the findings of this study.

Technical Considerations for Detailed Design

- Cover design, and a source of cover material.
- Vegetation of the cover.
- Human and environmental health related to airborne asbestos during construction activities.
- It would be difficult to install an effective cover over the tailings considering the slope of the pile.
- The additional weight of a cover would destabilize the tailings further, unless stabilization measures were also implemented (Option T-2). The stability of the tailings would need to be re-assessed with the additional weight of the cover in place, and stabilization measures should be implemented.

8.4 Option T-4: Remove Tailings to Pit

This option was discussed by UMA (2003a). Of the options considered, removal of the tailings blocking the valley is the only alternative that restores natural creek drainage through the Wolverine Creek valley. Restoring the valley and the associated natural drainage has the benefit of eliminating the risk associated with a breach of the tailings by the impounded water and the concern of chronic downstream sedimentation of tailings. Removal of tailings from the side slopes of the valley would have to start at the upper slope and proceed in a downslope direction to prevent the development of slope instabilities. Based on previous monitoring and results from the slope stability analysis, it is anticipated that a portion of the tailings at the top of the valley could be stabilized by re-grading.

Based on existing cross sections, approximately 4,000,000 m^3 of tailings would have to be excavated to achieve a stable geometry. The excavated material could be disposed of in the open pits on the south side of Clinton creek and/or along the top of the ridge at the former mill area. An additional 1,000,000 m^3 of re-grading would be necessary to achieve stability of the tailings in the upper slope area.

A cover could be provided to reduce the potential for wind and water erosion of the remaining tailings (waste rock may be a suitable cover material). The tailings pile is approximately 2 km from the Porcupine pit, but the surface haul distance would be considerably longer.

8.4.1 Discussion

Advantages

- Allows full restoration of the Wolverine Creek channel, but some tailings would still remain along the upper slope.
- Tailings are contained, or re-graded to be stable.
- Erosion of tailings by water will be eliminated.

Disadvantages

- Disturbing the tailings will likely result in unsafe concentrations of airborne asbestos fibres. Providing adequate protection for workers and the public would be difficult and expensive.
- Disturbing the tailings will likely result in high concentrations of airborne asbestos fibres. Asbestos abatement and worker protection programs will be required. The public would be banned from the site during construction.

Risks and Uncertainty

- This option would generally eliminate the risks associated with the tailings if a cover is provided over top of the tailings relocated to the pit and over the tailings remaining on the valley slope.

Technical Considerations for Detailed Design

- Drainage of ponds, and conveyance of water around tailings area during construction.
- It may be desirable to relocate the entire volume of tailings (approximately 12,000,000 tonnes) to the pit.
- Human and environmental health related to airborne asbestos during construction activities.
- Construction sequencing.
- Stabilization of tailings to remain.
- Cover system that is performs well while being durable and cost effective.

9. Costing

A cost estimate has been completed for options at Clinton Creek (including work required at the waste rock pile and Hudgeon Lake), Wolverine Creek and the tailings lobe(s). Cost estimates have not been developed for options which are generally not considered to be realistic or feasible at the current time. Where appropriate, the costs addressing individual elements can be summed to estimate the total closure costs. For example, the cost of armouring the existing channel, stabilizing the waste rock dump and installing a rock drain along the toe of the tailings would be $9,000,000 + $8,000,000 + $12,000,000 for an approximate total cost of $29,000,000.

A contingency of 30 % has been included to allow for uncertainty and items that have not been identified in the current estimate. The costs do not include engineering or operations and maintenance costs. For options CC-1, WR-1, WC-1, WC-2 and T1 there would be no capital cost outlay. However, maintenance costs (where applicable) may be significant though they have not been estimated. A summary of costs is presented in Table 9.1 below; detailed breakdowns of the costs associated with each option are presented in Appendix C. As discussed in Section 2, cost estimates have not been developed for every option presented in the previous sections.

The following cost estimates are Class 'D' cost estimates, and are intended to provide a comparison on an order of magnitude basis. The Treasury Board Secretariat of Public Works and Government Services Canada (PWGSC) provides the following commentary on Class 'D' cost estimates, also known as 'indicative estimates':

"(A Class 'D' cost estimate is) *to be in unit cost analysis format (such as cost per m² or other measurement unit) based upon a comprehensive list of project requirements (i.e. scope) and assumptions; the Class D estimate is evolved throughout the phases of the Project Identification Stage, finally being incorporated into the cash flows in the Analysis Phase; for more complex projects such as laboratories, elemental cost analysis and the input of specific disciplines may be required; the Class D Indicative estimates developed during the National Project Management System (NPMS) Feasibility Phase shall be revisited with cost planners in the Analysis Phase before finalizing."*

Furthermore, an indicative estimate is defined as:

"an estimate that is not sufficiently accurate to warrant Treasury Board approval as a cost objective and provides a rough cost projection used for budget planning purposes in the early stages of concept development of a project.

By definition, the cost estimates provided in this document satisfy the criteria for Class 'D' cost estimates, but it must be reinforced that they are based on the best available knowledge and will be re-examined as the closure option(s) are developed.

Some of the costs estimates are updates of cost estimates presented in:

- Abandoned Clinton Creek Asbestos Mine, Conceptual Design Report, UMA, 2002; and
- Abandoned Clinton Creek Asbestos Mine, Environmental Liability Report, UMA, 2003

Previous cost estimate have been updated to reflect increased unit rates and lump sums including:

- Mobilization and Demobilization Lump Sum cost of $ 600,000;
- Dewatering allowance of $600,000 and $300,000 for Hudgeon Lake and impounded water within Wolverine Creek, respectively;
- Excavation Cost (including any regarding, transport and placement) of 7 $/m;

Table 9.1. Summary of Cost Estimates

Option	Capital Costs
Clinton Creek	
Option CC-1: Status quo	$ 0
Option CC-2: Armoured channel over the waste rock	$ 31,000,000
Option CC-3: Tunnel through bedrock	$ 26,000,000
Option CC-4: Armour existing channel	$ 9,000,000
Option CC-5: Lower existing channel to bedrock	$ 10,000,000
Option CC-6: Restore to valley bottom	$ 100,000,000
Waste Rock	
Option WR-1: Leave as is – no remedial measures	$ 0
Option WR-2: Remove to expose valley bottom	Included in CC-6
Option WR-3: Stabilize waste rock	$ 8,000,000
Wolverine Creek	
Option WC-1: Leave as is – No annual maintenance	$ 0
Option WC-2: Status quo - Maintain armoured channel	$ 0
Option WC-3: Rock drain along toe of tailings	$ 12,000,000
Tailings	
Option T-1: Status quo – no remedial measures	$ 0
Option T-2: Stabilize tailings	$ 26,000,000
Option T-3: Provide Cover and armouring (includes stabilization of tailings)	$32,000,000

10. References

AECOM Canada Ltd., 2009a:
Former Clinton Creek Asbestos Mine Long Term Performance Monitoring – 2008. June 2009.

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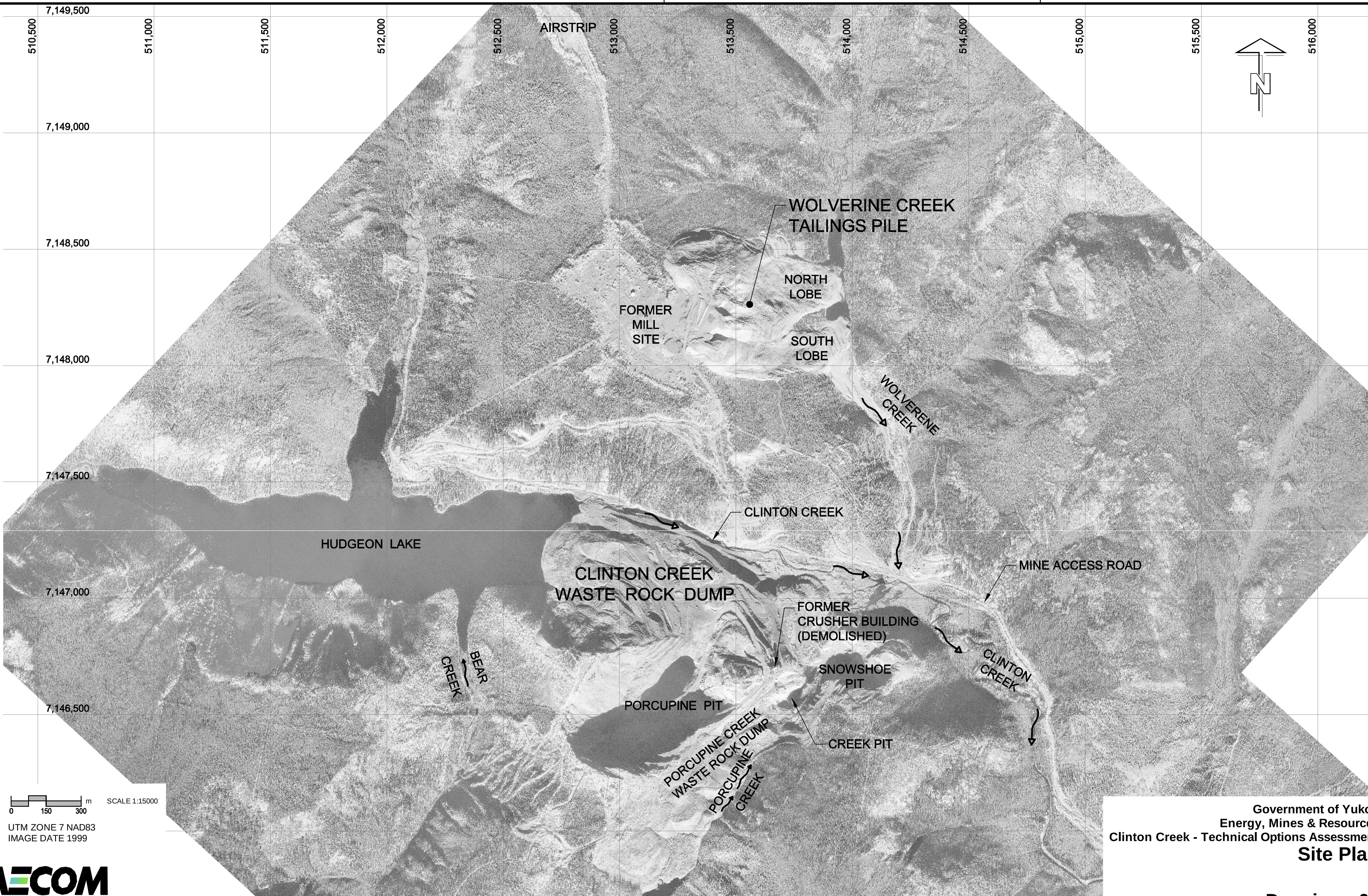
Appendix A

