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Government of Yukon
Former Clinton Creek Asbestos Mine
Review of Suggested Improvements to Hudgeon Lake

Prepared by:

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UMA Project No.: 6029 009 00 (4.6.1)

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Mr. Hugh Copland, P.Eng., P.Geo.
Government of Yukon
Energy, Mines and Resources
Box 2703 (K-419)
Room 210 – 419 Range Road
Whitehorse, Yukon
Y1A 2C6

Dear Sir:

Re: Former Clinton Creek Asbestos Mine – Review of Suggested Improvements to Hudgeon Lake

The attached report provides a preliminary assessment on the design and construction considerations of suggested measures to enhance fish habitat in Hudgeon Lake relative to the current situation. Recent fish and fish habitat assessment studies have indicated that grayling, juvenile Chinook salmon and a few other fish species are present during summer-time in Clinton Creek below the outflow from Hudgeon Lake, and that the gabion drop structures, installed at the lake outlet to mitigate the potential for a breach of the lake outlet, likely act as a barrier to fish passage. Our report briefly discusses the reasons why productive fish habitat is limited to areas of the Clinton Creek drainage that are downstream from the Hudgeon Lake outflow, especially in the context of potential for over-wintering survival. The report further evaluates suggestions that have been advanced to change this situation.

If we can be of further assistance, please contact Gil Robinson, P.Eng. or Doug Bright, Ph.D.

Sincerely,

UMA Engineering Ltd.

R. V. Typliski

Ron Typliski, P.Eng.
Regional Manager
Earth and Environmental
GR/dh

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This Disclaimer is attached to and forms part of the Report.

Table of Contents

List of Appendices

1.0 Introduction

This report provides the results of our preliminary assessment of measures suggested to enhance fish habitat in the Clinton Creek watershed by either i) partially infilling Hudgeon Lake with waste rock or ii) permanently lowering the level of Hudgeon Lake by removing the gabion drop structures and constructing a deeper creek channel. The terms of reference for this work are outlined in our letter proposal to Mr. Hugh Copland, P.Eng. P.Geo. of the Government of Yukon (GY), Energy, Mines and Resources dated May 18, 2007.

1.1 Background

Hudgeon Lake was created in the early 1970's when the waste rock dump at the Clinton Creek Asbestos Mine, Yukon, failed and blocked the Clinton Creek valley. The failure resulted in blockage of flows to Clinton Creek, just upstream of the confluence of Clinton Creek with Wolverine Creek. The subsequent impoundment of water has since come to be called Hudgeon Lake (Drawing 01). Clinton Creek enters Fortymile River, approximately 10 km downstream from Hudgeon Lake. The Fortymile River enters the Yukon River approximately 4.5 km farther downstream from the mouth of Clinton Creek. According to DFO (2007), the Clinton Creek watershed drains an area of approximately 206 km^2. Several unsuccessful attempts were made through the 1970s to1980s to stabilize the creek channel immediately downstream of the lake outlet. A summary of studies completed through this period is provided by RRU (1999).

Hazards associated with continued degradation of the Clinton Creek channel through the waste rock dump have been previously identified in UMA's Risk Assessment Report (UMA 2000). At that time, a major concern was the potential risks to human life and property downstream of the mine associated with a sudden breach of channel blockages, particularly in Clinton Creek where it passes across the toe of the Clinton Creek waste rock dump. In areas with significant relief, such as the Clinton Creek valley, flooding from failures of channel blockages can be especially dangerous and unrelated to precipitation events that would normally be expected to produce flooding conditions. The waste rock material is generally a fine grained material that is very susceptible to erosion despite that presence of some larger sized material such as gravel, cobbles and boulders. Profiles of the creek channel through the waste rock from 1986, 1999 and 2001, showed progressive channel degradation (i.e. erosion / down-cutting) was occurring spatially along the first 500 m of channel downstream of the outlet. As degradation continued, the toe of the waste rock pile was being undercut and localized slope instabilities were developing.

The possibility of future down-cutting of the waste rock blockage and subsequent release of impounded water from Hudgeon Lake over a contracted period led to at least three major concerns:

(i) 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;

(ii) massive changes in hydrology associated with downstream flooding and the subsequent erosion of fish habitat (banks, sand and gravel bars, spawning gravels); and

(iii) endangerment to human life and property within the floodplain and possibly higher areas downstream in association with the flood event.

By 2001, conditions had deteriorated to a point where it was feared that normal flow and/or an overtopping event could trigger a breach of the waste rock at the Hudgeon Lake outlet. To address this concern, channel stabilization works consisting of four gabion drop structures linked by a nearly flat graded channel were constructed in the first +/- 180 m of the channel directly downstream of the Hudgeon

Lake outlet between 2002 and 2004. The profile of the stabilized portion of the Clinton Creek channel before and after construction is shown on Drawing 02.

Anecdotal observations indicate that adult grayling occurred, at least in low numbers, within Hudgeon Lake prior to completion of outflow channel stabilization from 2002-2004. A large number of adult grayling were also recovered from the waste rock portion of the creek channel during the fish salvage operations conducted before construction of the gabion drop structures (UMA 2003a, 2003b & 2005). It has also been documented that Clinton Creek downstream from the Hudgeon Lake outlet, during summer-time, supports not just adult graylings, but also juvenile Chinook salmon and small numbers of slimy sculpins (DFO, 2007; RRU, 1999).

White Mountain Environmental Consulting (WMEC, 2008) conducted a study during July-August, 2007, of fish presence and habitat suitability in Hudgeon Lake and upstream tributaries. The tributaries include Easter Creek, Bear Creek, Upper Clinton Creek, a tributary to Upper Clinton Creek, and an unnamed tributary near Easter Creek. Evaluations for fish utilization within the creek environments consisted of several techniques to ensure capture of all species present, including electro-fishing, deployment of minnow traps (G-traps) set at all sampling locations with a variety of baits including chinook salmon roe, and angling with light spinning gear. Hudgeon Lake was sampled using gill nets and by beach seining, which was constrained by the large amount of submerged woody debris present.

According to WMEC –

> "No fish were found in any of the habitats investigated during this project during either of the sampling periods. Benthic invertebrate production was noted in all areas investigated."

The absence of fish within the watershed above the engineered control structure (i.e. the gabion drop structures) at the Hudgeon Lake outlet might be attributable to one or more of the following:

(i) the Gabion control structures might act as a barrier to fish passage (WMEC, 2008; DFO, 2007);

(ii) Hudgeon Lake has been observed to be anoxic in all but its surface waters, and the low oxygen conditions during both summer and winter (under ice) are not suitable for over-wintering survival of fish;

(iii) Alteration of flows in the system relative to historical conditions might lead to higher than normal water temperatures during the summertime and thermal stress (DFO, 2007)

(iv) The smaller tributaries leading into Hudgeon Lake (Easter Creek, Bear Creek, Upper Clinton Creek, a tributary to Upper Clinton Creek, and an unnamed tributary near Easter Creek) may be naturally poorly suited to fish presence based on foraging activities and/or overwintering survival.

It is inferred from the DFO (2007) Memorandum that there is an interest in increasing habitat availability especially for Chinook salmon within the Clinton Creek Valley drainage system, with a focus on the upper reaches of Clinton Creek, including Hudgeon Lake. It is important, therefore, to better understand the potential limiting factors for Chinook salmon and grayling productivity in the upstream watershed, so that any enhancement efforts result in the anticipated benefit.

When examining local Chinook salmon or grayling productivity, there is a further need to clearly evaluate habitat suitability based on either (i) presence of viable spawning habitat; (ii) presence of appropriate rearing habitat for juveniles, especially through the first year of growth; (iii) availability of over-wintering habitat for either juveniles or adults; (iv) access to temporary foraging areas; or (v) presence of natural or human-caused barriers to fish passage.

Based on the DFO (2007) Memorandum, it appears that 0+ age class juvenile Chinook salmon substantially enter Clinton Creek from Fortymile River in July and migrate up the creek through August. No 1+ age class juveniles were observed.

