The Missing Newfoundland-Labrador Fixed Link

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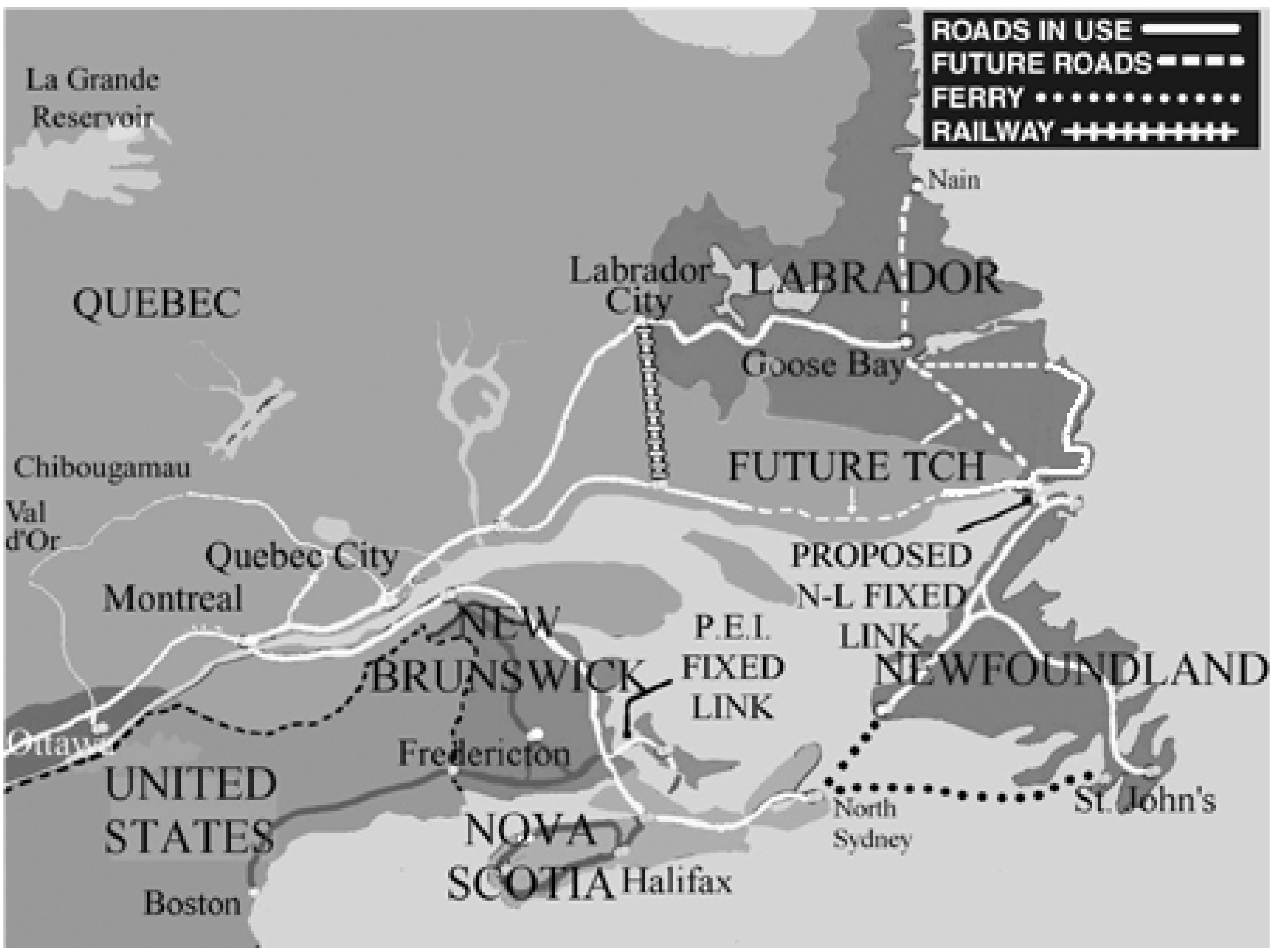
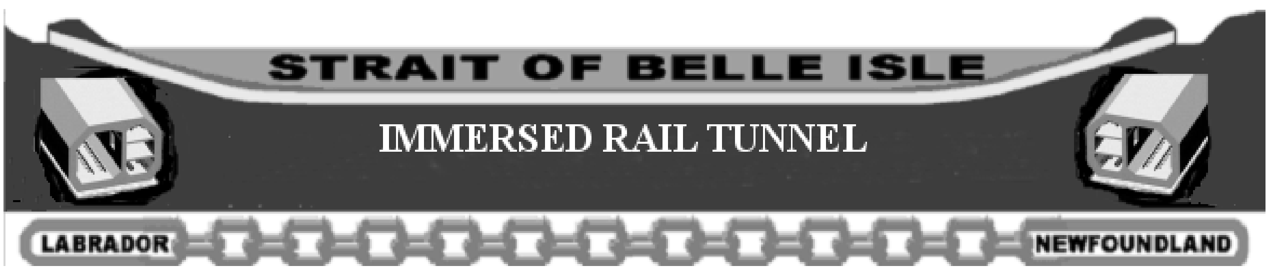


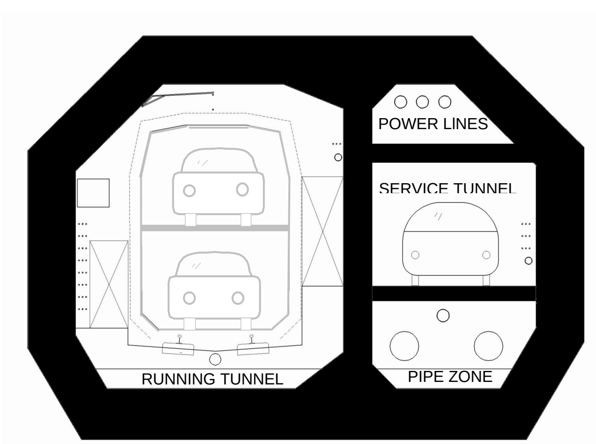
Contents Of This Submission

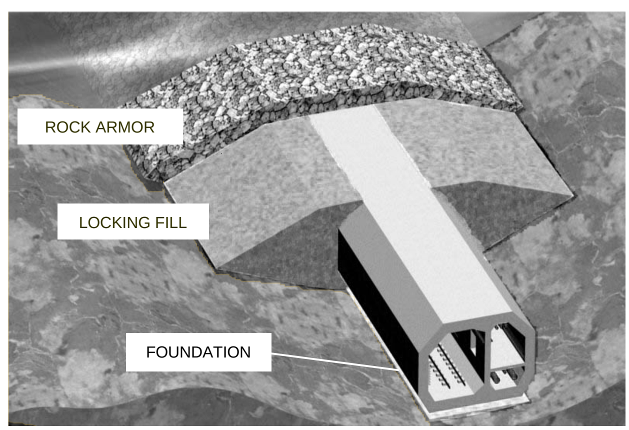
ABSTRACT

Only lack of 300km of Gulf of St. Lawrence North Shore highway and the missing Strait of Belle Isle fixed link now prevent a continuous Trans-Canada Highway, and 500,000 Newfoundland residents, their visitors and commercial vehicles from entering or leaving the Island except by ship or aircraft. These road travel gaps now cost Newfoundlanders in ferry tolls and lost time, import-export shipping costs, weak tourism, and no Labrador hydropower, an estimated $290 million/year. A rail tunnel across the Strait could carry all types of road vehicles, Labrador hydropower and piped fuel, and also significantly strengthen unity in both Canada and its easternmost Province. Its capital plus operating cost, subject to much-needed detailed study, can be only $70 million/year for 40 years.