Drawings



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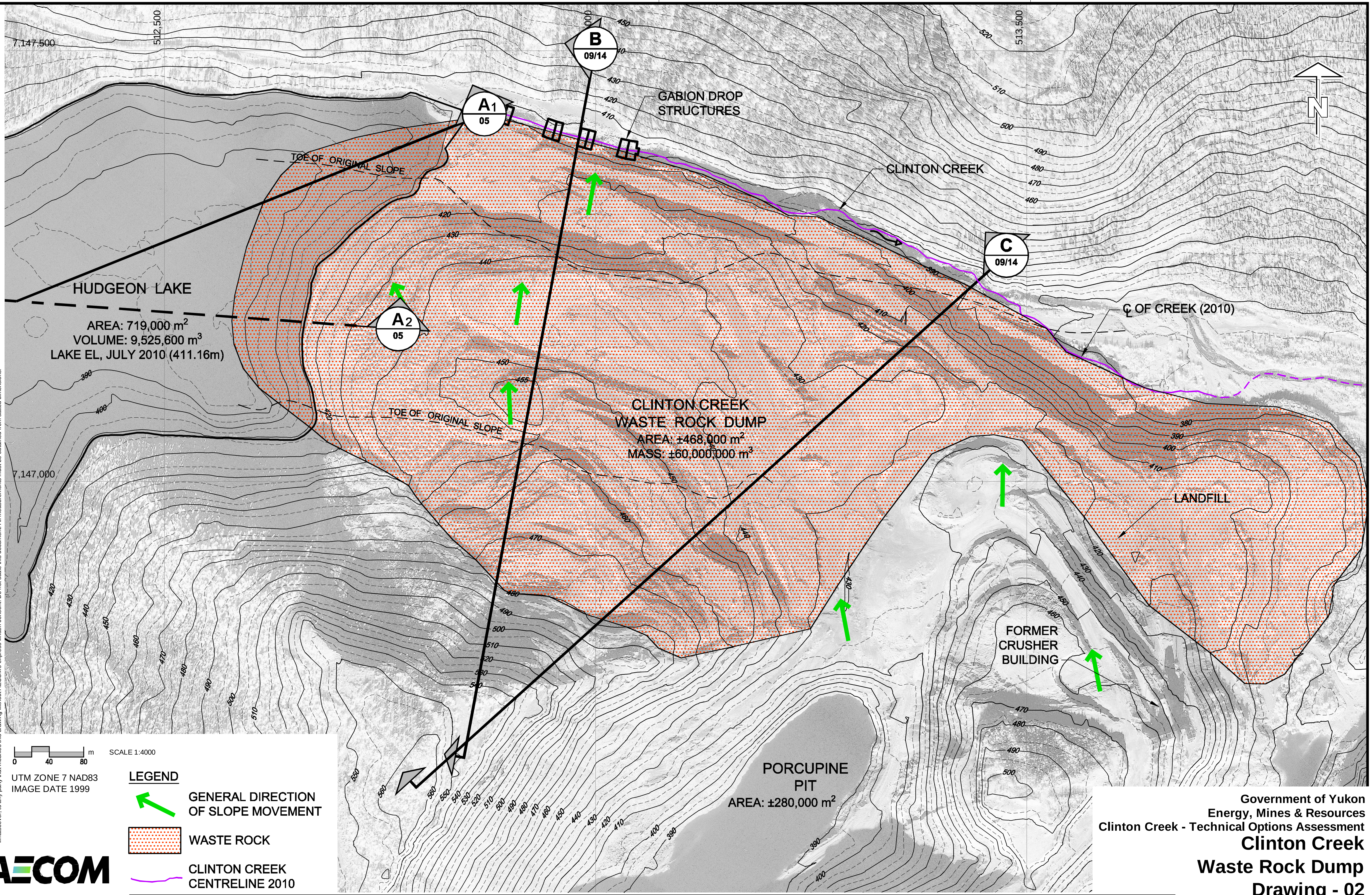
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Site Plan

Drawing - 01



LEGEND

- GENERAL DIRECTION OF SLOPE MOVEMENT
- WASTE ROCK
- CLINTON CREEK CENTRELINE 2010

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Clinton Creek Waste Rock Dump

Drawing - 02

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AECOM

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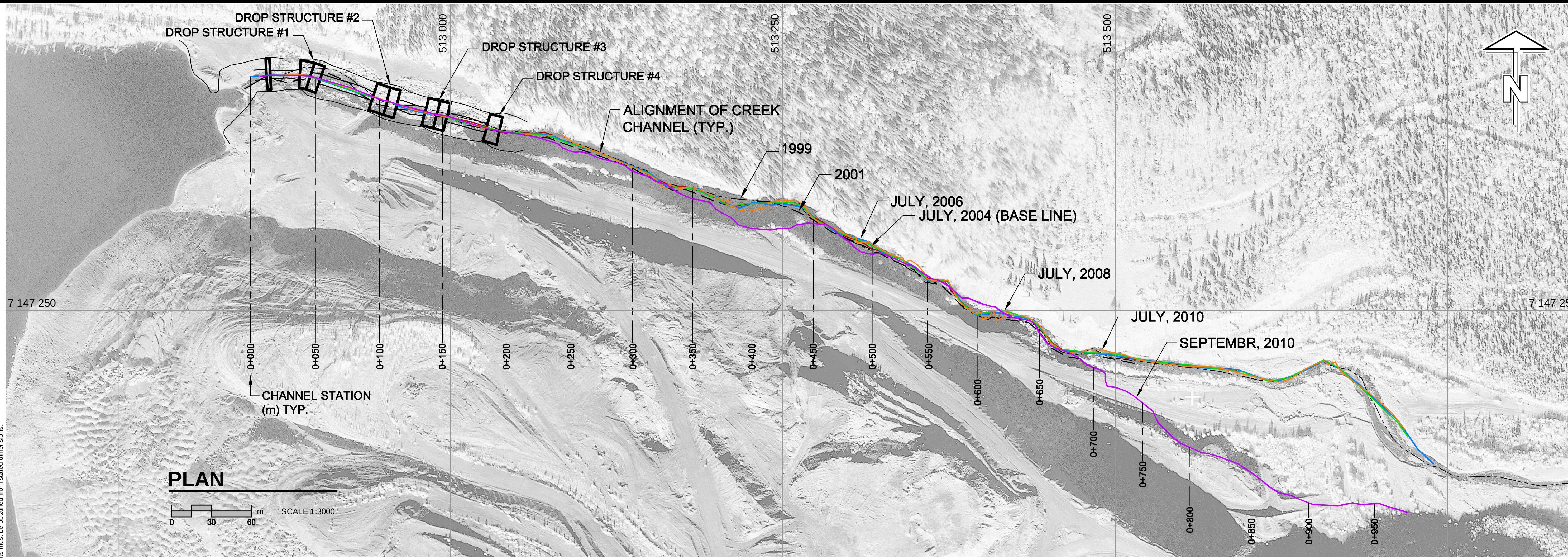
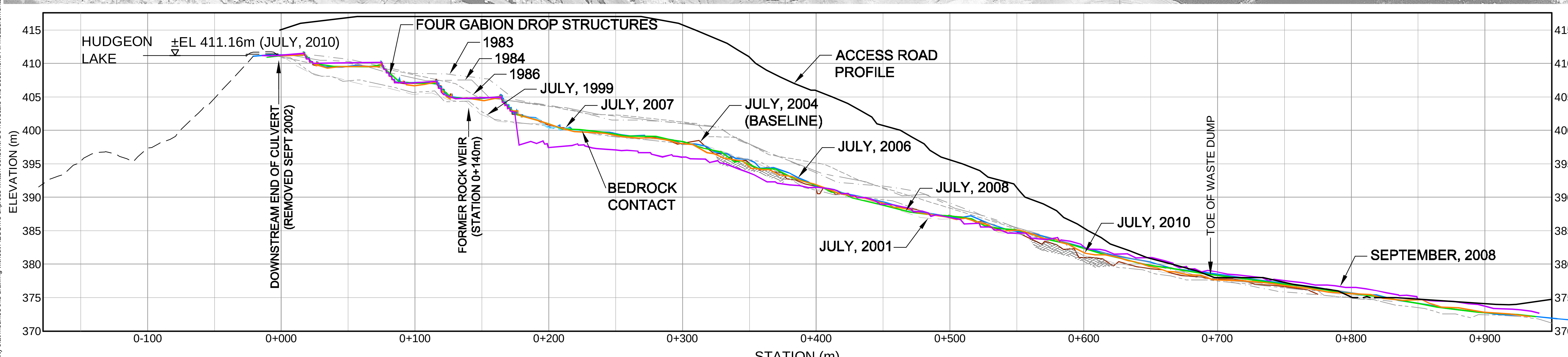


PLAN



PROFILE

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0 6 12 m V=1:600

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0+250	7,147,366	513,113
0+500	7,147,272	513,363
0+750	7,147,204	513,613

COORD: UTM ZONE 7W NAD83

LEGEND

- 1983 SURVEY
- 1984 SURVEY
- 1986 SURVEY
- 1999 SURVEY
- 2001 SURVEY
- 2004 SURVEY
- 2006 SURVEY
- 2007 SURVEY
- 2008 SURVEY
- JULY 2010 SURVEY
- SEPTEMBER 2010 SURVEY

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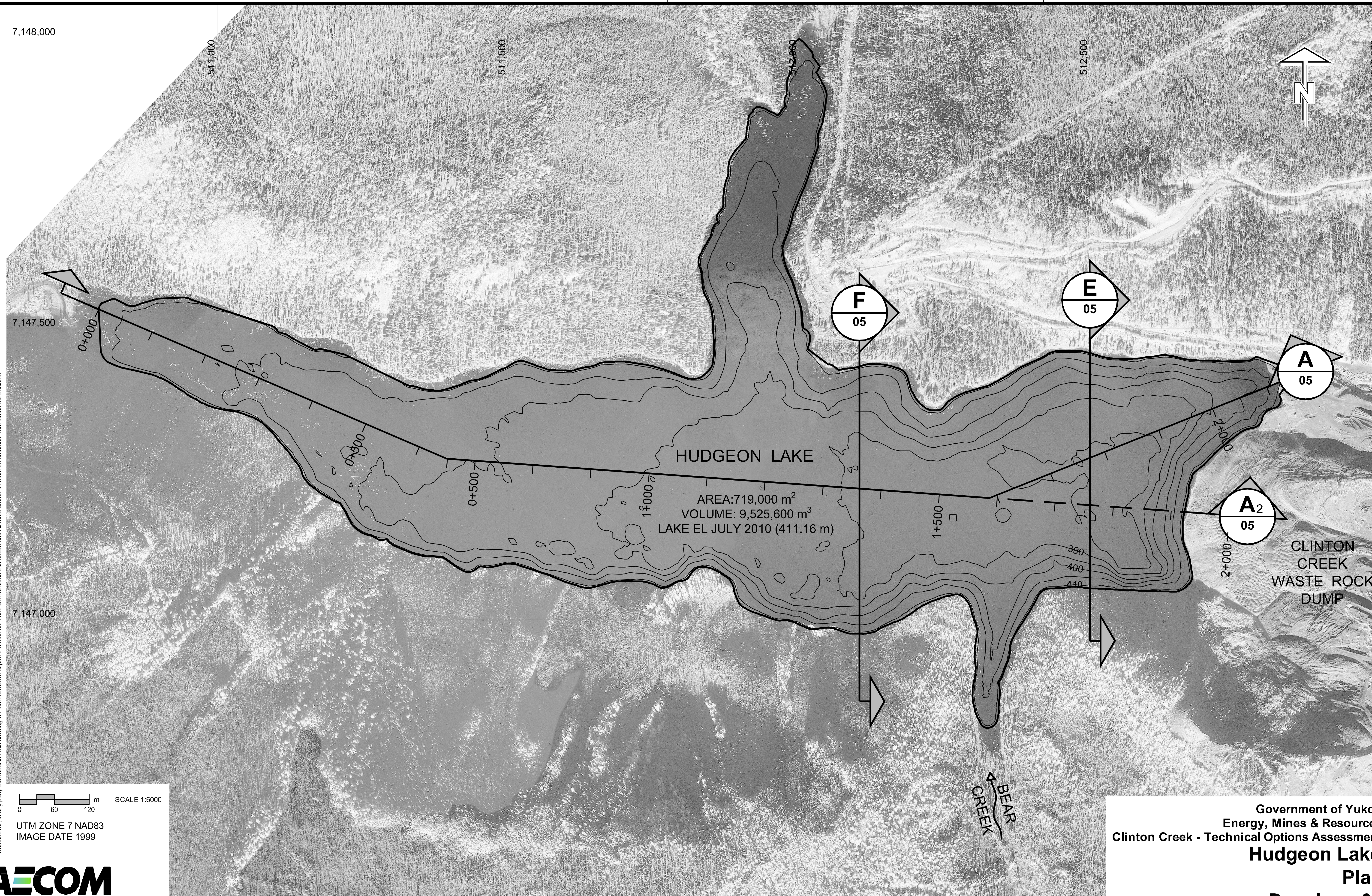
Government of Yukon
Energy, Mines and Resources
Clinton Creek - Technical Options Assessment

Clinton Creek
Plan and Profile
Drawing - 03



Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Hudgeon Lake
Plan
Drawing - 04