Based on the DFO (2007) Memorandum, it appears that 0+ age class juvenile Chinook salmon substantially enter Clinton Creek from Fortymile River in July and migrate up the creek through August. No 1+ age class juveniles were observed. It would have been informative if the 2007 study was able to assess the distance over which 0+ juveniles move up Clinton Creek from Fortymile River during foraging. The juveniles captured in Gee traps set near the former mine site, however, appear to have been fish that were re-located between July 18 and August, 2007 from the lower reaches of Clinton Creek (downstream from the lower-most of approximately 17 beaver dams) to a location at the mouth of Wolverine Creek. In particular, 2,070 juveniles were relocated by the Dawson District Renewable Resource Council (DDRRC) Stream Stewardship crew. To better assess the potential upstream distance of foraging movements from the mouth of Clinton Creek, additional Gee traps set between the mouth and mine site area would be useful in concert with observations during one or more years when juvenile distribution is not manipulated.

The DFO (2007) Memorandum is equivocal about the whether the stretch of Clinton Creek between Hudgeon Lake and the mouth at Fortymile River is conducive to upstream movements of 0+ juvenile Chinook, entering the system from the Fortymile River in July. It is stated on p. 8 that –

> "The canyon has multiple minor falls, chutes, etc, but also has very coarse substrate. Individual boulders in excess of 2 cubic meters are common. It is possible that surface access routes are only a component of the overall number of opportunities for juvenile Chinook to migrate upstream."

It is stated on p. 9:

> "It appears that the canyon section provided excellent, or at least highly productive, habitat for juvenile Chinook salmon in late summer 2007. "

In reconciling these statements, it is important to appreciate that the recognition of Clinton Creek immediately below the Hudgeon Lake outflow (referred to by DFO as the canyon section) as "highly productive" habitat for juvenile Chinook is based on the presence of food supply and subsequently on body index observations for individuals that had been transplanted to the reaches of interest. Hudgeon Lake and Clinton Creek tend to be highly eutropic, as evidenced by the large periphyton accumulations on the stream bed across and downstream from the gabion drop structures. The Chinook productivity categorization is not based on either (i) propensity for 0+ or other age classes to move upstream from the mouth of Clinton Creek during July-September for the purpose of foraging, relative to the available instream window prior to onset of winter conditions; or (ii) presence of viable spawning sites. Additional work is proposed by DFO in 2008 to better evaluate over-wintering success of juvenile Chinook in the vicinity of the former mine site.

An important outstanding issue is the extent to which lower reaches of Clinton Creek, downstream from the gabion drop structures would naturally support spawning and over-wintering survival of 0+ Chinook, as opposed to summertime foraging. It is well known that Chinook tend to spawn in deeper, larger channels than other Pacific salmon species such as chum. DFO data collected in 2007 suggests that little or no Chinook spawning occurs in Clinton Creek, as opposed to Fortymile River.

No grayling were observed during the DFO (2007) study; however, the Gee traps would not be appropriate for capture of other than juvenile grayling and observational techniques were not directed at assessment of grayling. Nonetheless, there was an apparent difference in the presence of grayling between 2005 and 2007:

> "No arctic grayling were seen or captured in 2007. Arctic grayling fry, juveniles, and adults were common in 2005, with a large school (and closely attendant bald eagle) observed at Station 1. Juveniles were captured at all stations except Station 4. Lesser numbers of Arctic grayling fry and juveniles were captured in 2006, and only a few adults were seen at Station 1"
>
> (DFO, 2007; p. 12)

1.2 Report Structure

The remainder of this report addresses the potential for improving fish habitat, including increasing over-wintering survival within Hudgeon Lake (or upstream creeks), by either partially infilling the lake, or reconfiguring the lake level through lowering the outlet structure. The major issue associated with Hudgeon Lake is that oxygen levels during the summertime would not be conducive to the survival of most fish species below a lake depth of approximately 5 – 6 m (DO < 5 mg/L) (Werner Liebau INAC, 2007; pers. comm.). The maximum lake depth is estimated to be 27 m (RRU, 1999). Furthermore, it is expected that under-ice oxygen levels within the shallow surface waters would be too low for fish survival. Major factors contributing to lake water quality conditions are discussed in Section 2. Sections 3 and 4 discuss issues associated with lake infilling or lowering of the lake level, respectively.

2.0 Hudgeon Lake Water Quality

Hudgeon Lake is permanently anoxic in its bottom waters. Based on data collected by Werner Liebau (INAC), the anoxia during open water periods extends from the lakebed (maximum depth of approximately 27 m) to within approximately 5 m of the surface or less. The lake bottom consists of former terrestrial vegetated areas that where inundated following the blockage of the Clinton Creek valley by mine waste rock. A photograph of the non-inundated Clinton Creek valley is illustrated in Figure 2.1. Additional organic detritus likely has been contributed to the valley bottom (and Hudgeon Lake) by downslope movements from the sides of the valley, which are very steep in some locations. As such, Hudgeon Lake contains large amounts of woody debris and other organic detritus, which is highly visible in shallow embayments and near the inlet end of the lake.

Figure 2.1 Clinton Creek Valley Prior To Blockage

Owing to the large amount of organic detritus and limited oxygen supply during under-ice periods, it is expected that anoxic waters would extend upward from the lakebed to the bottom of the ice surface during most, if not all winters. Another important factor for fish survival is that the anoxic waters are also very high in sulphide concentrations in comparison with most freshwater lakes.

From a geochemical perspective, the sulfide production occurs as a result of the following:

1) A large supply of detrital organic matter, with a sufficient annual flux to stimulate relatively high decomposition rates in lakebed sediments. The historical woody debris inputs are likely augmented by high levels of phytoplankton productivity in the summer, following by sinking of dead algal cells below the hypolimnion (termed "autochthonous" inputs).

2) A limited seasonal oxygen supply to lake bottom waters. Oxygen can enter the water only through the inflow of oxygenated water in streams and surface runoff, which for Hudgeon Lake is very limited, and via diffusion across the surface water – air interface.

3) Depletion of oxygen as a terminal electron acceptor for cellular respiration during decomposition, so that much of the organic matter is broken down by heterotrophic bacteria that utilize other substances (and redox couples) to biochemically decompose the detrital organic matter (DOM).

4) Dominance of microbial sulfate reduction as the major process organic matter decomposition in the Hudgeon Lake bed and waters. This is based on the documented presence of high concentrations of sulfate in inflow waters and lake water relative to typical freshwater systems (Werner Liebau INAC, 2007; pers. comm.). A major by-product of microbial sulphate reduction is sulfide. Sulfide, in turn, tends to be highly toxic to most forms of higher life, since it directly binds to an interferes with cytochrome C oxidase enzymes systems that are fundamentally important.

High rates of sulfide production in sediments would not normally happen as a result of DOM decomposition in freshwater systems where sulfate concentrations are low. In typical freshwater systems, the breakdown of organic matter is substantially aerobic, and - once oxygen is depleted - the next major set of processes linked to organic matter breakdown are fermentation-type reactions and methanogenesis. Aerobic degradation and sulphate reduction both result in relatively rapid breakdown of DOM, while fermentation and methanogenesis tend to result in much slower microbial decomposition rates. Liebau (2007; pers. comm.) has shown that there is a net influx of sulfate in Hudgeon Lake (influx rate exceeds efflux). The origin of high sulphate levels in surface waters is presumably attributable to mobilization through weathering from exposed geological source materials in the watershed, possibly sulfate rich argillite deposits that are visually evident in outcrops within the valley.

It also merits consideration of secondary geochemical interactions within the lake. In particular, many freshwater lakes have primary productivity (within the photic zone) which is phosphate-limited, since the P that is released as a result of DOM composition in not readily recycled back into the water column. This happens as a result of adsorption to iron and manganese oxyhydroxides in oxic surface sediments. In Hudgeon Lake, there is likely to be a very high degree of P recycle and release to the water since lakebed sediments are anoxic and Fe -oxyhydroxides will have undergone dissolution. Under such anoxic conditions, Fe-oxyhydroxides are not a major sorptive or controlling phase for phosphate. The resulting high rate of nutrient recycle from the lakebed would contribute to eutrophic lake conditions provided that nutrients can move via advection or diffusion to the photic zone. The higher primary productivity, in turn, would return more fixed organic carbon to the lakebed, thus exacerbating the problem.