Due to potential water inflows a bored rail tunnel may not be viable. Immersed tunnels consist of reinforced waterproof segments built on land, floated over and then lowered into a seabed excavated trench, joined to adjacent segments, and protected from ice-bergs and ships with a stone cover. The world has over 100 immersed tunnels. Like the bridge to Prince Edward Island, investors will tender to build, own, and operate the tunnel with income from tolls and government aid equal to current ferry subsidies for an agreed time, and then transfer it, debt free, to public ownership. Because a North Shore road and Strait of Belle Isle tunnel will provide a continuous Trans-Canada Highway and other vital benefits, both projects deserve the earliest possible federal-provincial studies.







IMMERSED TUNNEL ARRANGEMENT

INTRODUCTION

Canadian history is the chronicle of national and regional leaders who, despite many problems, continue to unite this nation from coast-to-coast-to-coast with roads, bridges, canals, railways, airlines, and tunnels as well as electric, communication, and pipeline networks. A recent example is the Confederation Bridge to Prince Edward Island. Vital remaining needs are a highway to end Gulf of St. Lawrence North Shore residents' land travel isolation, and a fixed link to unite Newfoundland and Labrador physically. These will also allow a continuous trans-Canada highway, and lower time and costs for return mainland road trips by Newfoundlanders, their visitors and commercial traffic by about 30%. The1975 Provincial government tried to bring Labrador hydropower to the Island in a *single-use* tunnel driven in rock. Costs and water inflow concern ended that project.

By bringing Labrador hydropower to Newfoundland rather than exporting it, the needed fixed link will create jobs within the Province. Road tourism will also be a major fixed link beneficiary. Recent terrorism in the U.S. and other world areas now adversely impact air and ship travel. Road tourism to stable, easily accessed areas like Atlantic Canada may benefit. The value of attractive access was demonstrated in 2001 when Newfoundland recorded 141,675 non-resident auto tourists, down 5.5% from 2000, due mainly to the necessity for ship transport of road vehicles. That year, Prince Edward Island welcomed 1,200,000 road tourists, a 60% increase since its Confederation Bridge opened in 1997. A North Shore highway and Strait of Belle Isle fixed link will benefit all Atlantic Canada because their visitor-users will travel via other Quebec or Maritime provincial roads.

In ferry tolls, import-export shipping costs, lost tourism, and no Labrador hydropower, the missing link now costs Island residents an estimated $290 million/year. A proposed immersed rail tunnel's $1 billion capital cost, if amortized over 40 years, plus operating charges could total only $70 million/year. Thus, Island residents are *now* paying about $220 million/year more than estimated annual costs to build and operate the tunnel.

The incomplete Trans-Labrador Highway, which originates in Quebec, is now the main Labrador West - Goose Bay supply road. Loss of the Lewisporte-Labrador shipping route will weaken traditional Newfoundland and Labrador ties. For Strait of Belle Isle north side residents to eventually access mainland highways, a North Shore highway is essential and the Newfoundland and Labrador government should support its earliest possible construction. But that government should also recognize the need for residents of Newfoundland to enter and leave their Island by road via the much-needed Strait of Belle Isle fixed link. That vital link will also assure the unity of that province's two major regions and help preserve their historic traditions, culture, and heritage. With new roads from Quebec to Labrador, and no fixed link, the people of Newfoundland and Labrador could pay a high price in losing effective management their natural resources to others.

The 1975 s*ingle-use* Strait of Belle Isle crossing experience and new tunnel technology suggest a *multi-use* immersed rail tunnel has most crossing benefits. Immersed tunnels consist of reinforced concrete or steel segments built on land. Complete segments are floated above an excavated seabed trench, ballasted and lowered to assigned sites in the trench, assembled, and covered with stone fill protection from icebergs and ships. The world has over 100 such tunnels. An immersed tunnel crosses the St. Lawrence River near Montreal. An immersed rail and road tunnel now links Sweden and Denmark.

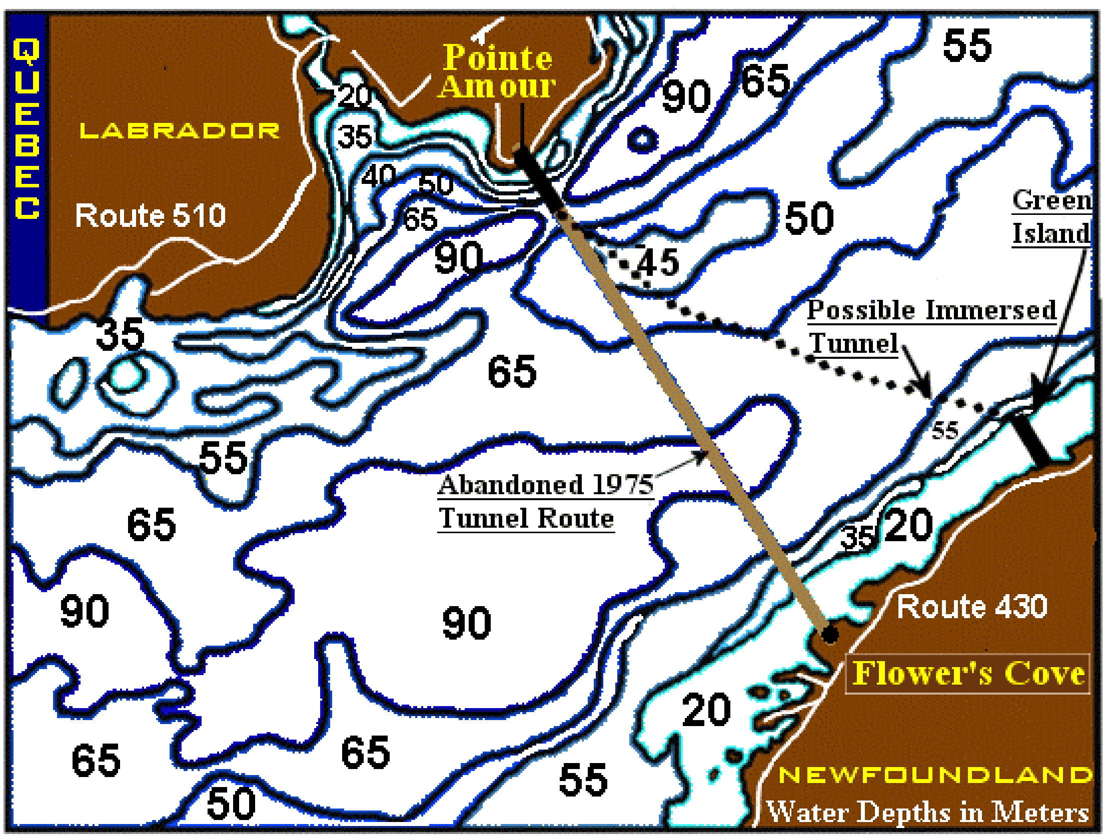
With low initial traffic expected across the Strait, a modest, electric-powered, immersed or bored rail tunnel can be designed to carry all types of road vehicles including large trucks and busses. As traffic grows tunnel capacity can expand. Newfoundland now has facilities at Bull Arm that, if modified, can build immersed rail tunnel segments.

Fixed link costs would not be paid from general taxation. Like financing the bridge to P.E.I., the Strait of Belle Isle-tunnel costs would be paid by users and investor/builders using the Build, Own, Operate, and Transfer (BOOT) financing system. This requires investor/builders to tender on project construction and temporary ownership based on revenue from user tolls and government aid equal to subsidies now paid to current ferry operators. At an agreed time, the link will be transferred, debt free, to public ownership.

To evaluate all fixed link options' benefits and costs, federal and provincial governments should jointly arrange for studies to assure that the final design will:
-- Comply with all required safety, emergency, environmental and operating standards;
-- Ensure that users and investors, not taxpayers, pay all capital and operating costs;
-- Profitably carry all types of road vehicles, large busses and heavy trucks;
--Transmit high voltage electricity and suitable pipeline commodities; and
-- Recover capital costs in 40 years with debt-free transfer to public ownership.

In brief, Quebec, Newfoundland and Labrador, as well as all Canadians urgently need the North Shore highway and Strait of Belle Isle fixed link. Both projects offer many construction jobs, lower travel and import-export shipping costs, improved road tourism, and new hydropower. But without a Strait of Belle Isle fixed link, the 500,000 people of Newfoundland Island in Canada's easternmost Province have by far the most to lose.

