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Memorandum

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Project: P1001 Casino Project

To: Mary Mioska, Casino Mining Corporation.

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cc Rick Palmer, Palmer Environmental Consulting Group.

Subject: Evaluation of a Casino Mine Dam Breach on Fisheries Values

1 INTRODUCTION

Casino Mining Corporation (CMC) is proposing the development of the Casino Project (the 'Project'), an open pit copper-gold-molybdenum mine in the Yukon. The project is located in the Dawson Range Mountains of the Klondike Plateau approximately 300km northwest from Whitehorse. The Tailings Management Facility (TMF) is located within the Casino Creek valley. Knight Piesold (KP) has completed a dam breach and inundation study for the Project TMF, in accordance with the Canadian Dam Association (CDA) Guidelines (2007; revised 2013). The CDA Guidelines also provide for the classification of dams in terms of the consequence of failure. The purpose of this technical memorandum is to support the classification of the Project TMF dam, by providing an evaluation of the potential effects of a hypothetical dam breach on fisheries in the area. The extent of impacts and the understanding of the potential failure of the dam are as outlined in the following documents by KP: TMF Dam Breach Inundation Study for Casino Mining Corporation, June 18 2015; Geomorphic Effects of Casino TMF Dam Breach (memorandum DRAFT), July 28 2015; Figure illustrating dam breach scenarios (DRAFT), August 14 2015.

2 FISHERIES BACKGROUND

Extensive baseline surveys have been conducted on fish and fish habitat in the Project area from 2008 to 2013 (Palmer Environment Consulting Group, 2013). The Casino Project is located wholly within the Yukon River watershed. The proposed mine is situated in the upper watersheds of Casino Creek and Canadian Creek (a tributary to Britannia Creek). The Project TMF is located within the valley formed by the headwaters of Casino Creek. Slimy sculpin (*Cotus cognatus)* and Arctic grayling (*Thymallus arcticus*) are the dominant species within the high-elevation mine area, where cold water temperatures, high gradients and velocities, a lack of overwintering habitat, and locally poor water quality and benthic community greatly limit productive capacity. Low numbers of burbot (*Lota* lota) and round whitefish (*Prosopium cylindraceum*) are present in the lower watersheds.

Fish abundance and species diversity generally increase downstream within the watersheds, particularly in close proximity to the Yukon River. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) have been captured in lower Britannia Creek, near its confluence with the Yukon River. Habitats in the Project area mainly support rearing, with limited opportunities for spawning, and overwintering restricted to larger, downstream watercourses with sufficient base flows and deep pools. According to the Yukon Placer Stream Classification Model, the entire Casino Creek watershed is classified as 'low' suitability habitat, whereas most middle to lower reaches of Britannia Creek have been classified as 'low-moderate' to 'moderate' suitability (Yukon Placer Secretariat, 2012). The lowermost reach of Britannia Creek has been designed as an 'area of special consideration', subject to the most restrictive conditions for placer mining in order to protect Chinook habitat near the mouth.

The remoteness and inaccessibility of the Casino and Dip Creek watersheds likely limits any recreational or Aboriginal fishing in the mine site area. However, watersheds in the Project area support important life history stages for subsistence, recreational and commercial species of Yukon River fish, including Arctic grayling and Chinook salmon. The Yukon river supports regionally significant commercial, Aboriginal and recreational fisheries, with an average of 14,000 and 16,000 Chinook and Coho salmon harvested per year, respectively, during the 1992 to 2002 period (Yukon River Panel, 2008). These salmon species are therefore at the forefront of people's mind in the local area.

3 EVALUATION OF IMPACTS TO FISHERIES

Catastrophic floods have been shown to seriously damage resident fish assemblages in mountain streams (George *et al.,* 2015). Although lotic fish communities have evolved with dynamic geomorphological conditions and are relatively resilient to extreme hydrologic events, severe floods may reduce fish density and biomass and influence community composition (Roghair *et al*., 2002; Carline & McCullough, 2003; Warren et al., 2009; Milner *et al*., 2012). Direct effects involve displacement-related mortality and destruction of incubating eggs, while indirect effects to habitat can affect carrying capacity or favor one species or guild over others (Elwood & Waters, 1969).

