Distribution and Habitat Utilization of Clinton Creek by Fish: State of Knowledge to March, 2012.

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Summary

Results of fish and fish habitat related field projects in Clinton Creek since 1976 have varied due environmental conditions and biological responses to them. Variation has also been due to the methods used, the conditions under which sampling occurred, and the objectives of each project.

Understanding of the life histories and habitat utilization of Yukon River species and stocks has evolved since 1976. Local capacity to meaningfully interpret results of past and recent field work in the context of environmental conditions has developed. This allowed the results of projects conducted to date to be interpreted and a State of Knowledge prepared.

Most direct effects of the Clinton Creek Asbestos Mine occur within a relatively confined area containing all pits, waste rock and tailings deposits, site management works and resulting impoundments and stream channel. This is the Clinton Creek Mine Complex (CCMC). The physical characteristics of this area have been, and will likely continue to be, highly dynamic.

Most future site management and abandonment related activities will likely occur in the CCMC. Fish distribution and habitat information within the CCMC is therefore most relevant to future processes.

Three fish species utilize the currently accessible habitats in the CCMC. Significant quantities of formerly accessible fish habitat were deferred when the Gabion Drop Structures were completed at the outlet of Hudgeon Lake in 2004.

Juvenile Chinook Salmon enter Clinton Creek in mid-summer, migrate upstream to the extent possible and rear. Access from the Fortymile River to the CCMC is affected to some extent by beaver dams. The intensity of beaver activity is believed related to the buffering of extreme flows in Clinton Creek by the CCMC. Growth of juveniles in the CCMC is rapid, implying that the habitat is productive and occasionally highly so. Overwintering occurs and is believed to be related to enhanced surface and ground water storage associated with the CCMC

Slimy sculpin spawn, rear and grow to adults in the CCMC.

Arctic Grayling enter the creek and have ascended to the CCMC by late May. Hudgeon Lake was utilized by Grayling prior to completion of the Gabion Drop Structure. Behaviour of Grayling since then indicate that re-colonization of upstream habitats will be rapid when access returns. Grayling spawn within the CCMC, and young-of-year rear there. Yearling and sub-adults enter the creek and migrate to the CCMC for summer feeding. Arctic Grayling migrate out of Clinton Creek in early autumn, and are effectively absent from the CCMC by mid-September.

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1 Introduction

A considerable body of fish and fish habitat information was collected in the Clinton Creek watershed between 1976 and 2011. Projects were conducted by Environment Canada, Fisheries and Oceans Canada, the Department of Indian Affairs and Northern Development (later Indian and Northern Affairs Canada, consultants, and the Dawson District Renewable Resources Council. The projects had a wide range of objectives. Not all were related directly to determining the effects of the Clinton Creek Mine. Field staff used, and modified, a number of methods to collect information and address project objectives. Environmental conditions influencing Clinton Creek varied seasonally and annually. The potential annual supply of fish to Clinton Creek varied. The channel morphology of Clinton Creek changed in response to the direct and indirect effects of the Clinton Creek Mine and natural events.

Concurrently, Yukon-based scientific/technical and community capacity to participate in resource management increased. Local and Traditional Knowledge became recognized as valid information sources and allowed insight into processes that science had not been able to investigate. Federal, Territorial and First Nation government resource management agencies matured. Staff developed personal capacities through experience and observation. They contributed to the corporate capacities of their respective Agencies. An organic consulting community developed in response to environmental assessment, management and grant-driven funding opportunities. All these factors contributed to the evolution in the understanding of habitat utilization and seasonal movements by fish species and stocks in Upper Yukon River Basin and potential effects of environmental conditions on them.

Authors of project reports generated since 1976 arrived at a wide range of conclusions. These were based on the general state of knowledge at the time the reports were written and by the various author's awareness of advances which had been made. The range was also due to the short term nature of field work on which the reports were based. As illustration, field work for the first three investigations of fish and fish habitat totalled 2 days in 1976 (Landucci, 1976), 6 days in 1980 (Delaney et al, 1981) and 6 days in 1998 (RRU 1999). Two of the three investigations took place in September and did not reflect summer distributions or degree of habitat utilization. An additional complication is that the topographical features and hydrological conditions described in each of the short term investigations continued to change after the reports were completed. Finally, the authors were often under institutional or corporate pressure to arrive at conclusions and composed their reports accordingly.

A result has been a confusing and occasionally contradictory array of information regarding fish and fish habitat in Clinton Creek. This has created difficulties for professionals retained to develop options and recommendations for site management and abandonment. In turn it has contributed to the challenges for custodial agencies, advisory government agencies and others considering the resulting options and recommendations and participating in the decision making process.

This State of Knowledge report summarizes and provides a context for fish distribution and habitat utilization information existing to March 2012. The regional context is described and a physical framework for Clinton Creek provided. This is necessary as investigators imposed their own frameworks (Landucci, 1976; Delaney, 1981). The common framework allows information to be grouped geographically. Within the framework, information is summarized and discussed by species. The focus is on the creek in the area of the Clinton Creek Mine Complex (CCMC). The CCMC includes all pits, waste rock and tailings deposits, management works and resulting impoundments and stream channels. The Complex does not include the access road to the east of the gabion borrow pit, the airstrip, the town site road, the Cassiar Creek pit or exploration trails. A brief overview of fisheries information on the lowest part of Clinton Creek and the Fortymile River will is included.

2 Regional context

Clinton Creek enters the Fortymile River from the west 4.6 km upstream of the confluence of the Fortymile and Yukon Rivers. The creek has a watershed area of approximately 205 square kilometers (adjusted from UMA 2000). The watershed is entirely within the Klondike Plateau Ecoregion (Smith et al 2004) and within what is considered to be the non-glaciated area of the Yukon. However, pre-Reid glacial deposits have been documented in the nearby Mickey Creek watershed (Lipovsky et al, 2005) and glacio-fluvial deposits are visible on the Clinton Creek Road within the Maiden Creek watershed. Glacial and glacio-fluvial deposits may therefore be present in the Clinton Creek watershed. This would increase the potential for ground water storage and the presence of future ground water discharge areas. If there are significant glacio-fluvial deposits, climate change related thermokarst of the Plateau surface may result in the short- or long term development of seasonal or persistent springs. This is considered more likely in the area of watershed to the north of the Clinton Creek valley, as this is closest to the known glaciated area.