AREA DESCRIPTION



The Strait of Belle Isle separates Newfoundland Island, with an area of 110,710km^2 and a population of about 500,000, from Labrador, with an area of 291787km^2 and about 30,000 people. From Blanc Sablon in Quebec to Red Bay in Labrador, the Strait's west to east length is 100km. Its north-south width ranges from 17km at Point Amour to 25km at Red Bay. The hydrographic data on the map shown here need to be updated in much greater detail. The Strait is blocked in winter by floating ice. Icebergs from the Labrador Current can be seen till October. Relatively shallow depths restrict large icebergs. There are strong tidal flows from the Atlantic to the Gulf of St. Lawrence.

Precambrian rocks of the Grenville Province underlie this area and are cut by many fault and joint systems. Such systems are often associated with permeable breccias. These are overlain by Cambrian-Ordovician sedimentary rocks which, although gently inclined are displaced by NE-SW trending faults that have displacements of hundreds of feet. Solution cavities in this sequence are to be expected. As some of the fracture systems may still be active today, seismic risk must also be evaluated.

This ecosystem's land area is about 25% coastal wetlands with plateaus and Northern Peninsula uplands extending to 630m above sea level. The area has cool summers and cold winters. Mean annual temperature is 2.5^0 C, with 10^0 C in summer and –5.5^0 C in winter. Mean annual precipitation ranges from 900 mm to 1100 mm. Fog is common year round. Vegetation includes dwarf white spruce and mosses. Many birds use this coastal region for migration. Permanent habitat is provided for caribou, arctic hare, rock ptarmigan, Atlantic puffin, and geese.

The Strait's aboriginal habitation goes back to the end of the glacial period. As this area is the closest in North America to Europe, it was the first explored by Europeans. About the year 1000, Norse explorers built the first known European colony on the Strait's south side. After Cabot's 1497 voyage, a Basque whaling station was created at Red Bay. Spain, France, and Portugal built fishing communities on both sides of the Strait. Trans-Atlantic ships still use the Strait due to relatively short distances it offers to many ports in Europe. The Strait's north side has a road from L'Anse au Clair to Red Bay. On the south side, roads connect most communities. Passenger air travel and a seasonal ferry are available. On the Gulf of St. Lawrence North Shore, several villages are now seeking a connecting road link with Canada's main highway system. This road and the Newfoundland-Labrador Fixed Link could finally create a true Trans-Canada Highway.

FIXED LINK OPTIONS AND THEIR EVALUATION

To evaluate all potential fixed link options detailed study will be needed of Strait of Belle Isle environments, geology, shore areas, hydrography, tidal flow, seabed materials, ice-bergs, and many other items. Newfoundland experience on Hibernia's GBS (gravity based structure) for water depths similar to those in the Strait will be invaluable. The **Page 4** provisional option evaluation is submitted subject to proposed federal-provincial detailed studies. Criteria for a multi-purpose fixed link system should include:

-- Ability to safely and quickly transfer all types of road vehicles, including large busses, trucks, and passenger cars between Labrador and Newfoundland Island;

-- Ability to transmit high voltage electric power as well as oil and gas by pipeline;

-- Full provision of all required safety, emergency, and service needs.

Options evaluated in this paper are as follows:

BRIDGE: A bridge's major drawbacks are: 90m water depths, 17km length, icebergs, environmental impacts, floating ice, fog, high wind, and required repair due to salt water corrosion. Bridge piers can also be a hazard to ships, especially in unfavorable weather.

CAUSEWAY: Icebergs, tidal currents and need for a wide ship channel place major constraints on this option. Water depths, tunnel length, and floating ice as well as the area's severe weather also inhibit use of a full causeway. However partial causeways may be used on both sides of the Strait to reduce immersed rail tunnel length.

ALL TUNNELS: Tunnels in rock usually have lower capital cost. But porous upper rock formations may mean that blasted or bored multi-use tunnels here must be located deep within the seabed. Bored tunnels will require long and costly access ramps.

ROAD TUNNEL: Ventilation for gas powered combustion engine vehicles in a 17km long Strait of Belle Isle road tunnel can cause prohibitive capital and operating costs. Many individual drivers also mean high accident and vehicle failure risks.

ELECTRIC RAIL TUNNEL: Operating risks will be lower due to the absence of gas or diesel engine vehicles for rolling stock. Moreover, a rail tunnel's moving equipment is usually better maintained than that for many personal road vehicles. Well trained locomotive operators have a lower accident probability than that for many vehicle drivers.

IMMERSED RAIL TUNNEL: Immersed tunnels are usually designed to overcome specific crossing problems, like those in the Strait of Belle Isle. If the proposed Study Group decides on an immersed tunnel as the Strait's fixed link, it will be the world's deepest and longest, at 17km long and up to 70 to 80m deep.

PROVISIONAL CONCLUSION* – *IMMERSED RAILTUNNEL

Subject to detailed study, this initial Newfoundland-Labrador fixed link option evaluation suggests, that an immersed, multi-use, single-track, electric rail tunnel, able to carry all types of road vehicles, as well as transmit high voltage electricity and piped materials is a challenging but not insurmountable project. It would offer investors in a Strait of Belle Isle fixed link the most benefits at lowest cost for the foreseeable future. A list of the world's largest immersed tunnels is contained in the Appendix.

RAIL TUNNEL TERMINALS

If proposed studies select an all-weather immersed rail tunnel as the Strait of Belle Isle fixed link, double deck vehicle loading and unloading terminals would be required on the Strait's North and South sides. The graphic on **Page 6** shows a terminal arrangement for an eventual two-rail tunnel. The low initial traffic expected will only require a single rail tunnel. In the single rail tunnel there would be three trains. The number of cars in each train would be selected to meet traffic needs. One locomotive system could serve three trains. Normally one train will be in transit in the tunnel and the other two trains will be loading or

unloading at the two terminals. For example, when Train A is at the South Terminal being loaded with vehicles, as shown on the left side of the roadway; at that time, the loaded Train B is on its way through the tunnel from the North Terminal, while train C is unloaded at the North Terminal. When train B arrives at the South terminal the locomotive system will pick up Train A for return travel through the tunnel to the North terminal. With a single locomotive system there is no possibility for train collision. A train compartment for walk on and bicycle passengers can be included. Note the **Page 6** graphic's upper left corner for electric power lines as well as an area to load busses and trucks on suitable train cars for carrying those large vehicles through the rail tunnel.

FIXED LINK BENEFITS

Regional Benefits

NEWFOUNDLAND-- For travel to and from this Island, ships or aircraft are now essential. A North Shore highway and Newfoundland-Labrador fixed link will make all mainland roads accessible to over 500,000 Newfoundland residents and their visitors. Reduced time and lower tolls to access and leave the Island will make tourism to the Island and Labrador as well as all Atlantic Canada much more attractive than now. As much as 30% lower import and export shipping costs and use of Labrador hydropower on the Island will mean new jobs and economic opportunities for a united Province.

LABRADOR- A fixed link will mean new long-term hydropower, forest and mining jobs. Power exports offer only short-term jobs. A fixed link will bring shared goals, plans, resources, and pride in a joint heritage to the then physically united Province.

ATLANTIC CANADA- The fixed link will mean more circle tour options and many new long-term tourism jobs.

ALL CANADA- A Quebec North Shore Road and Strait of Belle Isle Fixed Link will enhance national unity, resource development, and true trans-Canada road travel.

Tourism Benefits

The proposed all-weather, Strait Of Belle Isle Fixed Link, when combined with a Quebec North Shore Trans-Canada Highway, offers significant benefits for truck, passenger car and other vehicle travel between Newfoundland and mainland Canada or the U.S. It can eventually offer visitors and truckers two routes to enter and leave Newfoundland. The first will be complete when the present Trans-Labrador Highway extends from Happy Valley-Goose Bay to Cartwright and then to the proposed tunnel. A second route will be via Quebec's proposed North Shore Highway and tunnel to Newfoundland. Road travel saved between St. John's and Montreal via the latter route, over current travel via Cabot Strait, is estimated at 230km plus a time saving of about 10 hours, a virtual travel day.