AECOM

ISS/REV: 0A
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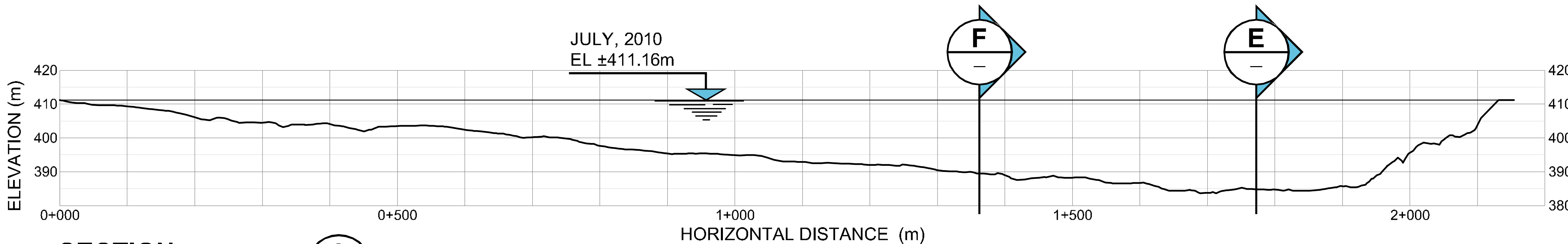

SECTION A1 / 04

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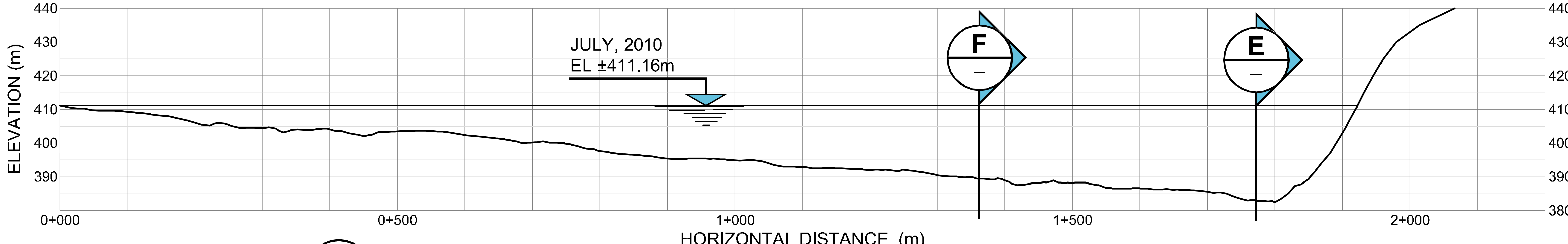

SECTION A2 / 04

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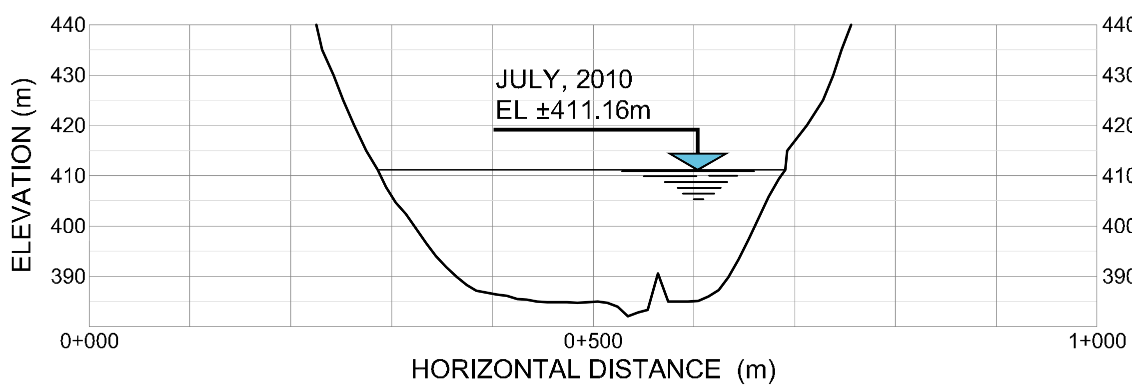

SECTION E / 04

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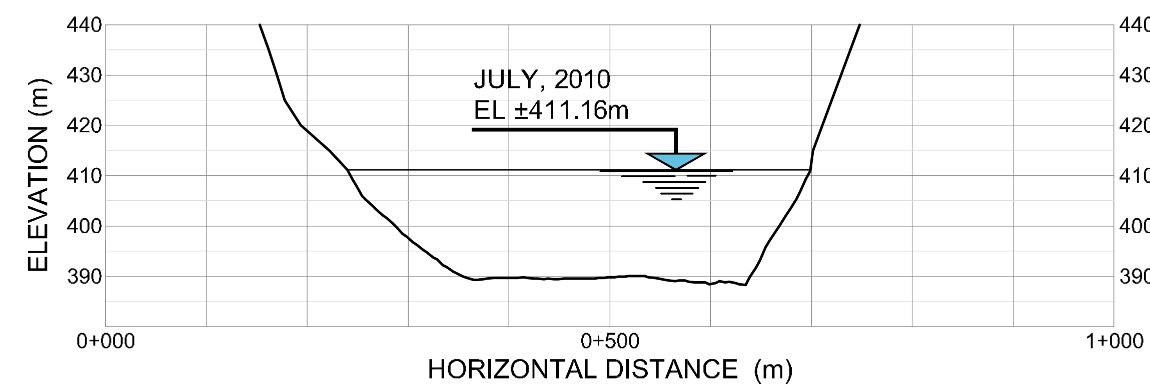

SECTION F / 04

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AECOM

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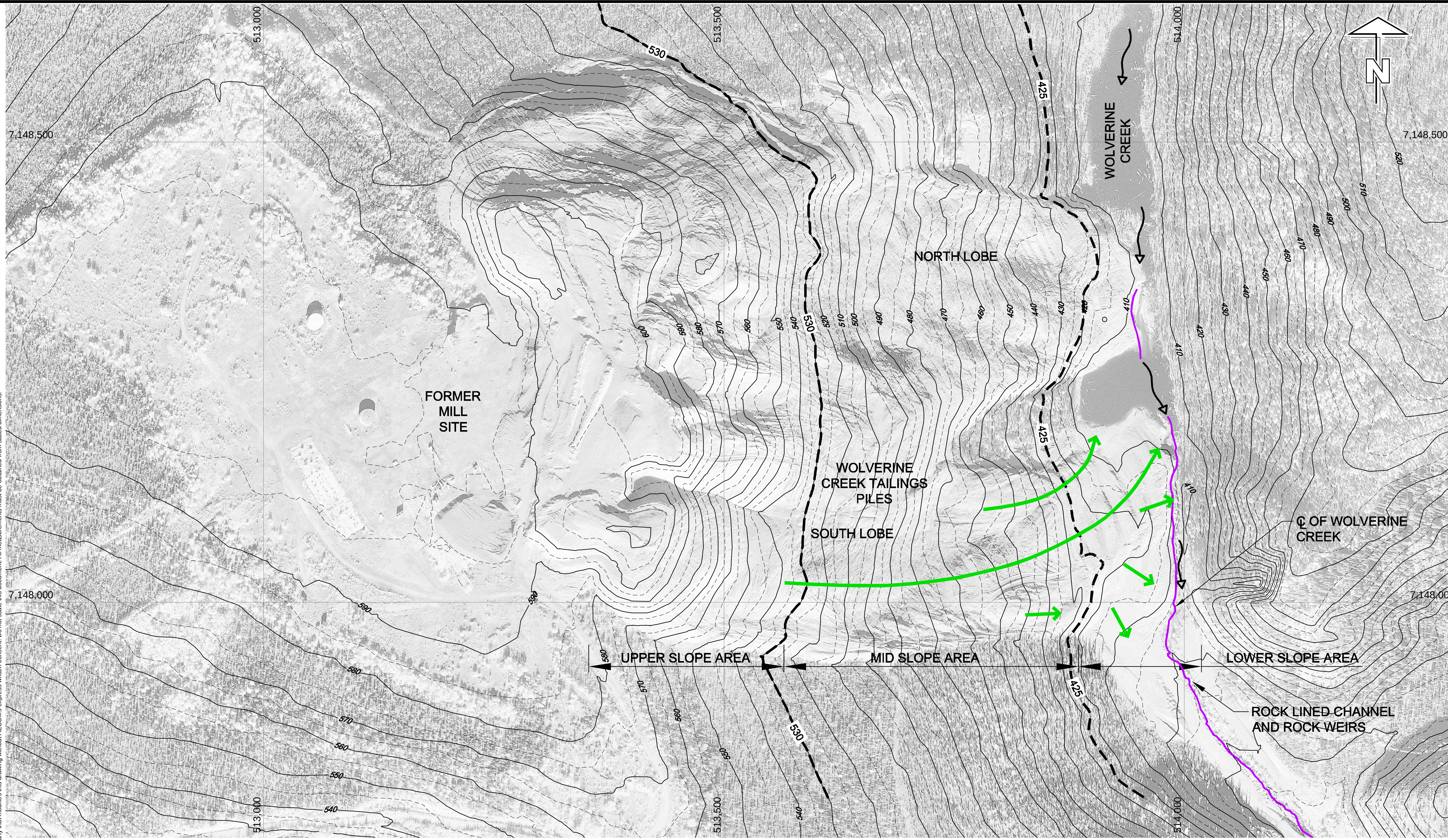
Clinton Creek - Technical Options Assessment

Hudgeon Lake
Sections
Drawing - 05



0 40 80 120 m

SCALE 1:4000

UTM ZONE 7 NAD83
IMAGE DATE 1999

LEGEND

GENERAL DIRECTION OF SLOPE MOVEMENT

WOLVERINE CREEK CENTRELINE 2010

AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Wolverine Creek and Tailings Area
Drawing - 06

B SIZE 11" x 17" (279.4mm x 431.8mm)

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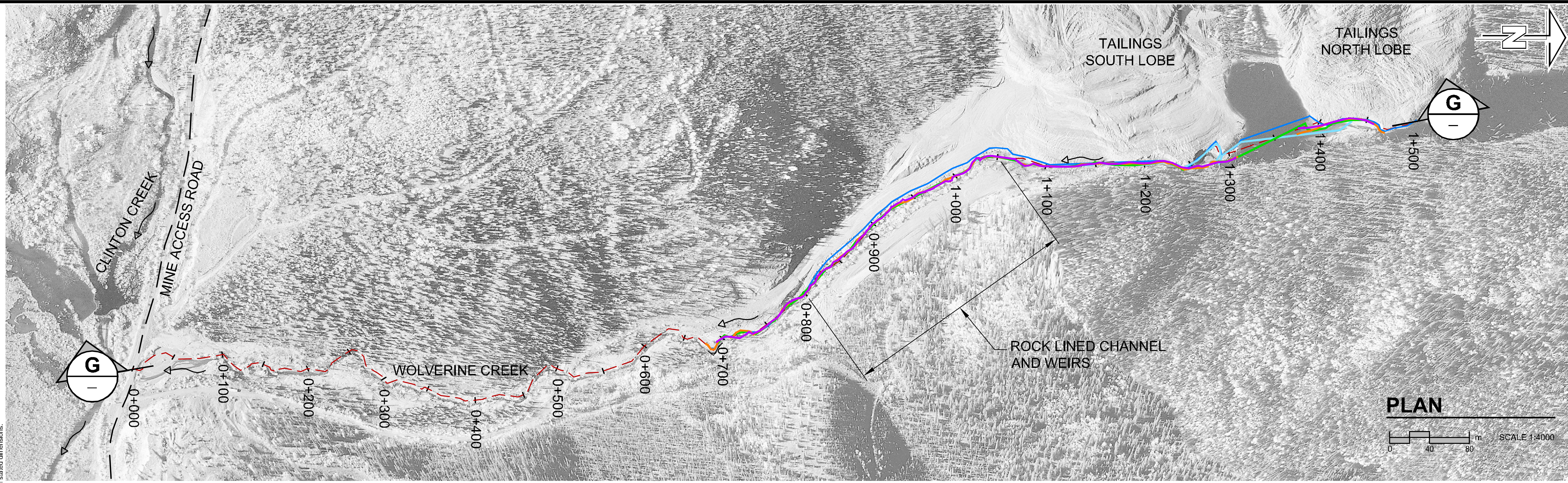