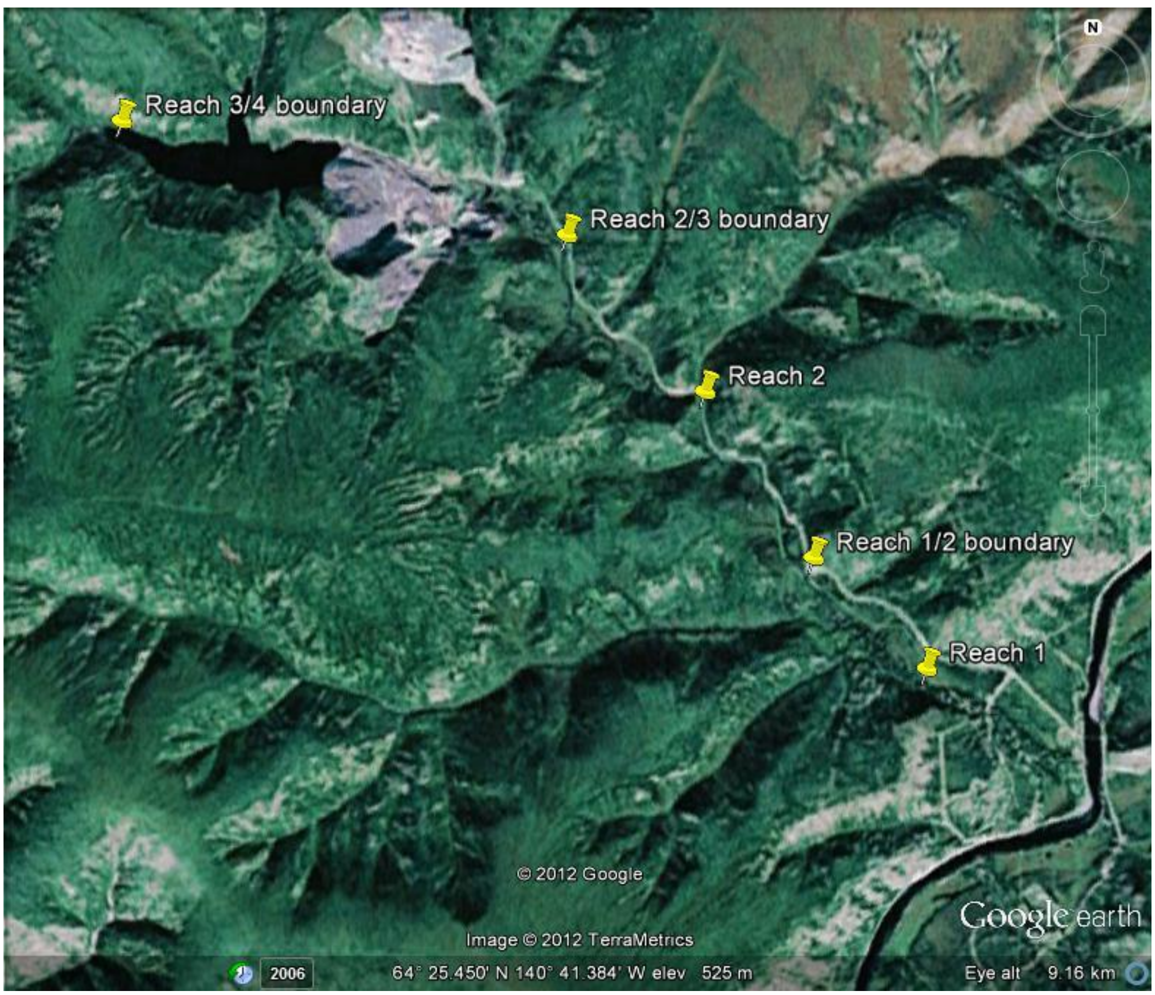
The main channel of Clinton Creek has the concave profile typical of creeks in non-glaciated areas. The channel gradient is low to moderate and increases rapidly only at the headwaters. Larger tributaries of the creek have “V” shaped valleys and variable gradients. These valleys are eroding into the surface of the gently rolling plateau. Drainage from much of the plateau surface is by overland flow until it reaches the sharp break in slope at the top of the valley wall. The valley walls tend to be steep. Slope failures on the valley walls are widespread, and most start at the break in slope.

Water clarity and colour in Clinton Creek is typical of creeks in non-glaciated areas. At low to medium flows the water is clear but is “tea” coloured. Sediment is mobilized in summer as flows increase and increase the turbidity of the creek.

3 Physical framework.

The Framework is based on the concept of stream Reaches. Each Reach is a relatively homogenous stretch of stream having a repetitious sequence of physical characteristics (Armantrout, 1998). Only those Reaches likely to have been utilised by fish prior to the mine development are described. The Reach descriptions are based on the pre-mine characteristics of the channel and valley.

Four Reaches were determined for the main channel of Clinton Creek. The length of each Reach was measured in a straight line from the downstream end to the upstream end. Reach 1 starts at the mouth of Clinton Creek. Map 1 illustrates the Reach boundaries.



Map 1. Clinton Creek Reaches and beach Boundaries. The Fortymile River is in the right foreground of the photograph.

Reach 1 – 3170 meters long. This Reach is in an unconfined valley. Bedrock exposures are uncommon and occur where the creek flows to- or along the southern valley wall. The channel form is sinuous to meandering. There is large timber along the creek and extending away from it, implying a long term thaw bulb under the creek channel and riparian zones. The valley bottom beyond the riparian zones has patches of dwarf black spruce and small tussock fields. These are situated within a forest matrix dominated by spruce and birch or aspen. It is probable that much of the valley bottom is now thawed ground or remaining permafrost is deeper than annual winter frost penetration. Winter stream flows are likely or almost certain to occur, although it is probable that portions of the creek will freeze to the bottom of the channel. Water in these areas flows through the substrate of the creek, or as aufeis above it. Beaver colonies were first reported in this reach in 2005 (von Finster, 2005) but had been present for a decade or more before. Beaver dams in the Reach do not generally last more than 3 years, as the ponds fill up with sediment from upstream areas or are breached by high water events.

Reach 2 – 3500 meters long. This reach is in a confined valley. Bedrock exposures are common and often extend partly or entirely across the creek. In some areas bedrock exposures are visible on both sides of the creek. The channel form is straight to sinuous. Large timber is present in some of the wider valley bottom areas. Most north-facing slopes appear to be underlain by near surface permafrost, and south facing slopes to be underlain by thawed ground or deep permafrost. Valley walls have bedrock exposures interspersed with extensive colluvial slopes. In most cases these extend to- or near the top of the valley wall. There were extensive but unquantified slope failures on both north and south valley walls following the midsummer 2010 precipitation event. Aufeis formation is likely in this Reach, with the annual extent influenced by volume of stream flow, snow cover, etc. Winter stream flow paths may be on, or between layers of aufeis or within cracks and joints of the bedrock. Stretches of the channel bottom may dewater as a result. Beaver activity in this area is similar to that in Reach 1, although the dams are more likely to be breached at high flows than filled by sediment. This is due to the confined channel.

Reach 3 – 3500 meters long. At present this Reach includes all direct effects of the works, undertakings, and unanticipated events associated with the Clinton Creek Mine Complex. The upstream section of Reach 3 is now submerged in Hudgeon Lake, the mid-section is buried by waste rock, and the lower section is an alluvial fan developing into a ground water supported wetland complex. The pre-mine characteristics will be described, followed by the descriptions of the sections of the post-mine channel.

Pre-mine conditions

Air photos (UMA 2000 & AECOM 2009) show pre-mine conditions in Reach 3. The valley was formerly wide and unconfined. The stream channel was sinuous to meandering and generally flowed along the south valley wall. There were narrow riparian stands of large spruce along most of the channel, implying a high degree of channel stability and a thaw bulb located under the channel but not extending any great distance from it. The portion of the valley bottom north of the narrow riparian strip of spruce was tussock and shrub and likely underlain by near-surface permafrost. There were no active beaver ponds or footprints of past ponds.

Post-mine conditions.