The fixed link will also benefit other Atlantic provinces, as many Canadian and U.S. tourists arriving via the tunnel will return via Nova Scotia and New Brunswick. Before current terrorism tensions, the World Tourism Organization (WTO) forecast that global tourism revenue would grow at 9.5%/year till 2010. It is assumed here that by the time the fixed link is operating (about 12 years) world tourism will return to WTO's forecast level. Newfoundland's current annual tourism growth is only 2% with 1999's revenue at $600 million (C). If Newfoundland's current tourism growth rate persists till 2010, revenue will then be $730 million. But if a fixed link increased tourism growth to only half WTO's forecast (4.75% per year) it can result in a 2010 tourism revenue of $1 billion or an added $270 million in that year alone. Without a fixed link, 2010 tourism jobs would total 31800. With a fixed link, tourism jobs in that year could reach 41650.

Construction Benefits

The Canadian Construction Association states that for every $1 million invested in non-residential construction, 15-20 direct and 45-60 indirect person-years of employment will be created. If the proposed fixed link capital cost is as estimated, $1 billion for 3.5 years, direct jobs per year for each of those years will be 4300 – 5700 and new indirect jobs will be 12900 -17100. It is not possible at this time to estimate new construction jobs for hydropower generation and transmission, road construction, and other associated work. But, it is reasonable to assume that the new jobs will total many thousands.

Reduced Shipping Costs

Newfoundlanders now import most of the goods they use or consume. Total retail sales now average approximately $5.0 billion/year*. In the estimate used for this submission it is assumed that 80% of all retail goods are imported, that the fixed link, when operating, will carry 50% of such imports, and resulting savings will be 3% of the total retail value. Using those assumptions, Newfoundlander’s annual fixed link savings on their imported retail goods could be about $60 million. Without detailed data, annual savings in using the fixed link to carry exports is assumed here to be the amount of $50 million/year.

Labrador Hydropower Benefits

With current data it is not possible to estimate all potential benefits from transmission of Labrador hydropower to Newfoundland via the fixed link. Newfoundland has only small amounts of undeveloped hydropower. With current oil price uncertainties, benefits may be substantial. Moreover, bringing Labrador hydropower to the Island would use local resources to create jobs in this Province rather than exporting them elsewhere. Need in the next ten years for new generating capacity in Newfoundland is estimated at 400MW. For a Fixed Link 40 year amortization period this is estimated to increase to 1500MW. It is assumed that transmission of this energy justifies a broad assumption in this initial analysis for a $20 million annual payment for services to a tunnel investor-builder group.

Other Fixed Link Benefits

The value of all Strait Of Belle Isle Fixed Link social, economic and other benefits can not be estimated in this initial analysis. For example, unification of Newfoundland and Labrador will solve jurisdictional problems between the Province’s two parts. Reduced shipping time and costs will also expand Canada’s Atlantic Rim trade. The main goal of this submission is to illustrate a need for a competent study group to conduct detailed studies of all potential benefits as well as costs and other meaningful considerations.

NO LINK COSTS

The following is a provisional estimate of current missing link costs.

Ferry tolls and time lost	$60 million/year
Import Shipping	$60 million/year
Export shipping	$50 Million/year
Costs of absent Labrador hydropower	$20 Million/year
Lost tourism revenue	$100 Million/year
Total Cost to Newfoundland residents	***$290 Million/year***
Provisional capital and operation costs	$70 Million/year
Provisional Current net cost of missing fixed link	**$220 Million/Year**

However, if new highways are built from Quebec only, the highest potential cost to Newfoundland and Labrador will be lost resource development management.

FIXED LINK COSTS & REVENUES

Estimated Capital Costs	**(Millions)**
Tunnel Construction (Over 3.5 years)	$ 500
Operating Equipment	50
Constructing Two Terminals	50
Management and Engineering	30
Total	$ 630
Escalation (11.9%)	75
Contingency (3.9%)	25
Direct Construction C	$ 730
Interest During Construction (3.5 years @ 7%)	150
Administration, Overhead and Miscellaneous	90
Total Capital Costs - $970 Million (Rounded for estimation purposes)	**$1000**

Average Annual Amortization Payments And Operating Costs	**(Millions)**
Payment on Principal.	$25
Payment on Interest	35
Operating and Maintenance Costs	10
Total Annual Payments and Cost	**$ 70**

Potential Revenue Sources & Average Annual Receipts

Vehicle Tolls (Initial Crossings 400/day; Max. 3000/day; Avg. 1500/day for 40 yrs @ $50/vehicle)	$27.5
Ferry Subsidy Offset.	10.0
Power Transmission Charges (Initial 400MW; Final 1500MW)	20.0
Negotiated Portion of Tax Revenue from New Jobs	7.5
Negotiated Portion of Increased Tourism Revenue	7.5
Annual Value of Natural Resource Transfers to Fixed Link Builder	5.0
Average Annual Total Revenues	**$77.5**

Even with the Trans-Labrador Highway still incomplete and difficult to travel, Quebec is now Labrador's major supplier by road. Detailed studies of a fixed link to preserve the traditions and culture of the Province of Newfoundland and Labrador are overdue and should have high priority to assure an enduring future for this Province within Canada.

FINANCING

This proposal recommends that investors (not taxpayers) will Build, Own, Operate and, after an agreed time, Transfer (debt-free) the proposed, much needed, multi-use Strait of Belle Isle immersed tunnel to Federal-Provincial governments. This BOOT method of financing the tunnel's capital cost is like that used to build the Confederation Bridge from New Brunswick to Prince Edward Island and other large infrastructure projects. These include Iceland's Hvalfjorour Tunnel near Reykjavik, and the combined bridge, artificial island, and immersed tunnel from Copenhagen, Denmark to Malmo, Sweden.

CONFEDERATION BRIDGE

Capital cost for the 12.9km Confederation Bridge was $730 million (C). It was financed by $660 million in guaranteed payment bonds, based on the Canadian Government’s former ferry subsidy, a contractor's $73 million letter of credit, and performance guarantee. Project finance charges as well as the construction partner’s return on investment and risk are paid from toll and other revenue after operating expenses. After 35 years the project partners will return the debt-free bridge to the Federal Government.

ICELAND'S HVALFJOROUR TUNNEL

Capital costs for this 5.76km tunnel, driven in sub-sea rock and opened in July 1998, were $98 million. None was underwritten by the state. Users are charged a toll to cover total capital and operating charges over twenty years, during that time it is owned by the contractor. After this, the tunnel will be transferred debt-free to Iceland’s government.