In the event of a Casino TMF sunny day failure (worse case scenario), the estimated peak discharge would be orders of magnitude greater than the natural flood with a 200-year return period for both Casino Creek (1000x greater), and Dip Creek (100x greater). In these watercourses, it is predicted that the debris flow/flood wave would strip the valley bottom and lower hillslopes within the complete inundated width of the valley. Some deposition of tailings, dam materials, and eroded valley materials are expected to occur along the margins of inundated area during the peak of the flood, and throughout the eroded area on the falling limb of the flood. This would mostly be comprised of sand-sized materials, while sizes finer than sand would be transported further downstream as suspended sediment.

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In the event of such a failure, the greatest effects on fish would be realized in both Casino and Dip Creeks due to their proximity to the TMF. During the flood wave, fish could be flushed out of Casino and Dip Creeks, and possibly stranded if a rapid rise and fall of water surface elevation occurred. Fish habitat in the Casino and Dip Creeks generally support low abundances of resident fish, although fish abundance and habitat size do increase in Dip Creek downstream of the Casino Creek confluence. The existing productivity of the fish habitat in these Creeks is low, and there exists suitable habitat for all life histories of the fish community in neighbouring streams and watersheds. Therefore, although the removal of the habitat in the inundated area would permanently alter the availability of fish habitat within the inundation zone, this would be unlikely to influence the resident fish community on a regional scale. The initial loss of vegetation, erosion of streambeds and chronic high levels of turbidity would mean that streambed and riparian habitat quality may remain degraded for some time, if left unrestored.

Moving further downstream from Casino and Dip Creeks, the estimated peak discharge in the Sunny Day dam breach scenario is on the same order of magnitude as the natural Q200 floods in these watercourse (7x greater in Klottasin, and approximately equivalent in Donjek). The debris flood wave generated by the dam breach would still constitute extreme flood events in these rivers, but it is less certain if the complete valley width would be stripped of vegetation, soil, and alluvium. There would likely be localized effects on fish that are present, including changes in behaviour over the short-term (including avoidance behaviour). As these peak discharges are likely to be on the same order of magnitude as naturally occurring Q200 flood, natural channel and biological processes would commence after the flood wave had passed.

There is evidence of Chinook salmon rearing in the Klotassin River at the confluence with Dip Creek, and salmon do migrate through the White River and into the Donjek and Klotassin to spawn in the headwaters of the Klotassin River. Depending on the time of year of the hypothetical dam breach, there could be impacts on this species, particularly if the peak discharge and sediment plume coincided with adult spawning behaviour and egg incubation. Such a peak discharge could flush eggs from gravels, as well as disrupt migration routes and successful spawning. Impacts at these life cycle stages would potentially have the greatest impacts and likely reduce recruitment back into the population on the short to medium term. Impacts are unlikely to have long-lasting impacts on a regional scale, although these species do support commercial, recreational and Aboriginal fisheries in the area. Even short-term effects could affect the productivity of local fisheries, and the impacts from this are difficult to predict.

The estimated peak discharge in the sunny day dam breach scenario is on the same order of magnitude as the natural mean annual flood in the White River valley. The debris flood wave generated by the dam breach would be similar to floods that occur fairly regularly, so the erosion/transport/deposition of channel bed material would not be unusual. The White River is a glacially fed river that presumably transports a large suspended sediment load, so the suspended sediment generated from the dam breach might not be exceptional compared to natural load during freshet flows. Any fisheries impacts from the flood wave in this river would therefore be similar to those observed on a natural scale. Based on existing information, it is also unlikely that Chinook salmon spawning occurs in the mainstem portions of the White, Donjek or Kluane Rivers because of high levels of suspended solids and the changeable nature of river channels that provide unsuitable habitat. These rivers are important migratory routes though, and provide access to clear-water side channels, where spawning often occurs. The White sub-basin did not appear to be an important producer of Chinook salmon because of a lack of good spawning and rearing habitat (Milligan *et al*., 1985). This sub-basin has received low priority in terms of escapement surveys and fisheries research.

