INNAVIK HYDRO

Innavik Hydroelectric Project

Fish Habitat and Wetland Compensation Plan

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1 Context

Innavik Hydro, a limited partnership (Translator's note: *société en commandite* or S.E.C. in French), received a certificate of authorization (CA) on August 23, 2019 for the construction and operation of the Innavik Hydroelectric Project. The project shall be completed and operated in conformity with the CA and in compliance with 13 conditions, including Condition 13, which states:

> *Before construction of the hydroelectric facility is completed, the Developer shall submit for authorization the compensation plans for fish habitat and wetland losses. In these plans the Developer shall present the consultations that were held as well as any feedback received. With regard to compensation of both fish habitat and wetlands, it shall be specified whether any auxiliary work is required, notably in terms of access or installation of infrastructure. Compensation plans shall also include monitoring of the planned measures. These compensation plans shall be implemented no later than two (2) years after the hydroelectric facility has been commissioned.*

This document describes the approach used by Innavik Hydro with respect to this condition. At northern latitudes, compensation for wetland losses should aim to improve the natural environment rather than attempt to create a new wetland or restore an existing one. In fact, there is no guarantee that such projects will be successful and they may be risky in a context where wetlands are abundant.

Fish habitat is an issue that has been discussed, in parallel, between Innavik Hydro and Fisheries and Oceans Canada as this federal agency is responsible for measures to protect fish and fish habitat. Following the analysis of the project, Fisheries and Oceans Canada determined that no compensation is required and issued an authorization under the *Fisheries Act* (Authorization 2019-023) indicating that:

> *Given the gains of 648,000 m^2 associated with forebay impoundment, which will notably provide nursery, wintering and foraging habitats as well as refuges for the species present (brook trout, lake whitefish, lake cisco, round whitefish, longnose sucker), DFO considers that no compensation projects are required.*

In light of the above, Innavik Hydro prefers an exploratory rather than a conventional approach to compensation with the objective of enhancing the natural environment and building on existing knowledge for the benefit of local communities. Such an approach is all the more justified and relevant since the Innavik project represents a unique opportunity to document the effects of a run-of-the-river hydro plant in northern conditions.

2 Description of Compensation Plan

Innavik Hydro has reached an agreement for collaboration with a team of university researchers, Hydro-Québec and three Indigenous communities in the context of a project entitled: "*Solving emerging environmental challenges of the hydroelectric sector in partnership with utilities and Indigenous communities*." Supervised by professor Marc Amyot, Canada Research Chair in Global Change Ecotoxicology, this project has received an Alliance grant from the Natural Sciences and Engineering Research Council of Canada (NSERC). Atikamekw (Wemotaci), Innu (Eukuanitshit) and Inuit (Inukjuak) communities will be involved in this project.

Part of the project's focus will be to understand the impact that hydroelectric development has on permafrost. Indeed, the Innavik project represents a unique opportunity in this regard given its northerly location and the fact that it is currently under construction. In this context, it will be possible to collect information prior to impoundment in order to clearly identify the plant's impact on permafrost, carbon transport, the mercury cycle and accumulation in traditional food.

Innavik Hydro's financial contribution, which totals $200,000, will help enhance certain aspects of the project, especially as they relate to the community of Inukjuak. This contribution will be distributed to each of the themes described below. A table summarizing the enhancement of each theme through the participation of Innavik Hydro is presented in Appendix A.

2.1 Theme 1: Monitoring the impact that forebay flooding has on the release of contaminants in permafrost

An article by Miner et al. (2021) mentions the possibility that various components trapped in the permafrost for thousands of years may be released when the permafrost thaws. These components include unknown and/or potentially dangerous bacteria and viruses (Burkert et al., 2019; Emerson et al., 2018; Legendre et al., 2015), toxic organic contaminants (Eickmeyer et al., 2016), radioactive waste (Nielsen et al., 1997) and toxic metals such as lead (Liu et al., 2012) and mercury (Schuster et al., 2018).