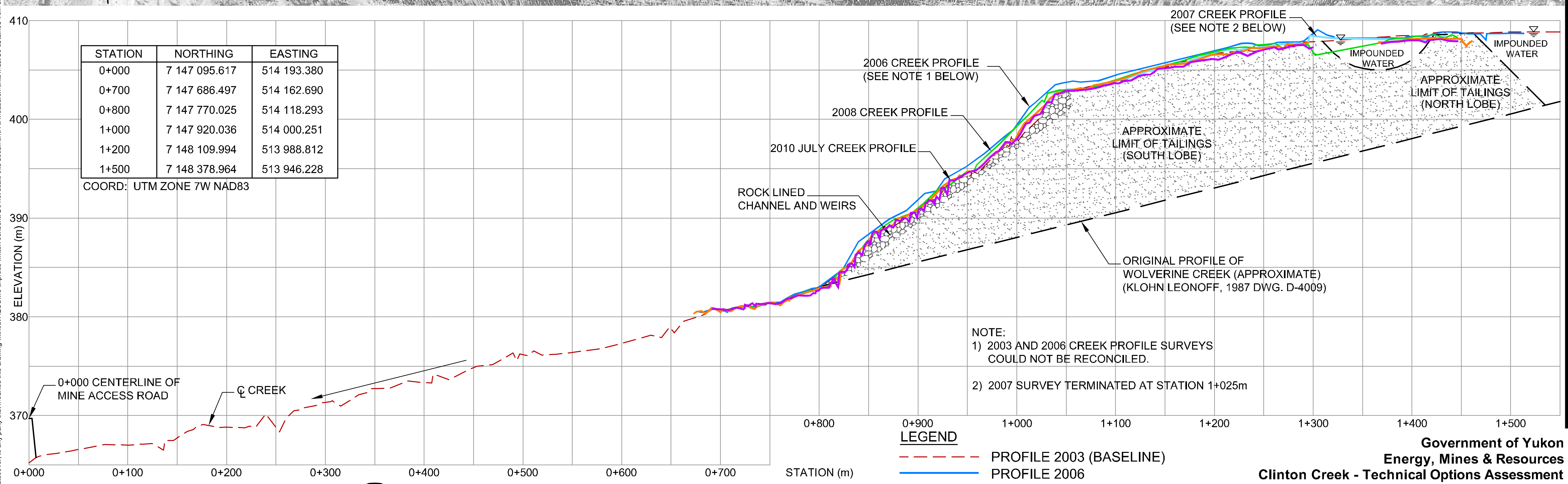

STATION	NORTHING	EASTING
0+000	7 147 095.617	514 193.380
0+700	7 147 686.497	514 162.690
0+800	7 147 770.025	514 118.293
1+000	7 147 920.036	514 000.251
1+200	7 148 109.994	513 988.812
1+500	7 148 378.964	513 946.228

COORD: UTM ZONE 7W NAD83

NOTE:
1) 2003 AND 2006 CREEK PROFILE SURVEYS COULD NOT BE RECONCILED.
2) 2007 SURVEY TERMINATED AT STATION 1+025m

LEGEND
- PROFILE 2003 (BASELINE)
- PROFILE 2006
- PROFILE 2007
- PROFILE 2008
- PROFILE JULY 2010
- PROFILE SEPTEMBER 2010

SECTION G
0 40 80 m H=1:4000
0 4 8 V=1:400

AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Wolverine Creek Plan and Profile

Drawing - 07

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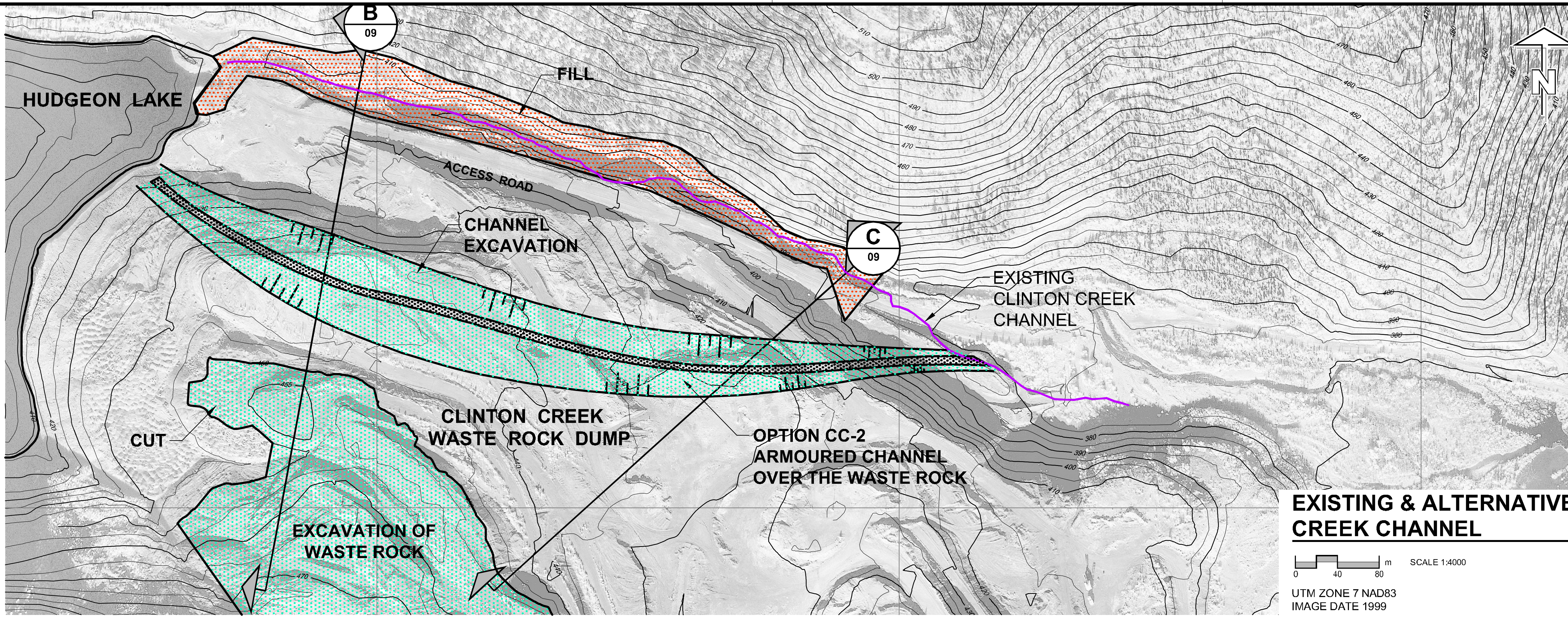
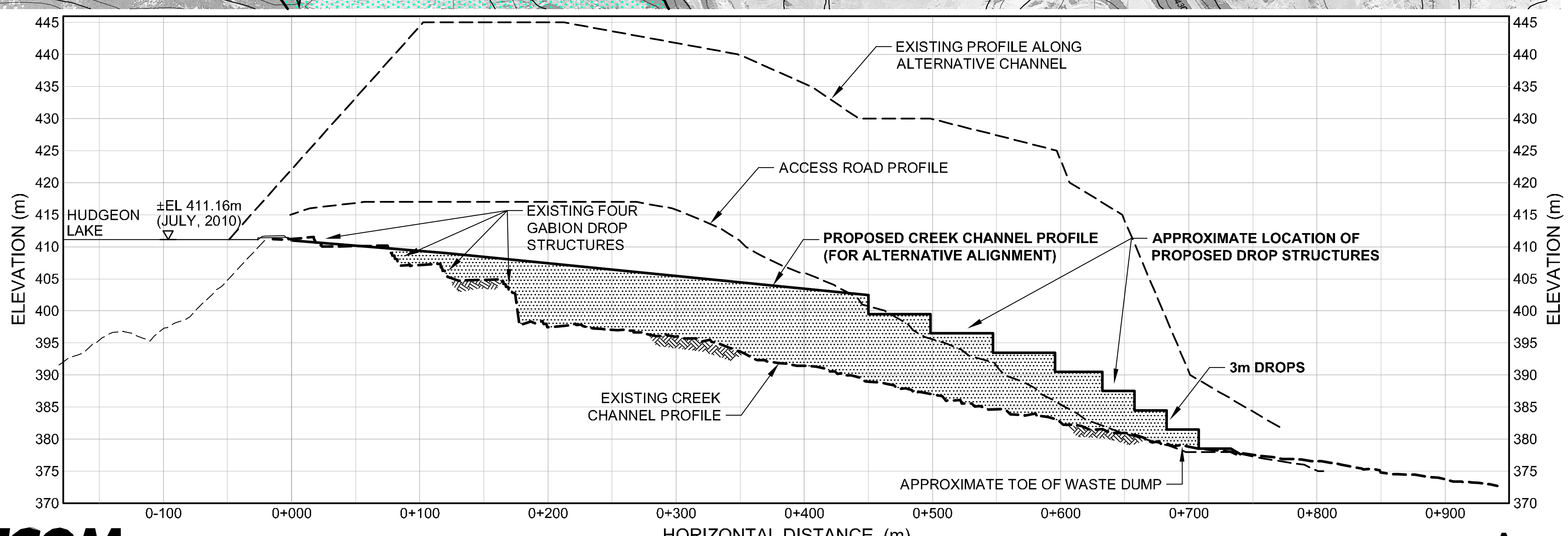


EXISTING & ALTERNATIVE CREEK CHANNEL

SCALE 1:4000 (0, 40, 80 m)

UTM ZONE 7 NAD83
IMAGE DATE 1999



EXISTING & ALTERNATIVE CREEK CHANNEL PROFILE

H=1:4000 (0, 40, 80 m)
V=1:800 (0, 8, 16 m)

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Option CC-2 Plan and Profile
Armoured Channel over Waste Rock

Drawing - 08

AECOM

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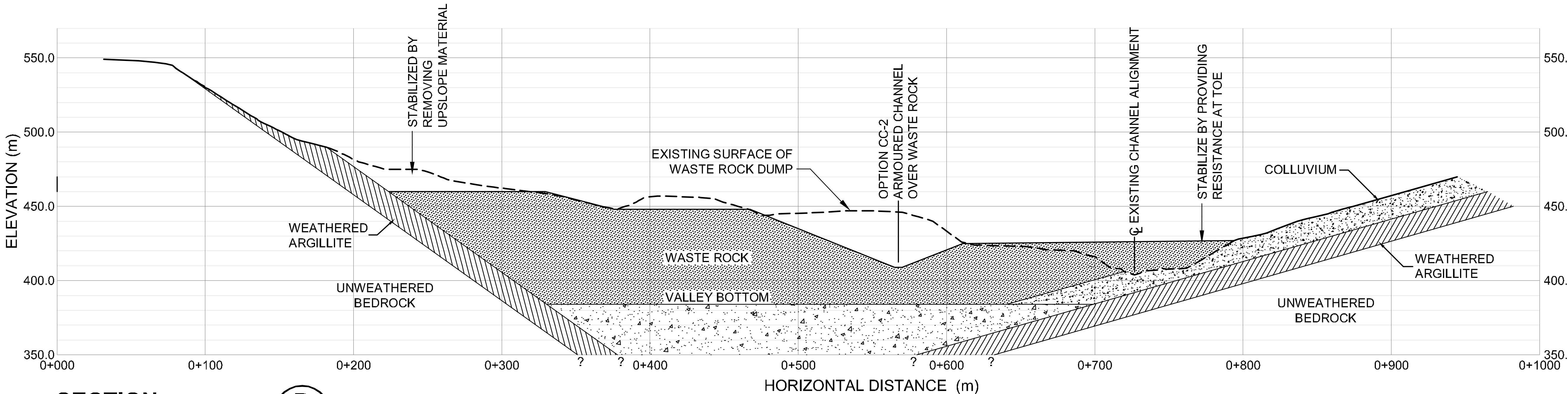
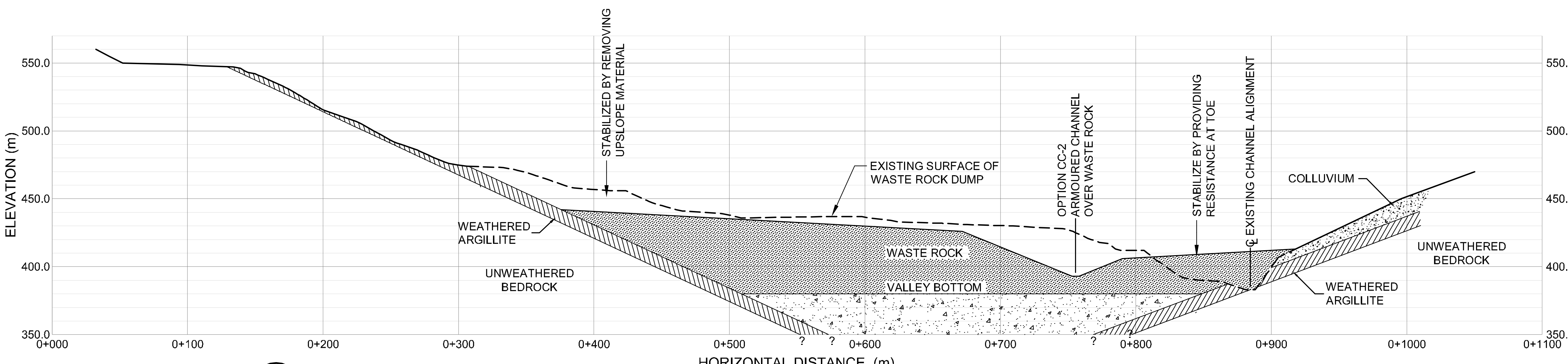


