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AN OVERVIEW OF WATER IMPACTS ASSOCIATED WITH PIPELINE ROUTE ALTERNATIVES IN CANADA TO TRANSPORT ALASKAN OIL

July 1979

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

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AN OVERVIEW OF WATER IMPACTS ASSOCIATED WITH PIPELINE ROUTE ALTERNATIVES IN CANADA TO TRANSPORT ALASKAN OIL[1/]

INTRODUCTION

Three proposals have been submitted to National Energy Board for transporting Alaskan oil through Canadian territory by pipeline to an existing terminal in Alberta. The Pacific & Yukon Region, DOE/DFO Oil Pipelines Working Group was asked by the Minister to make a preliminary environmental comparison of the pipeline routes discussed in these proposals.

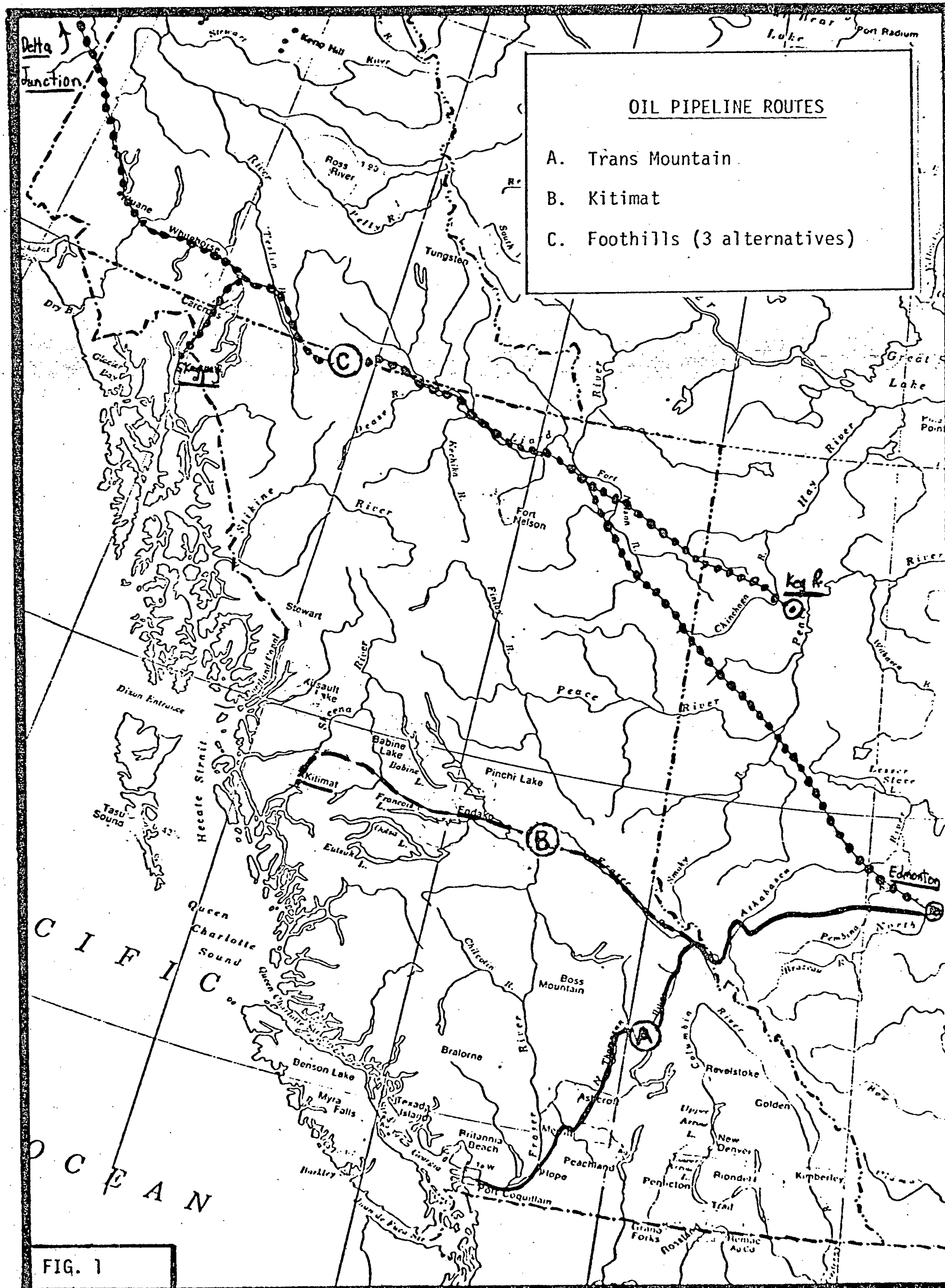
This report by Inland Waters Directorate covers the hydrologic, hydraulic and water quality aspects of the comparison. The primary objectives were to: (a) rank the three corridors on a common scale of values, and (b) identify major environmental concerns.