THE ORESUND DENMARK-SWEDEN PROJECT

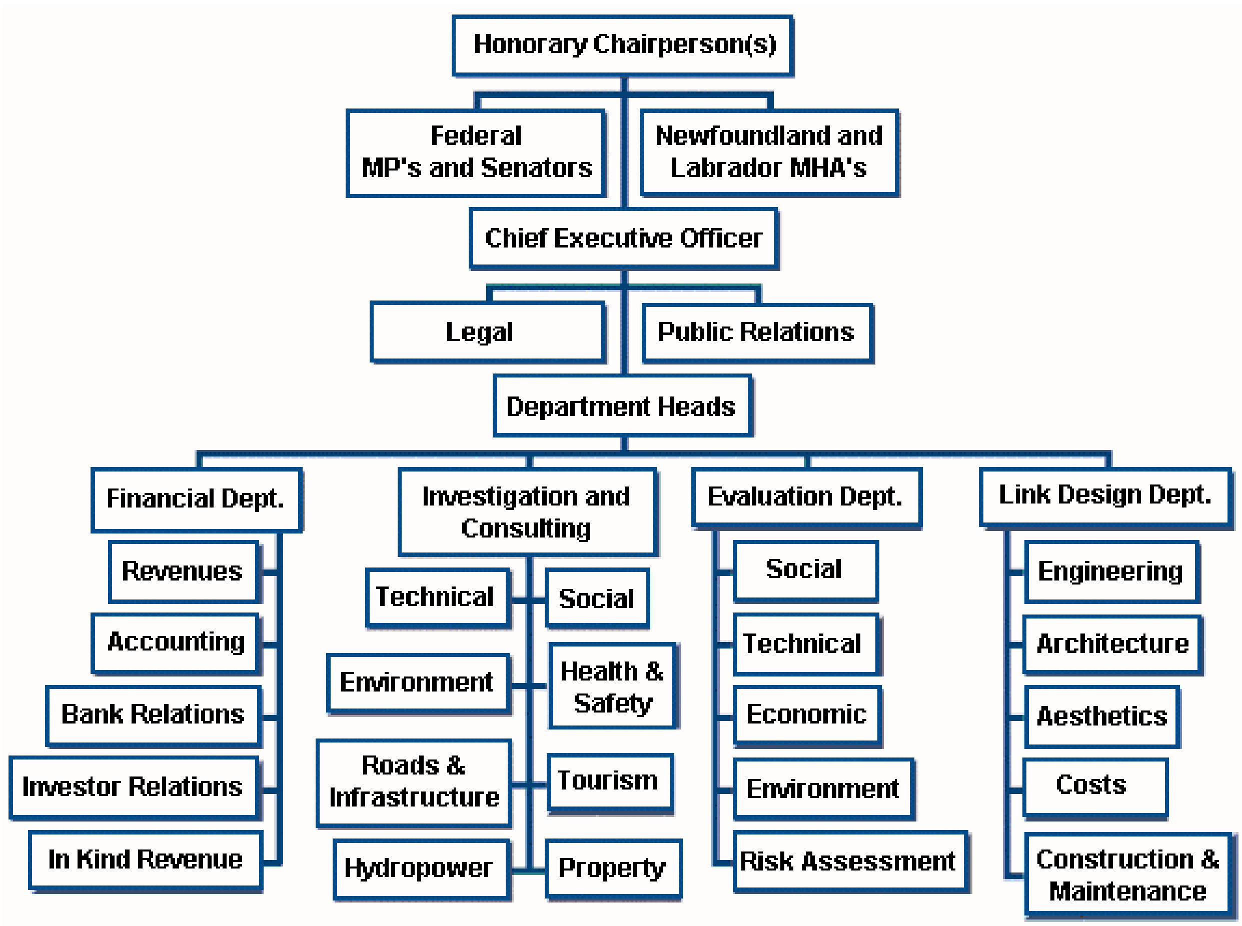
Capital costs for the Denmark-Sweden Øresund project (about four times the size of the Strait of Belle Isle Tunnel) amount to approximately $3 billion (C). This was funded by international market loans guaranteed by the Danish and Swedish states. Loans will be repaid from the link's user tolls and other revenues. Most revenue will come from motor traffic expected to be 11,800 vehicles per day over the first year and increasing at about 2% per year for the following 20 years. Rail operators will pay a fixed fee of $60 million (C) per year. The largest items of expenditure in the operational phase are interest and repayment of loans and operating costs. Loan repayment is expected to take 30 years.

Using experience at similar construction projects, a preliminary estimate of the Strait Of Belle Isle Fixed Link’s capital costs (amortized over a 40 year period at 7% interest), operating costs, revenue sources and profit projection is shown on page 8. All estimates are subject to revision by research to be conducted by the proposed study group.

REQUIRED STUDIES

Most Newfoundland and Labrador governments claim that one of their top priorities is creation of jobs. A Strait of Belle Isle fixed link can achieve this goal permanently. A first step to that objective is to form a Study Group to evaluate options and select a design for a safe, multi-use, fixed link that gains both public and investor approval. The need of Newfoundland and Labrador for such studies now is like that of England and France in 1957, when Europe restarted post war economies. An international Channel Tunnel Study Group then began detailed studies of options to end the need for ship transport of all road vehicles across the Channel. The Group’s 1962 Report led to 1993’s completion of the “Chunnel”. That Report can be a model for Strait of Belle Isle crossing studies.

This paper's goal is to encourage the governments involved to initiate a suitable Study Group. These governments and other appropriate sources would fund the Group work. It will employ competent individuals with leadership experience in legal affairs, design, engineering, and construction management. Its mission will be to evaluate all options for a permanent, multi-use link to safely transfer all types of road vehicles, electric power, and other suitable commodities across the Strait of Belle Isle and assure social, economic and other appropriate benefits for the Provinces involved and all Canadians. The Group will select a design that most effectively satisfies approved environmental, safety, and socio-economic criteria and report as required on its progress. A provisional Study Group organization chart is proposed below.



Fixed Link Study Group Organization

TUNNEL ENGINEERING

The proposed fixed link crossing poses significant, but not necessarily insurmountable, engineering challenges. This paper focuses on an immersed tunnel solution for the fixed link. The alternative of a bored tunnel solution is also compared. The key issues to be considered during any future study are described below.

Tunnel Location The fixed link's minimum crossing length can be 17 - 18 km depending on preferred landfall location. The line for the 1975 route was between Pointe Amour in Labrador and Flower's Cove in Newfoundland at the Strait's west end. For an immersed tunnel, the ideal route will minimize tunnel depth below the Strait surface. Previous immersed tunnels have been constructed at depths of 20 - 40m compared to the 65m (or possibly greater) for the Strait of Belle Isle fixed link.

Inclusion of causeways, viaducts and cut and cover tunnels at landfall approaches will reduce the total immersed tunnel length and relieve some production pressures on the tunnel's critical activities. An immersed tunnel length of 16km is assumed in this paper.

Placement of an immersed tunnel requires controlled dredging of the seabed, accurate alignment of the submerged tunnel segment being placed and its effective jointing with the previously placed segment. The depth of the seabed, water current velocities, and surface weather conditions affect the amount of control that can be sustained during these operations. It also constrains the type of technology that may be employed during the marine phases of tunnel construction.

Tunnel Arrangement A potential tunnel configuration is on Page 2 This arrangement comprises, firstly, a dredged trench for placement of the tunnel beneath the seabed horizon so as to avoid hard impacts from sunken ships, dragging anchors and icebergs, and to mitigate erosion of the tunnel foundation by seabed currents.

The tunnel is supported on a foundation layer of either a uniform bed of sand fill - pumped beneath the tunnel after positioning in the trench, or a gravel foundation onto which the tunnel element is lowered. Leveling of the gravel bed by an automated traveling screed rail can be achieved to a high degree of accuracy so as to minimize any differential stresses resulting from uneven founding surfaces. For deep marine tunnels, gravel foundations are more appropriate.

Around the tunnel, granular fill (locking fill) establishes the tunnel structure within the seabed material. Above this, rockfill armour is placed to resist scour and to distribute accidental loads. The armour and backfill materials are also used over the tunnel to provide permanent negative buoyancy. Variable grading of materials can be used to resist migration of fill materials through the rock armour under seabed current forces.

Tunnel Configuration The tunnel is proposed to be a multi-use tunnel incorporating a single-track standard gauge railway and secure spaces for the transport of power and/or fuel such as oil or gas. An initial tunnel concept shows the partitioning of the railway and fuel lines within separate bores of the tunnel. Due to the length of tunnel required, it is proposed that a service tunnel space is provided to allow maintenance and emergency access throughout the tunnel length.

Normally, long railway tunnels have means of access and escape to and from the main rail (running tunnel) bore. In the event of an emergency such as fire, the train may be required to stop at any point in the tunnel. Train evacuation is facilitated by provision of an emergency walkway to one side of the tunnel, and intermittent cross-passage doors giving access to a place of safety, – in this case the service tunnel. International standards normally require cross-passages at maximum spacing of around 250m.