SECTION B 08

0 30 60 m SCALE 1:3000



SECTION C 08

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AECOM

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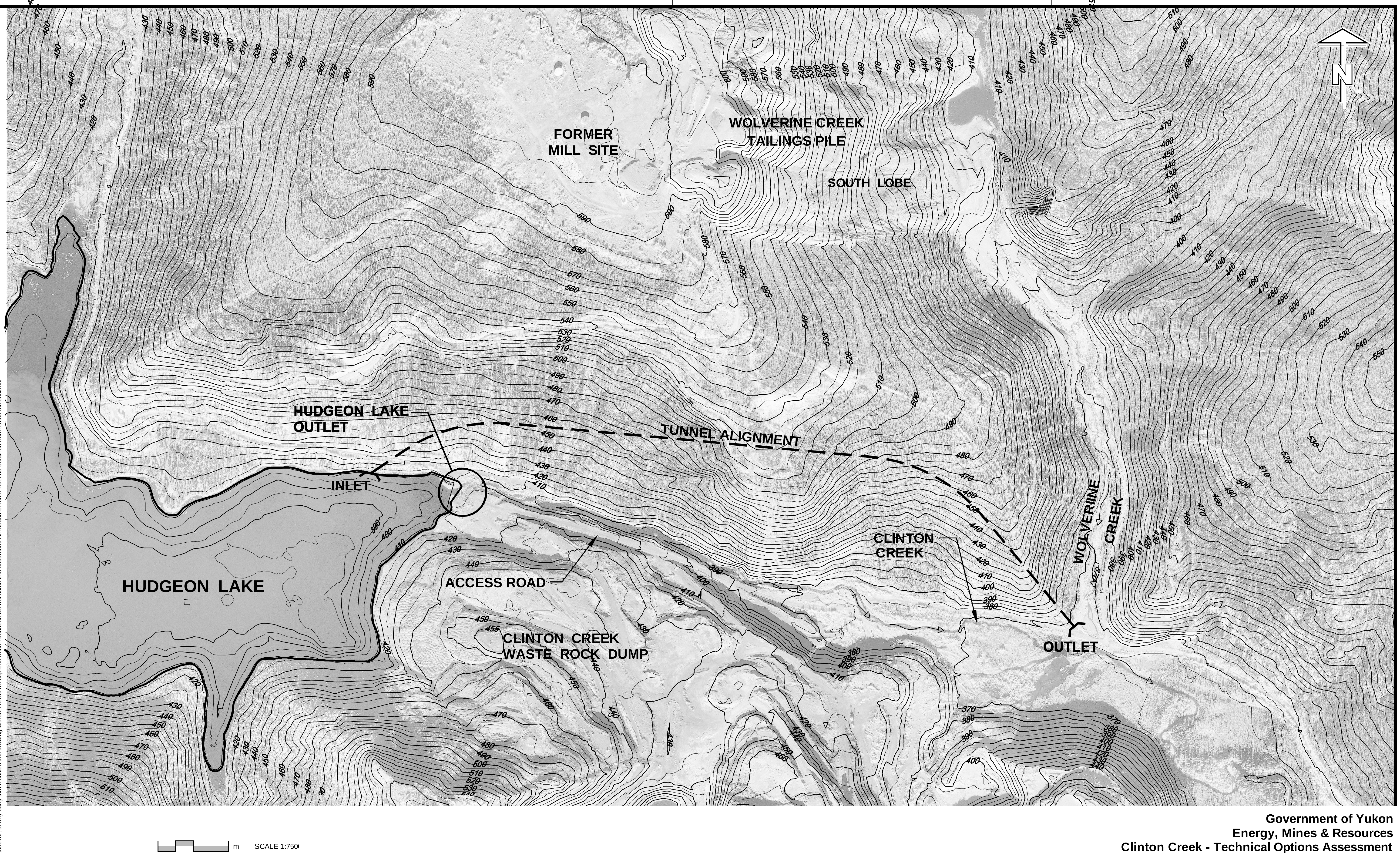
Clinton Creek - Technical Options Assessment

Option CC-2 Sections
Armoured Channel over Waste Rock
Drawing - 09



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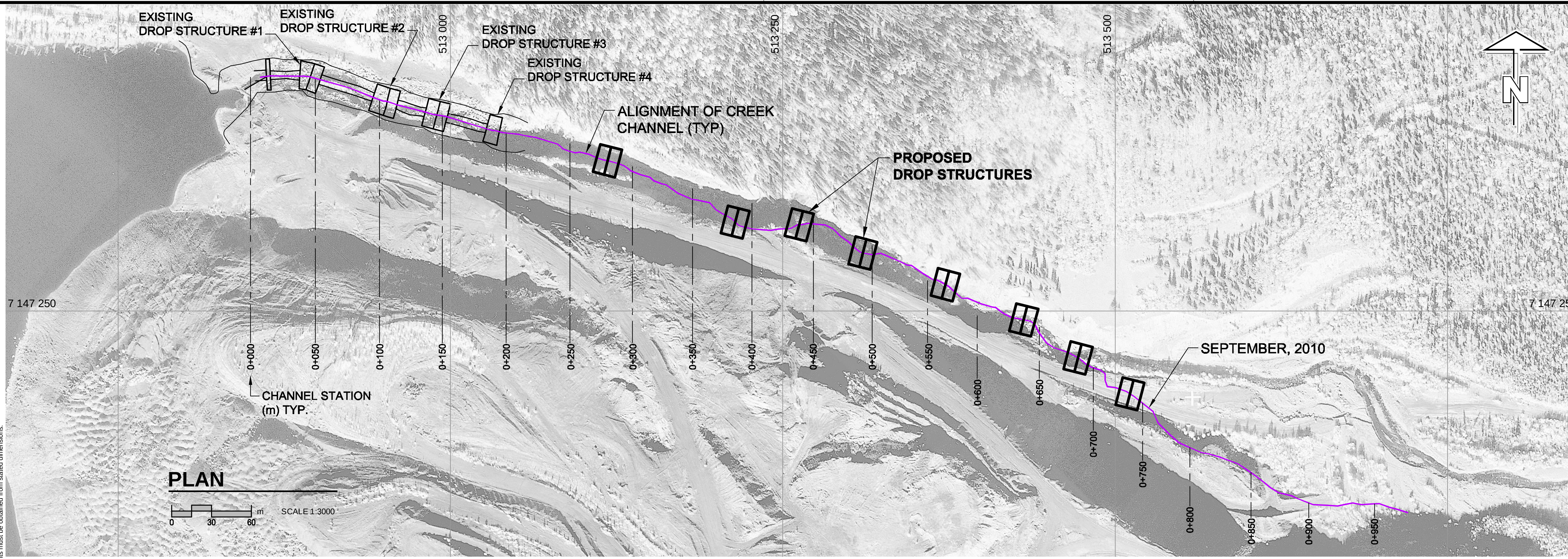
ISS/REV: 0A

UTM ZONE 7 NAD83
IMAGE DATE 1999

AECOM

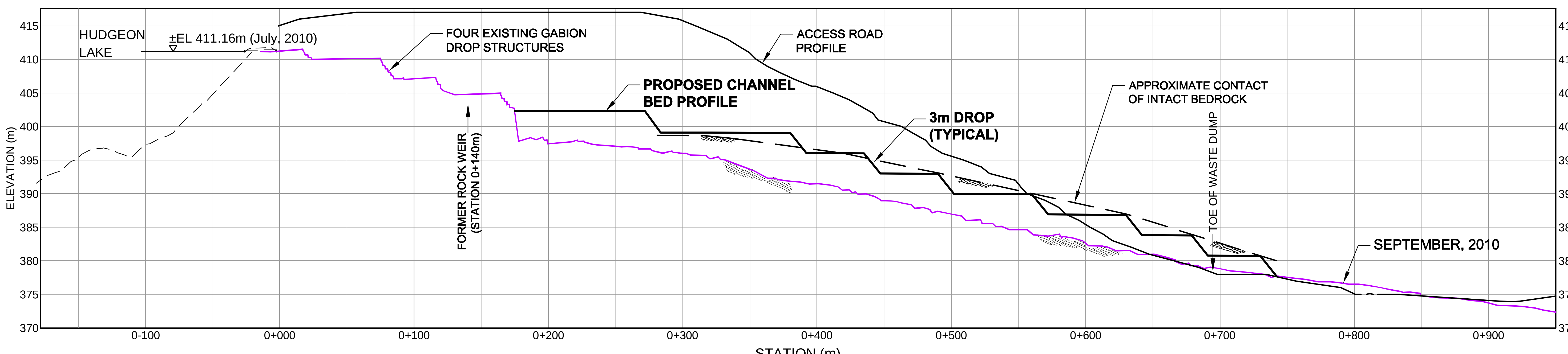
Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Option CC-4
Tunnel Through Bedrock
Drawing - 10