The brief overview of factors that influence water quality in Hudgeon Lake leads to a critical evaluation of specific mechanisms by which future production of sulphide or oxygen depletion might be altered. In particular, the potential for improving water quality in Hudgeon Lake depends on the relative fluxes into the lake of oxygen, sulphate, and organic carbon. Practical limitations associated with altering the flux of each of these are discussed below.

2.1 Organic Carbon Supply and Characteristics

The primary driving force for heterotrophic microbial decomposition (as well as oxygen depletion and sulfide production) is an available source of detrital organic matter (DOM). No specific information is available regarding DOM mass within Hudgeon Lake, annual influx via surface water inputs, or annual production within the lake. The quantity and characteristics of DOM are likely consistent with other temperate to sub-arctic lake systems that were created or expanded in volume through human-caused or natural flooding of previously terrestrial and riparian, vegetated areas. For example, the quantity and types of DOM would be consistent with land flooding associated with new beaver dams, albeit on a much larger scale.

It is expected that the DOM will exhibit a more rapidly degradable pool of organic carbon, as well as a more recalcitrant pool (ligins, e.g.), for which microbial decomposition rates would be much slower. Assuming that the major mass of DOM was introduced over a brief time period during the creation of

Hudgeon Lake, it is expected that the overall DOM decomposition rates would decrease over time. The situation is expected to be somewhat analogous to organic matter breakdown and methane production rates in landfills, which have been documented to decrease slowly over decades.

The decrease in DOM decomposition rates in Hudgeon Lake over time might be countered to some extent by the further annual introduction of DOM based on autochthonous production, as well as the annual influx of DOM and dissolved organic matter and nutrients from surface or groundwater inflows.

From the perspective of decreasing the overall annual rate of decomposition of DOM in Hudgeon Lake beyond the current long-term trends, the following possibilities are considered:

- Covering DOM on the current lake bed with waste rock to isolate it: placement of waste rock over top of organic detritus on the lake bed would not inhibit heterotrophic microbial decomposition unless sulfate fluxes into the zone of interest where strongly curtailed. If both oxygen and sulfate in the aqueous environment are limiting, then rates of DOM decomposition through methanogenesis and fermentation rates would be lower than at present. It is far from obvious, however, that advection or diffusion of sulfate in water would be decreased sufficiently based on placement of permeable waste rock on the lake bed that sulfate depletion would occur. An alternative is to 'cap' lakebed DOM with a low permeability material such as clays or a geotextile. Neither of these are pragmatically achievable given the lack of any borrow sources for clay soil and the expected rugose nature of woody debris on the lakebed, with a large number of whole trees present.

- Decreasing the lake level: a lowering of the lake level would result in a decreased aerial extent of inundated DOM (around the lake periphery), and could provide an opportunity to physically remove organic debris. However, the decrease in the lake level would also result in a lower lake volume (and possibly a lake-bed: lake volume ratio that is even higher than the current situation). Furthermore, lowering of the lake level would decrease the lake surface area available for oxygen re-supply via diffusion. Finally, such a proposal would need to be considered in concert with geotechnical considerations such as the stability of the waste rock pile and constructability issues, as well as potential of newly exposed foreshore areas to contribute nutrients and suspended sediments to the lake.

For either of the two manipulations discussed above, the extent to which oxygen depletion is relieved by a reduction on lakebed decomposition rates is unknown relative to demands associated with annual authigenic DOM production rates. Authigenic production (associated with phytoplankton productivity within the Hudgeon Lake photic zone) is an important consideration for oxygen depletion, since the type of DOM produced is expected to be highly labile; i.e., available for rapid microbial breakdown. The relatively high decomposition rates will result in more rapid oxygen depletion per mass of organic carbon than for more recalcitrant woody debris.

Lake bathymetry also has a role to play, since organic matter will accumulate over time if the current lakebed were capped. In particular, deeper areas of the lake will act as sinks for organic carbon.

2.2 Sulfate Supply

As discussed above, Werner Liebau (2007; pers. comm.) has shown that sulfate influx rate to Hudgeon Lake exceeds the annual efflux rate. A possible reason for this is the within-lake conversion of sulfate to free sulfide, and subsequent loss to the atmosphere.

The geological materials or portion of the watershed that contribute substantially to sulfate dissolution and input have not been elucidated; however, it is assumed that there is little if any potential to manipulate sulfate influx rates to Hudgeon Lake, or to lake bottom waters.

Placement of additional waste rock into the lake would need to take into consideration whether there is potential for sulfate dissolution from the placed material.

2.3 Oxygen Supply

Oxygen is important for fish survival, both during the open water season and under ice. Assuming that the rates of oxygen depletion through heterotrophic microbial decomposition cannot be substantially manipulated, then the instantaneous concentration of dissolved O_2 at any point in the water column of the lake will be amenable to variation based primarily on changes in the supply (influx).

The 'natural' mechanisms available for oxygen re-supply to lake waters are very limited:

- Oxygen diffusion across the air-water interface: The most important mechanism in most lakes for oxygen inputs is diffusion of oxygen into the water from the overlying air at the air-water interface. The surface area available for diffusion, both geographically and seasonally, is a major limiting factor for oxygen influx to surface waters. Decreasing the lake surface area by lowering the lake level would actually be counter-productive from the perspective of lake oxygen supply.

  Oxygen transfer rates across the lake surface are enhanced under windy as opposed to quiescent conditions, since surface waves introduce small to large gas bubbles into the water and create micro-zones of oxygen super-saturation. Lowering the lake level would likely decrease the influence of local air movements in the valley on the lake surface.

  Winds have a strong secondary role in driving mixing of surface waters with deeper water masses, and in destabilizing the thermocline in stratified lake systems. The potential for re-oxygenation of waters in Hudgeon Lake below ~5 m depth based on surface O_2 diffusion and wind-driven mixing is likely very low, regardless of whether the current lake level is maintained or altered.

- Oxygen inputs in infiltrating groundwater or surface water inflows: These are likely to be minor components of volumetric lake capacity, and probably not amenable to any manipulation.

Overall, the lake oxygen levels in all but the upper-most water will depend on lake morphoedaphic features (surface area, shoreline length, volume, bathymetry) as much as on lake productivity and lakebed DOM decomposition rates. Lowering of the lake level would not increase the surface area: volume ratio, while infilling the lake would not appreciably increase wind-driven mixing potential, unless the lake depth were reduced to less than ~5 m.

2.4 Associated Issues

One obvious question is whether the intent is to address lake water sulfide levels in Hudgeon Lake or further down the watershed. It appears sulfide levels in downstream areas are acceptably low and oxygen levels sufficiently high (DFO, 2007). Re-oxygenation would occur at and immediately beyond the outlet of Hudgeon Lake to re-convert S^{2-} to SO_4^{2-}, and to off-gas any residual H_2S. The four gabion drop structures likely contributes to the re-oxygenation of water leaving Hudgeon Lake.

If the lake bathymetry can be changed sufficiently to convert the lake from being seasonally stratified (meromictic) to being vertically mixed, this might solve the problem of low dissolved oxygen. This is not a trivial undertaking, however. Even if vertical exchange can be enhanced during open conditions (based on wind driven circulation) it would be very hard to avoid stratification and oxygen depletion under ice. Placement of massive amounts of waste rock might bring the bottom up to the point where wind-generated mixing more routinely penetrates through the entire depth of the water column, so that the lake would turn over twice or more per year.

3.0 Hudgeon Lake Infilling

3.1 Suggested Improvement

Infilling of Hudgeon Lake with waste rock material has been suggested to GY as a possible means to improve the lake water quality to support fish habitat. It is our understanding that the hope is for the anaerobic decomposition of the organic matter in the lake bottom to 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.

The waste rock material most readily available for deposition into Hudgeon Lake is located above elevation 415 m, which is the general site grade on both sides of the Hudgeon Lake outlet. Removal of waste rock below this elevation is not recommended since the water elevation can approach 413.5 to 414.0 m based on the outlet channel invert of 411.0 m and a design flow depth of 2.5 to 3 m.

Drawing 01 illustrates the approximate area from which waste rock is readily available for use. 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. In general, this corresponds to the deepest area of the lake as shown on Drawing 01. This coverage conservatively assumes that there is no change in density of the waste rock as it is moved from its current location and loosely placed in the lake.

