Economics of Airships for Northern Re-supply

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Canadian society places a high value on the equity of access to basic services and the elimination of regional disparities. In the urban centres and more densely populated parts of rural Canada, where transportation and logistics costs are low, economic development policy has been effective. Canadians enjoy quality healthcare, education and opportunities for employment. Where success has been elusive, is in the 70 percent of the landmass that has no all-weather roads. Without effective transportation, the standard of living in the North will always be inferior to the more densely populated south.

Former Prime Minister Mackenzie King encapsulated the economic problem of providing infrastructure to develop the remote parts of Canada, "If some countries have too much history, we have too much geography."[1] The Canadian population has always been too small, relative to the financial demand to construct and maintain all-weather roads or railway lines to most parts of the country. Moreover, the construction of surface infrastructure is difficult in Canada's northern regions. The rugged terrain, environmental concerns and the complications posed by the need to deal with muskeg and permafrost make road construction very expensive[2].

Transportation challenges discourage investment in resource industries, limit employment prospects and increase the cost of living. Without an efficient and economic means of transport, the natural resource opportunities in the North remain unreachable. High freight rates inflate the cost of inputs and limit the selection of consumer goods available. Often, Canadians living in the North are cut off from public services that are taken for granted in the rest of the country. These socio-economic disparities are greatest in the remote communities that have no all-weather road access.

The North is served best by air transport. The distances are vast, the infrastructure costs of air transport are low, and the service is available year round. The technological problem is the volume of goods that can be moved economically by small airplanes. If the operating costs of air transport could be reduced, the socio-economic benefits would be significant. It is for this reason that the development of a new generation of cargo carrying airships presents such an appealing opportunity for the North.

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[1] W.L.MacKenzie King (1874-1950)

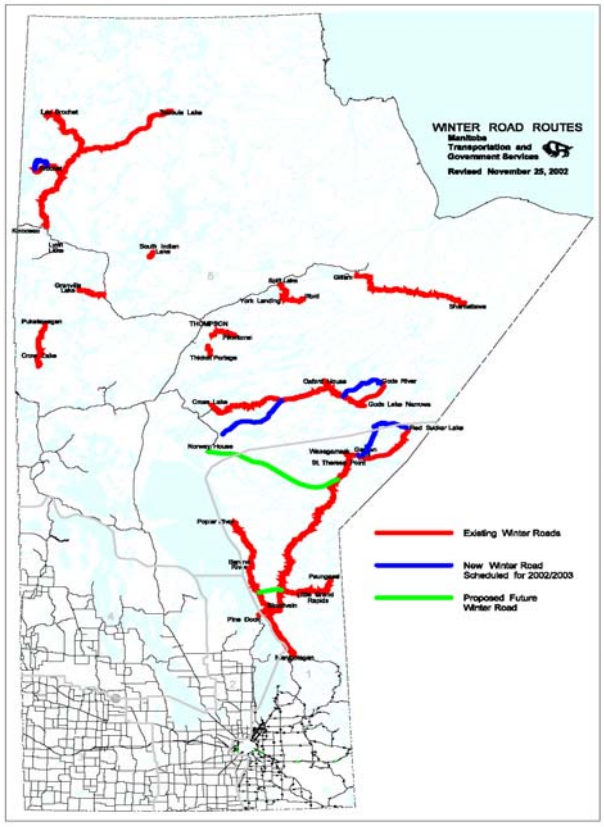
[2] Modern generations still marvel at the feat of Canada's early leaders who forged three transcontinental railways across the country. The cost of financing this effort almost bankrupted the country, and two of the three railways fell into receivership within 20 years of operation. The low population density and vast distances make the high fixed costs of surface infrastructure difficult to justify. In retrospect, the railway infrastructure investment paid handsome dividends because it opened a vast hinterland to settlement and economic development. Still 100 years later, Canada has yet to build a continuous four-lane highway from east coast to west coast, or a single paved road to the northern coast.

The purpose of this paper is to present an economic analysis of the airship option for re-supply in northern Manitoba. The current means of transport may not be the most efficient way to serve the North, but the prospect of shaving costs out of the transport system must outweigh the cost and risk of developing new airship technology. This paper addresses whether a cargo airship compete with the economics of conventional modes of transport.

Northern Challenges

Remote communities in Canada depend on annual sealift, winter roads and small airplanes for transportation services. These annual services are least expensive and necessary to transport heavy, indivisible, or bulky goods. These services are inconvenient however, even for storable cargo, because annual re-supply imposes significant inventory financing costs on buyers. Goods have to purchased and assembled in advance of transport, then inventoried for the balance of the year. Airplanes provide year round service for perishable and higher value goods that they can accommodate (typically less than 7 tonnes payload), but they are expensive. Perishable food product prices can be easily double the cost of the same goods in the south.

Construction of airstrips during the early 1970s improved the communications and services available to the remote communities in Manitoba. While some airports need upgrading, and few more need to be constructed, the long-term problem for aviation is the absence of replacement aircraft. Air service to the remote communities depends on aircraft that are reaching the end of their practical operating lives. Some airplanes have been identified that could be used, but they require longer runways and significantly higher freight rates to be economically viable in the North.



Significant distances are travelled to reach these broadly dispersed small population centres. Approximately 33,800 people live in 39 remote communities in Manitoba.

The Manitoba government spends about $5.5 million annually to build, maintain and operate over 2,000 kilometres of winter roads. The cost to build a winter road ranges from $2,000 to $3,000 per kilometre. Winter roads open in January and close during March each year. Most winter roads are a combination of ice roads built over frozen lakes with based portions built over muskeg or solid ground.

The cost of converting a winter road in to all-weather gravel roads is about $ 0.5 million per kilometre. For Manitoba, the cost of converting the winter road network would be about $1 billion in total.

Few kilometres of new all-weather roads are likely to be built in the North because the burden of sustaining the existing road infrastructure exceeds the financial ability of the Province of Manitoba. The Manitoba Government's 2020 Transportation Vision consultation process identified the following significant issues facing the existing road network:

- Rapidly aging highways
- Over 1/3 of the paved surfaces are rated poor
- Almost 1/4 of the bridges are at or beyond their normal service life of 50 years and need immediate repair
- Over 2/3 of the gravel surfaces are below standard
- Increased highway traffic and higher truck weights are impacting the road surfaces
- There are increasing restrictions on year-round RTAC/A1 routes

The 2020 Vision report estimates that 30 percent of the existing roads (4,600 km) need pavement rehabilitation, or reconstruction, at an estimated cost of $1.2 billion. A further 40 percent (5,100 km) need to improvements within the next 10 years at a cost of $1.1 billion. Given the backlog of deferred maintenance and reconstruction facing the existing highway network in Manitoba, residents in the North can expect only marginal improvements in the all-weather roads to their communities.[3]

Economic Development Limitations

The history of Canada is replete with examples of how the introduction of bulk transportation has underpinned the economic and social development of frontier regions. Had it not been for the river system in the fur-trading days, or the subsequent building of transcontinental railway, vast regions of this country would have remained undeveloped and its rich natural resources kept from market. Today, most of Canada's population lives in a narrow band that runs parallel to the US/Canada border. Only in this region do people and goods move freely and cost-effectively.

Much of Canada's vast territory remains underdeveloped, even though the availability of the ore bodies, forests and energy reserves are well known. Northern Manitoba is no exception. The prosperity and jobs that development of these resources can bring remain inaccessible. Resource based companies need reliable transportation to move in equipment and supplies, and to send harvested products to market.

Inuit leaders summed up the transportation demand in their remote territory in a recent Canadian Geographic article on the proposed construction of an all-weather road in Nunavut from Bathurst Inlet to connect with the winter road from Yellowknife.

[3] In 2004, the Province of Manitoba committed $37 million on improvements to the road network in the North. The largest project is a bridge on Provincial Road 374 at Pipestone Lake worth $10 million that will replace a ferry and provide all-weather access to the community of at Cross Lake.

> ***"The Two Charlies [Charlie Evalik and Charlie Lyall] see transportation not as problem but as the brass ring itself. If you provide the transportation links, they concluded several years ago, the mines will come."*** (Boychuk, 2004)

Approximately 30 active mineral exploration licences for activities related to metal, precious metal and diamond exploration are active in northern Manitoba. Companies such as Hudson Bay Exploration, Falconbridge Limited, BHP Billiton Diamonds Inc., Cominco Ltd, BEMA Gold Corporation and Anglo American Exploration, to name a few, have active exploration programs in effect. Like Nunavut, however, development of mining properties, and the jobs that follow, will only come if the mining companies can have a viable transportation link that will allow them to move their fuel and mine supplies in, and the ore concentrates out.