Features that have developed since the failure of the waste rock dumps and development of the current impoundment will be termed stream "sections". Lengths will not be provided as the rates of change of the sections is occurring too rapidly for the lengths to be meaningful.

<u>Wetland Complex</u>. Extends from the upstream end of Reach 2 to the downstream end of the Alluvial Fan. It currently includes the surface and subsurface confluences of Wolverine and Porcupine Creek with Clinton Creek. The Wetland Complex is inhabited by at least one beaver colony. This was first reported in1999 (RRU 1999) and probably existed for several years prior to then. A series of off-channel beaver dams were built on the right (looking downstream) side of the valley and impounded a number of ponds. Sediments mobilised from the Canyon by the mid-summer 2010 flood almost filled the largest pond. New off-channel dams were quickly constructed to the east, presumably by members of the same beaver colony. The long term success of the beaver colony is a strong indicator that ground water discharges from Porcupine Creek and/or the Alluvial Fan persist throughout the winter.

<u>Alluvial Fan</u>. Extends from the upstream end of the Wetland Complex to the downstream end of the Lower Canyon. In autumn 2011 the downstream margin of the Fan was approaching but had not yet reached the mouth of Wolverine Creek. The Fan receives sediment eroded from both sides of the canyon and transported downstream by Clinton Creek. Coarse particles such as gravels, cobbles and shale slabs from the north valley wall tend to be deposited on the upper Fan and finer particles are deposited on the lower Fan. However, occasional high creek flows provide sufficient energy to move some coarse material to the lower Fan and some finer material out of the Wetland Complex and into Reach 2. The stream channel(s) on the Fan tend to be laterally unstable. Surface

water has been observed draining into the ground on the upper and middle Alluvial Fan, and ground water discharging from multiple sites on the middle and lower Fan. This is consistent with the behaviour of surface-ground-surface water interactions in alluvial fans (Woods et al, 2006). This is hyporheic flow due to the relatively shallow depth and short flow path of the ground water, and the interactions between surface and ground water. Discharges will be cooler in summer and warmer in winter than the surface waters of Clinton Creek (Hynes, 1983). Beaver have occasionally constructed dams on channels crossing the Alluvial Fan. The dams have been rapidly washed away or the ponds filled with sediment.

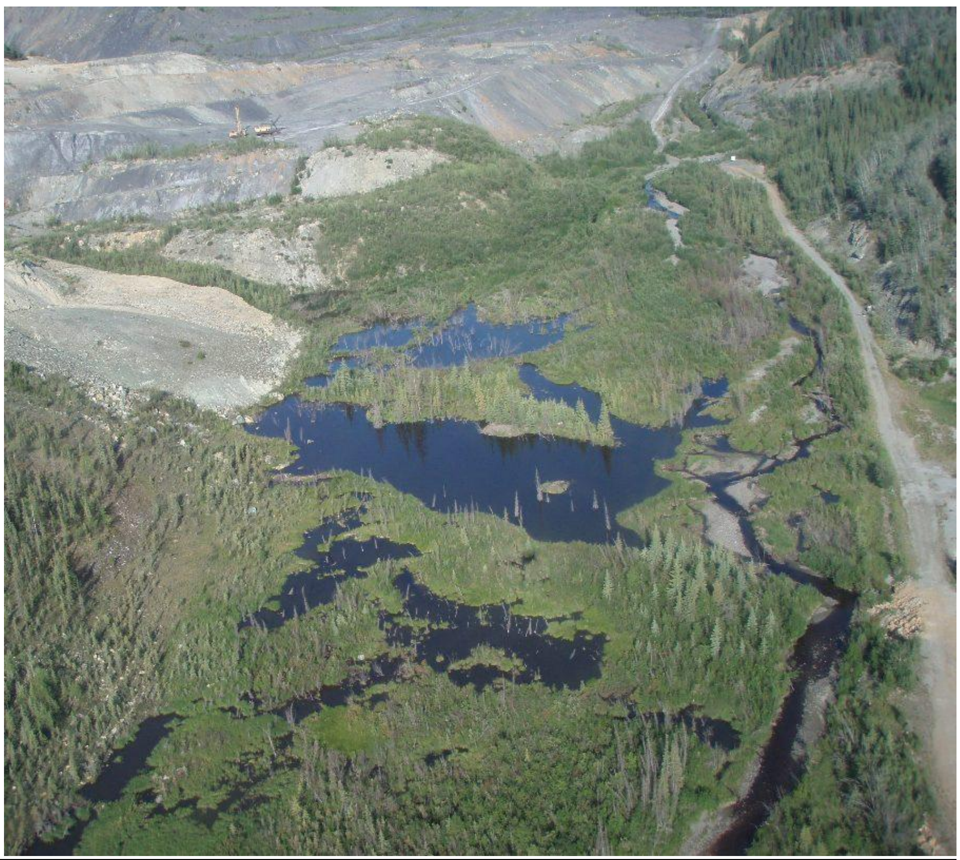


Photo 1. Wetland complex from the East prior to the 2010-mid summer flood. Wolverine Creek enters from the lower right of photo, and the Porcupine Creek valley from the upper left. The Lower Canyon boundary is upstream of the ford through Clinton creek in the top right, and the vegetated toe of the Alluvial Fan extends to the standing water in the Wetland Complex.

Photo 2. Taken in 2011from the west margin of the Porcupine Creek valley. This illustrates the dynamic nature of the CCMC, and in this case the advancing toe or lower margin of the Alluvial Fan. This area was standing water in Photo 1. The sediment which has filled it was deposited during, and subsequent to, the mid-summer 2010 flood. The pool in the foreground is largely fed by springs originating in the Porcupine Creek valley.

<u>Lower Canyon</u>. Extends from the upper end of the bedrock exposures on the left (looking downstream) of the channel to approximately 100 meters downstream of the crest of Gabion Drop Structure 4. The creek in this section is eroding an incised channel into bedrock. The bedrock wall on the left side of the creek is clearly visible. Bedrock exposures on the right side of the creek are much lower and often obscured by loose boulders etc. However, the bedrock on the right side extends along most of the channel length. Both the right and left canyon walls are unstable and respectively contribute waste rock and shattered or exfoliated bedrock to the stream channel. The stream bed material is very coarse and is composed mainly of boulders, loose slabs and bedrock. Short, steep

channel pitches appear to limit the upstream migration of some fish species and life stages in most years. These steep pitches are transient due to the continued erosion of the channel.

Photo 3.. Upstream end of the Lower Canyon from downstream on September 2010. The willow in the left of the photo is rooted in jointed bedrock and survived the mid-summer 2010 flood. The bedrock exposure it is rooted in was first observed in 1999. It was approximately 1.5 meters above the channel bottom at that time. In September 2011 the creek bed was about 1 meter deeper than when this photo was taken.

<u>Upper Canyon</u>. Extends from the upstream end of the Lower Canyon to the outlet of Hudgeon Lake. It includes the entire Gabion Drop Structure. This section has had the greatest variation in physical characteristics since 1976. Much of the variation resulted from repeated attempts to impose lateral and vertical stability on the channel downstream of Hudgeon Lake. The creek is eroding into bedrock on the left bank downstream of the Gabion Drop Structure, along the channel bottom, and on the right bank near the downstream end of the section. The profile and cross section(s) of the Upper Canyon was fundamentally altered during the midsummer 2010 flood. Significant channel down cutting occurred.