3.2 Impacts of Lake Infilling on Water Quality

As discussed in Section 2, infilling might decrease the decomposition rates of in place detrital organic matter, provided that the rate of flux of sulfate-rich waters through the fill material is rate limiting relative to microbial sulfate depletion rates. There are a few challenges with this suggestion however:

(i) It would need to be demonstrated that lakebed decomposition rates would not increase following the initial manipulation, based on the re-accumulation of organic matter from especially autochthonous inputs (in-lake primary productivity) and surface water inputs;

(ii) It would need to be demonstrated that the reduction in decomposition rate would be of sufficient magnitude to alleviate oxygen depletion during under ice conditions. Since the only justification for altering Hudgeon Lake would be to increase over-wintering survival of fish, the critical period for scrutiny will be the under-ice period. Without increasing oxygen delivery rates during the open water period, it is expected that lakebed decomposition rates would have to be very low so that the oxygen supply would not be reduced to critical levels for fish survival. Infilling could also be potentially counterproductive in this regard, since the oxygen storage capacity would be reduced proportionately to the reduced lake volume (and the lakebed: lake volume ratio would be substantially reduced).

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 cost of this type of study has not been included in Table 3.1.

3.3 Design and Constructability Considerations

No significant design issues are readily apparent however, placement of a uniform deposit of material on the lake bottom would be a significant challenge. The general considerations identified in this preliminary review of the suggested improvements are discussed below.

3.3.1 Design Considerations

Assuming that placement of waste rock on the lake bottom is feasible, design of the lake bottom covering would need to take into consideration the following as a minimum:

- Determine which areas of the lake will benefit from placement
- Confirm volume of material required and available
- Effect on waste rock dump stability
- Investigation of placement methods
- Sediment control

A field program would likely be required to determine which areas of the lake need to be covered with fill. The field program needs to be developed but would likely involve water sampling at various locations to determine if there are any trends in water quality associated with lake depth.

A digital terrain model would need to be developed to estimate both the volume of material required and the volume of material available. A bathymetric survey of Hudgeon Lake would be required to generate a terrain model of the lake. The existing digital terrain mapping for the waste rock pile could be utilized but may need to be supplemented with some test hole information to estimate where the valley slopes are located below the waste rock pile.

Removal of material from the waste rock pile will have a positive impact on the stability of the waste rock pile. However, the sequence of material removal may need to be modelled to ensure that the work does not reduce the existing stability. In general, the material would have to be removed from the upper area of the waste rock dump first.

Research into construction methods should be conducted to determine what methods are available to move and place the waste rock material. It might be advantageous to excavate some test pits to provide information to Contractors on the gradation of material expected.

Sediment control during construction will be required to prevent / minimize the amount of sediment entering the Clinton Creek channel from the lake outlet. It is expected that one or more floating silt curtains could be used however there may be other options. Winter construction and/or placement methods may also be advantageous in reducing the amount of sediment entering the Clinton Creek channel.

3.3.2 Construction Challenges and Costs

Excavation of the waste rock and placement of a uniform layer of material in the lake bottom would be challenging. The simplest way to do the work would be to push the waste rock directly into the lake, however this would severely limit the area of lake bottom that could be covered. To provide a reasonably uniform covering of material on the lake bottom would require a method of conveying the waste rock out on to the lake so that the targeted lake bottom areas could be covered. Depending on the method used, it may be necessary to screen out oversize material (e.g. rocks larger than 300 mm in diameter) not compatible with the system being used. Winter construction may be beneficial but site access, extreme temperatures and poor quality ice may preclude winter construction. With regards to poor quality ice, it is our understanding that the quality of ice formed on Hudgeon Lake is affected by the hydrogen sulphide gases that are constantly being released from the lake bottom. If winter construction is deemed a viable option, the ice quality on the lake should be checked.

3.4 Cost Estimates

A preliminary cost estimate is provided in Table 3.1 for the purpose of comparing infilling of Hudgeon Lake with lowering of the lake level. If the lake infilling work is deemed to be feasible then a preliminary design and revised cost estimate should be completed before proceeding with detailed design and construction.

The cost estimate for preliminary design includes field investigations to collect information to better assess the water quality in Hudgeon Lake, determine the bathymetry of the lake and complete some geotechnical investigations. Once this information has been obtained a preliminary design should be completed to provide a better scope of the work required, and understanding of the construction issues. Once completed a revised cost estimate could be completed.

It has been assumed that part time (50%) site inspection is required. The cost estimate is based on the work being completed over 2 summer construction periods running from June to the end of September each year.

The unit costs for excavation and placement of waste rock into the lake are very approximate as the method of placement is not known. It is expected the unit cost will be high due to the distance the waste rock will have to be moved on land and over the lake. The unit rate of \$25 per m^3 was selected to reflect the difficulty and cost of excavating, sorting and placing waste rock on the lake bottom relative to bull dozing waste rock material into the open pit, which was estimated to be about \$5 per m^3 in Table 4.1.

An allowance for sediment control has been included.

A relatively small volume has been included to account for regrading work. Some regrading work may be required to clean up the site, flatten some of the existing channel side slopes and provide access to the lake outlet area for inspections.

If the vast majority of the waste rock above elevation 415 m is deposited in the lake then there should be no concerns on the stability of the waste rock pile that would require a performance monitoring program. No allowance has been included for performance monitoring. There may be some maintenance costs for the existing channel stabilization works. The maintenance requirements would generally be related to inspecting the channel on an annual basis and undertaking any work to restore the channel erosion protection.

Table 3.1 Preliminary Cost Estimate For Infilling Hudgeon Lake

Description	Unit	Approximate Quantity	Unit Price	Amount
Preliminary and Detailed Design				
Hudgeon Lake Water Quality Study	Allowance	1		$150,000
Hudgeon Lake Bathymetry Survey	Allowance	1		$50,000
Geotechnical Field Program – test holes and test pits	Allowance	1		$75,000
Preliminary Design and Revised Cost Estimate	Allowance	1		$25,000
Detailed Design and Tender Package	Allowance	1		$50,000
Contingency	Percentage	30		$105,000
Sub-Total Detailed Design				**$455,000**
Construction				
Site Engineer - Part Time (50%)	Days	120	$2,000	$240,000
Mobilization	Lump Sum	1	$500,000	$500,000
Waste Rock Excavation, Sorting, Placement	Cubic Metre	3,000,000	$25	$75,000,000
Sediment Control	Allowance			$500,000
General Site Regrading	Cubic Metre	500,000	$5	$2,500,000
Contingency	Percentage	30		23,622,000
Sub-Total Construction				**$102,362,000**
Annual Inspection and Maintenance	Annual Allowance			$50,000
Total				**$+/- 103M**

4.0 Hudgeon Lake Lowering

4.1 Suggested Improvement

Permanently lowering the water level in Hudgeon Lake has also been suggested to GY as a possible means to improve the water quality in the lake to support fish habitat. It is our understanding that the hope 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. 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.

As illustrated on Drawing 02 there are four gabion drop structures in Clinton Creek just downstream of the outlet from Hudgeon Lake. The height of the individual drop structures range from 1.5 to 2.5 m and the total height of the four drop structures is 8.5 m. The creek channel between the drop structures has a slight grade of about 0.1 percent. The base of the creek channel at the lake outlet is about elevation 411.0 m and at the downstream end of the last drop structure the creek channel is about 402.1 m. The base of the creek channel at Station 0+225 m where argillite bedrock is exposed is about 400.0 m. Although argillite bedrock is exposed at this location, this bedrock is not massive but has numerous bedding planes and fractures and is therefore susceptible to erosion, albeit, to a lesser degree than the fine grained materials found in the waste rock pile and the valley slopes. The structure and erodable nature of the argillite bedrock is illustrated on Figure 3.1.