One of the most basic commodities required to support life in remote communities is fuel. Diesel fuel for power generation is loaded at fuel depots located in Winnipeg. An entire year's supply is shipped in bulk tanker trucks during the short winter road season. If a community runs out, emergency supplies are airlifted in at great expense. Lack of fuel for heating is not an option for life in the harsh climates of the north.

Bulk tanker trucks also transport Jet A fuel for aircraft and gasoline to supply cars, trucks and snowmobiles. All fuels are stored in tank farms located in the communities. For the most part, northern stores or independent fuel dealers operate the bulk storage sites.

Onsite inventories impose significant inventory carrying costs. For example, the Northwest Company delivers approximately 3.5 million litres of diesel to the 11 communities where it supplies fuel and maintains storage. If the inventory levels were reduced to a month's supply, the maximum amount of fuel that would have to be stored would be approximately 300,000 litres. The resulting reduction in carrying costs, assuming a fuel cost of $0.70/litre and an interest rate of 3.5 percent would be $80,000 annually. Another benefit of year round supply is the opportunity to manage fuel prices better by being able to purchase throughout the year rather than during a short window. Finally, the risks of environmental damage due to a major tank leak would be lessened.

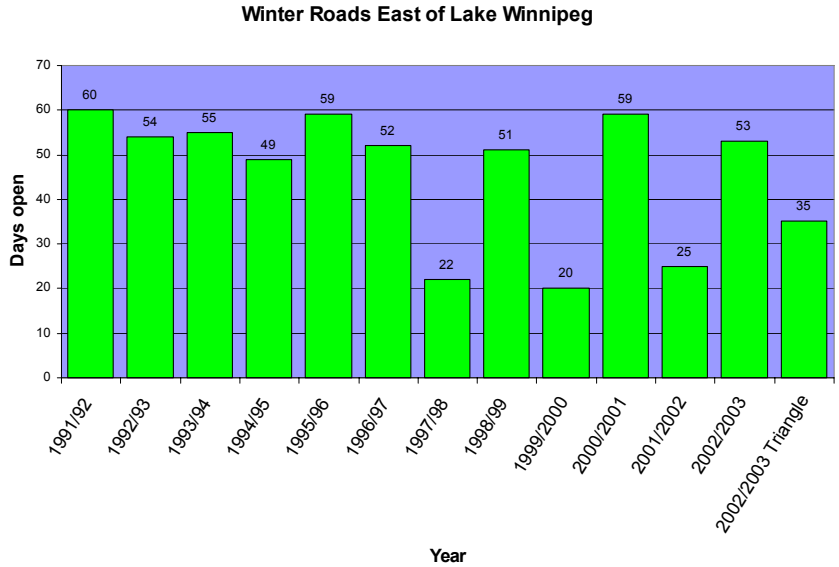
Winter roads are the lifeline for these isolated settlements providing them with access to storable goods, such as fuel, canned foods and durables. Winter roads also create employment for road construction and maintenance, and facilitate intercommunity travel. Transportation over winter roads is costly on a tonne-kilometre basis because of the low vehicle utilization and limited two-way hauling. Additionally, severe

weather affects reliability and adds an element of risk in terms of both safety and operational efficiency. In many years, some trucks layover until its safe to go back out on the road the following winter.

Climate Change

The supply of transportation services to the north has not changed greatly in the past three decades. Some refinements in the winter roads have occurred where sections have been re-routed to land and away from lake crossings. In addition, pre-fabricated wooden "Meccano" bridges have been installed over river crossings to cut the distances and improve the reliability of some winter road routes. On the other hand, the evidence of climate change is creating new concerns about the sustainability of existing transportation means.

The milder winters experienced in Manitoba are cutting the number of days that winter roads can operate in the province. Whereas 50 to 60 days of operation was the norm east of Lake Winnipeg prior to the mid-1990s, less than 30 days utilization is observed in half the years since 1997. Thus far, the problem is less pronounced further north, but the impact of climate change is expected to be greater there because the magnitude of global warming is accentuated in the higher latitudes. Warmer temperatures could make the sealift operations safer and extend their season, but this is of limited value in Manitoba that depends mainly on winter roads.



In 1998, due to mild weather, the winter roads serving the east shore of Lake Winnipeg did not open to full truckload freight, or in some cases, the roads did not

open at all. The average utilization in 1998 was 22 days compared to a normal winter when the roads would typically be available for 48 days, based on the average of the previous 12 years. As a result, communities that depend on winter re-supply to stock non-perishable items like fuel were at risk of having inadequate supplies. The Grand Chief of Manitoba requested assistance from the Province in coordinating the movement of essential goods into the affected communities. The Province contacted their Federal counterparts at Indian and Northern Affairs Canada (INAC) and developed a coordinated response through the Manitoba Emergency Measures Organization.

The outcome of this multi-level approach was to subsidize the cost of transporting essential supplies into the remote communities affected by air or partial truckloads. The terms of the subsidy were as follows:

> ***The ground haul subsidy rate was based on the difference between the cost of hauling freight on the winter roads and the cost of flying fuel into the communities (including the additional ground transportation costs). The cost of the aircraft was paid directly by the project management team. The fuel required by the affected communities is normally supplied out of Winnipeg. In this operation, the fuel was hauled by truck to Thompson, Red Lake or Lac du Bonnet and then flown to the isolated communities. The fuel was then moved from the community airport to its final destination by truck or helicopter.***

Table 1 presents a breakdown of the $12 million total cost of this program. The Federal Government contributed 98.4 percent of the funding requirement and the Manitoba Provincial Government contributed the balance, 1.6 percent. By comparison, the cost of this emergency program was approximately 10 times the cost of conventional transportation. This event serves to illustrate the potential risks and associated costs of having to rely upon winter roads in the face of climate change and the apparent warming trend.

Table 1 - 1998 Airlift Cost Breakdowns by Category

COST COMPONENT	TOTAL COST
Air Freight to Fly Fuel	$9,888,952.47
Air Freight to Transport Dry Goods	1,053,355.26
Truck Freight to Ground Haul Fuel	708,263.31
Project Management	381,898.39
Total Amount Spent	**$12,032,469.43**

Source: Province of Manitoba

Table 2 presents estimates of the impact of a warming trend in temperatures. Detailed statistical studies of climate change in the Berens River region have projected that warmer temperatures will reduce the winter road season by 5 to 14 days over the next 75 years.

Table 2 - Estimates of Winter Road Operations, 2020- 2080

SEASON	ROADS OPEN	SEASON DURATION
2020's	3 days later	5 days shorter
2050's	5 days later	10 days shorter
2080's	7 days later	2 weeks shorter

Source: Province of Manitoba

The warming climate trend has caused government planners to reconsider the viability of winter roads. Their response is to begin realigning winter roads over land to reduce their dependence on ice crossings that are no longer reliable or safe. The costs per capita of upgrading and maintaining these road systems is high because of the difficult terrain, including muskeg and multiple stream and river crossings, and the length of road that must be built to service a community of only a few thousand people.

Airships Economics

For the airships to be truly useful in addressing northern transportation needs, they must provide a better economic option to conventional transportation. Each of the following components affects the value of airships.

- ***Direct cost/benefit*** – typically comparisons between various transportation options do not take into account the infrastructure, such as the roads and bridges, which is provided by the state. Northern residents want all-weather roads because they feel that they are being held hostage by the high cost of airfares and the isolation of seasonal roads. Yet if these same residents were charged a full-cost recovery toll on roads based on the traffic flow, they might change their minds. Drivers act as if roads are free because someone else is paying for the infrastructure, specifically the various levels of government. If airships are capable of competing with existing passenger and cargo services on a direct cost basis, they become much less expensive than conventional transportation using a full cost accounting approach.

- ***Avoided costs*** - these costs relate to planned activities, such as the realignment of the winter roads, which may no longer be required if airships were available, or the inventory carrying costs, associated with having to stock a full year's supply of bulk and non-perishable items delivered during the winter road season.

- ***Risk related costs*** – this category refers to factors that are not controllable or predictable but must be responded to when they occur. Examples of these types of costs include fire suppression and the fuel airlift that occurred in 1998 because of an abbreviated winter road season. Containing the spread of forest fires that threaten communities is another emergency response mission that is costly.