Temporary stabilization works conducted in 2011 mitigated the potential for further short term down cutting immediately below the Gabion Drop Structure. During the 2011open water period the channel was re-establishing itself between these works and the upper end of the Lower Canyon.

Hudgeon Lake. Extends west from the upstream end of the Gabion Drop Structure. The most recent estimate of the lake area is approximately 72 ha at a surface elevation of 411.6 m. The volume is approximately 10 million cubic meters (AECOM, 2011). A well developed delta has been formed by upper Clinton Creek where it enters the lake, indicating substantial bed load transport from upstream. The lake is meromictic: that is, the waters remain stratified throughout the year. The annual total lake mixing characteristic of mid-latitude lakes does not occur. The lake is anoxic at depth and during the winter months. In summer there is an oxygenated surface layer nominally 5 meters in depth which supports aquatic life. The structure of the lake and the processes which have resulted in it being meriomictic are discussed in detail in Liebau (2010). During open water periods Hudgeon Lake captures significant thermal energy and warms accordingly.

Reach 4 Extends from the upstream end of Reach 3. It has not been investigated in any depth. There has been little industrial development in the upper watershed. The headwaters are in the United States. The valley is “V” shaped and confined, with steep walls leading upward to the plateau surface. Naturally re-vegetating slope failures are common. They are at different stages of succession, indicating that valley wall stability is low and has been so for an extended period. The mid-summer 2010 precipitation event resulted in numerous slides, many of which spanned the valley floor and contributed bed load to Clinton Creek.

Porcupine Creek. Enters from the south and has a drainage basin of nominally 4 square kilometers. The lower and middle creek valley is filled with waste rock. A small lake has formed upstream of the waste rock deposits. The waters of the creek appear and disappear as it flows downstream from the lake through a series of mine related deposits and excavations. Flows eventually discharge as springs into the southern margin of the Wetland Complex at or near the original mouth of the creek.

Wolverine Creek. Enters from the north and has a drainage basin of 28.6 square kilometers. The lower valley was fundamentally altered by unanticipated movements of tailings into the valley bottom. This resulted in the formation of small lakes and the transport of tailings downstream. Subsequent channel stabilization undertakings downstream of the tailings further modified the pre-existing channel. A perched culvert on the mine access road currently conveys surface flows into Clinton Creek. An unfrozen spring has been observed in the upper watershed during late winter. This may be a developing feature associated with permafrost degradation, or it may be a long-standing spring. Of interest, a section of Clinton Creek at the mouth of Wolverine Creek was open water at the time the upper spring was observed, implying ground water discharge from the Wolverine Creek valley.

4 Fish sampling, distribution and habitat utilisation.

Sampling

A brief description of fish sampling methods used in collecting the information is warranted, as the methodology used largely determines the fish species and life stage captured.

Most of the fish sampling in Clinton Creek has been conducted using Gee type minnow traps baited with salmon roe, with the roe placed in perforated plastic bags. Some of the minnow traps were modified by increasing the entry hole to allow the capture of larger fish. The traps were typically distributed in different types of habitat, placed in low velocity areas and left overnight. Juvenile Chinook Salmon are highly vulnerable to this sampling method. Slimy Sculpin are regularly caught, and Longnose sucker occasionally. Juvenile Arctic Grayling are not vulnerable, and usually captured only when there are high densities and they stray into the trap.

Catch Per Unit Effort (numbers of fish/per trap/per hour) can be calculated from minnow trapping data. However, the data generated it is at best weak and must be used cautiously. Shortcomings include the potential for fish to both enter and exit the trap, the attraction of the fish to the bait, and a sensitivity of the method to environmental conditions: as an example, trapping success falls rapidly under rising stream flows.

With minimal training of the field staff, minnow trapping can be a low-risk and low-cost methodology. It is safe for staff and will not stress the fish captured. In small streams it is well suited for use by an individual sampler.

Photo 4. Typical Gee type minnow trap deployment. The plastic bag with bait is visible in the centre of the trap. Note the large numbers of juvenile Chinook Salmon which have been attracted to the bait. No fish were visible when the trap was set approximately 30 minutes prior to the photo being taken.

Electro-fishing with back-pack mounted electro-fishers has been the second most common method of capturing fish in Clinton Creek. An electro-fisher typically converts electricity from a source (usually a battery) to pulsed power. This power is transmitted to the creek though an anode and flows to a cathode. This creates a high voltage field and affects fish. Outputs from the electro-fisher, such as voltage and pulse width can be manually adjusted. This allows the equipment to be used in water of different conductivity and for fish of different sizes. Larger fish are more vulnerable than smaller fish. Higher power settings must be used for the smaller fish. Used perfectly, fish will be drawn to the anode and captured: however, the fish are usually stunned and netted by a second crew member.

Critical to the success of electro-fishing is the expertise of the operator. S/he will assess the section of creek to be electro-fished and operate the equipment in such a manner as to maximize the potential to capture the fish species or life stage likely to be present, and on which the investigation is focussed. An unskilled operator is likely to kill or injure fish due to setting the power outputs too high. Failure to capture fish may be due to low output or the electro-fisher simply not working.

Electro-fishing is potentially hazardous to the operator and crew. It requires training, certification, Personal Protective Equipment and the implementation of rigorous safety measures.

Under normal (ie not flood) flows, electro-fishing in small streams in the upper Yukon River drainage basin can be effective for capturing most species and life stages. However, it may under-represent adult Arctic Grayling as they move rapidly away from disturbance. Stop nets must be carried around (ie overland when sampling a small stream) the area to be sampled and set upstream and downstream prior to sampling commencing. This adds to the time spent and overall expense of the study, and tends not to be done. Electro-fishing effectiveness declines with rising water levels. It is ineffective in waters with either low or high conductivity levels.

There are protocols for using electro-fishers to determine fish populations in sections of creek: however, they are time consuming, expensive, and have seldom been used in the Yukon. Electro-fishing is generally used as a tool to determine presence/absence of fish, or for fish salvage related to in-stream construction, demolition, etc.

Gill netting has been conducted in Hudgeon Lake on 3 occasions. To be effective, gill nets must be set where the fish will be swimming, be of low visibility to them, and of a mesh size and configuration that will capture the target fish.

Fish Species

As most future activities related to the site management and abandonment of the Clinton Creek Mine Complex will occur in Reach 3, only the three species consistently observed or captured there will be addressed in detail below. These species are Chinook Salmon, Slimy Sculpin, and Arctic Grayling, and are those typical of small stream in the unglaciated areas of the Yukon. Longnosed sucker and Lake Chub have occasionally been captured.

In the following section, distribution will be the geographical extent to which the species has been found. Habitat utilization will be based on the temporal extent of presence in the stream. It will be described primarily as the life stage that has been captured or observed. The numbers of fish captured or observed will provide a measure of the range of the population size in the section of creek at the time of sampling.

Critical considerations in understanding fish distribution and habitat utilization of Clinton Creek include:

- The migratory nature of Arctic Grayling and juvenile Chinook salmon;

- The unregulated flows in Clinton Creek; and
- The dynamic nature of the stream channel and the fish habitats within it.