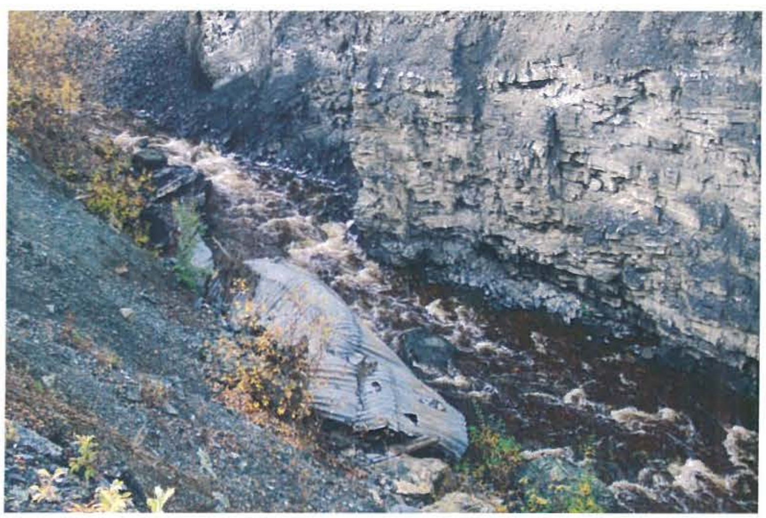

Figure 3.1 Argillite Bedrock In Clinton Creek Channel

Assuming that construction of a new channel is technically feasible if the gabion drop structures are removed, the lake level could be lowered by approximately 9 m down to an elevation of about 402 m. The final lake elevation would be determined in detailed design but as a minimum it would be influenced by the grade of the channel, construction challenges and site limitations among other considerations.

The only information available on the bathymetry of Hudgeon Lake is contained on Figure 4.1 from the Environmental Review report from Royal Roads University (RRU 1999). A copy of this figure is included in Appendix A. This information is considered to be reasonably accurate for the purpose of considering the suggestion of lowering the level of Hudgeon Lake. Based on this information, lowering the lake by about 9 m would drain the western +/- 800 m of the lake however, the horizontal change in shoreline around the other areas of the lake is expected to be relatively minor. Drawing 03 illustrates the approximate shoreline if the lake was lowered by about 9 m.

The eastern half of the lake from Easter Creek valley to the lake outlet is typically about 18 m deep although there is an area just upstream of the lake outlet that is about 24 m deep. Lowering the lake level by about 9 m would result in a lake that is generally about 9 m deep. The deep area just upstream of the lake outlet would be reduced to a depth of about 15 m. The lake depth in the Easter Creek valley would be reduced from about 12 m to 3 m deep. The changes in Bear Creek valley would be relatively minor.

4.2 Impacts of Lake Level Lowering on Water Quality

Contrary to some expectations, lowering of the lake level would not result in greater seasonal turnover potential, based on either wind-driven or density-driven phenomena. In particular, a lower lake surface would exhibit a lower position in the confined valley (would be more sheltered), and would have a lower surface area available for wind – wave interactions (smaller fetch). Rather, our expectation is that there would exist during the open water conditions a surface oxygenated layer that is not appreciably different than current day conditions (~5 m depth) underlain by anoxic waters. During the critical under-ice period, we expect that DOM decomposition rates would occur unabated, which is the primary driving force for oxygen depletion, sulfide production, and nutrient recycle within Hudgeon Lake.

Lowering the lake level would not substantially decrease the available DOM supply, sulfate concentrations at the lakebed, or oxygen supply.

In addition, as discussed in Section 2, lowering of the lake level could be counterproductive, since the alteration of lake surface area could result in a lower surface area: lake volume ratio, while the surface area component is very important for oxygen flux into the lake water.

While removal of the gabion drop structures would remove a barrier to fish passage, the potential negative consequences of this for fish mortality need to be fully considered. In particular, the most recent study by DFO (2007) suggests that juvenile Chinook and potentially other species primarily use the lower ~10 km of Clinton Creek for summertime foraging. While the issue has not yet been formally examined, it is likely that juvenile Chinook retreat to Fortymile River at the onset of freeze-up, since over-wintering habitat in Clinton Creek is likely limited. There is likely limited or no available under-ice habitat at maximum ice thickness in most of Clinton Creek, except perhaps behind beaver dams.

If fish were able to move into Hudgeon Lake, and if over-wintering survival was less than might occur in Fortymile River and the Yukon River, then entrapment in Hudgeon Lake at the start of freeze-up could result in excessive mortality and loss of especially juvenile Chinook from local populations. It must be considered that any benefit in terms of added foraging and spawning capacity might be more than offset by higher over-wintering mortalities of juveniles emerging from spawning areas downstream. Given the current condition of the lake the gabion drop structures currently act favourably as a fish barrier preventing entrapment and mortality.

4.3 Design and Constructability Considerations

Assuming that permanently lowering the lake by excavating a deeper channel is feasible, there are a number of design and constructability issues that need to be considered before proceeding with detailed design of the suggested work, which requires removal of the existing channel stabilization works and excavation of a deeper channel. The general considerations identified in this preliminary review of the suggested improvements are discussed below.

4.3.1 Design Considerations

Design of a deeper channel through the first +/- 225 m of the existing Clinton Creek channel and the waste rock dump would need to take into consideration the following as a minimum:

- Channel cross-section
- Review of dam breach risk assessment
- Erosion of the channel
- Location, alignment and tie-in to existing creek channel
- Impact on stability of the waste rock dump
- Impact on stability of valley slopes below the existing lake level

Based on the general design criteria used to establish the existing stabilized creek channel, a conceptual cross-section of a deeper channel was prepared and is shown on Drawing 02. The total depth of the channel relative to the existing site grade is about 10 m at the Hudgeon Lake outlet and would likely be deeper with distance downstream of the lake outlet. Using 3H:1V side slopes for the lower slope area of the conceptual channel section where water flow is expected and 2H:1V side slopes above this point, the total width of the channel section will be at least 70 m. The channel slope stability would have to be confirmed in detailed design.

A dam breach analysis of the Hudgeon Lake outlet was completed in the Risk Assessment Report for the site (UMA 2000). The existing stabilized creek channel has significantly mitigated the risk of a breach of the Hudgeon Lake outlet. Any changes to the current configuration warrant a review of the dam breach analysis and design of a new channel should incorporate proper erosion protection features to maintain long term integrity of the channel. Well planned and executed construction sequencing would be required to lower the lake level without triggering a breach of the lake outlet. The risk of triggering a breach during construction are thought to be significant.

Erosion of a new creek channel would need to be addressed in detailed design to mitigate the potential for a breach of the lake outlet and maintain serviceability of the channel indefinitely. Erosion is of significant concern because of the easily eroded fine grained material through which a new channel would be excavated, either the argillite waste rock and/or the silt located on the valley side of the existing creek channel. It is not expected that bedrock will be encountered upstream of station 0+225 m. Erosion protection could be provided by lining the channel with a granular material of sufficient particle size and layer thickness or through the use of gabion mats. Based on our experience during preparation for and construction of the gabion drop structures, there is a shortage of suitable material on the former mine site that could be used to protect a new channel. Much of the available granular material has already been used to construct the existing gabion drop structures.

Drawing 02 shows the approximate location of a 70 m wide channel to illustrate how much area would be required to accommodate the channel. A significant amount of the waste rock would have to be removed to accommodate a new channel and as a result the stability of the waste rock pile would have to be checked. Transition of a new +/- 70 m wide channel into the relatively narrow channel section at station 0+225 m would be required and is illustrated in concept only on Drawing 02. The channel hydraulics of the transition would need to be accounted for in detailed design.

Assessment of the waste rock pile stability would require a geotechnical investigation and stability modelling in order to determine the impacts of a new channel on the stability of the waste rock dump and the amount of earthmoving work required to stabilize the waste rock dump. It is expected that the most effective way to stabilize the dump would be to remove material (i.e. off loading) from the upper (i.e. south side) of the dump. Based on the waste rock stabilization options presented in the Conceptual Design

Report (UMA 2002), removal of a large volume of material (1 to 3 million m^3) from the upper portions of the waste rock dump may be required.

Depending on the final location and configuration of a new channel, stability of the existing valley side slopes on the north side of the existing creek channel may need to be checked. These slopes are impacted by permafrost so any changes in the thermal regime may affect slope stability.

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 prevalent in the area. 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. There are a few locations around the lake (e.g. near Bear Creek) where at least one slope failure has already occurred, possibly due to degradation of permafrost. Stability of the valley slopes could possibly be addressed through staged construction to prevent rapid drawdown of the lake level.