- ***Foregone opportunities*** - some resource developments are impossible to develop and support using conventional road based infrastructure. The opportunity costs associated with the capabilities of a new technology need to

be considered. For example, energy companies exploring in the McKenzie Delta in the NWT must first build an expensive ice road to the drilling site before they can even begin to drill. One energy company spent $5 million to build a 73 km ice road that lasted only one winter season. Exploration companies are reluctant to explore for oil or minerals given such high costs for road access to exploration sites.

Advanced Technologies Group (SkyCat), AeroVehicles Inc (AeroCat), and World Aeros (Aeroscraft) have put forward catamaran-shaped hybrid airships for cargo usage. The catamaran design has several advantages that would favour its use in the North. They are amphibious and could operate out of the myriad of lakes in northern Canada. They do not require large landing crews, which in remote areas may not be available. They can operate without ballast, which may be difficult to obtain in the frigid temperatures of winter. This latter feature may also enable hybrid airships to serve support roles in forest fire suppression. Large quantities of fire retardants need to be applied quickly around communities endangered by the progress of large fires.

AeroVehicles has spent considerable effort modelling the economics of a 30-ton hybrid[4]. They have shared their cost simulation spreadsheet with the authors, who have adjusted it for this specific application. This costing model is modified to simulate a scheduled service to remote communities in northeastern Manitoba. It is clear that a larger hybrid airship would be more economic, but the 30-ton size may be an appropriate starting point for service in northern Manitoba. A similar analysis was conducted for the larger 150-ton version to examine these economies of size.

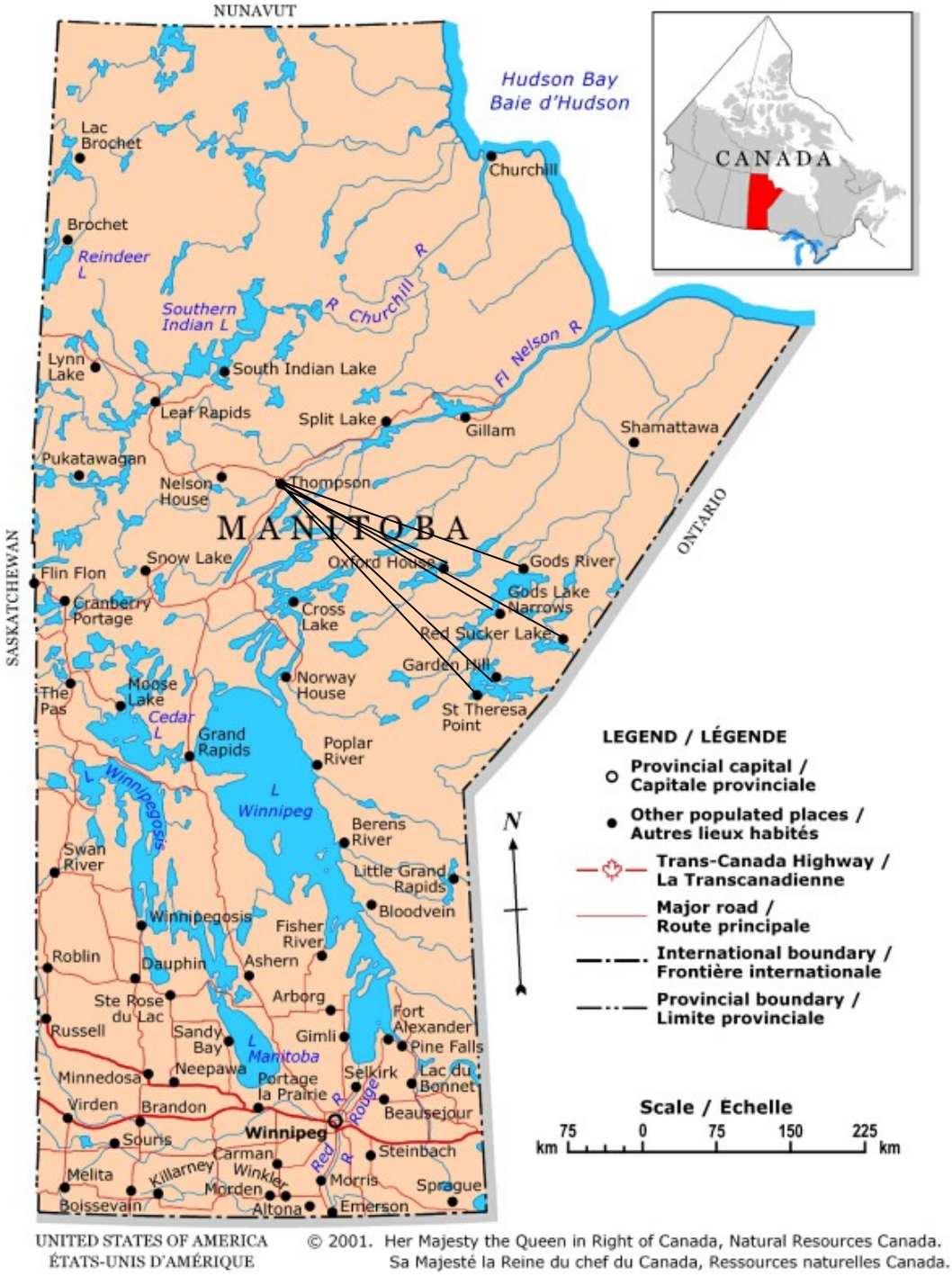
Logistics Plan

The Manitoba Government's 2020 Transportation Vision provides transportation cost information for a number of northern communities. Using this data as a benchmark, transportation costs for a 30-ton and 150-ton hybrid airship are developed and compared to the conventional winter road/airplane service. To simplify the analysis, the scope of the cost comparison focuses on a cluster of communities east of Thompson. The map of Manitoba illustrates the point-to-point routes from Thompson to the targeted communities.

The communities that are analysed do not have year-round rail, marine or all-weather road access. Thompson, which is the northern terminus Highway 6, was selected as the supply point from which the airship operations are assumed to be based. All flight costs are calculated on the basis of individual missions, in which the airship flies from Thompson to its destination and back. No backhaul freight is assumed available for the return trip. While point-to-point operation simplifies the analysis, a flight model with multiple deliveries would reduce empty miles of the return trip and lower overall costs. Consequently, the airship costs comparisons presented are overstated.

[4] This is also the size that was chosen by DARPA because it matches the payload of a C130 transport that is now used for cargo logistics by the US military.

Map of Communities to be served by the Hybrid Airship



The analysis assumes a combi-configuration for a 30-ton hybrid airship that includes passengers and freight. The vehicle is assumed to carry up to 18 passengers plus groceries and re-supply items. This passenger configuration compares with conventional airplanes currently serving these routes. However, the hybrid airship

could be configured to carry many more passengers if there is sufficient demand. Space is not a constraining factor for hybrid airship.

Frequency of flights is an important consideration for passenger service notwithstanding costs and capacity. In this respect, the 30-ton size is a better fit for passengers than a larger airship.

A profile of the remote communities is presented in Table 3. Some differences are evident between these communities. For example, Garden Hill/Island Lake seems to have a disproportionately high volume of freight and passenger demand relative to similar sized communities. These peculiarities are not addressed in the analysis.

Table 3- Profiles of Remote Communities

COMMUNITY	POPULATION	ESTIMATED ANNUAL FREIGHT	NUMBER OF PASSENGERS	NUMBER OF FLIGHTS
St. Theresa Point/Wasagamach	4,021	11,600	14127	6,061
Garden Hill/Island Lake	3,204	13,000	37,933	11,245
Red Sucker Lake	773	3,200	6,073	1,923
Oxford House	1,998	8,150	9,649	3,102
God's Lake Narrows	1,393	6,260	9,741	3,396
God's River	466	2,100	5,957	2,399

Source: 2020 Transportation Vision

The cost and operational assumptions for a catamaran hybrid airship are presented in Table 4 for a 30-ton and a 150-ton payload vehicle. All goods are transported by trucks on paved all-season roads from Winnipeg to Thompson, and then delivered by hybrid airship to the specific remote community. The trucking cost from Winnipeg, which is the main supply point for the north, to Thompson is estimated at $1,995 per 25 tons.

The analysis assumes that hybrid airship operate year-round, but fly only 285 days per year. Missing days are assumed for maintenance, crew rest and inclement weather. Having the ability to provide steady re-supply would provide shippers and customers with greater flexibility in how they manage their inventories. The avoided inventory carrying costs would be significant, but are not factored into the present analysis. Similarly, the annual costs building and maintaining the winter weather roads, airports and ferries are not included in this comparison.