These profoundly limit any attempted determination of optimal population sizes, carrying capacities or productivity.

Chinook Salmon

Chinook Salmon have high social, cultural and economic values in the Yukon River Basin. This perception of value has focussed technical and scientific effort on the species. Adult population sizes (or “spawning escapement”), life histories, and habitat utilization have been extensively investigated and to some degree formally studied.

Chinook Salmon do not spawn in Clinton Creek. It is unlikely that they ever did or ever will. Normal flows in the creek are too low during upstream migration and spawning periods.

Clinton Creek is utilized by non-natal rearing, overwintering, and migrating juvenile Chinook Salmon. The salmon are from spawning areas in the upper Yukon River drainage basin. Genetic samples were collected in 2009 by the DDRRC, DFO and Alaska Department of Fish and Game (ADF&G), analysed by the DFO genetics lab in Naniamo, BC and reported in Mackenzie-Grieve (2010). The Yukon River Chinook Salmon genetic baseline available at the time of analysis indicated that most juveniles originated from the Yukon River Mainstem spawning population. This population includes spawning in the mainstem between the mouths of the Pelly and Tatchun Rivers and a number of tributaries to that portion of the Yukon River. The findings were consistent with a parallel study on non-natal stream on the Alaskan side of the border (Daum and Flannery 2011).

In any given year, the numbers of juvenile Chinook Salmon entering Clinton Creek are influenced by conditions beyond the watershed. They include the preceding year`s spawning escapement to the Yukon River Basin upstream of the Fortymile River. Estimates of spawning escapements have ranged from a low of 25,870 in 2000 to a high of 80,594 in 2003 (JTC 2011). The success of Chinook spawning depends on the condition of the migration and spawning habitats and the health of the spawners. Incubation of eggs is influenced by environmental conditions such as temperature and flow in the redds (excavated fish nests) between egg fertilization and fry emergence the following spring. It is likely that downstream movement by the young-of-year is also influenced by environmental conditions, but this has not been yet determined.

Juvenile Chinook Salmon enter Clinton Creek in early to mid July (Smart, 2006 & 2007; Fraser, 2009; & Taylor, 2010). Once in the creek, they migrate upstream. The distance migrated may be in excess of 10 kilometers (Hunka, 1988). The upstream migration from the Fortymile River to the CCMC included swimming over or around a series of beaver dams.

Beaver dams are considered to exert a greater influence on upstream migrating juvenile Chinook Salmon than on other fish species or life stages utilizing Clinton Creek. The effects of beaver, including current distribution and implied past distribution in Clinton Creek, will therefore be discussed here.

Beaver dams in unglaciated areas of the Yukon tend to be limited to off channel areas along large rivers. They are rare to absent on small streams. This is likely due to the rapid and violent response of streams in unglaciated terrain to snow melt and major precipitation events. Low winter flows probably also have an effect, as there tends to be little surface or subsurface water storage in unglaciated watersheds. Without water inflows in the winter, ponds will dewater and colonies perish.

Beaver were not reported in the first two fish related investigations on Clinton Creek (Landucci, 1976 & Delaney et al, 1981). This was in spite of significant in-stream field work, including 2.9 linear kilometers of electro-fishing (Delaney 1981). There are no signs of beaver activity in aerial photographs of Reach 3 prior to the formation of Hudgeon Lake (UMA 2000 & AECOM 2009). Beaver were first documented by RRU (1999) in the Wetland Complex in Reach 3. The current presence of beaver in Clinton Creek may be explained by the buffering effect of Hudgeon Lake. Beaver colonies can maintain themselves by constructing a series of short term dams. Short term is used advisedly, as the high bed load travelling down Clinton Creek quickly fills the ponds and high flows breach the dams. Most dams on the main channel of Clinton Creek last for less than three years and some for less than one year. On two occasions beaver dams were counted along the creek from a helicopter while in transit from the mouth to the CCMC. On August 10, 2006, 17 dams were counted (von Finster, 2006) and on July 15, 2008 a total of 30 beaver dams were observed between the mouth of Clinton Creek and the downstream end of Reach 3. Only 2 of the dams appeared to have survived spring high water (von Finster, 2009). Of note, the colony in the Wetland Complex and at least one other colony residing in Hudgeon Lake provide a constant supply of young beavers to form new colonies.

Few individual beaver dams totally obstruct the upstream migration of all Yukon River juvenile Chinook Salmon in a stream. However, sampling immediately below the furthest downstream beaver dam in a stream after the start of the upstream migration tends to result in high catches of juvenile Chinook Salmon and sampling upstream of the dam results in low captures (von Finster, 1987; von Finster & Mackenzie-Grieve, 2005). This implies delay or obstruction at the dam. It is likely that the effect of dams is cumulative, with each successive beaver dam obstructing some juveniles while other juveniles successfully pass over it. This was considered to be an explanation for the low numbers of juvenile Chinook Salmon captured in Reach 2 and 3 (von Finster,

2005) after beaver were first documented in the creek. It formed the basis of the annual DDRRC Stream Stewardship projects restoration project.

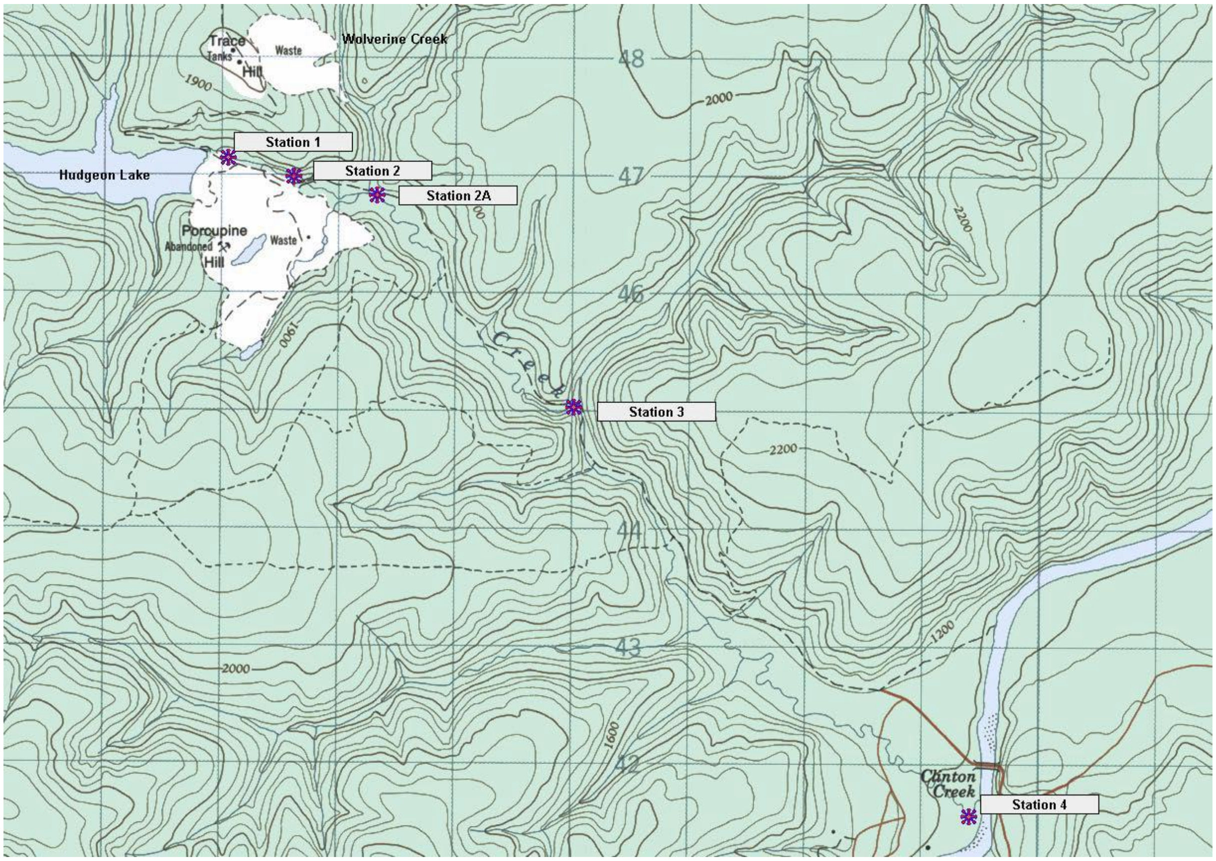
Prior to the implementation of the DDRRC projects, juvenile Chinook Salmon were able to successfully access the Wetland Complex in low numbers (von Finster, 2005) and the Canyon (Delaney et al, 1981; Roach, 2003). Juveniles may have utilised the outlet of Hudgeon Lake prior to the installation of the Gabion Drop Structures. More recently, they were documented in the Upper Canyon only in 2007 (von Finster, 2007; WMES 2007). Annual access likely depends on stream flows and the characteristics of the channel in the Lower Canyon.