4.3.2 Constructability Considerations

Construction of a deeper, wider channel along the first +/- 225 m of the existing channel would need to take into consideration the following as a minimum:

- Impact on stability of the waste rock pile
- Passage of flow from Hudgeon Lake during construction
- Draw down rate of Hudgeon Lake level
- Dewatering to prevent seepage and piping conditions from developing
- Controlled breach of cofferdams
- Excavation of new channel upstream of the existing lake outlet

Since excavation of a new channel that is +/- 70 m wide and up to 9 m deeper than the existing channel (i.e. at the lake outlet) would likely result in a reduction in stability of the waste rock dump, the waste rock dump would have to be stabilized before a new channel is excavated.

Flow from Hudgeon Lake during construction can be temporarily dammed off as done during construction of the gabion drop structures or there may be a practical means of maintaining some flow from the lake (e.g. pumping / diversion channel). The disadvantage of temporarily damming off flow from Hudgeon Lake is that the duration of the available construction window is greatly dependent on precipitation events. As illustrated on Drawing 02, the aerial extent of the new channel would limit the space available to provide a temporary diversion channel during construction. Winter construction of a new channel may be worth considering as the flow from the lake should be relatively small.

The rate of lake drawdown may have an impact on the stability of the valley sides slopes forming the sides of the lake. Staged construction would likely be required to allow sufficient time for the saturated soil on the valley slopes to drain.

Gradual drawdown of the lake levels resulting from staged construction will also allow time for the groundwater levels in the waste rock pile to drawdown down. This is important from a channel excavation perspective because excavating below the groundwater table can result in high exit gradients and piping conditions to develop in the channel excavation. The development of piping conditions near the lake outlet is of great concern because a breach of the outlet could be triggered and likely very difficult to halt once initiated.

Groundwater dewatering systems may be required to prevent seepage and piping conditions from developing in the channel excavation. As noted on Drawing 02, there are at least two locations where springs (i.e. groundwater seepage) were observed during construction of the existing channel stabilization works. The seepage is directly related to the level of the water in the lake.

If cofferdams are installed to temporarily halt the flow of water from Hudgeon Lake, good construction practises will need to be followed when the cofferdams are breached to prevent a breach of the lake outlet form occurring. This would likely require the use of temporary erosion control works in the freshly excavated portions of the channel. For example, if the first stage of construction was to remove part or all of the first drop structure followed by a breach of the cofferdam to drawdown the level of the lake then the newly excavated area would have to be protected against erosion until the lake draws down and the cofferdam is reconstructed. As each subsequent drop structure is removed and the channel deepened, the length of channel requiring temporary erosion protection would increase. Control of sediment released during cofferdam breaching would be difficult to control.

As illustrated on Drawing 02, channel excavation upstream of the existing lake outlet will be required. The material to be excavated will be saturated and likely in a very loose state due to the method of deposition. This material will be difficult to remove.

These construction challenges are significant and would have to be well thought out before construction begins. The risks and consequences of some form of failure during construction that leads to a breach of the lake outlet are significant.

4.4 Cost Estimate

A preliminary cost estimate is provided in Table 4.1 for the purpose of comparing the lake level lowering suggestion with infilling of Hudgeon Lake. If the lake lowering work is deemed to be feasible then a preliminary design and revised cost estimate should be completed before proceeding with detailed design and construction.

The cost estimate for preliminary design includes field investigations to collect information to assess the stability of the waste rock pile and determine the lake bathymetry. Once this information has been obtained a preliminary design should be completed to provide a better scope of the work required, and understanding of the construction issues. Once completed a revised cost estimate could be completed.

It has been assumed that full time site inspection is required during construction. The cost estimate is based on the work being completed in the summer months (June to end of September) over a three year period.

The amount of waste rock material to be moved is very approximate as it will depend on the final channel geometry and the amount of waste rock that needs to be moved to provide adequate stability of the waste rock dump. It has been assumed that any waste rock would be pushed directly into the open pit.

The channel excavation is expected to be relatively costly as it would likely require staged construction, removal of the existing drop structures, temporary erosion control measures, excavation of boulders, hauling spoil material to the open pit among other considerations.

Allowances for groundwater control, erosion control of the permanent channel and site regrading have been included. The estimates are accurate to an order of magnitude only given the conceptual nature of the suggested works.

It has been assumed that a 5 year performance monitoring program will be required to ensure that the regraded waste rock pile and new channel slopes are stable. Monitoring would include surveys of surface movements as a minimum but may also include installation and monitoring of slope inclinometers and piezometers.

The maintenance requirements are unknown but would generally be related to inspecting the channel on an annual basis and undertaking any work to restore the channel erosion protection.

Table 4.1 Preliminary Cost Estimate For Lowering Level Of Hudgeon Lake

Description	Unit	Approximate Quantity	Unit Price	Amount
Preliminary and Detailed Design				
Geotechnical Investigation of Waste Rock Dump	Allowance	1		$250,000
Hudgeon Lake Bathymetry Survey	Allowance	1		$50,000
Preliminary Design and Revised Cost Estimate	Allowance	1		$75,000
Detailed Design and Tender Package	Allowance	1		$250,000
Contingency	Percentage	30	1	$187,500
Sub-Total Detailed Design				**$812,500**
Construction				
Resident Site Engineer	Days	$2,000	360	$720,000
Mobilization	Lump Sum	1	$500,000	$500,000
Waste Rock Stabilization	Cubic Metre	2,000,000	$5	$10,000,000
Channel Excavation	Cubic Metre	50,000	$50	$2,500,000
Groundwater Control	Allowance			$1,500,000
Permanent Channel Stabilization	Allowance			$3,000,000
General Site Regrading	Cubic Metre	500,000	$5	$2,500,000
Contingency	Percentage	30	1	$6,216,000
Sub-Total Construction				**$26,936,000**
Performance Monitoring (5 year program)	Allowance			$500,000
Annual Inspection and Maintenance	Annual Allowance			$50,000
Total				**$+/- 27.5M**

5.0 Conclusions

The goal of enhancing fish habitat in the Clinton Creek watershed is commendable however, our conclusions are that the potential is extremely low for further increasing over-wintering survival through additional engineered solutions such as lake infilling or a permanent reduction of the level of Hudgeon Lake. The following points support this conclusion:

- Hudgeon Lake Infilling
  - Between the Easter Creek valley and the lake outlet at least 3 million m^3 of waste rock material would likely be required to partially infill the deepest areas of the lake by about 10 m.
  - From a geotechnical perspective the only benefit of completing this work is off loading of the waste rock dump which would help to stabilize the waste rock dump. It would be more cost effective to stabilize the waste rock dump by determining the amount of material that needs to be off loaded and push the material directly into the open pit. The volume of material and the unit cost of moving the material would be significantly less than that estimated for partially infilling the lake.
  - Fish habitat in Hudgeon Lake would likely not be substantially improved by covering the lake bottom with waste rock material, since such action would not alter over the longer term (i) the mass of organic matter resident within the lakebed, and annual flux of new detrital organic matter; (ii) rate of re-oxygenation at the lake surface; or (iii) supply of sulfate in water that is available for microbial sulfate reduction (and sulfide generation).

- Hudgeon Lake Lowering
  - Removal of the gabion drop structures could result in a lake level that is about 9 m lower than the current level and the corresponding creek channel would be order of 70 m wide.
  - Unloading material from the upper portions of the waste rock pile would be required to account for the destabilizing effects of excavating a deeper creek channel at the toe of the waste rock pile.
  - A new channel would need to be designed that provides a comparable level of erosion protection to minimize the risk of a dam breach at the lake outlet. Suitable material of sufficient volume for channel armouring is not readily available on the mine site.
  - Lowering the lake level would have a negative impact on the stability of the valley side slopes currently below the water line of the lake due to the permafrost degradation that has occurred. Some land slides should be expected.
  - Staged construction over multiple years would be required to minimize channel excavation problems related to groundwater seepage and also to minimize the potential for landslides of the valley slopes below the surface of Hudgeon Lake.
  - From a geotechnical perspective this work is not recommended because of the potential for a breach of the lake outlet to occur during construction.