However, the fine tailings (sizes finer than sand) would be carried in suspension and are expected to remain in suspension downstream of the confluence with the Yukon River. This factor would likely result in the most significant impact to fisheries, particularly to salmon which are migratory species that rely on chemical cues for critical life processes, including spawning. The sediments and fine tailings would be carried in suspension downstream of the confluence with the Yukon River and may affect fish (salmon) migratory behaviour in these systems, and possibly smother gills that cause some mortalities over the short-term. The turbidity levels in the creeks would remain high for an extended period of time (during the thaw seasons) due to erosion of exposed surface materials, and the reworking of deposited tailings and dam materials. There exists potential for significant deterioration of critical fish habitat. There also exists potential for adverse effects on salmon habitat in the Yukon River, depending on the transportation and deposition of suspended solids.

Depending on the timing of the peak concentration, the suspended sediment concentrations could significantly affect salmon migration and spawning in the larger downstream rivers (White and Yukon). The peak concentration of turbidity may restrict access to tributaries and upstream spawning areas, which could be considered critical if on a spatial and temporal scale that would affect recruitment back into the populations. Based on an analysis of Chinook salmon migrating past the Eagle sonar site near the Yukon-Alaska border, the major regional stocks contributing to the run were the Teslin River (38%), mainstem Yukon River (19%), Carmacks area tributaries (13%), Pelly River (10%), Stewart River (6%), upper Yukon tributaries (6%), lower Yukon tributaries (4%), and White River (4%) (Beacham and Candy, 2012). There are therefore several sources of potential resilience in the Yukon River Chinook salmon, including multiple age classes in spawning runs, which reduces the risk of production failure across several cohorts. Complex and interacting environmental and biological factors contribute to variation in annual run sizes, and these can be difficult to predict.

George *et al*. (2015) recently investigated the effects of extreme floods on trout populations and fish communities in a Catskill Mountain river. Study findings indicated that within 10-11 months post-disturbance, that fish assemblages were not strongly impacted (density/biomass) and appeared highly resilient on a basinwide scale. Community composition did not differ significantly between years of the study or between the pre- and post-flood periods. These data provide evidence that resident fish species and their communities may be able to resist or recover rapidly from extreme flood events. Chance events play a large role in determining the effects and recovery from this major flood. George *et al.* (2015) determined that the seasonal timing of the flooding was significant: late summer floods may have been less damaging to stream fish communities than winter or spring floods because spawning activity is negligible and early life stages of many fish species are generally larger and less susceptible to displacement and mortality (George *et al.,* 2015). The timing of any failure of the Casino TMF dam will therefore be any important factor in the severity of any impacts to fisheries.

4 EVALUATION OF RESTORATION POTENTIAL

Historically, watershed restoration efforts following catastrophic disturbance (*e.g.* a large flood) have sought a return to preexisting conditions, and this approach was typically equated to achieving "recovery;" (Bradshaw 1993; Norton *et al*., 2009), or, in this hypothetical case, a return to pre-dam breach conditions. Over the past three decades, however, a new understanding of disturbance and recovery has emerged: that these processes are dynamic and site-specific, and re-attainment of pre-existing steady-state conditions may be unrealistic due to numerous complex and interacting factors (abiotic, biotic, and societal/anthropogenic) (Stanley *et al*., 2010).

After the initial flood wave, and stabilization of the new channels, fisheries recolonization could occur due to seasonal migrations from White, Klotassin and Donjek River systems, depending on the time of year. Benthic macro-invertebrate recolonization could occur from downstream drift and tributaries downstream of the dam. However, restoration of the channel and riparian systems in the inundation area would be prolonged and it is unlikely that aquatic habitat will be restored to 'previous conditions'. Complete restoration at Casino and Dip Creeks would be impractical given the change to unstable, fine-textured bed material and lack of riparian vegetation. The post-event soft muddy conditions would make channel restoration difficult.