The research project initially aimed to characterize the release of contaminants (including mercury) during and after flooding of the Innavik hydro facility's forebay. The Innavik Hydro's financial contribution allowed the team of researchers to enhance the project and to include the organic contaminants in the monitoring. Organic contaminants that have accumulated in the permafrost over the past century could be released into the water if the state of the permafrost deteriorates. Some of the organic contaminants that will be monitored are potentially toxic. This study is all the more relevant given that the water intake for supplying the Northern Village with drinking water is located at the mouth of the Inukjuak River and the fact that the community consumes fish taken from this river. This study will therefore be innovative and of interest to Inuit communities, in addition to making a significant contribution to knowledge acquisition. To date, no study has ever sought to observe the impact a run-of-the-river hydro plant built on permafrost might have on the release of a series of organic contaminants.

Water samples will be taken from the Inukjuak River every month, when accessible, at a sampling site located at the plant, with the assistance of a community member, and over a four-year period beginning in

2023. Sediment samples will also be taken sporadically during this period within areas of sedimentation previously identified, when accessible, and on a yearly basis. Consequently, the research team will have water quality and sediment data before and after impoundment of the forebay. Parameters measured in the water will include suspended matter, major ions (e.g. calcium, sodium, chloride), dissolved organic carbon, trace metals, nutrients as well as the release of greenhouse gases. Monitoring will also include benthic organisms, when available, on a yearly basis. These data will be used to estimate carbon and mercury fluxes between the river and Hudson Bay.

The results will be shared with health and social service agencies to later help inform and educate the local population. A follow-up of results will also be prepared to inform the Kativik Environmental Quality Commission (KEQC) members (see section 4).

2.2 Theme 2: Science camp for Inukjuak youth

The project plans to promote knowledge transfer through science camps in the various Indigenous communities involved. The research team initially considered organizing a camp in Inukjuak. Innavik Hydro's financial contribution will be used to organize a second camp.

The aim of these camps is to bring together youth and elders from Inukjuak as well as scientists to share their respective know-how and expose the community's youngsters to traditional and scientific knowledge. These camps will allow youth members to become a little more familiar with their traditional way of life, in addition to expanding their knowledge of environmental sciences. The frequent presence of Ms. Jeanne Gaudreault and Mr. Eric Atagotaaluk of Innavik Hydro in an around the community of Inukjuak is a major plus for the preparation of these day camps.

The second camp is planned for the summer of 2025, once the first results have been obtained. In addition to the camps, the research team wishes to recruit high school students for summer jobs as scientific assistants or local guides between 2022 and 2026.

Several members of the research team have already been involved in this type of exchange in recent years (Figure 1). Over time, these camps will increase the likelihood that certain members of the community will go on to pursue university studies and become role models for the younger generation.

A similar project was recently initiated in Nunavik by graduate students of professor Marc Amyot. A video of the 2019 camp can be viewed at the following address: https://www.youtube.com/watch?v=EUhdCs7Aodg. The camps scheduled for this project will be based on the same model.

Figure 1 Example of science day camps organized by the research team

Each science camp will last 5 days. The preliminary program is described below:

- Day 1: Presentation of the team and each participant, games designed for participants to get to know one another and create relationships, brief presentations of how the camps work and a few concepts related to the natural environment, ecosystems and run-of-the-river hydro facilities;
- Day 2: Safe visit to the river with guides and elders, discussions on environmental changes, sampling (water, sediments, benthic organizations and fish), and handling of measurement devices (YSI instruments);
- Day 3: Processing of samples taken in the field: identification of invertebrates, microscope observation of micro-organisms, particle size analysis of sediments;
- Day 4: Visit to the tundra with elders: discussion on their knowledge of the local environment, environmental changes, and applied training (e.g. how to build a shelter);
- Day 5: Recap of what was learned over the previous days, advantages and benefits of traditional cuisine ('country food') with health agency professionals.