- Fish habitat in Hudgeon Lake would likely not be substantially improved by lowering the lake level through removal of the gabion drop structures, since this would not address the root cause of current anoxic conditions; i.e., organic C supply, limited oxygen exchange at the lake surface, and presence of high sulfate levels. Furthermore, lowering the lake level would directly result in a reduction of wetted area, which - in spite of the very poor quality of fish habitat in Hudgeon Lake - might trigger habitat compensation requirements under the *Fisheries Act.*

Respectfully Submitted,

UMA Engineering Ltd.

PROFESSIONAL
GR
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Date 28-April-2008
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Association of Professional Engineers of Yukon

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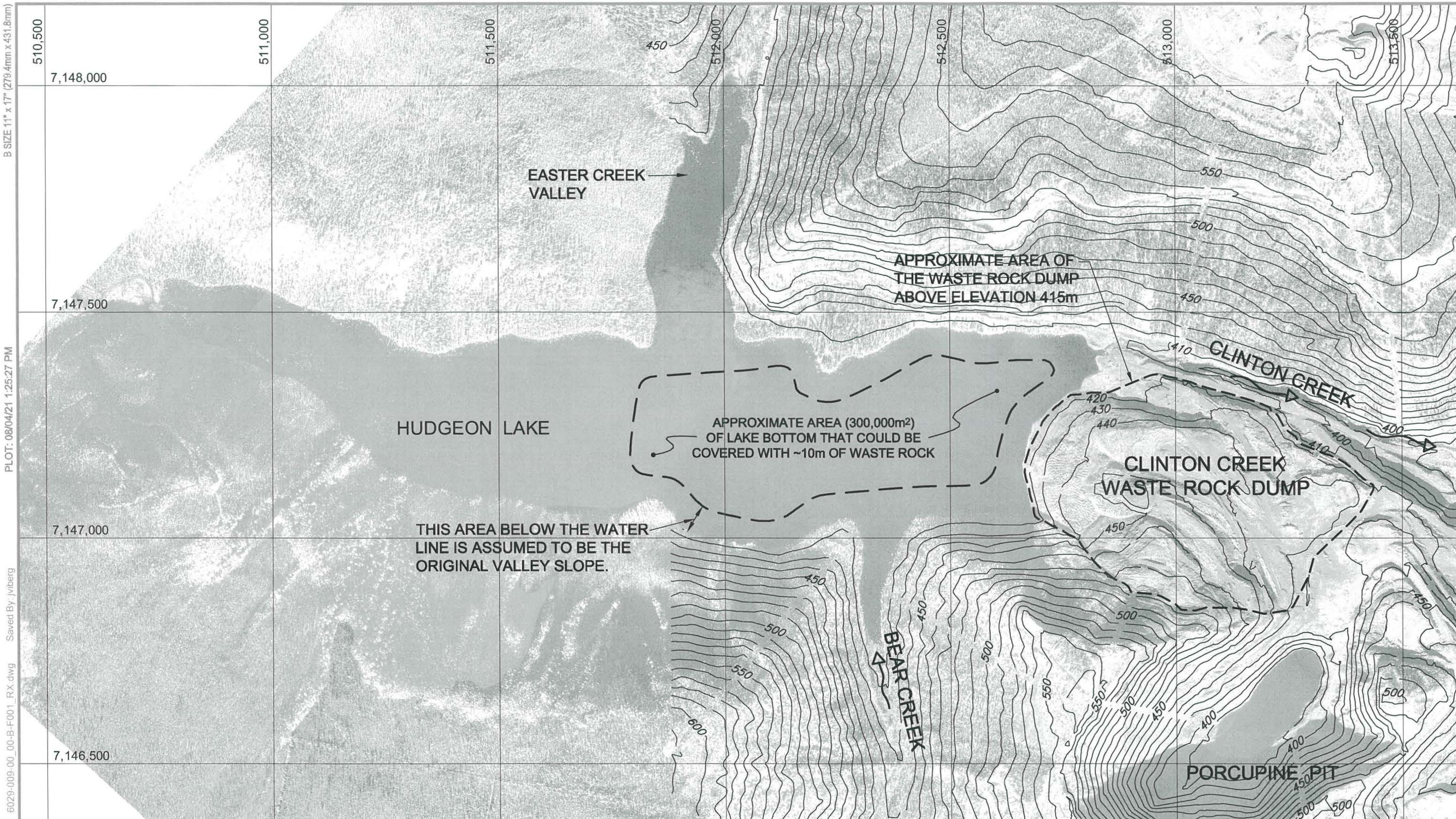
Drawings



PLAN

0 80 160 m SCALE 1:8000

UTM ZONE 7 NAD83
IMAGE DATE 1999

Government of Yukon
Former Clinton Creek Asbestos Mine

Conceptual Infilling of Hudgeon Lake

Drawing - 01

UMA | AECOM

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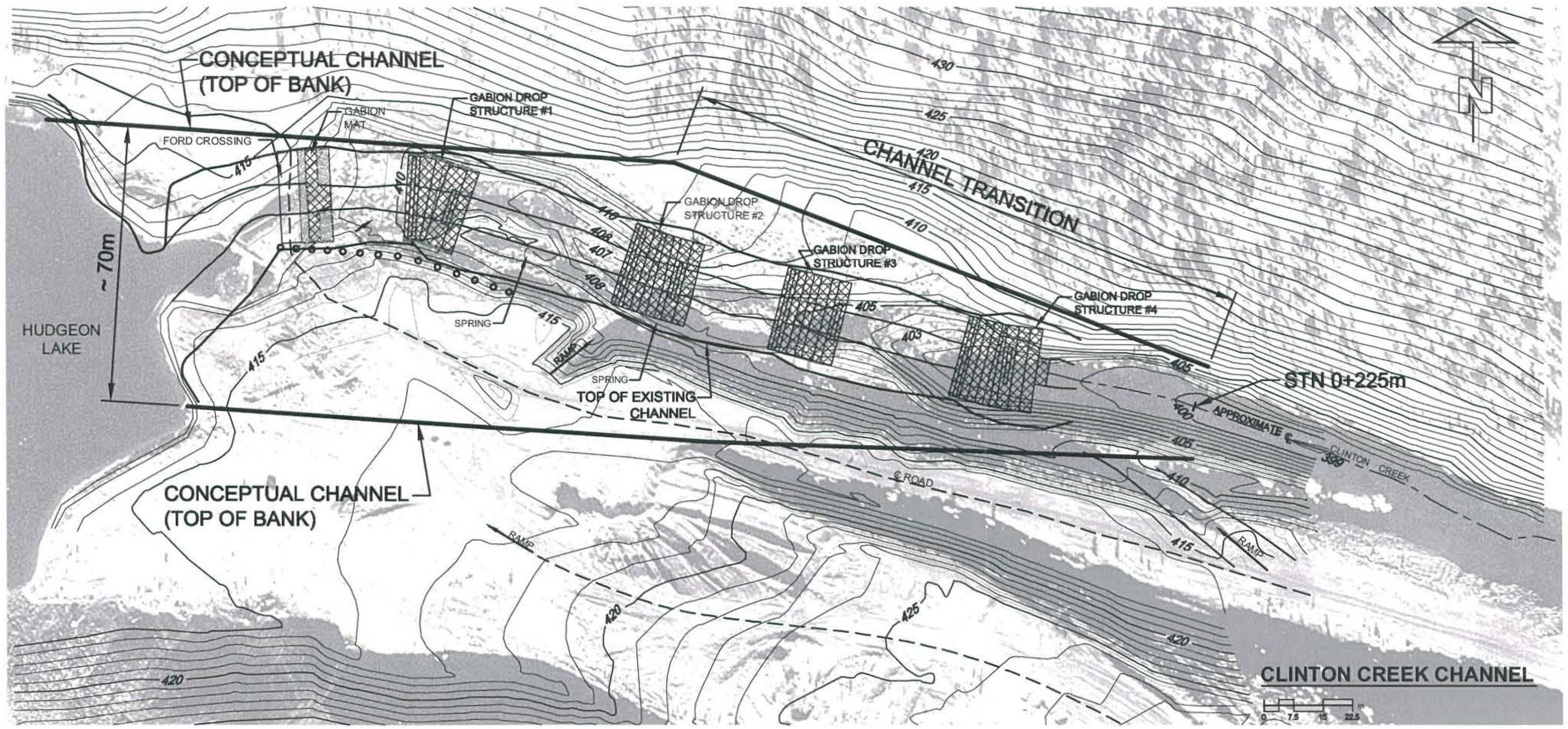
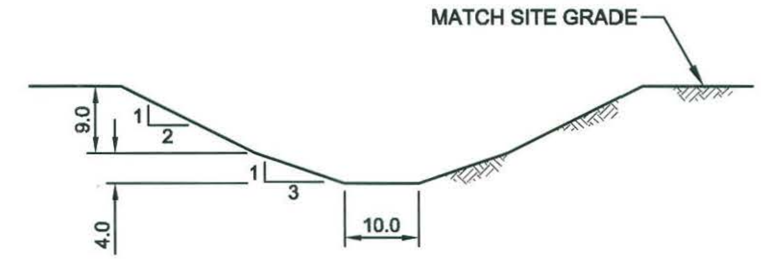
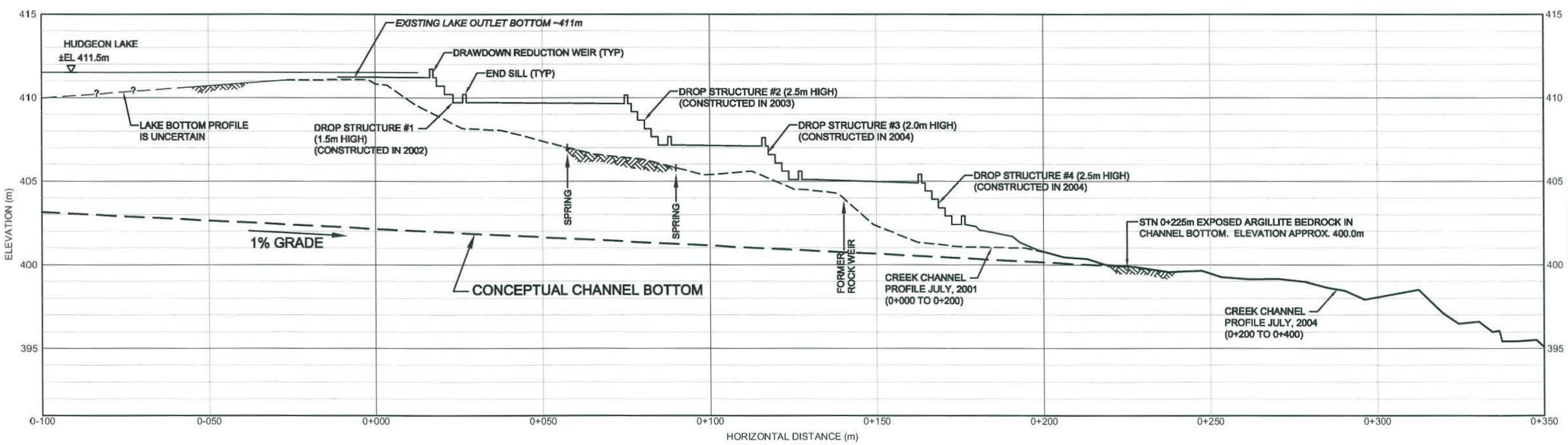