Table 4 - Catamaran Hybrid Airship Assumptions

ASSUMPTIONS	ATTRIBUTES 30 Ton	ATTRIBUTES 150 Ton
Payload	30 tons	150 tons
Configuration	dual cargo passenger	same
Flight speed	70 knots or 130 kph	same
Fuel costs	$3.52 USD per US gallon	same
Operations	9 hours operation per day with 285 days of weather available flight conditions	same
Ground support	All ground handling and maintenance costs are included plus fees for airport landings	same
Routes	Point-to-point operations for Thompson based on one-way loads	same
Financing Purchase price Interest rate	C$40 million (US$30 million) 4.51 percent	C$150 million (US$112million)
Insurance	2.90 percent of hull value	same
Depreciation	80 percent straight line based on a 15 year useful life or 5.3 percent annually	same
Trucking costs Winnipeg to Thompson	$1,995 per truckload	same
Passenger airfare	Equivalent to fixed-wing scheduled air services	Not included
Profit and overhead	Administrative overhead of 5 percent and a profit factor of 15 percent of the estimated per flight costs	same
Crew costs	$2.7 million based on FAA requirements	same

Hybrid Airship versus Conventional Transportation Cost and Operations

Table 5 presents the cost comparison for a 30-ton hybrid used nine hours per day (flight time) for scheduled cargo/passenger operations. The conventional cost numbers used for comparison purposes are based on an assumption that 25 percent of the freight rate is for air movements and 75 percent of the freight would be moved by truck over winter roads. Conventional fixed wing airfreight is considerably more expensive than trucking. Moreover, the maximum payload of available airplanes is about 15,000 lbs, and the freight dimensions are limited by the door and cargo bay size.

On a direct cost basis, the 30-ton hybrid with passengers competes with conventional transportation costs in three of the seven communities shown. However, if the full costs of the publicly funded infrastructure, the lower inventory carrying costs and intangible benefits of the airship, such as the ability to handle bulkier transport, were taken into account, the 30-ton hybrid airship would be the clear choice for serving all of these communities.

Table 5 – Comparative Costs for a 30-Ton Hybrid Airship

DESTINATION	CONVENTIONAL COSTS ($/TONNE)	HYBRID NO PASSENGERS ($/TONNE)	HYBRID WITH PASSENGERS ($/TONNE)
St. TheresaPoint/ Wasagamach	$435	$671	$304
Garden Hill/Island Lake	$450	$676	$366
Red Sucker Lake	$500	$696	$550
Oxford House	$530	$591	$456
God's Lake Narrows	$500	$648	$502
God's River	$525	$650	$552

With a more detailed understanding of the conventional requirements and cost, a flight schedule could be designed that would optimize the use of the airship and enhance its cost/benefit. The hybrid airship could add flexibility to conventional transportation options that may further reduce some costs and/or make other transportation choices possible. For example, during the shoulder seasons when winter roads are not passable and barging is not possible, perishable items must be flown in. Hybrids could level the purchasing and re-supply requirements for the stores and perhaps allow the stores to stock items that cannot be flown in. The result is better food options for northern residents. In addition, the northern stores are able to reduce their inventories of non-perishable items and thereby reduce the prices to northern residents.

The cost comparison for the same freight movements using a 150-ton hybrid airship is presented in Table 6. A larger airship has economics that are more advantageous because the fixed costs are spread over more units of revenue. In addition, the variable costs of airships are non-linear and increase at a decreasing rate. The 150-ton airship is competitive without passengers and provides significant direct costs advantages as compared to conventional transportation options. This larger airship could fly a circular route that makes multiple stops without having to come back to the base empty to re-load. This would greatly reduce the number of “dead miles” flown on the empty return trip versus an out-and-back flight.

Larger airships are very competitive with conventional costs, disregarding any additional revenue that could be obtained from passenger transport. A 150-ton airship would need to carry all the freight currently moved to these communities, but at the lower cost, it would likely stimulate demand to exceed the single hybrid capacity.

Table 6 – Comparative Costs for a 150-Ton Hybrid Airship

DESTINATION	CONVENTIONAL COSTS ($/TONNE)	HYBRID NO PASSENGERS ($/TONNE)	HYBRID WITH PASSENGERS ($/TONNE)
St. Theresa Point/Wasagamach	$435	$301	N/A
Garden Hill/Island Lake	$450	$305	N/A
Red Sucker Lake	$500	$219	N/A
Oxford House	$530	$249	N/A
God's Lake Narrows	$500	$285	N/A
God's River	$525	$286	N/A

Observations and Comments

Hybrid airships offer some new transportation options that are simply impossible using conventional modes of transportation. For example, it may be possible to transport a fully equipped portable medical/dental facility between communities on a regular basis. This may allow government agencies to provide better quality and regular health care that would reduce the movement of residents to larger urban facilities for routine medical procedures. These portable facilities would be fully equipped with living quarters for the medical personnel making the local delivery of medical services possible.

New options for economic development become possible if access to cost-effective transportation is available. These options might include forestry or light manufacturing, which could be developed locally thus providing jobs within these remote communities. If the hybrid could make market access possible, it is conceivable that local job creating industries could be established in these remote communities. The need for transportation to support a new sawmill was raised during a meeting at Berens River that was part of the 2020 Transportation Vision consultations. The potential social and economic benefits of job creation could be substantial. Finally, affordable transportation may also provide the much-needed support to other new non-community development activities such as mining that would bring economic activity to the North.

The cost model assumes that all four engines are powered for the full trip. With a 10 percent loss in speed, two of the engines can be powered back to idle for cruising. This would greatly reduce fuel costs, and greenhouse gases, while not having a major impact on fixed costs. As well, the dual use passenger/cargo configuration for the 30-ton hybrid may be a very appealing option for daily scheduled service to these remote communities. If the costs of passenger service could be reduced by the cross-subsidization of cargo, many more passengers may decide to fly. This is consistent with the discount airlines model where reduced prices expand the market thus improving airship utility thereby allowing the carrier to offer low fares and still be profitable.

The basic economics of all airships, and especially hybrids, is that the larger the airship is, the better the economics become. Thus a 150-ton airship, which is the

equivalent of approximately six tractor-trailer loads, can move freight for considerably lower cost than conventional means. The numbers presented here are intended for illustrative purposes only and are presented to show the relative benefits of airships. Many simplifying assumptions have been made, but with a bias to err on caution. Optimizing route planning and airship payload sizes would reduce flight costs. Moreover, operating more than one airship would allow for better crew planning and ground handling. These issues aside, airships are a lower direct cost option to conventional costs of a mixed system of transportation modes.

Some interesting conclusions can be drawn from this preliminary economic analysis:

- A 30-ton hybrid airship could be competitive on direct costs and may offer significant advantages over conventional transportation options on a purely commercial basis. When the additional costs advantages and operational flexibility capabilities are factored in, the economic case for the hybrid airship becomes compelling.

- The ability to fly combinations of passengers and cargo increases flexibility and potential for hybrids in the north. Ideally, rates for passenger service can be reduced such that the costs of transporting people to larger urban medical centres for recurring medical treatments may be greatly reduced. Moreover, the passengers could be carried in beds with much greater comfort than on small airplanes. As airfares are reduced, it becomes more practical for people to fly thus reducing the isolation of these remote communities.

- The ability to use hybrid airship in emergencies for fire suppression, disaster relief and other non-recurring events may greatly reduce the burden on Provincial and Federal Governments. This could also help increase vehicle utilization.

- Cost effective transportation may make resource development feasible in areas that have no existing ground based infrastructure.

- The costing model assumes that FAA flight rules for airplanes are applied. The actual hours of service regulations for flight crews are likely to be modified because pilots can rest on board (bunks) and crewmembers can rotate duties in the same manner as an ocean-going ship. Fewer crewmembers, and correspondingly lower costs are likely possible once the industry is established.

Further work to develop a proper flight operations plan, and refine the cost assumptions for operating the hybrid are necessary to develop a proper business case to support investment in this industry.

Airships Make Sense for the North

Airships represent a breakout technology for the North. Aviation technology has developed such that airships can be fabricated mainly from existing off-the-shelf components. The airship industry is re-awakening and a ground swell of

manufacturing and customer activity is building. The mood has gone from "if" this technology will be available to a question of "when".