2.3 Theme 3: Monitoring the presence of contaminants in fish

As per Innavik Hydro's commitment (stipulated in Condition 10 of the certificate of authorization), a monitoring program has been put into place to track mercury levels in fish tissue. This monitoring will cover a 15-year period after the commissioning of the Innavik facility and will consist of several fish tissue sampling campaigns. Fish sampling was also carried out in 2019 in order to describe baseline conditions, i.e. to document mercury levels in fish flesh before the forebay was flooded. It should be noted that this survey will be carried out at the same time as the monitoring of fish community composition required by Fisheries and Oceans Canada in the authorization issued under the *Fisheries Act*.

Fish will be caught using experiment gillnets at three stations:

- Upstream of the Innavik facility (in the forebay and in Lake Qattaakuluup Tasinga)
- Downstream of the Innavik facility
- In a reference lake that will serve as a control site

Three species were targeted, being relatively abundant and prized by fishers in the community of Inukjuak: lake whitefish, brook trout and lake trout. The involvement of the local population is essential. For this reason, Inuit fishers will be involved in various fish monitoring activities and their knowledge will serve as a basis for developing the best approaches to achieve the objectives of this monitoring.

Innavik Hydro's collaboration with the research team as well as its financial contribution will help expand the scope of this monitoring through 2027 as well as the addition of organic contaminants into the fish tissue analyses. In this context, in addition to mercury, the monitoring may include methylmercury, organic contaminants, stable carbon and nitrogen isotopes, radioactive carbon-14 (if preliminary results show the value of this measure), fatty acids and various trace metals. These analyses will be used for long-term monitoring of fish tissue quality for the Inukjuak community, in addition to being a source of data before and after commissioning of the Innavik power plant.

Two run-of-the river dams on the St-Maurice River have had an influence on mercury concentrations in fish, despite the small surface areas that were flooded (Ponton et al., 2021). Five years after these plants were commissioned, mercury concentrations in fish had more than doubled. In-depth analyses conducted over a period of more than 3 years would therefore be an opportunity to properly study the impact the dam and permafrost degradation have on mercury concentrations in fish populations. The project will enable an analysis of the risks and benefits of traditional food.

2.4 Theme 4: Long-term monitoring of impact of flooding of the forebay on permafrost

The impact of building a run-of-the river hydro facility on the permafrost thermal regime below and adjacent to a river is unknown. When permafrost thaws, new subsurface flow channels form and allow the flow of water, solutes, dissolved organic carbon and potentially contaminants (McKenzie et al. 2021; Mu et al. 2019). Below a river bed, increased degradation of the permafrost created by a thicker layer of water can potentially result in the formation of permanently unfrozen areas called taliks. These taliks can be closed (within the permafrost) or open (spanning the entire thickness of the permafrost) and therefore provide hydrological connectivity and flow between the waters of the river and deep aquifers. However, the configuration and geotechnical/geothermal properties as well as the rate at which taliks develop are poorly understood (Stephani et al. 2020).

The Alliance project plans to install instruments and boreholes in 2022 in an area that will be flooded during the impoundment and at a non-flooded control site. Two 15 m deep wells will be drilled as well as other shallower wells in the vicinity. These 15 m deep wells will be used in the long-term monitoring of the temperature and other characteristics of the permafrost. Potential sites are presented in Figure 2.

The Innavik Hydro's financial contribution allowed the team of researchers to include a geophysical monitoring of the permafrost. In order to identify the potential presence of taliks and their configuration, the research team selected two sections of the Inukjuak River: one section above the dam where water levels will not be affected and one section where the dam will cause water levels to rise. Two geophysical techniques will be used to characterize and monitor the state of the permafrost: 1) Lateral profiles using electrical resistivity tomography will be carried out in order to determine the physical state of the soil (frozen/unfrozen); 2) A georadar will be used to characterize soil stratigraphy and the geometry of potential taliks. Such an approach was successfully used in the village of Salluit to characterize the taliks of the Kuuguluk River in order to describe the dynamics of the aufeis (icings) (Liu et al. 2020).

Geophysical profiles will be carried out before the forebay is flooded in order to characterize the physical and thermal state of the permafrost below and adjacent to the river. Other profiles will be performed shortly after impoundment in 2023 and in 2027. These data will help determine the evolution of taliks in response to dam construction, as well as their potential evolution in undisturbed environments in response to global warming, as the case may be.