PLAN

0 30 60 m SCALE 1:3000



PROFILE

0 30 60 m H=1:3000
0 6 12 V=1:600

STATION	NORTHING	EASTING
0+000	7,147,427	512,863
0+250	7,147,366	513,113
0+500	7,147,272	513,363
0+750	7,147,204	513,613

COORD: UTM ZONE 7W NAD83

LEGEND

SEPTEMBER 2010 SURVEY

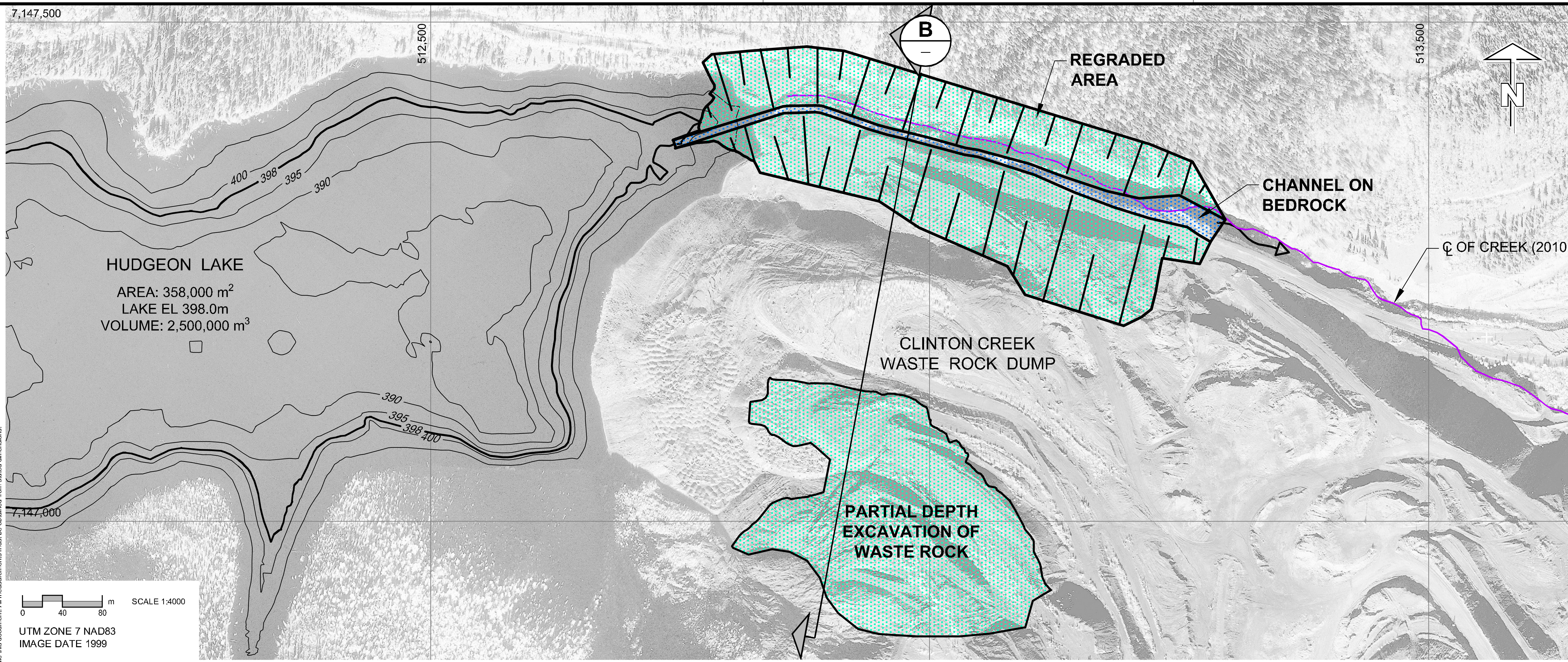
AECOM

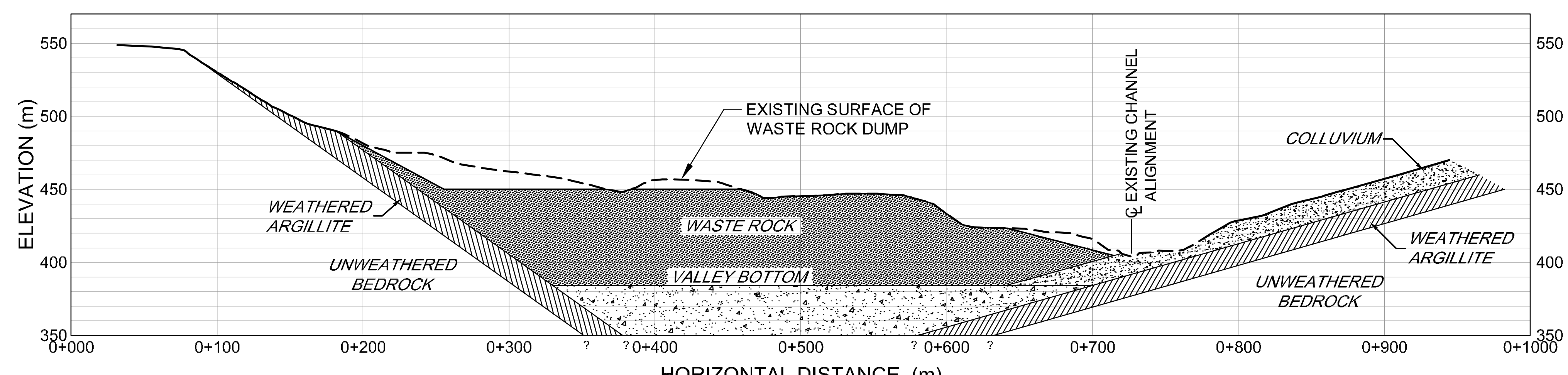
Government of Yukon
Energy, Mines and Resources
Clinton Creek - Technical Options Assessment

CC-4

Armour Existing Clinton Creek Channel

Drawing - 11





SECTION B

0 40 80 m SCALE 1:4000

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Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

CC-5

Drawing - 12

AECOM

B SIZE 11" x 17" (279.4mm x 431.8mm)

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ISS/REV: 0A

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B SIZE 11" x 17" (279.4mm x 431.8mm)

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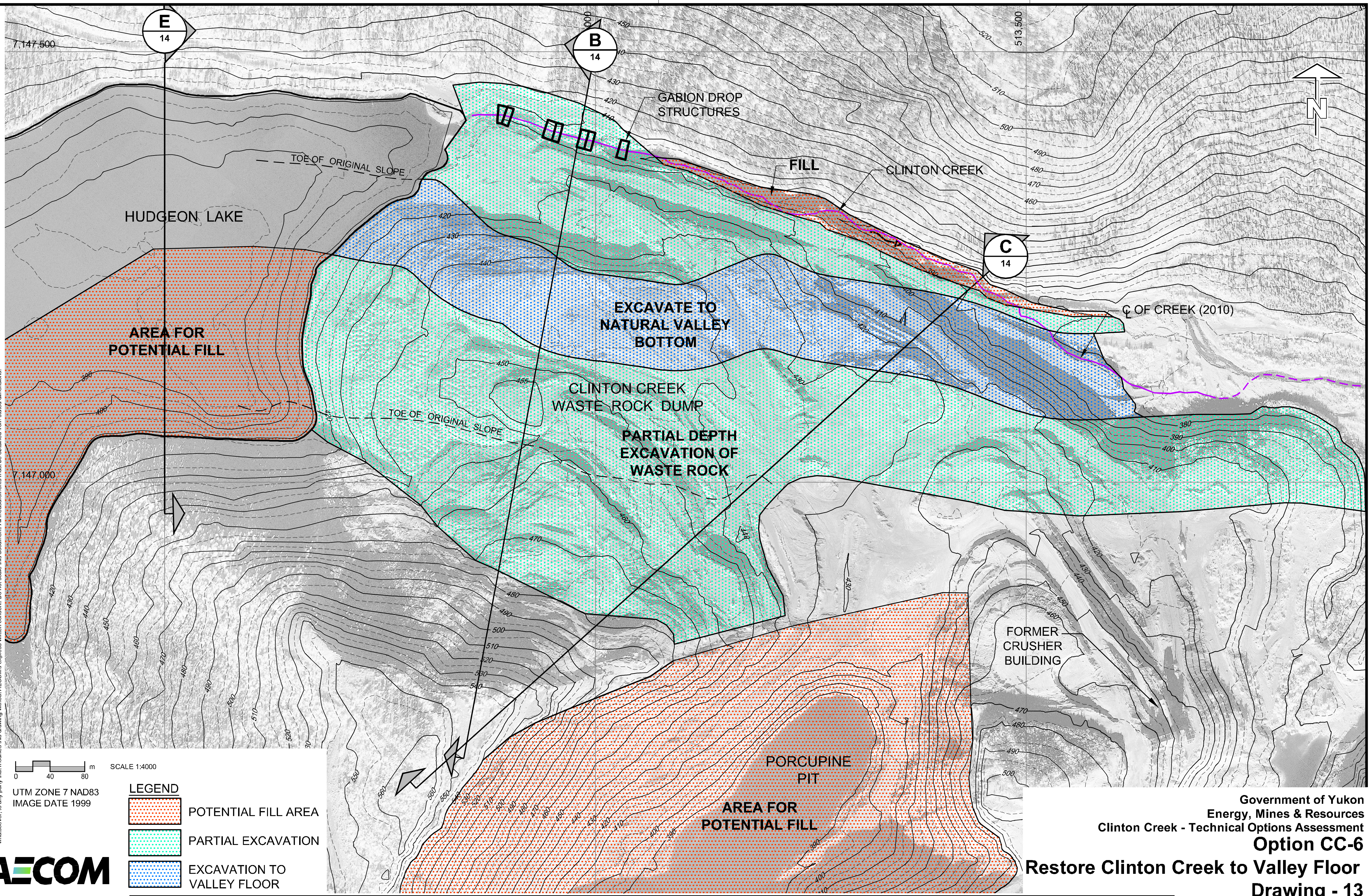


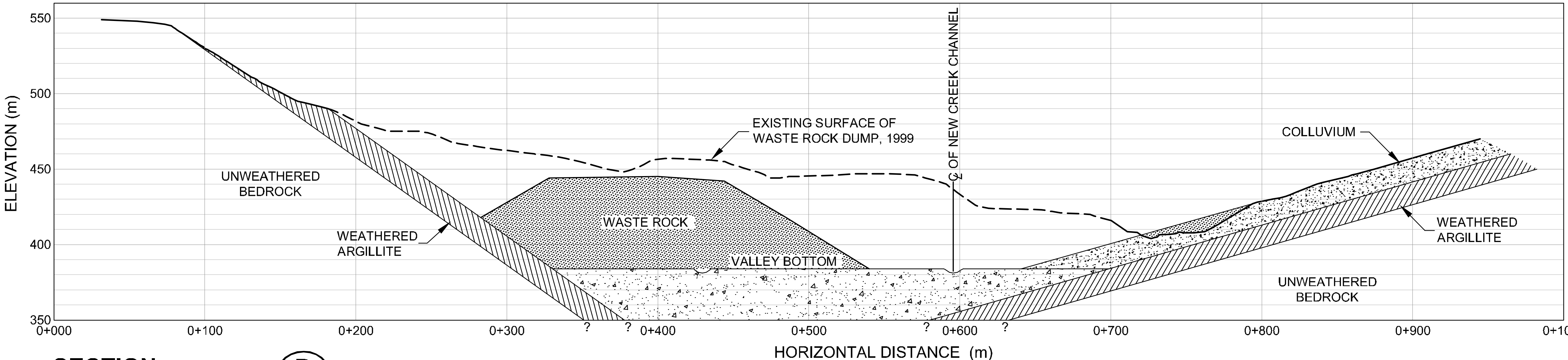
AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Option CC-6

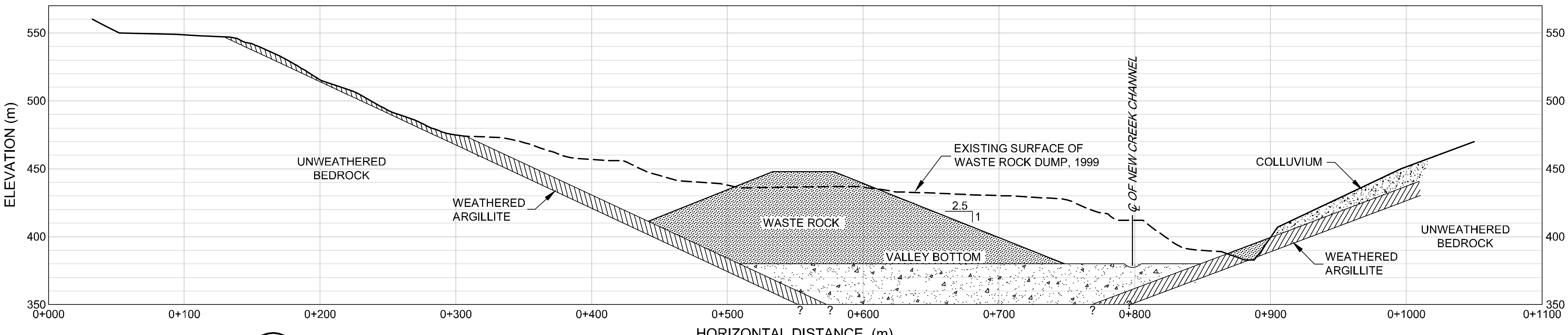
Restore Clinton Creek to Valley Floor

Drawing - 13



SECTION B
13

SCALE 1:3000 (0, 30, 60 m)



SECTION C
13

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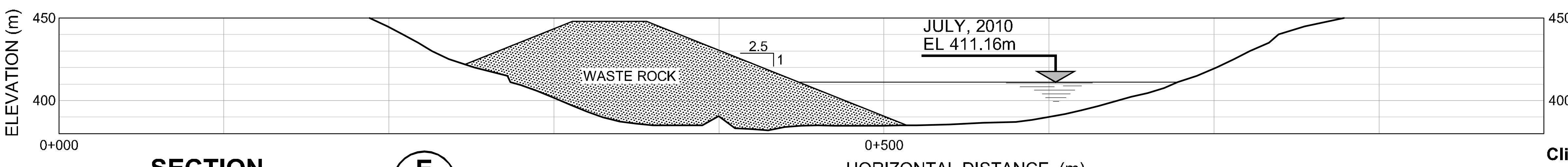

SECTION E
04

SCALE 1:3000 (0, 30, 60 m)