During a running tunnel gas or fire event, evacuation to the place of safety must be supported by an over-pressure of air in the place of safety such that smoke does not creep into the safe areas. For a long tunnel such as this, over-pressuring the full service tunnel may be inefficient. An alternative solution can be to provide automated bulkhead doors within the service tunnel at 500m spacing so that during an emergency evacuation, any and only two, adjacent compartments of the service tunnel can be provided with local over-pressure. The tunnel cross-section also accommodates a track-level access space on the opposite side to the emergency walkway so that emergency and maintenance personnel can access both sides of the train and its undercarriage.

Although only single-track running is envisaged, it is possible to provide short sections of double track tunnel. This will allow two-way track running at passing places, and/or provisions for temporary train siding facilities for train failures or storage of train maintenance vehicles or emergency rolling stock. The length of double track sections will be determined from analysis of optimum train length and headway times.

Tunnel Design Tunnel structural design requires particular consideration of: hydrostatic loading at significant depth; effects of very cold ambient temperatures (-35°C) during construction, transient wave and dynamic loading during long-sea towing; exceptional internal loads due to fire, explosion, derailment or flooding; high current loadings during sinking and placement; possible seismic or seabed displacement loadings during operation (the tunnel is located in a highly faulted zone with large fault throws although the area is classed as a very low to low seismic zone in Canada's National Building Code); sediment overburden loading; and ice compaction and snow loads during storage.

It is envisaged that a reinforced concrete tunnel will be employed. Steel immersed tunnels also require large volumes of concrete for final ballasting and significant quantities of this can be required close to the final tunnel location during the sinking process, and as such the method is largely impractical for a long sea crossing. Consequently, the concept is not currently preferred.

For the waterproofing of concrete immersed tunnels two basic approaches can be adopted. The first type incorporates an external waterproofing membrane to the tunnel perimeter. This may be formed by a steel membrane, spray applied synthetic material, rigid plastic or combinations thereof. The consequence of providing a membrane is that each tunnel element needs to be of rigid continuous construction so that multiple membrane and sealing joints are avoided, and reinforced such that large flexural strains in the membrane and tunnel structure are avoided.

Alternatively, each tunnel element may be formed by a series of articulated sections – normally around 20m long – without any external waterproofing membrane. In this case each tunnel element is required to be temporarily pre-stressed lengthwise so that it may be maneuvered as a single item. After placement in the seabed trench, the pre-stressing is cut to allow natural bedding and articulation of the tunnel segments. This reduces flexural stresses, which may lead to structural cracking and leakage. Under some situations, the pre-stressing may be left in place.

For long-sea towing, either type of tunnel is expected to be longitudinally pre-stressed to resist the large forces arising from wave actions. The advantage of the latter method is that material quantities and therefore costs are minimized. The disadvantage is that very careful control is required to prevent cracking of the tunnel concrete during casting.

Typically tunnels are designed for a notional design life of 100 or more years. This calls for high quality control of the materials and workmanship, and rigorous consideration of design parameters for detailing concrete and reinforcing components. Many standards and codes of practice exist for implementation of these criteria. In the case of immersed tunnels, the structure is exposed to highly aggressive seawater with its high chloride (salt) content. Interestingly, this aggressivity is partly mitigated by the low temperature and low oxygen content of the deep seawater itself, as these reduce the rate of the chemical reactions occurring in the corrosion process. Also, to mitigate steel corrosion rates, marine structures can be equipped with cathodic protection systems. Provisions for any future activation of these systems can be readily incorporated.

Tunnel Construction It is envisaged that the dry-dock casting yard facility for construction of tunnel sections will require a base area of at least 110m by 200m to accommodate concurrent construction of four 167m long by 12m wide by 8.5m high tunnel elements. In the casting yard, tunnel-concreting works will require protection from the severe cold ambient temperatures. This may take the form of temporary enclosures, for vulnerable stages of casting, or a complete enclosed environment. The latter option has the disadvantage of being difficult to incorporate into the batch casting process required for the project. Incremental launching of tunnel sections from a permanent casting factory may satisfy these special constraints. This method was successfully used on the recent Õresund immersed tunnel between Denmark and Sweden.

Marine Works The particular issues that will need to be addressed for marine working include: the procurement and operation of deep dredging equipment; the accuracy and maintenance of the foundation at depth and under high current flows which may deposit marine debris into the working area; and the operation of equipment such as hydraulic jacks used to pull the segments together.

Some of these operations normally require the support of divers to make inspections of the trench and tunnel seals and to operate the closure jacks. The length of the working shift for divers is dependent on the water pressure and temperature. For this tunnel, special facilities, equipment and working regimes for divers will need to be investigated to demonstrate the practicalities of the immersed tunnel method.

Similarly, specially developed automated equipment and remote monitoring technology is likely to be required to supplement these operations. Although this implies a higher cost premium than normally expected for immersed tunnel construction, some reassurance may be derived from obvious success of the oil industry in comparable conditions.

One of the most severe challenges arises from the Strait's climatic conditions. Typically, the Strait freezes over between January and May. This leaves only six to seven months available to perform dredging, sinking, placement and backfilling of tunnel elements. Because of the length of the tunnel, it is envisaged that tunnel marine working will need to be spread over three years. This means that between successive working seasons, the tunnel will be exposed to the winter submarine environment prior to resumption of seabed construction activities. Development of methods for subsequent exposure of the last tunnel placed, and continuation of adjacent dredging activities will be required.

Other uncertainties which will need to be resolved include: the survey of seabed levels, as well as salinity and current magnitude and stratification; location of shipwrecks and ordnance; impacts of construction on marine ecology; impacts on marine traffic; and the depth and composition of seabed deposits for potential route options. In the latter case it is expected that the seabed could vary from soft marine deposits to exposed rock.

Normally, immersed tunnels are constructed in soft marine deposits, and the presence of rock will affect the difficulty of dredging. Ideally, the seabed should consist of firm materials which can be dredged by cutter-suction equipment, and such that steep marine slopes can be excavated, which both minimizes the amount of material to be removed and the amount of sediment that could be re-deposited in the dredged trench by the deep current. If very hard founding rockhead or large boulders are present then marine blasting may be required. The feasibility of this technology at depth and the impacts on marine life will need to be addressed in deciding the preferred route option.

Other key marine activities include the provision of an easily re-usable casting yard for tunnel units, a marine storage and fit-out area for completed sections, and long sea towing equipment and routes. The recently constructed Hibernia offshore gravity base platform fabricated at Bull Arm, Trinity Bay, Newfoundland, demonstrates that relatively local facilities can be provided. Although much of the facility has been dismantled, the re-use of the site has some potential for tunnel dry-dock construction, and the Trinity Bay area has potential for temporary storage of tunnel elements prior to towing to the Strait of Belle Isle fixed link – a distance of some 500km. Towing could be achieved within two weeks at a speed of 2km per hour.

Bored Tunnel Alternative Any fixed link study must consider a bored tunnel alternative. Tunneling by drill and blast methods are considered impracticable due to the depth of sea overburden and permeability of underlying bedrock. The abandonment of shafts for a cross-strait mined tunnel in the 1970’s demonstrates these difficulties.

Many deep submarine tunnels have however been driven by mechanized methods – i.e. Tunnel Boring Machines (TBMs). The single most important factor affecting feasibility of a deep rock TBM tunnel is the potential risk of high water inflows at the tunnel face. Such inflows constrain the ability to change the TBM cutters at the front of the drive. Uncontrolled, high inflows at high pressures can render this method infeasible. The use of ground treatment at the TBM face can mitigate the difficulties, but the deeper the alignment, the less practicable this becomes if there is a high degree of connectivity between the surrounding groundwater and the sea.