Airships are an enabling technology that can unlock the economic potential of northern Canada. They can do so in a way that is respectful of both the environment and the people of the North. The features of the airship that make it a solution to Northern transportation challenges are presented with a brief description of each point.

- ***Limited new infrastructure requirements***

  The hybrid airship is the infrastructure. Airships do not require airports and runways to be built, or upgraded. Many airships can land on any flat surface including water, ice, meadows, etc. Airships have tremendous operating flexibility to deliver a load to where it is needed. Currently, no other technology can deliver large or indivisible payloads to remote sites anywhere in the North without first having to build new infrastructure, including winter roads.

- ***Low utility challenges***

  Northern ground based infrastructure is challenged by long distances, low traffic volumes and limited support services such as fuelling and repair stations. Thus, the cost to provide these services on a per capita or traffic volume basis becomes exceptionally high.

- ***Flexibility***

  The transcontinental railway was built to serve an agricultural heartland. It was reasonable to expect that settlers would come and thereby create an ever-increasing need for the transportation system. Things are different with the non-renewable resources of the north. The climate is harsh and opportunities for new settlement are limited to the life of the natural resource. Thus, the transportation system must reflect its expected usage in resource extraction. Airships offer a high degree of flexibility. Unlike roads, which become stranded assets when the mine runs out, if the needs for an airship change, they can be re-deployed to a new location.

- ***Infrastructure scalability***

  Design capacity is a challenge often facing northern road or airport system planners. Usually systems are over-built for the initial volumes and possibly undersized for future requirements. Alternatively, roads for mega-projects, such as the McKenzie Valley pipeline, require high capacity during a construction period, which is greater than the subsequent base load. Planners must design a system that does not unduly affect the construction, or overbuild the system.

  Airships are easily scaled to fit changing requirements, and can provide peak load capacity. Airships could support an existing ground based system by

providing flexible incremental capacity to manage temporary demands. This could greatly lower the costs of bridges and alleviate transportation bottlenecks.

- ***High payload lift capacity and over dimensional cargo capability***

  Airships have the potential to lift payloads up to 500 tonnes and accommodate over-dimensional loads. The large cargo capacity makes airships an enabling technology. Likely, any airship greater than 150 tonnes could haul ore concentrates economically and permit mines to be opened without all-weather roads.

  Most other transportation alternatives in the North are non-competitive. Helicopters are expensive to operate and have a maximum payload of 10,000 lbs. Large airplanes are very expensive to operate and need long runways capable of bearing their weight. Barges are slow and work only if there is open water. Hovercrafts are noisy, limited by terrain and expensive to operate. Cargo airships have the potential to carry more freight, year round, at lower transportation costs than any of these other options.

- ***Multipurpose payload configurations***

  The scale of the airships allows for many different cargo configurations and dual-purpose uses. For example, airships can haul large cargo lifts while also providing passenger services. It is also possible that tourist cabins could be included that would enable over-night trips to be combined with scheduled services. The ability to configure for multiple uses improves the utility of the airship and very positively affects its operating economics.

- ***Environmentally respectful***

  Conventional development in the north requires construction of roads, bridges and airplane landing strips. These types of infrastructure are invasive and permanently alter the landscape of this fragile ecosystem. Airships leave only small footprints at regular destinations and no footprint in areas where they visit infrequently.

  Airships are very fuel-efficient so they produce less greenhouse gas emissions. Work on high altitude airships may also yield new solar energy collection films that can be combined directly into the airship's envelope to provide clean power.

  The risk of a major spill resulting from a truck breaking through the ice on a winter road is a serious hazard both to the environment and to the drivers. Airships operate in a safer environment and have high survivability. Even if they lose power, their buoyancy enables the airship to be landed safely with limited risk to the passengers or cargo.

- ***Year round operating capability***

  Much of the bulk transportation takes place when winter roads are able to provide access to remote areas. While winter operations are necessary, they present the worst type of operating conditions. The cold is hard on equipment and darkness affects productivity. Moreover, the heating costs to operate during very cold conditions are potentially very high.

  An airship would increase the connectivity of remote communities for economic and social purposes. Most northern operations receive their full-year supplies over a short period. This results in high carrying costs and, in the case of fuel storage, an increased risk of a large spill.

- ***Climate change risk mitigation***

  Climate change in the North is a reality. These uncontrollable changes introduce new risk elements and costs that negatively affect northern development (NRCAN, 2003). Existing surface transportation infrastructure needs to be re-thought. The necessary, but costly airlift of fuel in 1998 could be a harbinger of future expense. Winter road re-alignment is illustrative of monies spent to address the impact of climate change. The use of airships to support forest fire containment efforts is unproven, but could be very useful if climate change does lead to more droughts in the boreal forest areas.

- ***Socio-economic benefits***

  Taxpayers are paying a hefty premium to deliver goods and services to remote communities. This remoteness premium is paid directly through subsidies and social assistance, and indirectly through higher costs to deliver health care, education and other services.

  The dual passenger-cargo capability of airships could provide easier and less expensive access for northern residents who either wish to, or need to, visit a larger service center. Airships could reduce the remoteness premium added to the cost of delivering essential public services, and subsidies used to compensate for the economic isolation of these communities.

- ***Reduced transportation costs***

  The costs of building roads falls to the provincial and territorial levels of government, and are not included as part of the direct cost for providing transportation. The costs of building new roads to the North must be factored into the total transportation costs. Even the smallest entry point airship (30 tons) is economical compared to the direct costs of conventional transportation. Airships become even more attractive if the infrastructure is fully costed.

  Governments are being asked to invest billions in upgrading northern transportation systems to support economic development in the North. There

are strong financial reasons why governments should consider investing in the airship industry.

- ***Economic development opportunity***

  A worldwide market exists for heavy lift transportation. In Russia, the challenges of northern re-supply and transportation are as great as Canada's needs. Additionally, airships could improve the economics of many resource development projects, such as the energy development in the NWT and Alaska. Projects that are uneconomic with existing transportation technology, such as the Izok Lake mine in Nunavut, could become commercially feasible with airships.

  Primary resource industries are the foundation of Canada's economic success. They have also been the source of heartbreak when resources are exhausted and communities are abandoned. Airships could strengthen existing mining communities, like Thompson, Noranda and Yellowknife. These communities could become airship-mining hubs that serve many large and small mining camps in the manner of offshore oil drilling. The airships would ferry fuel and fresh crews to the mine, and return with ore concentrates and crews on leave. All the families, services and logistical supply bases could remain at the mining hub city, which is connected by road or rail to world markets.

Conclusions

Governments are responsible to provide and maintain access to northern and remote communities. The cost to sustain transportation services in the North is expensive. Consequently, governments have little choice but to pay a premium to deliver on their social and economic obligations in remote communities. Without reliable and cost-effective transportation access, the remoteness premium will grow with the expanding population of the North. Governments can choose to invest in the development of conventional ground based transportation infrastructure, but it is very costly to build and maintain. The other alternative is to channel some of this investment into assisting the fledgling airship industry to create a more sustainable alternative.

Hybrid airships present a completely new cargo transportation option for the North. No other means of transport is capable of filling the gaps that can be satisfied by airships. They are infrastructure independent and can land on water or any flat surface. Airships can carry large indivisible cargoes and load greater volumes of low-density products than any comparable transport means. If market demands change, airships can be re-deployed, and leave no stranded assets. Dual passenger/cargo configurations are possible and easily accommodated. Finally, airships are an environmentally responsible means of transport that add minimal impact on the land or air, and are capable of mitigating the instability caused by advancing climate change. Airships represent a technology breakthrough that has the potential to free the remote communities of northern Canada from their isolation and to transform their economy.

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WOODLAND CARIBOU AND THE WUSKWATIM HYDROELECTRIC PROJECT

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This document represents a short review of caribou biology, management, and the Environmental Impact Statement (EIS) pertaining to the proposed Wuskwatim hydroelectric project in central Manitoba. The primary focus is on those EIS sections explicit to woodland caribou, especially the Transmission EIS Volume 4 (Wildlife Environment) and Generation EIS Volume 6, Sections 7 (Terrestrial Environment) and 9 (Mammals).

Some features of caribou ecology

The single most salient aspect of caribou ecology and conservation may be space. Indeed, even though all caribou and reindeer belong to one species (*Rangifer tarandus*), two ecotypes are identified based on the extent of their movements and the space-use strategy of females at calving time. Bergerud (1988) distinguished between the migratory ecotype (long distance movements, aggregation of females at calving) and the sedentary ecotype (less extensive movements, over-dispersion of females at calving). The woodland caribou in the Wuskwatim project area belong to this sedentary type. This is part of the "boreal population" listed by the Committee on the Status of Endangered Wildlife in Canada.