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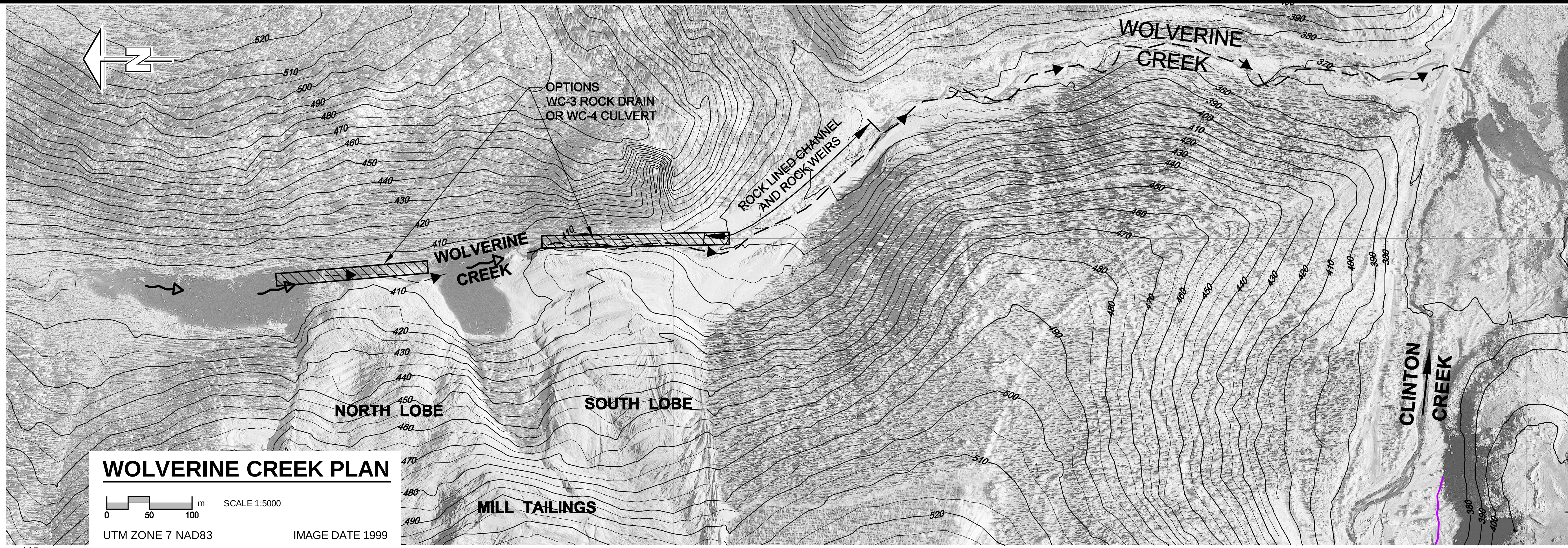
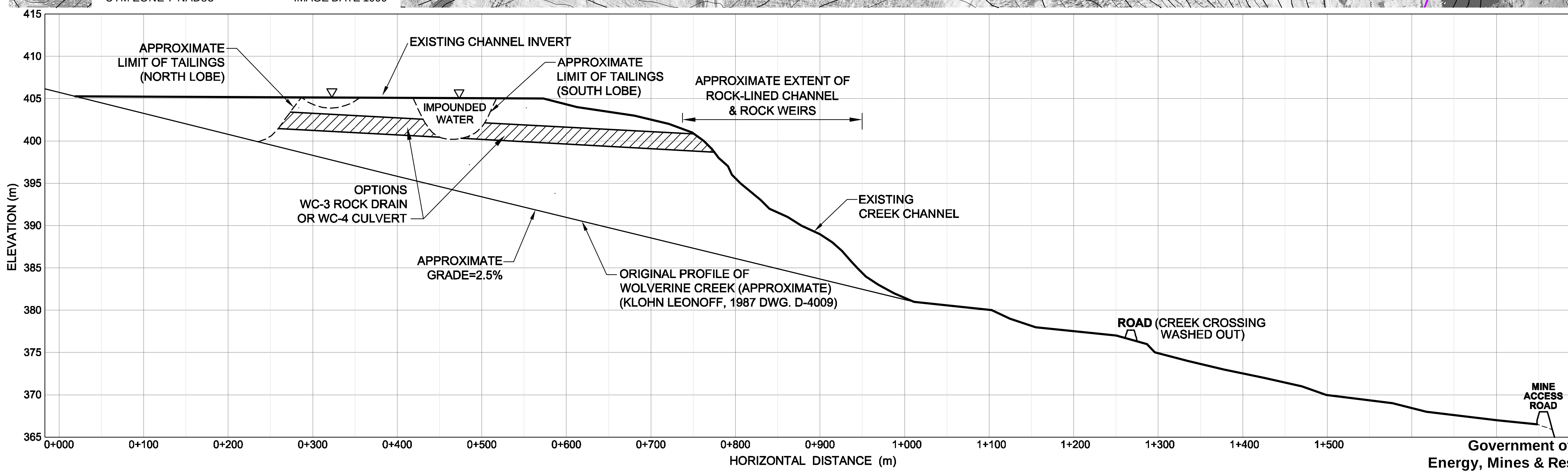
AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Options CC-6
Restore Clinton Creek to Valley Floor
Drawing - 14





PROPOSED WOLVERINE CREEK CHANNEL PROFILE

H=1:5000 (0 50 100 m)
V=1:500 (0 5 10 m)

AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Options WC-3 (Rock Drain) and WC-4 (Culvert)
Plan and Profile
Drawing - 15

ISS/REV: 0A
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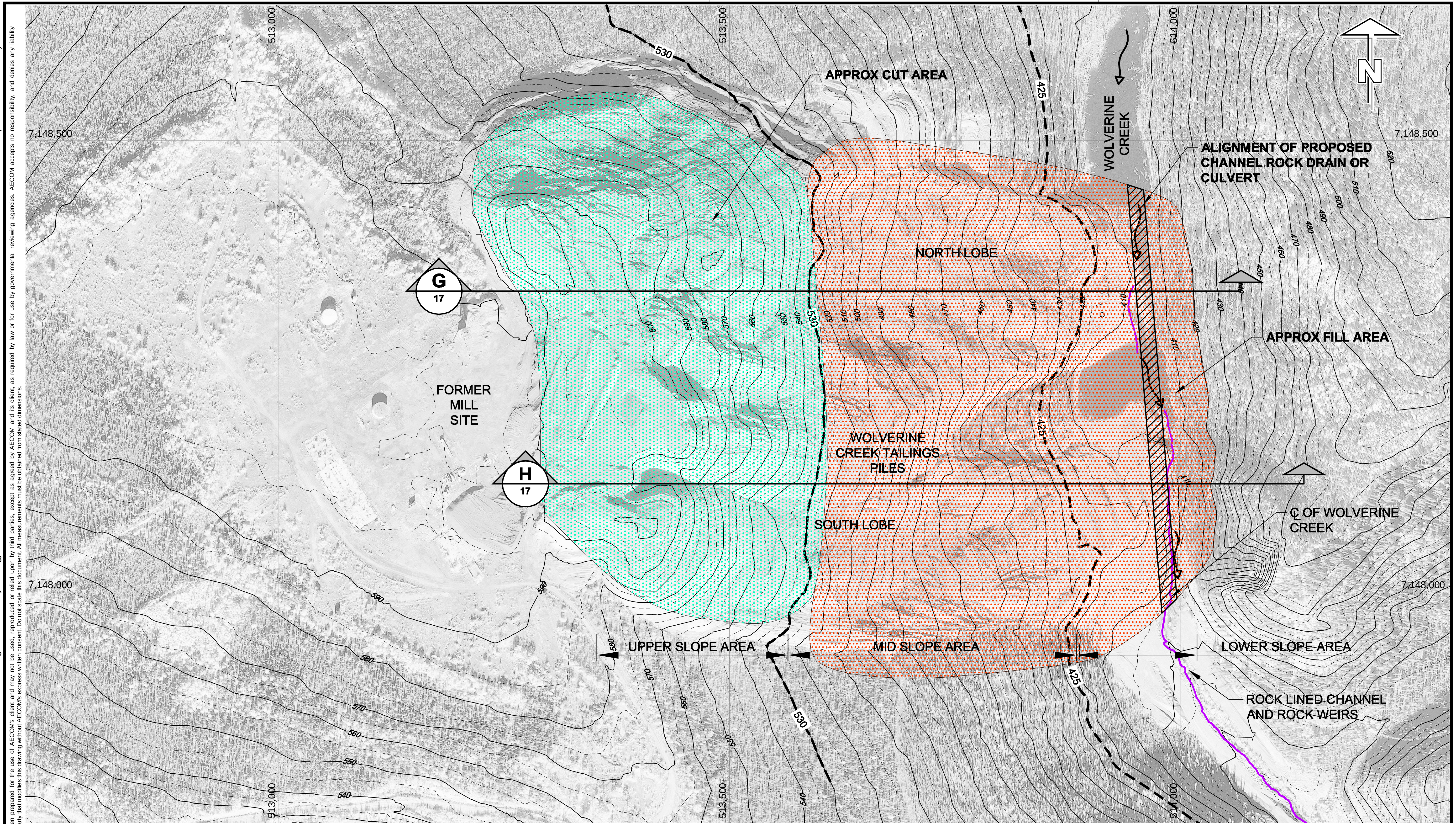

m SCALE 1:4000
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UTM ZONE 7 NAD83
IMAGE DATE 1999

LEGEND

APPROXIMATE FILL AREA

APPROXIMATE CUT AREA

WOLVERINE CREEK CENTRELINE 2010

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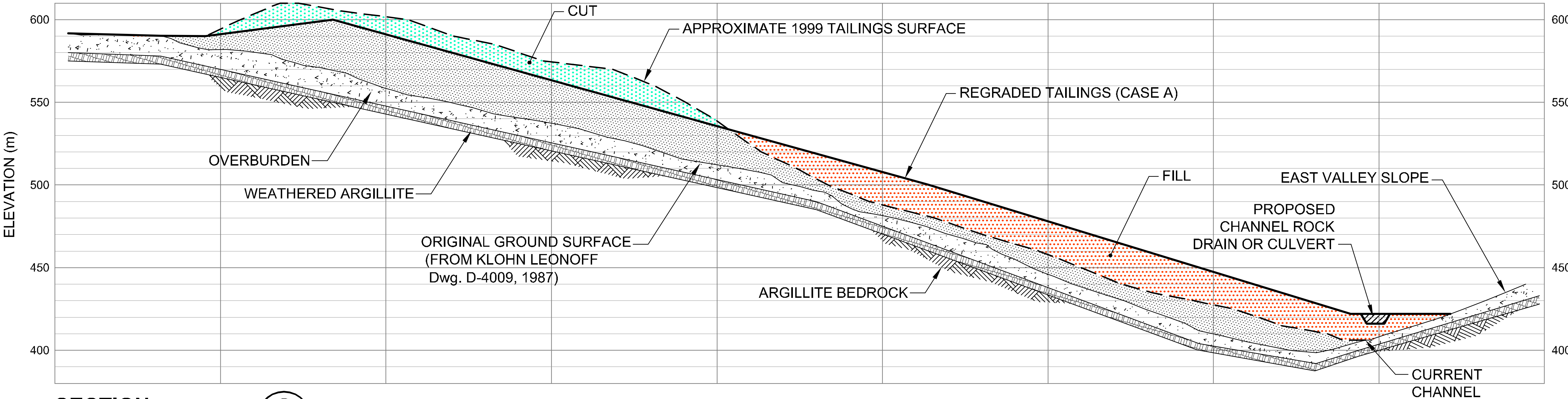
AECOM

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

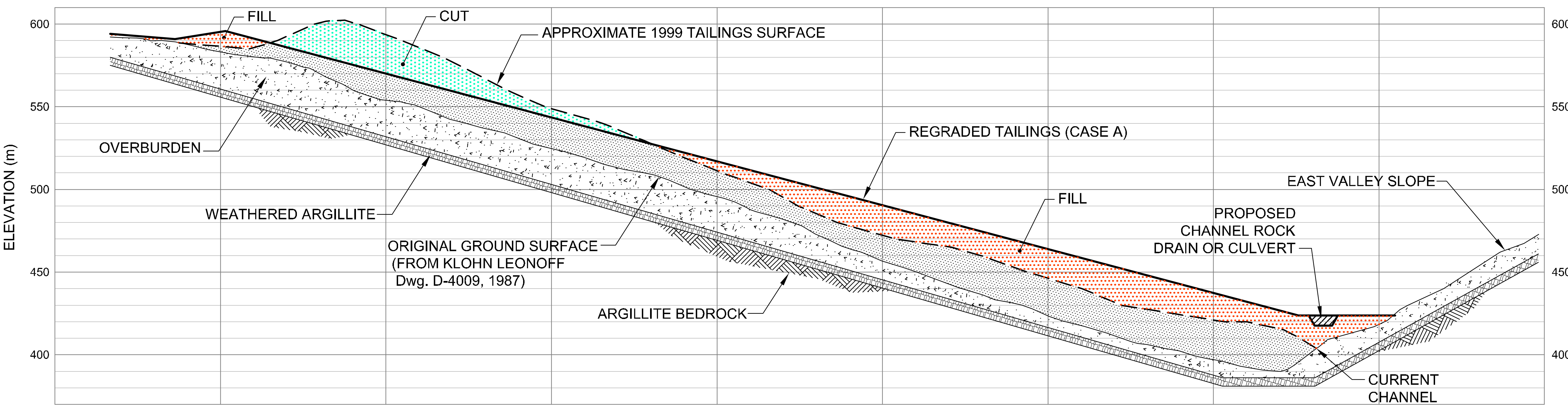
Option T-2
Wolverine Creek and Tailings Stabilizaiton
Drawing - 16