The depth of any Strait of Belle Isle bored tunnel could lie between 90 and 130m below sea level depending on geological conditions and the elevation of a suitable tunneling rockhead for preferred alignment. High groundwater pressures must also be resisted by the TBM and tunnel lining seals. In particular, the seals between the TBM and the concrete segmental lining must be assured. Typically, this seal is achieved by a series of wire brushes with grease infill between. This type of seal would need to be especially assessed for the working depths expected, as the tunnel depth would be at the limit of current experience for a sealed TBM. Submarine tunnels have been constructed by open TBMs in rock in Hong Kong at depths of 120m, and lining gaskets are now readily available for such pressures. Sealed TBMs were employed at 80m depths on the Great Belt crossing in Denmark.

For the preferred elevation of tunneling, the alignment is expected to lie within the upper sedimentary Labrador Series, comprised predominantly of limestone and sandstones.

This material also includes gypsum, dolomites, pebble conglomerates, breccia, coal and shale, which could exhibit squeezing properties on excavation. Beneath, are the metamorphic rocks of the Canadian Shield, substantially comprising granitic gneiss and schist. It is also characterized by igneous granitic intrusions and these may intersect the tunnel alignment, possibly through to the seabed level. The presence of coal may indicate a risk of methane seepage into the tunnel.

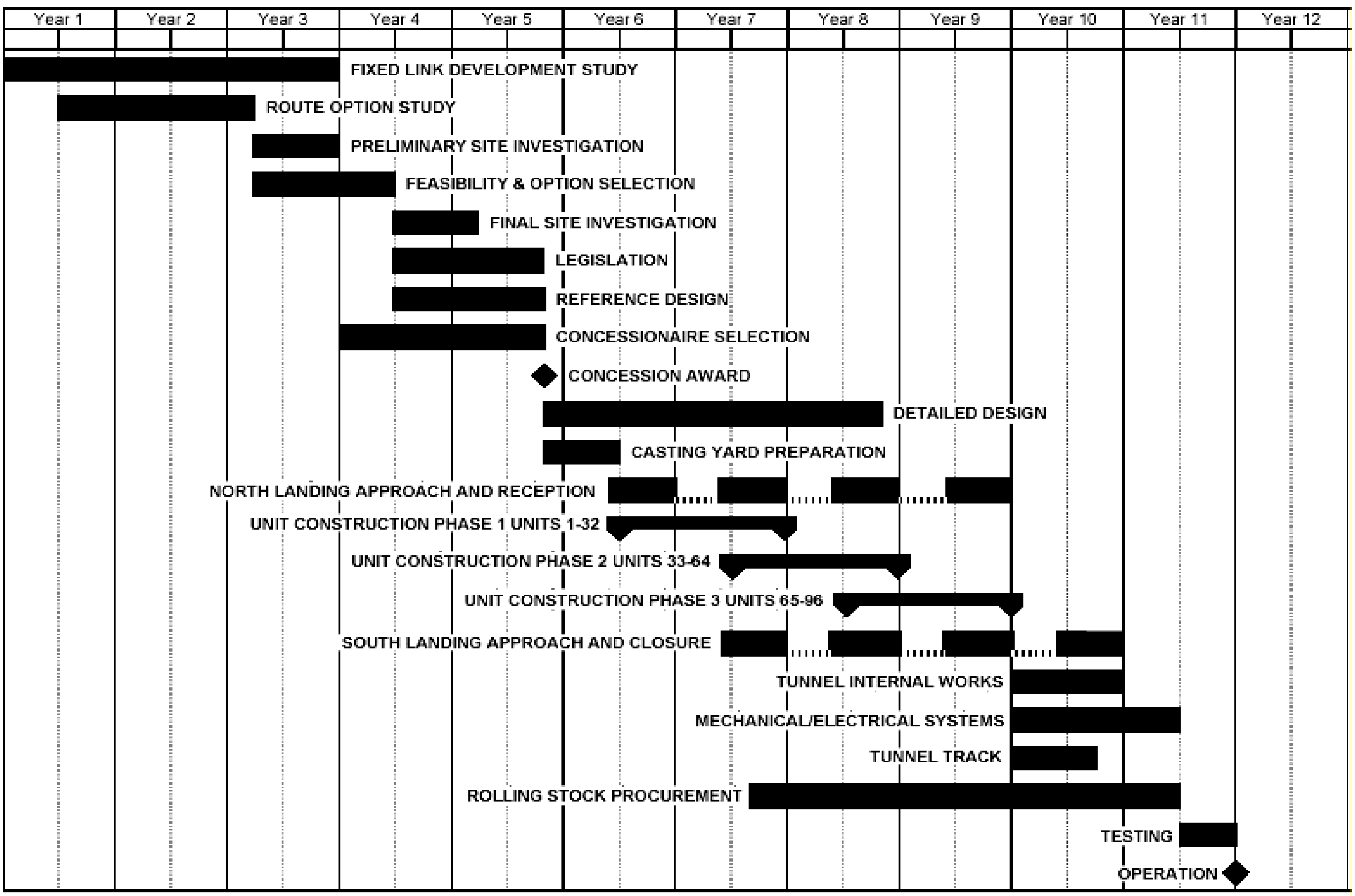
There are also many substantial regional fault lines, likely to intersect the alignment. This may result in variable tunneling conditions that can affect the TBM rate of advance and the difficulty of changing machine cutters. Also, the presence of limestone within the tunnel alignment may indicate the presence of solution cavities (voids). Normally, these can be located by advance probing ahead of the TBM and if necessary filled with grout. Again, these add to the difficulty and risks associated with TBM tunneling. Other key issues affecting TBM tunneling include: fabrication, storage and delivery of tunnel lining segments under severe climatic conditions; the type of TBM to be selected for the variable tunneling conditions; processing of any excavation slurries in cold conditions; and the method of cross-passage construction in permeable ground under high ground water pressure. Possible arrangements for bored tunnels are well known in the industry.

Implementation Program A fixed link outline implementation program is presented on Page 17. The program assumes that an overview ‘Fixed Link Development Study’ is conducted to assess the fixed link’s regional benefits and identify related infrastructure and other socio-economic issues associated with the link. Three years are allowed for this study. Within the main study framework a two-year route option study is identified as the precursor to any commitment to the link. A preliminary site investigation to assess basic feasibility issues is included to finalize the scheme feasibility. Following the development study, and subsequent commitment to implementation of a fixed link, a process of procuring a privately operated concessionaire design, build and operate arrangement is envisaged. Legislation to enable the project is assumed. Once the final site investigations and reference design are completed, the concessionaire agreement can be tendered and awarded. Some overlap in these activities can be expected.

The subsequent design and construction phase is anticipated to take six years. Assuming tunnel placement takes place from the northern shore toward Newfoundland, then landfall works on the Labrador side of the Strait would commence first. Seasonal climatic constraints are assumed to require a ‘stop-start’ program of landfall approach construction. In general, this work is not a critical activity. Three phases of immersed tunnel unit construction are envisaged in this paper.

For an immersed tunnel length of 16km, 96 segments at 167m long are required. If constructed in batches of four, then eight batches will be required each year to correspond to three seasons of tunnel placement. This means that each batch of four tunnel segments will need to be constructed within about one and a half months, including yard flooding, tow-out to the storage area, de-watering of the yard and preparation for casting the next batch of tunnel segments. This assumes of course that climatic conditions and local sea freezing do not adversely affect construction and marine storage of the segments. After marine storage and ice break-up in April/May, segments can be towed to the tunnel site in time for placement. The 32 segments of each season’s clear-weather window will need to be placed at a rate of more than one per week. Dredging and marine backfilling operations will need to match this production rate. The resultant cycle indicates that for a three-season tunnel construction program - with continuous segment fabrication - each phase must take eighteen months to meet the subsequent phase commencement date.

Tunnel internal works, mechanical/electrical fit-out and tunnel track work must follow tunnel completion. Allowing six months for testing, then the total implementation period is eleven years. For a bored tunnel, all-weather working may be feasible. Allowing for a TBM procurement and mobilization period of eighteen months after award, and progress rate of 400m per month working from both landfalls, then tunnel boring could be complete in around three years – one year earlier than the immersed tunnel option.