The population densities of sedentary caribou tend to be low and relatively invariant. The median density of 28 populations in North America was 0.066 animals/km^2, and the majority (75%) were less than 0.12 animals/km^2 (Schaefer & Mahoney 2003). Bergerud (1992) suggested that sedentary caribou tended to stabilize at 0.06 animals/km^2. Unlike their migratory counterparts, where herds may show 100-fold changes in abundance (e.g., Mahoney & Schaefer 2002b), there is no evidence that sedentary caribou experience dramatic variations in numbers, unless perturbed by humans.

Caribou have immense requirements for space. Home ranges tend to be in the hundreds to thousands of square kilometres. In the Wabowden population, for instance, the average individual home range was 581 km^2 (Brown et al. 2000). Population ranges are considerably larger. The median area of sedentary populations in North America was 9,000 km^2 (Schaefer & Mahoney 2003). Moreover, studies have repeatedly shown that caribou require vast tracts of mature forest (Klein 1982, Schaefer & Pruitt 1991, Terry *et al.* 2000). In southeastern Manitoba, we concluded that forests less than 50 years old (following fire) were unsuitable for woodland caribou (Schaefer & Pruitt 1991).

These demands for space are most acute during calving and post-calving (from late May until late summer). Caribou females "space out", a strategy for avoiding predators (Bergerud 1996), such that they

occupy their entire population range during this time (Figure 1). It is hypothesized that the effects of disturbance may be greatest during this season, when young calves are particularly susceptible to predation (Harrington & Veitch 1992). Sedentary females also show strong fidelity to these calving and post-calving sites. Their occupancy is predictable from one year to the next; this is generally not true of winter locations (Brown et al. 2000, Schaefer et al. 2000, Ferguson & Elkie 2004).

There is a fine balance between gains and losses in caribou populations (Bergerud 1974). Females give birth to a single calf, but not in every year. Typically, much mortality occurs in the first few weeks of life (Mahoney et al 1990), such that the rate of recruitment (the number of additions to the adult population) tends to be low to moderate. To offset this limited capacity for increase, the survival of adult females is critical. It is imperative that survival rates remain high, at least 80-85% (Bergerud 1996, Stuart-Smith et al. 1997, Rettie & Messier 1998, Brown et al. 2000). Heightened mortality of adult females, due to predation or hunting for example, tips the demographic balance and causes populations to dwindle rapidly (Schaefer et al. 1999).

Trends in sedentary caribou populations

Woodland caribou are in trouble. In Canada, where they are deemed "threatened", nearly all studies have reported declining populations (Table 1), the recapitulation of a worldwide trend (Mallory & Hillis 1998). In Ontario, for example, forest-dwelling caribou have experienced a dramatic range collapse. Extirpated from one-half of their historic range, they have undergone a northward range recession of 34 km per decade since the late 19th century. If sustained, this implies virtual extirpation from the province before the end of the century (Figure 2; Schaefer 2003). Elsewhere in North America, woodland caribou have disappeared entirely from Vermont (the last caribou was seen in 1840), Prince Edward Island (1873), New Hampshire (1881), Maine (1910), Nova Scotia (1912), Cape Breton (1925), Brunswick (1927), as well as from Minnesota and Wisconsin (Kelsall 1984, Cumming & Beange 1993).

There is no doubt that we are to blame for these declines, although the precise mechanism remains elusive (Bergerud 1974). There is a clear, negative relationship between caribou persistence and human encroachment, whether expressed as the extent of roads (Figure 2), forest harvesting (Schaefer 2003), or a composite indicator. Laliberte and Ripple (2004) used a *human influence index* (which incorporates human population density, landcover changes, access by roads or rivers, and satellite imagery of electrical lighting). This index was compared to an Electivity Index of caribou where negative values indicate avoidance, positive values preference. Of the 17 species of large mammals that showed at least 20% range loss, caribou (and grizzly bears) exhibited the most pronounced sensitivity to human encroachment. With respect to human intrusions, areas of caribou disappearance are the mirror image of their persistence (Laliberte & Ripple 2004).

Anthropogenic habitat alterations bring with them a host of landscape changes that are known to be detrimental to caribou – increases in forest fire frequency, predation, parasitism, and hunting. Increasingly, studies have pointed to refugia from landscape disturbances and these associated factors as key to the persistence of woodland caribou (Bergerud and Page 1987, Seip 1992, Bergerud 1996, Cumming et al. 1996, Stuart-Smith et al. 1997, Rettie and Messier 1998, Nellemann et al. 2003, Schaefer 2003).

Caribou and industrial developments

The most compelling signal of environmental impact on wildlife is demographic, i.e., impairments to survival or reproduction. However, because of the long-lived, mobile nature of caribou, few studies have satisfactorily investigated demographic effects of industrial developments (but see below). Caribou biologists, therefore, generally have relied on the examination of differences in distribution or movements. Given the importance of space in caribou biology, I believe that these attributes are reasonable indicators of anthropogenic impact. For example, restriction of the movements or distribution of parturient females could conceivably compromise their "spacing out" strategy, leading to greater rates of predation, and population demise.

It is important to note that, when inferring impacts, "avoidance" of an affected area need not be complete; nor are anecdotes of animals crossing a corridor a demonstration of the lack of effect. Detrimental effects are demonstrated when use of an area is lower than expected (often determined from a before-after experiment).

There are growing examples of avoidance, well beyond the precise bounds of the landscape change. For example, Shane Mahoney and I (unpublished manuscript) recently investigated the response of caribou from the Middle Ridge herd, Newfoundland, in 9 years of clearcutting (Figure 3). Radiocollared females (but not males; see also Chubbs et al. 1993) exhibited a clear, negative response to clearcuts: they maintaining an average buffer of 9 km from active cutovers which continued to expand after harvest. Such a reaction is consistent with the effects of other anthropogenic landscape changes, where diminished occupancy within 1 km to 5 km is common, although it is occasionally higher, as much as 10 km, for females (Table 2). Dyer et al. (2001) considered their estimate of 250 m from roads and seismic lines as "undoubtedly conservative and a function of small sample size." What is clear is that the physical footprint of industrial developments underestimate the effective loss of caribou habitat (Dyer et al. 2001). In Norway, Nellemann et al. (2003) documented that power lines and roads, covering <1% of reindeer range, left only 25% of the area beyond 4 km of a power line or road.

Differences in this avoidance zone (Table 2) may reflect the degree of human activity associated with the infrastructure (Dyer et al. 2001, Mahoney & Schaefer 2002a, Nellemann et al 2001). This loss of habitat

is likely permanent, or at least long-term. In Norway, for example, wild reindeer showed no sign of habituation 6 years after development ceased (Nellemann et al. 2003).

The impact of power lines, in particular, was studied by Nellemann et al. (2001). In 6 of 8 years, diminished use occurred within 2.5 km of power lines (without any specific traffic related to them); density was 79% lower in the 0-2.5 km zone next to the lines versus the 2.5-5 km zone, and females were more sensitive than males. The authors noted that some of these lines were used by hunters and other traffic.

Linear corridors may also fragment caribou range. In Alberta, improved gravel roads with moderate vehicular traffic acted as a semi-permeable barrier to caribou movements, especially in late winter when crossings occurred at 19% of the rate expected (Dyer et al. 2002). Effects were also discernible during other periods; the impact was only marginally significant during calving. The response may depend on traffic volume, but altered caribou behaviour has been detected at as few as 15 vehicles per hour (in Dyer et al. 2002).

In addition to these space use changes, caribou may be at higher risk of predation in the vicinity of linear corridors. James & Stuart-Smith (2000) documented that caribou in Alberta tended to avoid corridors, and that deaths due to predation occurred in closer to corridors than expected. Wolves appear to capitalise on corridors as travel routes, increasing access to caribou range. Humans likely to do the same, but observations of caribou hunting mortality were too infrequent to test this hypothesis rigorously (James & Stuart-Smith 2000).

The Wuskwatim project

The foregoing discussion provides us with some insight of the potential effects of the Wuskwatim hydroelectric development. We can note, in particular, that:

– Caribou operate on broad spatial scales, and need to be managed at commensurate, landscape scales;
– Sedentary caribou appear to be among the most sensitive wildlife species to anthropogenic landscape disturbances;
– The impacts of the project on caribou, both the generation and transmission components, can be anticipated to extend beyond the footprint of the development *per se*.

