

**Arctic Resource Development and Climate Impacts, Adaptation and Mitigation Project:
Initial Summary of Climate Impacts and Adaptation for Energy, Mining and
Infrastructure in Canada's North**

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Climate Change Impacts for Energy, Mining and Infrastructure in Canada's North

Climate impacts throughout Canada's North and the circumpolar region affects energy, mining and related terrestrial and marine infrastructure. Some significant climate impacts are briefly discussed below.

Energy

Changing climate affects the capacity and operations of hydroelectric developments on small and large rivers and impoundments. Projected increases in winter runoff from rainfall and enhanced winter snowmelt lead to a decline in the water stored in snow. Changes in the magnitude and seasonality of flows place stress on existing impoundments, particularly the most severe inflow flood design. Changes in river-ice regimes may increase threats of downstream ice jamming. Risk assessment for the circumpolar region requires hydrological modeling in regions that often lack flow gauges.

The hydrocarbon industry engages in exploration, production and transportation, but exploration activities may be most affected by climate change. For example, projected decreases in sea-ice cover may result in increased exploration activity in the Canadian Arctic Archipelago. Permafrost thaw and snow cover shifts require lower impact vehicles and changes in the scheduling of exploration. Unpredictable winter seasons and ice-roads in turn require more flexible schedules.

The greatest impact may relate to the use of in-ground sumps for drilling wastes, as this disposal relies on permafrost to prevent subsurface movement of drilling wastes into the environment. Increased ground temperatures could increase contaminant transport for hydrocarbon and mining wastes. Offshore exploration drilling will also be affected by decreasing sea-ice cover and shifting weather, could require change to drilling platforms due to increased wave action and storm surges

Processing facilities need to consider changing permafrost and ground stability. For facilities located on river channels or coasts, such as in the Mackenzie Delta region, additional factors such as river-ice break-up and ice-jam flooding, coastal erosion and sea-level rise must be considered.

For pipelines changes in the ground thermal regime, drainage and terrain stability, all of which may result from a warming climate over the lifetime of such a project, must be considered. In turn, there is the need to closely monitor the performance of the pipeline and right-of-way to maintain pipeline integrity and minimize environmental impacts.

Mining

The development of integrated land and marine transportation networks as a result of sea ice decline will encourage mine exploration and development. Re-supply of mines is generally limited to winter periods and the availability of ice roads, while exploration is restricted to air access in the summer. Climate change will affect in the engineering design, operations, closure and abandonment of mines. Reduced ice roads could require the development of all season roads and water transport.

Another concern is the impact of climate change on permafrost and ground stability. Similarly to the hydrocarbon sector, the stability of waste-rock piles, tailings piles and tailings-containment impoundments depends on permafrost to ensure that contaminants and acid-rock drainage are not discharged to the environment.

Infrastructure

Permafrost present challenges for the design, construction and operation of infrastructure in northern Canada and throughout the circumpolar region. Thawing of the ground can lead to loss of strength, settlement and instability. The removal of insulating vegetation and other ground disturbances can lead to warming and thawing of permafrost. Additional warming may occur due to heat generated by the mine such as heated buildings and water, sewage and hydrocarbon pipelines. For runways, roads and pipelines, settlement and slope instability may occur

Climate warming presents future challenge for northern resource development and infrastructure design. In the short term, the impacts associated with ground disturbance and construction may be greater. Climate becomes significant over longer time scales. Failure to properly design infrastructure can have serious consequences. Current engineering practices already minimize ground disturbance and the impacts on structures, where locations are chosen to avoid thaw, and modern infrastructure is designed to preserve permafrost.

Reductions in the duration and extent of sea-ice cover could present new opportunities for marine transport in the Canadian North encouraging mining development. A longer shipping season supports the construction of a deep-water port along Canada's northern coastline connected by an all-weather road with the inland mine sites.

For earlier structures change can result in increased maintenance costs and remedial work for structural integrity. Waste-containment facilities present a particular challenge, as were not

designed for the warmer conditions presently being experienced or likely in the future. Failure of tailings ponds and piles could result in contaminants being released into the surrounding environment, with impacts on ecosystems and human health. Remedial action may be required at these older sites, and new containment structures in the southern part of the continuous permafrost zone may need to consider techniques presently used in the discontinuous permafrost zone. An important element of understanding climate impacts is monitoring.

Although lake and river ice have historically served as natural transportation routes, with sophisticated methods of winter-road construction, there is restricted analysis on the effects of climate on these systems. Ice roads and ice bridges that are constructed and maintained each winter provide a relatively inexpensive way to supply northern communities and industry, particularly the rapidly expanding mining sector that relies on ice roads to move heavy equipment, materials and fuel for the remainder of the year.

Climate Change Adaptation for Energy, Mining and Infrastructure in Canada's North

Overview

Adaptation is the response to climate impacts, and often occur in tandem with the impacts. Some of these adaptive measures are already occurring. Major changes are expected across resource sectors, including hydroelectric generation, hydrocarbons, and mining. Hydroelectric facilities and operations will need to be adapted to changing flow regimes associated with an altered timing and magnitude of snowmelt runoff. There will be the need to consider how best to construct and operate future impoundments particularly on the Mackenzie River as the needs for renewable energy increase. Where older infrastructure in the Arctic overlies thaw-sensitive permafrost, some form of structural or operational adaptation may be needed to deal with permafrost thawing.