SECTION G 16

0 25 50 m SCALE 1:2500

NORTH LOBE



SECTION H 16

0 25 50 m SCALE 1:2500

SOUTH LOBE

Government of Yukon
Energy, Mines & Resources
Clinton Creek - Technical Options Assessment

Option T2
Wolverine Creek Tailings Stabilization
Drawing - 17

AECOM

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Appendix B

Summary Table

QUALITATIVE ASSESSMENT OF OPTIONS

Ratings:

Primary Objectives
- High : Satisfies primary objective
- Medium : Partially satisfies primary objective
- Low : Does not meet primary objective

Technical Challenges and Liabilities
- Significant: Option has major challenges or significant cost
- Moderate: Option has moderate, challenges that can be addressed
- Minor: Option has challenges that are easily addressed

Notation:

Bold - Options to be considered

Grey- Options not considered

		PRIMARY OBJECTIVES									Technical Challenges and Liabilities					
		Protect human health and safety		Protect environment				Enables original and traditional use of land	Maximizes local, Yukon and FN benefits from work	Manage, reduce or eliminate risk and liability						
Option	Description	On-site	Downstream	Air quality	Water/Fish habitat	Terrestrial habitat	Vegetation				Constructability Challenges	Design Issues	Uncertainty	Long-Term Maintenance	Lifecycle Costs and Effort	Capital Costs
	CLINTON CREEK															
CC-1	Status quo - maintain gabion drop structure	Medium	Medium	-	Medium	-	-	Low	Low	Medium	Minor	Minor	Moderate	Significant	Significant	$0
CC-2	Armoured channel over the waste rock	Medium	Medium	-	Medium	-	-	Low	High	Medium	Minor	Minor	Significant	Significant	Significant	$31,000,000
CC-3	Tunnel through bedrock	Low	Medium	-	Low	-	-	Low	Low	Medium	Significant	Significant	Significant	Moderate	Moderate	$26,000,000
CC-4	Armour existing channel	Medum	Medium	-	Medium	-	-	Low	Medium	Medium	Significant	Minor	Moderate	Significant	Significant	$9,000,000
CC-5	Lower existing channel to bedrock	Medium	Medium	-	High	-	-	Medium	Medium	High	Moderate	Moderate	Moderate	Minor	Minor	$10,000,000
CC-6	Restore to valley bottom	High	High	-	High	High	High	High	High	High	Significant	Significant	Moderate	Minor	Minor	$100,000,000
CC-7	Leave as is - no annual maintenance	Low	Low	-	Medium	-	-	Low	Low	Low	Minor	Minor	Significant	Minor	Minor	
CC-8	Rock trench with overflow channel	Medium	Medium	-	Low	-	-	Low	High	Medium	Significant	Significant	Significant	Moderate	Moderate	
CC-9	Tunnel through waste rock	Low	Low	-	Low	-	-	Low	Low	Low	Significant	Significant	Significant	Significant	Significant	
CC-10	Gabion chute along existing channel	Medium	Medium	-	Low	-	-	Low	Medium	Medium	Moderate	Moderate	Moderate	Significant	Significant	
CC-11	Concrete along existing channel	Medium	Medium	-	Low	-	-	Low	Low	Low	Significant	Significant	Moderate	Significant	Moderate	
CC-12	Pressure grouting along existing channel	Medium	Medium	-	Medium	-	-	Low	Low	Medium	Moderate	Moderate	Moderate	Minor	Minor	
CC-13	CSP half-round chute	Medium	Medium	-	Low	-	-	Low	Medium	Medium	Moderate	Moderate	Moderate	Moderate	Moderate	
	Waste Rock Dump															
WR-1	Leave as is - no remedial measures	Low	-	-	-	Low	Low	Low	Low	Low	Minor	Minor	Moderate	Minor	Minor	$0
WR-2	Remove to expose valley bottom	High	-	-	-	High	High	High	High	High	Moderate	Significant	Moderate	Minor	Minor	Part of CC-6
WR-3	Stabilize waste rock dump	Medium	-	-	-	Low	Low	Low	Medium	Medium	Moderate	Significant	Moderate	Minor	Minor	$8,000,000
	Hudgeon Lake															
HL-1	Leave as is - no remedial measures	Low	Low	-	Medium	-	-	Low	Low	Low	Minor	Minor	Moderate	Minor	Minor	Note 1
HL-2	Fully drain lake	High	High	-	High	High	High	High	High	High	Significant	Significant	Significant	Minor	Minor	Note 1
HL-3	Lower lake water level	Medium	Medium	-	Medium	Medium	Medium	Medium	Medium	Medium	Moderate	Significant	Significant	Moderate	Minor	Note 1
HL-4	Partially backfill Lake	Medium	Medium	-	Low	-	-	Low	Medium	Low	Moderate	Moderate	Significant	Minor	Minor	Note 2
	WOLVERINE CREEK															
WC-1	Leave as is - no annual maintenance	Low	Low	-	unknown	-	-	Low	Low	Low	Minor	Minor	Significant	Minor	Minor	$0
WC-2	Status quo - maintain armoured channel	Medium	Medium	-	unknown	-	-	Low	Low	Medium	Minor	Minor	Moderate	Minor	Minor	$0
WC-3	Rock drain along toe of tailings lobe(s)	Medium	Medium	-	unknown	-	-	Low	Medium	Medium	Significant	Significant	Moderate	Moderate	Moderate	$12,000,000
WC-4	Culvert along toe of each lobe	Medium	Medium	-	unknown	-	-	Low	Medium	Medium	Significant	Significant	Moderate	Moderate	Moderate	
WC-5	Armoured channel over tailings	Medium	Medium	-	unknown	-	-	Low	Medium	Medium	Moderate	Moderate	Moderate	Moderate	Moderate	
WC-6	Armoured channel around tailings	Medium	Medium	-	unknown	-	-	Low	Medium	Medium	Significant	Significant	Minor	Moderate	Minor	
	Tailings															
T-1	Leave as is - no remedial measures	Low	Low	Low	unknown	Low	Low	Low	Low	Low	Minor	Minor	Significant	Minor	Minor	$0
T-2	Stabilize tailings	Medium	Medium	Low	unknown	Low	Low	Low	High	Medium	Significant	Signicant	Moderate	Moderate	Minor	$26,000,000
T-3	Provide cover and armouring	High	Low	High	unknown	High	High	Medium	Medium	Medium	Significant	Signicant	Significant	Significant	Significant	$32,000,000
T-4	Remove tailings to pit	High	High	High	unknown	High	High	High	High	High	Significant	Moderate	Moderate	Minor	Minor	

Notes:

1: Estimated costs are included in appropriate Clinton Creek Options

2. Estimated costs are included in WR-3, assuming that material could be pushed into lake.

Appendix C

Quantity and Costing Summary

Clinton Creek Option CC-2 Armour Channel Over Waste Rock

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Dewatering	Allowance	---	---	$600,000
Excavation (including channel filling, regrading and disposal of excess material in pits)	m3	3,000,000	$7	$21,000,000
Channel Stabilization (Hydraulic Structures)	Allowance	---	---	$1,500,000
Sub-Total	---	---	---	$23,700,000
30% contingency	---	---	---	$7,110,000
Total Estimated Cost	---	---	---	$30,810,000

Say 31,000,000

Clinton Creek Option CC-3 Tunnel through Bedrock

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Tunnelling	Metre	1,700	$8,900	$15,130,000
Inlet and Out Structures	Allowance	---	---	$3,000,000
Channel improvements on Wolverine Creek channel	Allowance	---	---	$600,000
Re-grade Clinton Creek channel	Allowance	---	---	$600,000
Sub-Total	---	---	---	$19,930,000
30% contingency	---	---	---	$5,980,000.0
Total Estimated Cost	---	---	---	$25,910,000

Say 26,000,000

Clinton Creek Option CC-4 Armour Existing Channel

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Dewatering	Allowance	---	---	$600,000
Excavation (including regrading and filling)	m3	600,000	$7	$4,200,000
Channel Stabilization	Allowance	---	---	$1,500,000
Sub-Total	---	---	---	$6,900,000
30% contingency	---	---	---	$2,070,000
Total Estimated Cost	---	---	---	$8,970,000

Say 9,000,000

Clinton Creek Option CC-5 Lowered Channel

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Channel Excavation	m3	280,000	$7	$1,960,000
Waste Rock Pile Unloading	m3	700,000	$7	$4,900,000
Sub-Total	---	---	---	$7,460,000
30% contingency	---	---	---	$2,240,000
Total Estimated Cost	---	---	---	$9,700,000

Say 10,000,000

Clinton Creek Option CC-6 Restore to Valley Bottom

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Excavation	m3	10,000,000	$7	$70,000,000
Dewatering	Allowance	---	---	$600,000
Regrading	m3	1,000,000	$7	$7,000,000
Subtotal	---	---	---	$78,200,000
30% contingency	---	---	---	$23,460,000
Total Estimated Cost	---	---	---	$101,660,000

Say 100,000,000

Clinton Creek Option WR-3: Stabilize Waste Rock

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Re-Grading	m3	300,000	$8	$2,400,000
Channel filling	m3	300,000	$10	$3,000,000
Subtotal	---	---	---	$6,000,000
30% contingency	---	---	---	$1,800,000
Total Estimated Cost	---	---	---	$7,800,000

Say 8,000,000

Wolverine Creek WC-3 Rock Drain Along Toe of Tailings Lobe(s)

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Excavation (including regrading and filling)	m3	20,000	$7	$140,000
Dewatering	Allowance	---	---	$300,000
Regrading	m3	1,000,000	$7	$7,000,000
Reconstruct Road to bottom of Lobe(s)	Allowance	---	---	$300,000
Place Rock (d x w x l, 2 m x 5 m x 500 m)	m3	5,000	$150	$750,000
Subtotal	---	---	---	$9,090,000
30% contingency	---	---	---	$2,730,000
Total Estimated Cost	---	---	---	$11,820,000

Say 12,000,000

Tailings T-2 Stabilize Tailings

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Excavation (including regrading and filling)	m3	2,700,000	$7	$18,900,000
Dewatering	Allowance	---	---	$300,000
Rehabilitate Rock-Lined Channel	Allowance	---	$150,000	$150,000
Reconstruct Road to bottom of Lobe(s)	Allowance	---	---	$300,000
Subtotal	---	---	---	$19,950,000
30% contingency	---	---	---	$5,990,000
Total Estimated Cost	---	---	---	$25,940,000

Say 26,000,000

Tailings T-3 Provide Cover and Armouring (includes stabalize tailings)

Description	Unit	Approximate Qty.	Unit Price ($)	Amount
Mobilization and Demobilization	Lump Sum	1	$600,000	$600,000
Excavation (including regrading and filling)	m3	2,700,000	$7	$18,900,000
Dewatering	Allowance	---	---	$300,000
Rehabilitate Rock-Lined Channel	Allowance	---	$150,000	$150,000
Reconstruct Road to bottom of Lobe(s)	Allowance	---	---	$300,000
Provide Cover and Armouring	m2	410,000	$10	$4,100,000
Subtotal	---	---	---	$24,350,000
30% contingency	---	---	---	$7,310,000
Total Estimated Cost	---	---	---	$31,660,000

Say 32,000,000

Appendix D

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