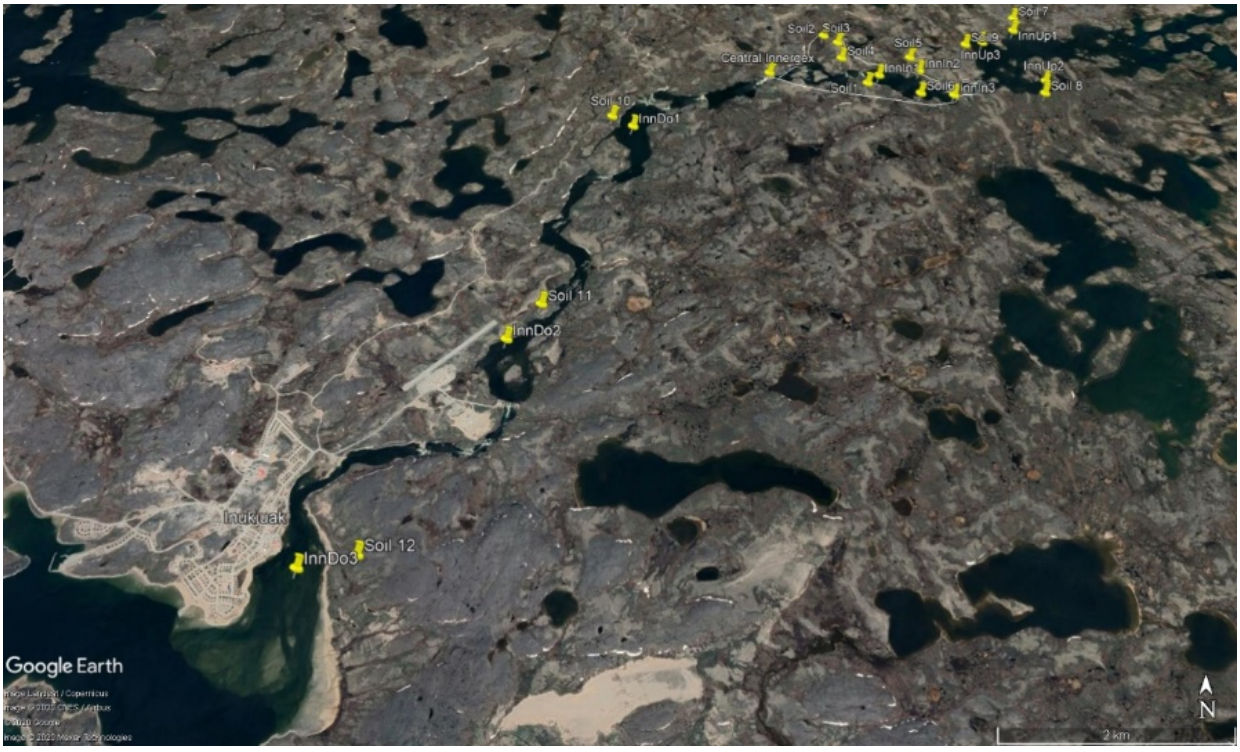

Figure 2 Distribution of potential sites for water and soil sampling

Core samples of surface soils will be analyzed to characterize their physical and chemical properties. Parameters retained notably include the water content, density, quality, quantity and age of organic material (carbon-14 dating), as well as ions, minerals, mercury, mercury isotopes, methylmercury and trace elements.

3 Expected Results and Benefits for the Community

This project would contribute to significant scientific advances while integrating the research interests of Inukjuak's Inuit community. The knowledge that will stem from this ground-breaking study on the mercury cycle, carbon transport, water quality and fish tissue in a dammed river in the North will help better manage these types of sites in the future and provide the community of Inukjuak with data on its exposure to environmental contaminants.