I have some specific comments on some components of the EIS, below.

The HSI model

In the EIS, alternate routes for the transmission line were evaluated on the basis of caribou habitat types intersected within a 2-km buffer. The HSI approach has its limitations, some of which are acknowledged in the document (Appendix C). Although providing "objective and replicable evaluation" (p.53), the results might also be somewhat misleading. A few points:

– HSI was conducted at the stand level, an inadequate scale to predict caribou occupancy, which is a landscape phenomenon. Forest structure and composition are necessary, but insufficient, attributes for the persistence of woodland caribou. The factors not included in the model (predation, human disturbance, fragmentation; Appendix C, p.4) are often identified as the major limiting factors for forest-dwelling populations.

– The designation of immature forest stands with HSI value of 1 (Table 1-1) is not supported by the literature (e.g., Schaefer & Pruitt 1991).

– A more definitive assessment of alternate routes would be based on space use of caribou in the study area. For instance, evaluation would more convincingly be founded on the number of home ranges intersected by a potential transmission route or the frequency of caribou calving sites in a series of distance classes (up to 10 km) from the transmission route.

Effective habitat loss

It is concluded that both the transmission and generation components of the project will result in effects on caribou that are negative to positive, small, short to long-term, regional and insignificant. Losses due to habitat change are estimated at 0.27 caribou (Transmission EIS, Volume 4, p. 35) to 0.44 caribou (p. 41).

There is inescapable uncertainty with respect to the precise extent of these impacts, but current knowledge (Table 2) clearly implies that the project boundaries *per se* are insufficient. Negative effects on caribou, due to avoidance or heightened mortality, are likely to extend a few hundred metres or perhaps several kilometres. I have explored some plausible scenarios based on 100% loss due to the direct impact of reservoir, road, transmission lines as well as buffers of 250 m, 2.5 km, and 5 km (Table 3) . For simplicity, I assumed that the flooding from the reservoir was a circle of radius of 400 m. The results show a wide range of possible consequences: losses of 230 km^2 for the 250 m buffer, 2032 km^2 for the 2.5 km buffer, and 4073 km^2 for the 5 km buffer (Table 3). These impacts are all considerably larger in magnitude than the 31 km^2 directly impacted by flooding and clearing for rights-of-way.

Based on the density of 0.01 animals/km^2 (itself a rather low figure), these results suggest that population losses of 2 to 41 caribou (1-21% of the total population) due to diminished habitat from the project. These estimates would not include any mortality from hunting or the disruption of movements across these linear corridors.

Hunting mortality

Increased access by subsistence hunters and poachers would severely jeopardize the persistence of woodland caribou in the study area. As one of the measures to minimize this impact, it is stated that the "Province of Manitoba will be asked to establish a Wildlife Road Refuge under *The Wildlife Act*" (Table 10.7-3). I believe, however, some greater precaution is warranted. Given the clear, detrimental effects of over-harvesting on woodland caribou (Bergerud 1967), such a refuge should be considered a prerequisite, prior to initiation of project construction.

Adaptive management

Predictions of impact have been made. In my view, it is incumbent on the proponent (if this project proceeds) to follow through with testing of these predictions. Indeed, the adaptive management of wildlife, particularly for large-scale developments, means that each such project needs to be treated as an experiment. Long-term monitoring of woodland caribou would support adaptive management, such as the mitigation measures outlined in the EIS.

Baseline data, however, are crucial. Once construction begins, the opportunity for pre-disturbance information is lost forever, a major impediment to understanding (Nellemann et al. 2003). For caribou, such monitoring would entail annual determination of survival rates, movements, home ranges, calving sites (information which can be gleaned from radiotelemetry) and recruitment (which can be gathered from late winter aerial surveys). The benefits of the Wuskwatim project, if approved, must include more than just hydroelectricity. It should include enhanced understanding of the effects of such developments on sensitive species like woodland caribou.

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Table 1. Rates of population growth (*r*) of sedentary caribou in Canada.

Study location	*r*	Reference
Alberta	-0.04	Fuller & Keith 1981
Alberta	-0.12	Edmonds 1988
Alberta	-0.02	McLoughlin *et al.* 2003
Alberta	-0.08	Stuart-Smith *et al.* 1997
Saskatchewan	-0.05	Rettie & Messier 1998
Manitoba	0.17	Brown *et al.* 2000
Ontario	-0.15	MNR unpublished
Québec	-0.09	Ouellet *al.* 1996
Labrador	-0.22	Bergerud 1967
Labrador	-0.20	Schaefer *et al.* 1999

Table 2. Examples of avoidance distances by caribou of anthropogenic infrastructure and developments, as reported in the literature.

Infrastructure	Avoidance	Reference
Roads and seismic lines	250 m	Dyer et al. (2001)
Oil and gas wells	1 km	Dyer et al. (2001)
Power lines	2.5 km	Nellemann et al. (2001)
Hydroelectric reservoir, access road	3 km	Mahoney & Schaefer (2002a)
Power lines and roads	4 km	Nellemann et al. (2003)
Forest access road	2-5 km	Cumming & Hyer (1998)
Tourist resort	5-10 km	Nellemann et al. (2000)
Clearcuts	9 km	Schaefer & Mahoney (unpublished)
Clearcuts	11 km	Smith et al. (2000)

Table 3. Projected loss of caribou habitat under three scenarios of avoidance beyond the limits of the project.

Project item	Distance (km)	Width (km)	Area directly impacted (km^2)	Additional losses (km^2) with 250 m buffer	Additional losses (km^2) with 2.5 km buffer	Additional losses (km^2) with 5 km buffer
Access road	48	0.06	2.9	24.0	240.0	480.0
Reservoir			0.5	1.3	26.4	91.6
Birchtree to Wuskwatim	45	0.06	2.7	22.5	225.0	450.0
Wuskwatim to Herblet	137	0.11	15.1	68.5	685.0	1370.0
Herblet Lake to Ralls	165	0.06	9.9	82.5	825.0	1650.0
Totals			31.1	198.8	2001.4	4041.6