The DDRRC project was piloted in 2006 and implemented from 2007 – 2011 inclusive. It has been funded by the Yukon River Panel. Annual reports are available on the Yukon River Panel Website http://yukonriverpanel.com/salmon/ The objective of the annual projects was to build community capacity by retaining youth to conduct positive salmon related works. An experienced Field Supervisor leads the project and two youth complete the crew. From 2005 – 2009 DFO Salmon Enhancement Program staff provided direct technical support for the project. Beyond the annual positive effects to the juvenile Salmon, the project provided an opportunity to collect time series information on fish entering and using Clinton Creek. Annual assessment sampling associated with the DDRRC project was reported from 2005 – 2008 (von Finster 2005, 2006, 2007 & 2009).

Juvenile Chinook Salmon were captured in Clinton Creek near the mouth, transported to the mine site and restored to the creek. From 2007 to 2011 the release site was immediately upstream of the confluence of Wolverine Creek. This allowed the annual ability of juvenile Chinook Salmon to swim up through the Lower Canyon to be determined. Numbers of juveniles varied. In 2006, 782 were restored to the creek; in 2007, 2070; in 2008, 58; 2009, 901; 2010, 586; and 2011, 15. This was despite the same techniques being used, a similar degree of effort, the same Field Supervisor from 2008 to 2011 inclusive, and the same technical advisor from 2006 – 2011 inclusive. It illustrates the range of results that can be expected in sampling for juvenile Chinook in this or similar creeks over a period of years.

Annual assessment sampling was usually conducted in mid-September at 5 stations. These are described below and shown on Map 2:

Station 1 – at the downstream end of the Gabion Drop Structure - Upper Canyon;
Station 2 – at the pre-2010 ford – Alluvial Fan;
Station 2A – at the mouth of Wolverine Creek – Wetlands Complex;
Station 3 – mouth of Eagle Creek – Reach 2; and
Station 4 – in Clinton Creek immediately upstream of the mouth – Reach 1.



(from von Finster,2007)

Map 2. DFO sampling Stations. Station 1 is furthest upstream and Station 4 is at the mouth. Station 2A was added due to channel instability at Station 2.

The results of sampling allow comparison of fish sizes and implied growth rates. Growth rates are important, as the rate of formation of new tissue by stream organisms is a measure of stream productivity (Armantrout, 1998). In salmonids, growth may be expressed as the mean fork length or weight of a group (or population) of fish for comparison to another group or to a reference length/weight. Comparing mean fork lengths of juvenile Chinook Salmon captured in Reach 3 at Station 2A in the CCMC and those captured in Reach 1 at Station 4 at the creek mouth in September provides indication of the productivity of the waters at the Clinton Creek Mine Complex. In 2005, mean fork lengths were 11.2mm greater at Station 2A; in 2006, 17.9mm greater; in 2007, 9.3mm greater; in 2008, 0.2mm greater; and in 2009, 6.1mm greater.

Additionally, juveniles captured in the Alluvial Fan and the Upper Canyon in September 2007 were very large: at Station 2 on the Fan, the mean fork length was 13.4mm greater than at Station 2A in the Wetlands Complex and 22.7mm greater than at Station 4 at the mouth. At Station 1 in the Upper Canyon the mean fork length was 19.8mm greater than at Station 2A in the Wetland Complex and and 29.1mm longer than at Station 4 at the creek mouth. One of the juveniles captured at Station 1 had a fork length of 111mm, and remains the largest young-of-year Chinook salmon ever reported in the Yukon River drainage (von Finster, 2007). This remarkable growth probably represented near optimal environmental conditions throughout the juvenile Chinook salmon growing season. It is believed to be related to the very warm temperatures measured in 2007 at Station 1, and the presence of ground water seeps into the channel which contributed to thermal heterogeneity and provided refuges for the juveniles during extreme warm water periods.

(from von Finster, 2007)

Photo 5. Very large young-of-year Chinook Salmon captured at Station 1 in the Upper Canyon on September 15, 2011.

It is likely that juvenile Chinook Salmon inhabiting Reach 3 in late autumn remain there through the winter. Discharge areas of high quality ground water have been identified as primary overwintering areas for juvenile Yukon River Chinook Salmon in small streams (Bradford et al, 2001). The ground water discharges associated with the Alluvial Fan, Porcupine Creek, Wolverine Creek and possibly other sources are believed to have augmented pre-mine discharges or to have been created as a result of the mine. Evidence of overwintering Chinook was not collected until 2009, in part as spring access to Clinton Creek by investigators is difficult or expensive until the road is cleared. Spring freshet is over by then and the creek has warmed. Most overwintered juvenile Chinook Salmon probably leave the creek at freshet or shortly afterward and are gone prior to the arrival of samplers. To date, yearling juvenile Chinook Salmon were captured at Station 2A in the Wetland Complex in late May of both 2009 and 2011 (Mackenzie-Grieve, 2011).

In summary, juvenile Chinook Salmon enter Clinton Creek in early/mid July. Supply of juveniles varies. Juveniles migrate upstream in the creek and rear during the summer. Growth of juveniles in the mine area may be very rapid under ideal conditions. There is no evidence that the juveniles in the CCMC vacate the creek in the autumn. It is almost certain that many or most start the overwintering process in the creek. Those that survive until the following spring probably migrate downstream with, or shortly after, the spring freshet. Very few remain in Clinton Creek by late May, and the creek is empty of Chinook Salmon until the in-migration commences in July.