IMPLEMENTATION PROGRAM

CONCLUSION

As Labrador's population and economy expands, it is vital that the roads joining this area of the Province to mainland highways are maintained and strengthened. The Trans-Labrador Highway, which now allows road travel from central Canada to Goose Bay, urgently needs to be completed to Cartwright and the Strait of Belle Isle. A Gulf of St. Lawrence North Shore Road to join the Strait's north side to mainland roads is now endorsed by Quebec political leaders and will probably be realized in the next five to ten years. But without a fixed link to Labrador, a half million Newfoundland residents, their visitors and commercial vehicles will continue to be isolated from mainland highways, except by ferries that are subject to weather conditions. Action to correct this very costly condition is growing but still inadequate. This paper's goal is to urge Newfoundland and Labrador residents, Canada's federal government, and all Canadians to work for early construction of an effective fixed link across the Strait of Belle Isle. This connection is urgently needed to unite Newfoundland with its historic Labrador heritage and preserve the traditions and culture of this Province's two major regions. There is no task more vital in the Province at this time than creation of a Federal-Provincial Study Group that is dedicated to the earliest possible fixed link construction. This goal has major political, economic and engineering challenges, but they are by no means insurmountable.

AUTHOR RÉSUMÉS

Tom Kierans started in mining by prospecting across Canada by canoe and bush aircraft. A McGill graduate Mining Engineer, he worked in Sudbury mines, specializing in industrial safety and rock mechanics. In 1960 he designed a system to alleviate drought in North America by recycling James Bay Basin's huge freshwater run-off. From 1967 to 1973 he was responsible for mining at Labrador's Churchill Falls underground hydropower project. He was professor of engineering at Memorial University of Newfoundland until 1978 where he continued work as an editor of the American Society Of Civil Engineers Manual on Structural Analysis and Design of Nuclear Plants. In 1978 he was engaged as Director of the College of Cape Breton's Alexander Graham Bell Institute. He was advisor to the Northumberland Strait Fixed Link Environmental Review Panel. He is a life member of the Canadian Society of Civil Engineers, the Association of Professional Engineers and Geoscientists of Newfoundland, and Canadian Institute Mining and Metallurgy. He received APEGN's Order of Merit for 2000 and a CSCE fellowship in 2001.

Howard Markham is a UK civil engineer currently based in Hong Kong. He is a consultant with international experience covering the design and construction of seven immersed tunnel projects including the Fourth Harbour Rail Crossing (Hong Kong), the Öresund Crossing (Denmark to Sweden), the I-93 Fort Point Channel Tunnel (Boston, USA) and other immersed tunnels in Hong Kong, the UK and Ireland. He has also been involved in the design of several other sub-aqueous bored tunnels including the Channel Tunnel (UK to France) and many underground rail, highway, power, water and sewerage tunneling projects, as well as off-shore gravity platform design and several private initiative tunneling transport project proposals.

Overton Colbourne is senior civil engineer with Corner Brook Pulp and Paper Limited and a former employee of Proctor and Redfern Limited, consulting engineers. A Memorial University graduate, he was a student of Professor Kierans in studies on Labrador resource developments. He is now second vice president of the Association of Professional Engineers and Geoscientists of Newfoundland, and will take on the duties of president in 2004. A native of St. Anthony on the Great Northern Peninsula, he is keenly aware of traditional ties between the two major parts of the Province of Newfoundland and Labrador, the adjacent Province of Quebec, and Canada, as well as the Newfoundland-Labrador Fixed Link's immense potential benefits for all Canadians.

Appendix: The World ´s Largest Immersed Transportation Tunnels

Name	Country	Year	Length (m)	Width (m)	Area (m^2)	Rail Tracks	Auto Lanes	Foot Paths	Depth (m)
Drogden-Oresund	Denmark/Swedenennn	1999	3510	42,0	147 420	2	4	0	22,0
Bay Area Rapid	USA	1970	5825	14,6	85 045	2	0	0	40,5
Fort McHenry	USA	1987	1646	50,4	82 958	0	8	0	31,7
Hong Kong Eastern Harbor	Hong Kong	1989	1859	35,0	65 065	2	4	0	27,0
Tama River	Japan	1994	1550	39,9	61 825	0	6	0	30,0
Kawasaki Fairway	Japan	2000	1181	39,7	46 882	0	6	0	26,0
Western Harbour	Hong Kong	1997	1364	33,4	45 541	0	6	0	25,3
Elbe	Tyskland	1975	1056	41,7	44 035	0	9	0	29,0
Tokyo Port Road	Japan	1999	1329	32,2	42 787	0	4	0	29,2
Baltimore Harbor	USA	1957	1920	21,3	40 896	0	4	0	30,0
Piet Hein	Holland	1997	1265	32,0	40 480	2	4	0	17,0
Tokyo port	Japan	1976	1035	37,4	38 709	0	6	0	23,0
Osaka South Port	Japan	2000	1025	35,2	36 080	2	4	0	27,0
Liefkenshoek	Belgien	1991	1136	31,3	35 500	0	4	0	0,0
Hemspor	Holland	1980	1475	21,4	31 609	0	3	0	26,0
Willemspoortunnel	Holland	1994	1014	28,8	29 223	0	4	0	17,5
TedWilliams	USA	1994	1173	24,4	28 654	0	4	0	30,0
Rotterdam Metro	Holland	1966	2855	10,0	28 550	2	0	0	0,0
Lafontaine	Canada	1967	768	36,8	28 224	0	6	0	27,5
Sydney Harbour	Australien	1992	960	29,4	28 224	0	4	0	25,0
Kawasaki Tunnel	Japan	1981	840	31,0	26 040	0	4	0	22,0
Parana	Argentina	1969	2367	10,8	25 564	0	2	0	32,0
JF Kennedy	Belgien	1969	510	47,9	24 404	2	6	0	25,0
Niigata Port Road	Japan	2000	850	28,6	24 310	0	4	0	23,0
Hampton Road	USA	1957	2091	11,3	23 524	0	2	0	37,0
Kobe Port	Japan	2000	520	34,4	17 888	0	6	0	22,6
Drecht	Holland	1977	347	49,0	17 017	0	8	0	15,0
Maas	Holland	1943	584	24,8	14 466	0	4	2	22,5
Limfjord	Denmark	1969	510	27,4	13 974	0	6	0	20,8
Tingstad	Sweden	1968	454	29,9	13 575	0	6	0	16,0
Detroit River	USA/Canada	1910	782	17,0	13 294	2	0	0	24,4
Aktion-Preveza	Grekland	2000	900	12,6	11 340	0	2	0	26,5
Guldborgsund	Denmark	1988	460	20,6	9 476	0	4	0	13,8
Oakland-Alameda	USA	1928	742	11,3	8 385	0	2	0	25,5
Harlem River	USA	1914	329	23,4	7 699	4	0	0	15,2
Detroit Windsor	USA/Canada	1930	669	10,6	7 091	0	2	0	18,5
Liljeholmsviken	Sweden	1964	124	8,8	1 094	2	0	0	13,0

Source: Department of Structural Engineering at KTH in Stockholm, Sweden

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The two authors of this paper who live in Newfoundland; Tom Kierans, of St. John's, and Overton Colbourne, of Corner Brook, wish to acknowledge their appreciation to its third author, Howard Markham, who is now a resident of Hong Kong, China. For one with his professional résumé as seen on Page 18, his out-of-the-blue, e-mailed offer to participate as one of the authors of this submission to the 2003 Annual Meeting of the Transportation Association of Canada is both invaluable and exceptionally generous.

Mr. Markham's outstanding engineering qualifications and important contributions to this paper make his conclusion that "*The proposed fixed link crossing poses significant, but not necessarily insurmountable, engineering challenges*" a very compelling argument for early initiation of this paper's proposal for a Federal-Provincial Fixed Link Study Group.

That Study Group is now also the goal of a fast-growing list of Newfoundlanders.