This project will encourage the involvement of Indigenous communities, notably the community of Inukjuak. Knowledge transfer and youth-elder sharing are critical components of this project. Science camps will provide opportunities to encourage youth to pursue a scientific career and to become role models for their community. Additionally, the research team wishes to recruit high school students for summer jobs as scientific assistants or local guides. The current agreement stipulates that community members should account for 50% of each field team (ratio of one Inuit guide for every field scientist).

Health agencies – who will enjoy access to robust data on human exposure to contaminants in traditional foods – also stand to benefit from this project.

4 Related Work and Follow-up

As described above, the compensation plan for fish habitat and wetland losses does not include any auxiliary work, construction of accesses or installation of infrastructure. Consequently, no follow-up is required.

However, a follow-up of results will be prepared at the end of the compensation plan in 2027 to inform KEQC members of the conclusions of the study and the benefits that have been observed. Additionally, Innavik Hydro undertakes to organize a workshop with the Inukjuak community, which will also take place in 2027.

Lastly, the research team's work will be made public through scientific articles and conferences.

5 Consultation

Throughout the project development process, Innavik Hydro listened to the concerns of the local population and organizations, notably on issues related to fish habitat and fish contamination levels. Moreover, the monitoring program for tracking mercury levels in fish tissue was put into place in response to these concerns. The above-described compensation plan enhances this monitoring effort by expanding the number of parameters that are tracked and providing more information to the community on this issue. As

for wetlands, the comments received were generally to the effect that there is no shortage of wetlands in the region.

The approach used by Innavik Hydro to compensate for fish habitat and wetland losses has been discussed in the Follow-up and Cooperation Committee on May 18, 2022 in Inukjuak. This committee brings together representatives of the Northern Village; the Pituvik Landholding Corporation; the Hunting, Fishing and Trapping Association; Uumajuit wardens, the Avataq Cultural Institute; the local population (one elder and one woman representative from Inukjuak); as well as representatives of Innavik Hydro and CRT Construction.

The Follow-up and Cooperation Committee accepted the proposed compensation plan but requested the addition of a monitoring of the water salinity along the mouth of the Inukjuak River. This is a concern due to situations in James Bay where dams infrastructures and the decrease in flow of some rivers have altered the salinity at the mouths of these rivers (by reducing freshwater input). This salinity monitoring will be added to the program according to a methodology that will be discussed and elaborated with the researchers involved in the project.

6 References

Burkert, A., Douglas, T.A., Waldrop, M.P., Mackelprang, R. 2019. Changes in the Active, Dead, and Dormant Microbial Community Structure across a Pleistocene Permafrost Chronosequence. *Applied and Environmental Microbiology*, 85,

Eickmeyer, D.C., Kimpe, L.E., Kokelj, S.V., Pisaric, M.F.J., Smol, J.P., Sanei, H., Thienpont, J.R., Blais, J.M. 2016. Interactions of polychlorinated biphenyls and organochlorine pesticides with sedimentary organic matter of retrogressive thaw slump-affected lakes in the tundra uplands adjacent to the Mackenzie Delta, NT, Canada. *Journal of Geophysical Research-Biogeosciences*, 121, 411-421

Emerson, J.B., Roux, S., Brum, J.R., Bolduc, B., Woodcroft, B.J., Jang, H.B., Singleton, C.M., Soden, L.M., Naas, A.E., Boyd, J.A., Hodgkins, S.B., Wilson, R.M., Trubl, G., Li, C.S., Frokings, S., Pope, P.B., Wrighton, K.C., Crill, P.M., Chanton, J.P., Saleska, S.R., Tyson, G.W., Rich, V.I., Sullivan, M.B. 2018. Host-linked soil viral ecology along a permafrost thaw gradient. *Nature Microbiology*, 3, 870-880

Legendre, M., Lartigue, A., Bertaux, L., Jeudy, S., Bartoli, J., Lescot, M., Alempic, J.M., Ramus, C., Bruley, C., Labadie, K., Shmakova, L., Rivkina, E., Coute, Y., Abergel, C., Claverie, J.M. 2015. In-depth study of Mollivirus sibericum, a new 30,000-y-old giant virus infecting Acanthamoeba. Proceedings of the National Academy of Sciences of the United States of America, 112, E5327-E5335