Slimy Sculpin

Slimy Sculpin carry out all life processes in Clinton Creek and are considered to be resident in the CCMC. The species currently has no direct economic or social value in the Yukon. In other jurisdictions Slimy Sculpin have been determined to be non-migratory. The species serves as a “sentinel species” for potential water quality effects of industrial manufacturing, agricultural and other impacts (Grey et al, 2004; Arciszewski et al, 2010). It is likely that Slimy Sculpin have utility as a sentinel species in the Yukon River drainage, at least as a coarse indicator of winter flows and overwintering habitat within a general section of stream. However, the degree to which Slimy Sculpin behaviour in the Yukon River differs from elsewhere in its range remains to be determined.

Slimy Sculpin have not been captured in the Upper Canyon or in any location upstream of it. This was despite electro-fishing of the most likely areas of Reach 4 of Clinton Creek and tributaries of Hudgeon Lake by highly competent field workers (WMEC, 2008). The lack of Sculpin upstream of the Lower Canyon may be considered strong evidence that there was little or no overwintering habitat in Clinton Creek upstream of the Porcupine/Wolverine confluence area prior to the waste rock slide and formation of Hudgeon Lake. .

Farther downstream, Slimy sculpin were well represented in the partial fish salvages in 2003 and 2000 in the Lower Canyon and upper Alluvial Fan (Roach, 2003 & Copland, 2004). However, the salvage activities were ineffective in the areas of boulder/bedrock slab channel bottom and many or most Slimy Sculpin in this type of substrate were not salvaged and perished. Numbers of Sculpin reported or estimated by the salvage crew are therefore low. Both salvages took place in mid- to late summer. It is possible that the Sculpin captured may have moved upstream from overwintering habitats in the lower Alluvial Fan or Wetland Complex.

Slimy Sculpin were captured in the lower Alluvial Fan and the Wetland Complex from 2005 onward whenever sampling occurred there. This included sampling in late May. The May captures strongly support the conclusion that overwintering habitats now exist for fish in the CCMC and specifically the Wetland Complex.

Slimy Sculpin spawn in the spring. Spawning in the Wetland Complex was documented during DDRRC evaluation sampling on May 21, 2010. A total of 23

Sculpin were captured, of which 15 were females that were ready to spawn or had completed spawning. Two of the remaining sculpins were males in spawning condition.

In summary, Slimy Sculpin are present in Clinton Creek in the Wetland Complex throughout the year. In the summer they are present in channels crossing or originating in the Alluvial Fan and in the Lower Canyon. These may be the result of short seasonal movements. Longer distance migrations are unlikely. The Wetland Complex and possibly the lowest section of the Alluvial Fan provide overwintering habitat. Spawning in the Wetland Complex occurs after freshet.

Arctic Grayling

Arctic Grayling is primarily a sports fish in the Yukon. Grayling had a much greater social and economic value in the past. During and after the Klondike Gold Rush the species supported commercial fisheries in the Dawson City area (Seigal & McEwan, 1984). The commercial fishery appears to have been by gill net in streams and rivers. This may have included the Fortymile River.

Grayling in the unglaciated area of the Yukon are migratory. During their migrations they are vulnerable to capture. In autumn the stocks generally leave streams and migrate to overwintering areas in larger waters. This is a period of maximum vulnerability of capture in fence type traps, and was exploited by aboriginal peoples prior to and following contact. Streams that were easy to trap and supported consistently large Arctic Grayling populations usually supported fish traps and attendant fish camps. Traditional knowledge of fish camp sites on small streams has been used as an indicator of fish stocks and values in the Porcupine River basin (Anderton and Frost, 2002). More relevant to Clinton Creek, Arctic Grayling were captured in October 1894 in a trap that spanned the Fortymile River near the mouth and captured downstream migrating adults (Duncan, 1997).

Grayling congregate at the mouths of rivers in spring in preparation for spawning migrations. People from Eagle Village in Alaska ascended the Yukon River by dog team in the early spring to catch grayling in the Yukon River at the mouth of the Fortymile River. Grayling were harvested in hook and line fisheries. As many as eight dog sleds were filled with grayling over a two day period (Mishler & Simeone, 2004).

Grayling distribution in, and utilization of, Clinton Creek is almost entirely seasonal. Adults ascend the creek prior to spawning. Timing of the upstream migration has not been documented but may start on the rising limb of the spring freshet and extend until after the end of the freshet (Stewart et al, 2007). Grayling tend to be numerous in Reach 3 in late May. Young-of-year juveniles emerge from eggs deposited on the creek bed and grow rapidly. Juvenile and sub-adult (ie prior to the first spawn) Grayling migrate into Clinton Creek to feed during the spring and summer. The migration may be extended, as fresh sub adults may be seen in Reach 3 throughout the summer in higher stream flow years. The fresh grayling are silver blue in colour and are thought to have recently migrated from the light coloured, turbid waters of the Yukon River. Grayling that have been in the stained waters of Clinton Creek for a more extended time tend to turn brown in colour. This allows the fish to blend with their surroundings and avoid predation (Price et al, 2008).

Photo 6. Juvenile and sub-adult Arctic Grayling in a ground water fed scour hole on the Alluvial Fan on August 8, 2011. On September 14, 2011, the pool was vacant, implying that the Grayling had migrated downstream before then.

Prior to the completion of the Gabion Drop Structure in 2004 Arctic Grayling were able to access Hudgeon Lake. They may also have used Reach 4 of Clinton Creek upstream of the lake. During summer months large Grayling were easily angled from shore just above the lake outlet. Smaller fish thought to be grayling were seen rising in the lake outlet bay whenever the winds were calm and were documented in RRU (1999). Adult Arctic Grayling were captured by gill net in the lake near the outlet in 1980 (Delaney et al, 1981). Gill netting in 1998 did not result in any captures. This may have been attributable to the mesh sizes used (RRU, 1999).

Upstream migration of Arctic Grayling through the canyon was disrupted by construction of the Gabion Drop Structure in 2003 and 2004. In both years fish access to the creek was blocked downstream of the construction area with stop nets immediately before salvage began. Flows were cut off and salvage occurred as flows dropped. Salvage was conducted with nets and an electrofisher: however, the conductivity of the water in the creek was too high for the electrofisher to be effective. Fish in the Upper Canyon, Lower Canyon and Alluvial Fan were captured during the salvage. They were returned to surface waters either up- or downstream of the construction site. A partial count of the fish was kept in 2003, when 1345 Arctic Grayling were reported. Many were large, from 30 – 50 cm total length (Roach, 2003), or an estimated 27 – 46 cm fork length. Relative abundance was estimated in 2004, when the majority of the 1200 fish captured were Arctic Grayling (Copland, 2004).

No fish were seen rising in Hudgeon Lake in 2005 or at any time since. A gill net was set in the lake near the outlet on September 2, 2005 and a second near the inlet to the lake. A single adult female Arctic Grayling was captured in the latter net (von Finster, 2005). This fish must have found an overwintering area in the preceding winter, as the channel into Hudgeon Creek was blocked in late summer 2004.