Norton *et al*., (2009) defined "recovery" as the probability of an environment to re-attain "valued attributes", given its ecological capacity to regain lost functionality, its exposure to stressors, and the social context affecting efforts to improve its condition. An understanding of "restoration potential" in the aftermath of a hypothetical Casino TMF dam breach would assist resource managers in formulating restoration strategies for two primary reasons: 1) the large spatial scale and ecological connectivity of the affected area; and 2) long-term exposure of affected stream habitats to environmental stressors (e.g.: "press disturbances" such as chronically elevated levels of suspended and dissolved fine sediments (Lake, 2000).

Geomorphological processes, such as those occurring in a flood, can operate in sequence down gravitational flowpaths, forming a cascade of disturbance processes that can drastically alter stream and riparian ecosystems (Nakamura *et al*., 2000). In the aftermath of a catastrophic flood, the affected stream and its watershed can be viewed through time as a network containing a shifting mosaic of disturbance patches. In between patches of disturbance, the pockets of "biological refugia" that persist lend resilience by providing the organisms and energy sources for recolonizing degraded habitats, thereby promoting initial recovery of the disturbed stream network structure (Nakamura *et al*., 2000).

Restoration of riparian and stream systems in Casino Creek and Dip Creek following a Casino TMF breach would be problematic and prolonged, and could have direct ramifications on the recovery of fisheries and benthic macroinvertebrate populations, despite the ability of some local biota to recolonize disturbed habitats relatively quickly. In the Casino drainages, fisheries recolonization could occur due to seasonal migrations from mainstem White River, mainstem White River tributary habitats, and potentially from tributaries within the Klotassin and Donjek systems, depending on depending on time of year. Benthic macro-invertebrate recolonization could occur from habitats upstream of the Casino Dam (downstream drift), as well as from tributaries downstream of the dam (Klotassin and Donjek systems), and mainstem White River and its tributaries (aerial movements).

However, the initial massive loss of vegetation, erosion of streambeds and floodplains, and chronic high levels of turbidity would inhibit initial recolonization efforts since stream and riparian habitat quality are likely to remain heavily degraded for some time. The soft, muddy, partially frozen, and unstable terrain will create logistical hurdles for vehicle and heavy equipment access, as well as create poor conditions (low probability of success) for restoration techniques ranging from riparian tree planting to instream habitat enhancement.

This information indicates it would not likely be feasible to restore affected aquatic habitats to “previous conditions” in the event of a hypothetical Casino TMF breach (for both rainy day and sunny day scenarios). Restoration objectives for aquatic habitats would need to be based on realistic expectations of recovery.

5 CONCLUSION

Based on the known fisheries in the Project area, as well as the likely scenarios from the hypothetical dam breach, the impact on fisheries could range between ‘High’ and ‘Very High’ according to the CDA Guidelines. There are no known endangered fish species that would be displaced from the dam failure. Direct mortality of fish in the initial flood wave would likely be limited to the immediate downstream reaches of Casino and Dip Creek. Both these creeks have existing low fish productivity and the fish species are present in neighbouring streams and watersheds. This could facilitate any recolonization after the event.

The effects on Casino and Dip Creek however, would make restoration efforts impractical and there would be a significant loss of habitat in this area. The effects further downstream would likely be less severe on a habitat scale as the magnitude of the event becomes more similar with natural flood events. The deposition of tailings and sediment into the White and Yukon River does have the potential to cause a significant deterioration of critical fish habitat, in particular for salmon species. These species are an important component of Yukon River fisheries and depending on the timing of turbidity, may restrict fish access to tributaries and upstream spawning areas. This could be considered critical if on a spatial and temporal scale that would affect recruitment back into the populations.

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PALMER ENVIRONMENTAL CONSULTING GROUP INC.

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