Demand for electricity is rising in all three territories due to increasing population and heavy industry, such as diamond mines in the Northwest Territories and Nunavut. Alternative renewable energy sources, such as solar, wind, wood and even geothermal power, could meet increasing electricity demand.

An important issue for the hydrocarbon and mining industry is the containment of wastes. Historically, permafrost has been used for long-term storage, but future thaw could eliminate this storage and require older sites to be remediated. For the hydrocarbon sector, the changing climate could positively affect exploration, production and delivery. Reductions in sea ice could lead to a more exploration and development in the energy and mining sectors, leading to further economic development throughout the circumpolar region.

Reductions in the thickness and seasonal extent of river, lake and sea ice will require adaptation for marine and freshwater transportation. These will vary from changes in the types of vessels use, and the routes to a shift to more barge- and land-based traffic as ice roads and crossings decrease. Expansion of marine and land-based transportation supports further resource exploration, as previously remote resources would become more accessible and economically viable.

Changes in the magnitude and seasonality of river flows require a focus on the safety of existing impoundments. Of particular importance is the need to redefine the most severe inflow flood for which an impoundment is designed. Fuller assessment of the risks to hydroelectric facilities will require hydrological models to predict flow

Adaptation Responses

A few specific examples of adaptation are considered for energy, mining and infrastructure in Canada's North.

Thawing of permafrost and changes in snow cover will require an increased focus on low impact vehicles and changes in the scheduling for hydrocarbon exploration activities. The unpredictability of the winter season and the winter ice-road system will necessitate greater flexibility in scheduling of exploration and extraction activities. The greatest impact of changing climate on hydrocarbon exploration relates to the use of in-ground sumps for drilling wastes. As disposal in sumps relies on the presence of permafrost to prevent subsurface movement of drilling wastes into the surrounding environment, increased ground temperatures resulting from increases in air temperature and snow cover will increase the likelihood of contaminant transport. Alternate drilling-waste practices, including remote sumps, central processing facilities, impermeable linings, or down-hole injection or transportation of waste outside the territories are represent potential adaptations to climate change.

Offshore exploration and drilling will be affected by decreasing sea-ice cover. Future development may require design changes to drilling platforms to counter the effects of increased wave action and storm surges. One possible adaptation would be to increase the use of exploration drill ships. Processing plants are one of the largest infrastructure components of hydrocarbon production, and must maintain their structural integrity over the life of a project. Design of production facilities needs to consider the effects of climate change on permafrost and ground stability. One proposed adaptive strategy is to avoid potential impacts is to use a barge for production, rather than a land-based facility.

Permafrost contains present challenges for the design, construction and operation of infrastructure in northern Canada and throughout the circumpolar region). Although ice-bonded frozen ground can provide a strong foundation for infrastructure, thawing of the ground leads to loss of strength, as well as to settlement and instability. The removal of insulating vegetation

cover and other disturbances of the ground surface through construction can significantly alter the ground thermal regime, resulting in warming and thawing of permafrost. Additional warming may occur due to heat generated by the structure itself such as buildings and buried water, sewage or hydrocarbon pipelines.

Adaptation present significant challenges for all these infrastructure issues due to the breadth of the impacts. Failure to take proper precautions in the engineering design of infrastructure in permafrost regions can have serious consequences. This occurred in the Yukon Territories in the 1890s, when construction in Dawson proceeded with no consideration for the ice-rich alluvial sediments that underlay the site. For larger structures such as runways, roads and pipelines, concerns include differential settlement due to spatial variations in soil characteristics and ice content, and slope instability resulting from permafrost thawing. Current engineering practices minimize the disturbance to ground and impacts on structures. Locations are chosen to avoid thaw-sensitive soils, and infrastructure is designed to preserve thaw-sensitive permafrost, and limit and withstand thaw settlement

Dredging selected portions of river channels may offer localized, short-term solutions to decreased water levels for hydroelectricity but are not practical long-term adaptive measure. Upstream flow regulation could be used to increase late summer flows but would, negatively impact hydroelectric-generating potential. As obvious adaptation measure to increasingly difficult river transport is an increase in all-season road networks. However, that could be a significant engineering challenge to construct and maintain such roads over permafrost, requiring quite innovative strategies.

Adapting ice roads will also require greater documentation and sharing of knowledge and best practices. Although records are kept of the opening and closing of ice roads and crossings, there has been no comprehensive trend analysis of these dates. Reductions in ice thickness associated with climate warming cold reduce the maximum loads that can be safely transported. Initially, modifications in ice-road construction could function as an effective adaptation. Where transportation is not overwhelming, it is possible to concentrate shipping during the time of the winter when ice thickness is greatest. The combination of impacts associated with decreased length of the ice road season and reduced ice thickness will cause problems with winter resupply of northern communities, and industrial energy and mining sites. Over time as ice roads becomes impractical, there will be a need to provide alternative transportation. If there is navigable river, increased use of barge transport might be possible. For inland locations, construction of land-based roads is likely the only viable option to carry the annual freight. However, all-weather roads are more costly than winter roads to build and maintain.