In 2005 and 2006 a large school of sub adult and adult Arctic Grayling was observed in the Upper Canyon downstream of Drop Structure 4 (von Finster 2005 & 2006). In 2006 a Bald Eagle was repeatedly observed perched on a boulder above the Grayling and presumably predated on them throughout the summer. Two adult Grayling were observed between Drop Structures 3 and 4 on July 27, 2005, but none were observed in 2006. Young-of-year Arctic Grayling were captured in minnow traps set below Drop Structure 4 in both 2005 and 2006 (von Finster, 2005 & 2006). No young-of-year Grayling have been captured in the Upper Canyon since then. The presence of the young-of-year fish indicates strongly that Arctic Grayling spawned in the Upper Canyon in spring of 2005 and 2006.

In 2007 Arctic Grayling were not captured or seen in the CCMC during sampling conducted in July, August and September (von Finster, 2007). The DDRRC minnow trapping at the mouth resulted in the capture of only 7 Arctic Grayling (Smart, 2007). The reasons for the almost total lack of Arctic Grayling in Clinton Creek in 2007 are unknown, but illustrate the difficulty in determining stock sizes of Arctic Grayling utilizing the creek unless multi-year programs are conducted.

Arctic Grayling returned to the CCMC in 2008. The large school of Grayling seen in 2005 and 2006 at Station 1 was not observed. This was in part due to the reduction of the pool where they had been formerly observed as the headwall of the downstream channel receded. Adult and sub-adult Grayling were present in the Upper Canyon. Angling resulted in the capture of three adult Grayling between Drop Structure 3 and 4, and sub-adult Grayling downstream of Station 1. Yearling Grayling were captured in minnow traps set at Station 1(von Finster, 2009).

In late July and early August 2010 heavy rainfall resulted in exceptionally high flows in Clinton Creek. A significant scour hole developed downstream of Drop Structure 4. Access to Station 1 became excessively hazardous for samplers. No sampling was conducted in the Upper Canyon in late 2010 or in 2011. Grayling were seen rising in the scour hole in the summer of 2011.

The large numbers of Arctic Grayling captured in 2003 and 2004 and observed in 2005 and 2006 in the Canyon imply that a large seasonal population of Arctic Grayling utilized Hudgeon Lake and possibly the tributaries draining to it prior to the completion of the Gabion Drop Structure. The annual (except for 2007) presence of Grayling below the Gabion Drop Structure imply that re-colonization of the waters upstream of the current barrier by Arctic Grayling will be rapid when access returns. This includes Hudgeon Lake.

Downstream of the Canyon, and with the exception of 2007, Grayling were observed between late May and mid August in channels crossing the Alluvial Fan, in the Wetland Area and the section of Clinton Creek flowing through it, and at Station 3 in Reach 2. Congregations of juveniles and sub-adults were often visible in small scour pools in ground water fed channels such as that shown in Photo 6.

Grayling are seldom seen or captured in Clinton Creek during mid-September sampling, implying that the annual downstream migration has occurred before that date. A small but undetermined number are thought to remain in the creek in autumn.

In summary, Arctic Grayling are present in Clinton Creek in most years but may be inexplicably absent in any given year. Adults enter the creek in the spring and some spawn there. As the creek channel is constantly moving, fidelity to specific spawning locations is unlikely. Grayling utilized Hudgeon Lake seasonally prior to the completion of the Gabion Drop Structures in 2004. Large numbers of grayling were observed in the Upper Canyon from 2003 to 2006 inclusive. Grayling were observed in or captured in the Upper Canyon from 2008 to 2011 inclusive. It is likely that some or almost all would have migrated into- or through the lake had access not been obstructed by the Gabion Drop Structure. Grayling continue to migrate upstream in the canyon as far as is possible for them. It is likely that they will recolonize the lake for seasonal feeding and possibly spawning if access is re-established. Grayling are usually abundant in channels on- or associated with the Alluvial Fan, Wetland Area and Reach 3. They leave the creek in the autumn, and the creek is usually almost barren of Arctic Grayling in mid September.

Lower Clinton Creek

Lower Clinton Creek serves as migration and seasonal habitat for Arctic Grayling and juvenile Chinook Salmon. A number of other species have also been captured there. Minnow trapping by the DDRRC has resulted in the annual capture of Longnose Sucker and Slimy Sculpin. Small numbers of Burbot are captured in most years, and Round Whitefish were captured in 2010. Landucci (1976) reported the capture of a Lake Whitefish. It is likely that there is transient use by other species.

Fortymile River

The Fortymile River is a large, trans boundary tributary of the Yukon River. There is little surface or subsurface water storage in the drainage basin, and flows increase rapidly with snow melt or major precipitation events. In the summer the water in the river is clear and stained at low flows. Turbidity increases with volume of flow. Winter flows are present but may be very low.

Most sampling in the watershed was for the purpose of stream classification for placer mining and focussed on salmon (Jaromovic & von Finster, 1988; DFO, 1994a, b, & c). It is likely that more species utilize the river than have currently been documented. There is little information on the life history stages of non-salmon species.

Most or all of the species listed are migratory and may be expected to migrate through the mixing zone of Clinton Creek and the Fortymile River. A listing of the fish potentially possible may be found in:

http://www.pac.dfo-mpo.gc.ca/yukon/archive/habitatevergpaper.htm

5 Conclusion

The geomorphology, stream channel patterns, impoundments and hydrogeology of the Clinton Creek Mine Complex are dynamic. They have been so since the mine was in production, and it is safe to predict that they will be so for an extended period into the future.

Fish distribution and habitat utilization within the CMCC has also been dynamic. Relatively simple and stable stream channels with limited quantities of habitat of limited complexity have been replaced by a relatively wide range of types of habitats with limited stability, greater potential quantity, and much greater complexity.

The potential quantity includes the waters of Hudgeon Lake that seasonally sustain aquatic life. This distinction is important, as a significant portion of the present lake volume does not support aquatic life and may not be considered to be fish habitat.

The habitat complexity in the CCMC includes the currently inaccessible waters of Hudgeon Lake. Areas currently accessible to fish include the boulder-slab-bedrock channel through the Canyon, the many ground water fed channels on the Alluvial Fan and the ponds, pools and associated channels in the Wetland Complex. All surface features in this area are transitory: none will persist. However, the features are demonstrably stable enough to provide habitat for seasonal use by spawning, rearing and feeding Arctic Grayling; rearing and overwintering Chinook Salmon, and a resident population of Slimy Sculpin. On the basis of a 5 year data set, juvenile Chinook Salmon thrive in the CCMC, indicating that the habitats are generally highly productive.

Fortunately, no attempts have been made to determine the population size of any of the fish species in the creek at any time of the year. All indications are that annual numbers of Chinook Salmon and Arctic Grayling entering Clinton Creek vary widely. A population estimate in any given year could seriously under- or over-estimate the number of fish in the system. Additionally, environmental conditions such as the mid-summer 2010 flood could result in displacement of fish.

Finally, the CCMC has resulted in the impoundment of significant volumes of water in the ponds and lakes in the Porcupine Creek, Wolverine Creek and Clinton Creek valleys, and the development of aquifers both associated with the impoundments and in the developing Alluvial Fan. It is likely that winter flows in Clinton Creek at the CCMC were very low prior to the mine. All indications are that the discharges of water from mine-related aquifers persists through the winter and sustains overwintering juvenile Chinook Salmon and Slimy Sculpin.

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