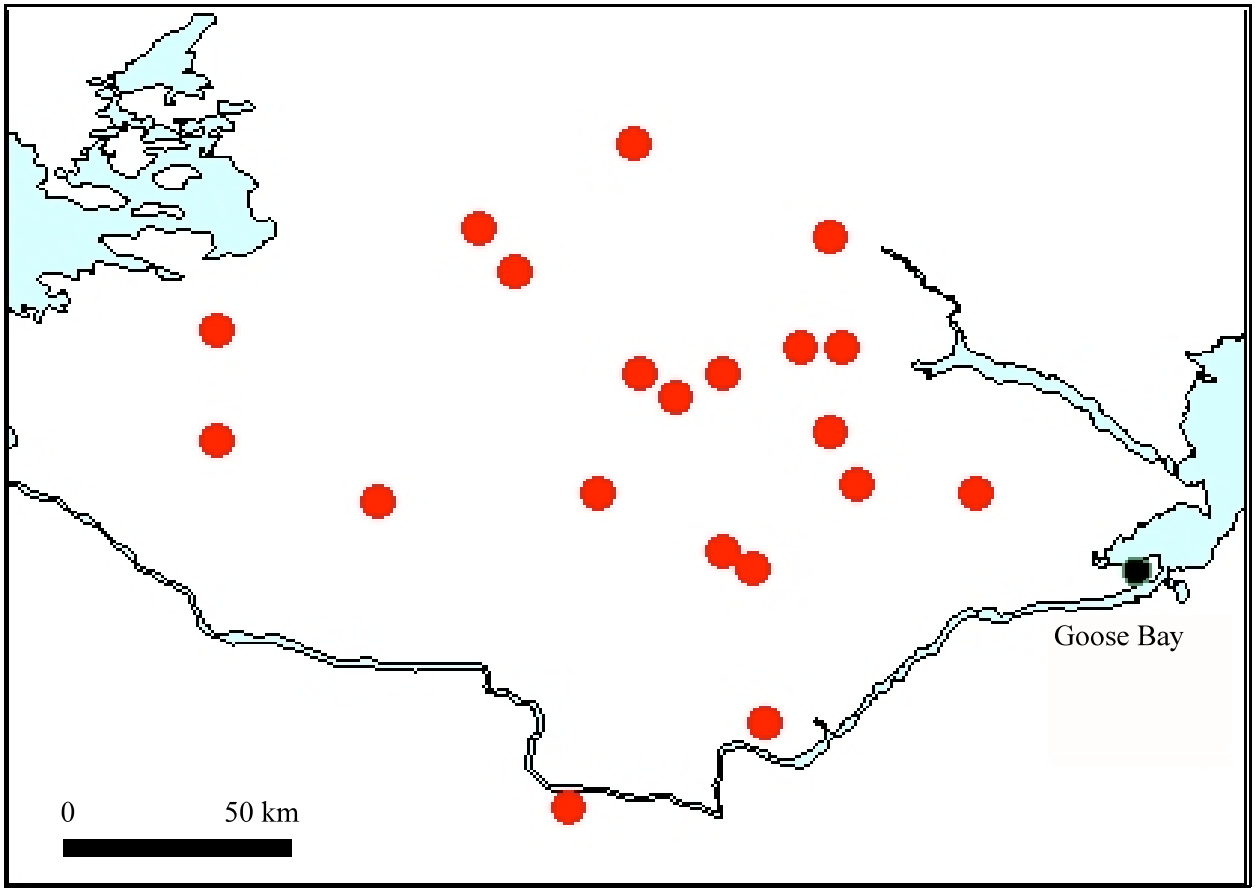

Figure 1. Over-dispersed calving distribution by radiocollared females of the Red Wine Mountains caribou herd, Labrador, 1984. (From Brown 1986, MSc. Thesis, University of Waterloo).

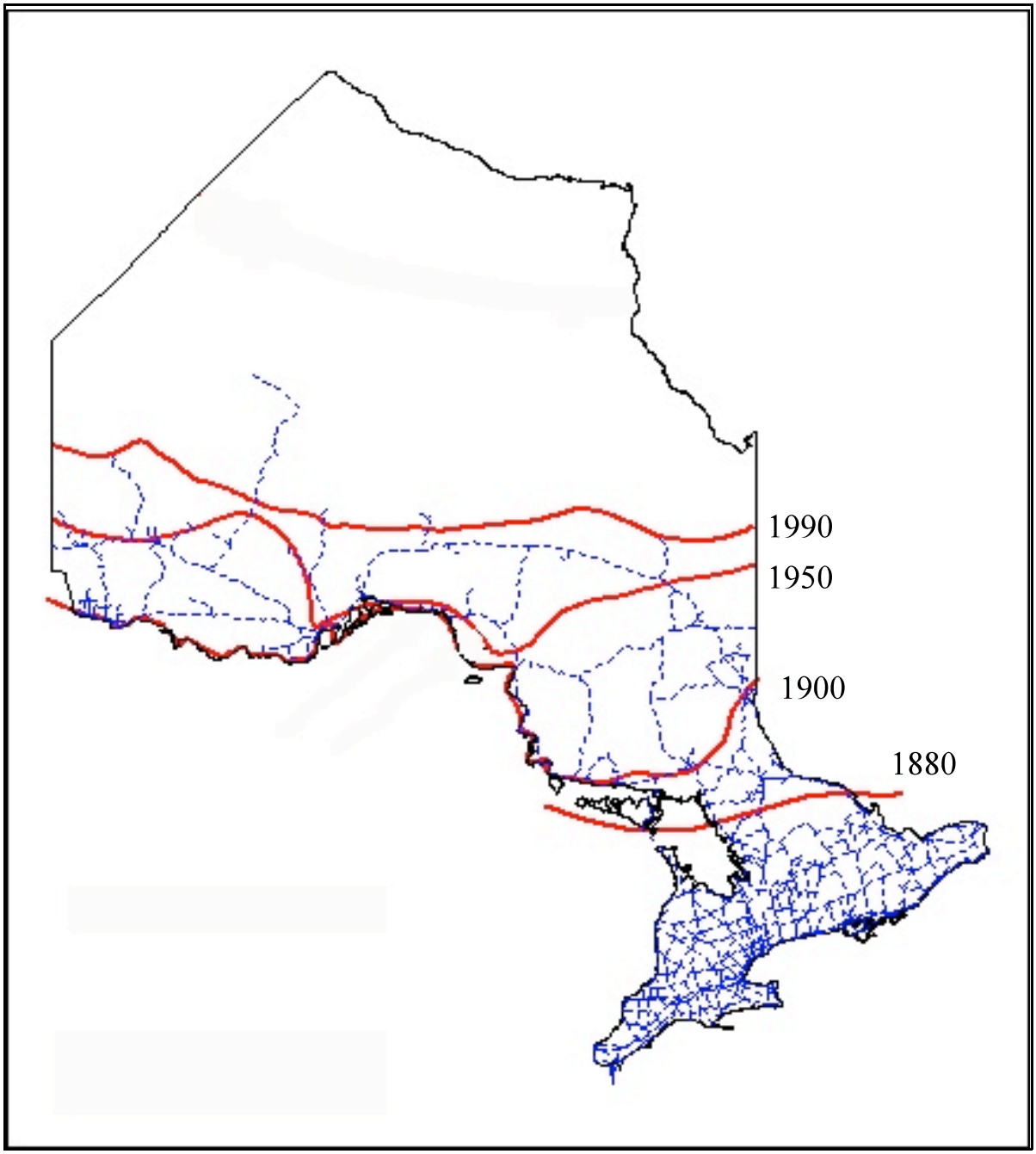

Figure 2. Caribou range recession in Ontario, 1880-1990 (from Cumming & Beange 1993), in relation to current road networks (dashed lines).

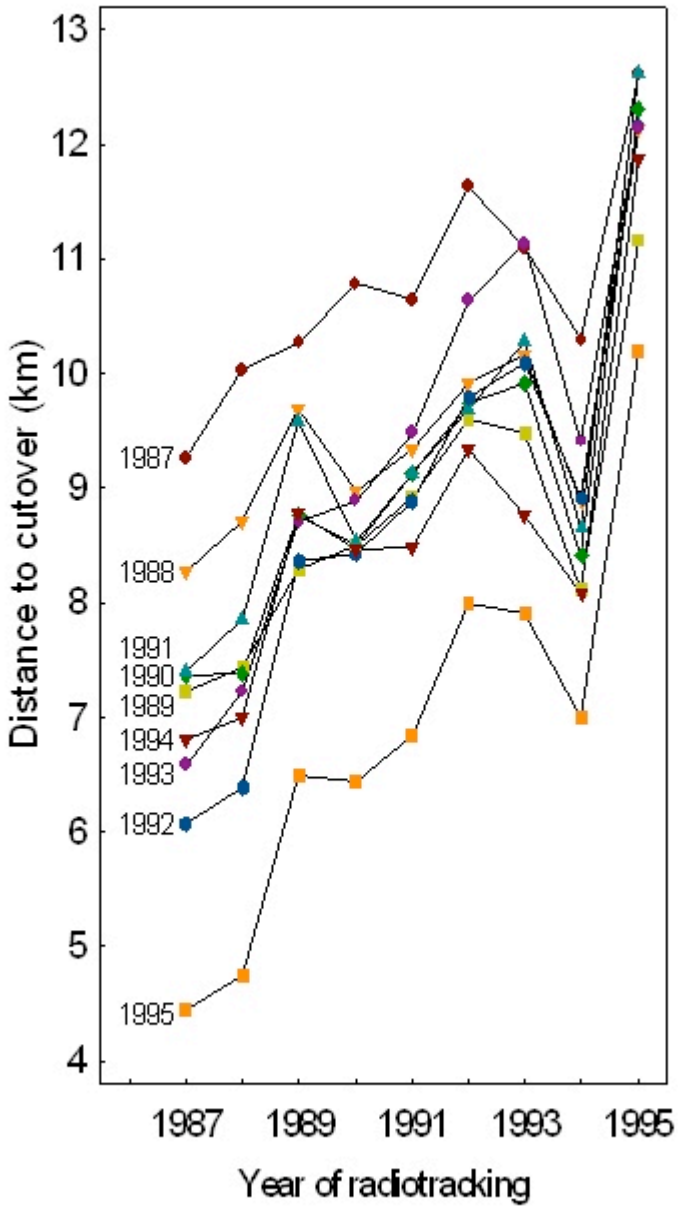

Figure 3. Progressive avoidance by female caribou of the Middle Ridge herd, Newfoundland, to cutovers, 1987-1995. Average distance to the nearest cutover of each age class is shown. (From Schaefer & Mahoney, unpublished manuscript.)