CLINTON CREEK CHANNEL



CONCEPTUAL CHANNEL SECTION 0+00

AT LAKE OUTLET



CLINTON CREEK CHANNEL PROFILE

Government of Yukon
Former Clinton Creek Asbestos Mine

Hudgeon Lake Lowering
Conceptual Plan and Profile
Drawing - 02

UMA | AECOM

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PLAN

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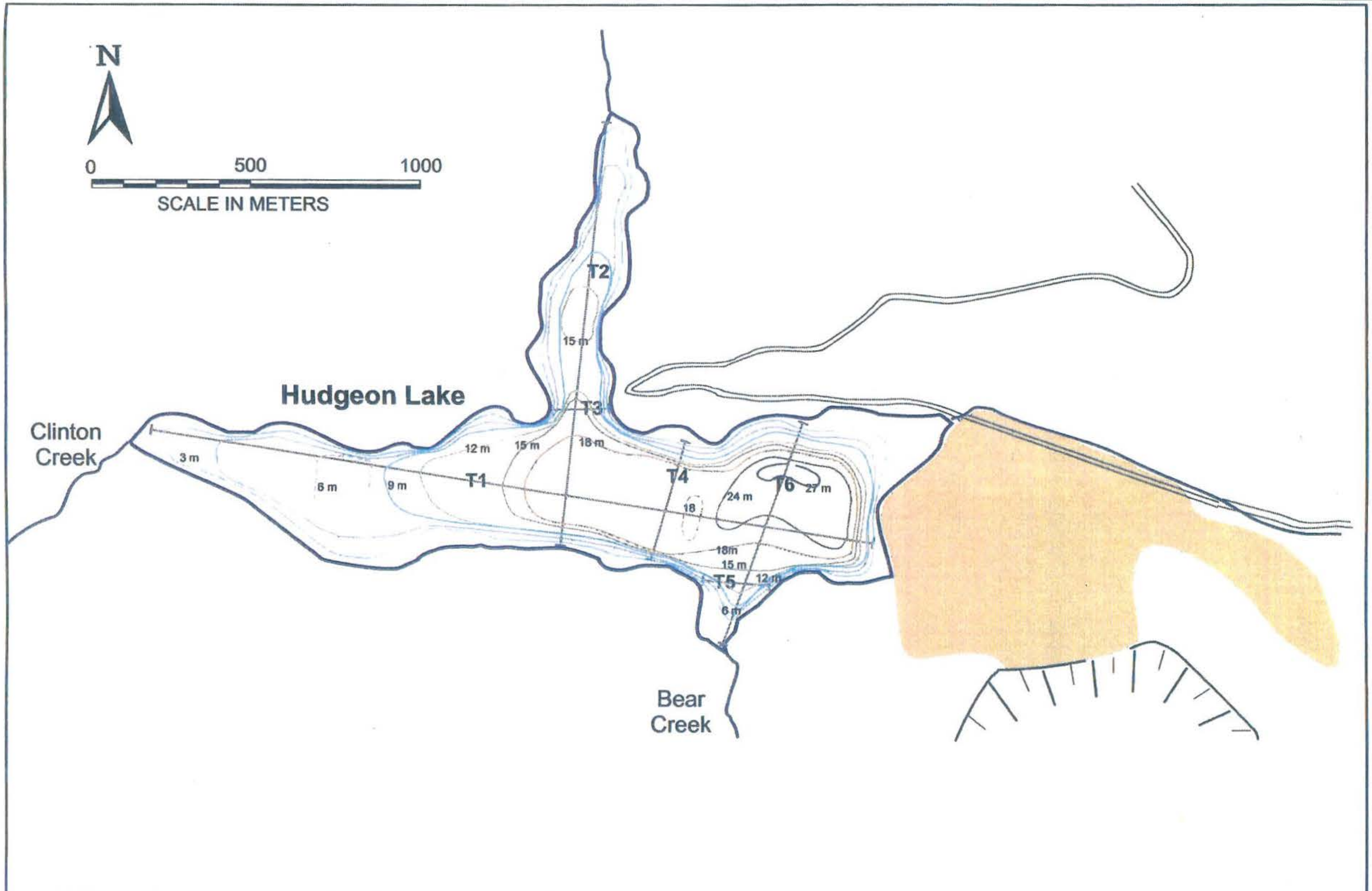
UTM ZONE 7 NAD83
IMAGE DATE 1999

UMA | AECOM

Government of Yukon
Former Clinton Creek Asbestos Mine

Hudgeon Lake Lowering
Approximate Shoreline
Drawing - 03

Appendix A
Hudgeon Lake Bathymetry
(RRU 1999 - Figure 4.1)



ROYAL ROADS UNIVERSITY

Indian and Northern Affairs Canada
Waste Management Program
Yukon Region

CLINTON CREEK ABANDONED ASBESTOS MINE		
HUDGEON LAKE BATHYMETRY		
Project No: 98-008	Date: March 1999	Figure 4.1