Liu, X.D., Jiang, S., Zhang, P.F., Xu, L.Q. 2012. Effect of recent climate change on Arctic Pb pollution: A comparative study of historical records in lake and peat sediments. *Environmental Pollution*, 160, 161-168

Liu, W., Fortier, R., Molson, J., Lemieux, J.-M. 2020. A conceptual model for talik dynamics and icing formation in a river floodplain in the coninuous permafrost zone at Salluit, Nunavik (Quebec), Canada. *Permafrost and Periglacial Processes*, 32, 468-483.

McKenzie, J.M., Kurylyk, B.L., Walvoord, A., Bense, V.F., Fortier, D., Spence, C., Grenier, C. 2021. Invited perspective: What lies beneat a changing Arctic? *The Cryosphere*, 15, 479-484.

Miner, K.R., D'Andrilli, J., Mackelprang, R., Edwards, A., Malaska, M. J., Waldrop, M.P., Miller, C.E. 2021. Emergent biogeochemical risks from Arctic permafrost degradation. *Nature Climate Change*, 11, 809-819

Mu, C.C.; Zhang, F.; Chen, X.; Ge, S.M.; Mu, M.; Jia, L.; Wu, Q.B.; Zhang, T.J. Carbon and mercury export from the Arctic rivers and response to permafrost degradation. *Water Research 2019*, 161, 54-60, doi:10.1016/j.watres.2019.05.082

Nielsen, S.P., Iosjpe, M., Strand, P. 1997. Collective doses to man from dumping of radioactive waste in the Arctic Seas. *Science of the Total Environment*, 202, 135-146

Ponton, D.E., Lavoie, R., Leclerc, M., Bilodeau, F., Planas, D., Amyot, M. 2021. Understanding food web mercury accumulation through trophic transfer and carbon processing along an impacted river. *Environmental Sciences & Technology*, 55, 2949–2959

Stephani, E., Drage, J., Miller, D., Jones, B.M., Kanevskyi, M. 2020. Taliks, cryopegs, and permafrost dynamics related to channel migration, Colville River Delta, Alaska. *Permafrost and Periglacial Processes*, 31, 239-254.

Schuster, P.F., Schaefer, K.M., Aiken, G.R., Antweiler, R.C., Dewild, J.F., Gryziec, J.D., Gusmeroli, A., Hugelius, G., Jafarov, E., Krabbenhoft, D.P., Liu, L., Herman-Mercer, N., Mu, C.C., Roth, D.A., Schaefer, T., Striegl, R.G., Wickland, K.P., Zhang, T.J. 2018. Permafrost stores a globally significant amount of mercury. *Geophysical Research Letters*, 45, 1463-1471

Appendix A Enhancement to the Initial Research Project through the Compensation Plan

Research Plan	Initial Research Project (Alliance grant)	Enhanced Research Project (Innavik Hydro contribution and Compensation Plan)
Theme 1 Monitoring the impact that forebay flooding has on the release contaminants in permafrost	The research project initially aimed to monitor water quality with a specific focus on mercury.	In addition, the enhanced project now also includes organic contaminants in the monitoring.
Theme 2 Science camp for Inukjuak youth	One camp was initially planned in Inukjuak	Two camps are now planned in Inukjuak
Theme 3 Monitoring the presence of contaminants in fish	The research project initially aimed to monitor several contaminants (including mercury) until 2025	The enhanced project is expanded 2027 and now also includes organic contaminants in the monitoring. Innavik Hydro will provide the fish samples collected during a monitoring program specific to the Innavik Project.
Theme 4 Long-term monitoring of impact of flooding of the forebay on permafrost	The research project was initially based on thermic monitoring at two 15 m deep wells	In addition, the enhanced project now also includes a geophysical monitoring of the permafrost: 1) Lateral profiles using electrical resistivity tomography; and 2) Permafrost characterization using a georadar. Those additions will allow extrapolation to a larger area representing the variability of local field conditions.