Activities to accomplish this included:

- a review of information contained in the three applications,
- a review of available data base for surface and sub-surface discharge and water quality,
- identification of major environmental concerns,
- an overview comparison of all alternatives with respect to potential for environmental impact.

Inland Waters Directorate, Pacific & Yukon Region, participants consisted of Dr. V.G. Bartnik, R.N. Neumeyer and P.W. Strilaeff. Input also was received from Directorate personnel in the Western and Northern Region.

1/ Submitted to the Chairman of the Pacific & Yukon Region DOE/DFO OIL PIPELINE WORKING GROUP


OIL PIPELINE ROUTES
A. Trans Mountain
B. Kitimat
C. Foothills (3 alternatives)
Delta Junction
Whitehorse
Carcross
Teslin
Ross River
Pelly R.
Tungsten
Port Radium
Great Lake
Liard
Fort Nelson
Stikine
Stewart
Kitimat
Babine Lake
Pinchi Lake
Endako
Peace River
Edmonton
Athabasca
Dixon Entrance
Hecate Strait
Tasu Sound
Queen Charlotte Sound
Boss Mountain
Bralorne
Benson Lake
Myra Falls
Texada Island
Britannia Beach
Port Coquitlam
Revelstoke
Golden
New Denver
Penticton
Rondell
Kimberley
Trail
Ashcroft
Peachland
Hope
OCEAN
FIG. 1

A. ROUTE DESCRIPTIONS

1. Trans Mountain

The 762 mm (30 in.) pipeline will parallel the present 610 mm (24 in.) pipeline from the International Boundary near Sumas, through the Fraser Valley to Hope, from where it will enter the Coquihalla Canyon (Fig. 1). From the Coquihalla Canyon the pipeline will parallel the Canadian Pacific Railway through the Coldwater Valley, emerging near the town of Merritt. Between Merritt and Kamloops, the pipeline reaches its highest elevation of 1 222 m (4,009 ft.) above sea level. From Kamloops, the pipeline will run north through the North Thompson Valley, through the Yellowhead Pass running east parallel to the Canadian National Railway, and through Jasper to Edmonton (Application page 1-3-1).

Total length of the pipeline route is 1 089 km (675 mi.) of which 927 km (575 mi.) is new. There will be a total of 13 pumping stations of which 5 are new.

2. Kitimat

The proposed route (Fig. 1) lies near Highway 25 from Kitimat to Williams Creek, and near Highway 16 from Telkwa to Edmonton. It passes through three incorporated communities (Kitimat, Prince George and Edmonton) and close to many others. There would be a dock at Kitimat with an access road paralleled by a 1,219 mm (48 in.) pipeline. Oil pumped through this line would be stored in a tank farm in Kitimat, then transmitted to Edmonton via a 762 mm (30 in.) and 914 mm (36 in.) pipeline. The right-of-way would run beside existing B.C. Hydro and Power Authority or Pacific Northern Gas rights-of-way from Kitimat to Prince George, except Miles 30 to 56 (Williams Creek). From Prince George to Rearguard (Mile 460), the route follows Highway 16, and from Rearguard into Edmonton, runs beside the existing Trans Mountain Pipeline right-of-way. The total length of line is 1,211 km (753 mi.). There would be ten pumping stations, including one at Kitimat. At Edmonton, the line would join an existing pipeline. (Application page 6-1, Volume V).

3. Foothills (3 alternatives)

a. Skagway to Keg River

A 914 mm (36 in.) diameter pipeline will be laid from Skagway through the White Pass and across the Canadian boundary to Carcross, Yukon, from which point an 864 mm (34 in.) diameter pipeline will proceed northeastward to join the Alaska Highway Gas Pipeline corridor near Squanga Lake (Fig. 1). From this point the route is almost entirely contiguous with the proposed gas pipeline route until reaching the Fort Nelson area. At Kledo Creek, 72 km west of Fort Nelson, the oil line route leaves the gas line route and proceeds eastward to Keg River. The length of pipeline from the Alaska/British Columbia boundary to Keg River will total approximately 1,120 km (696 mi.). (Application page E-19).

b. Delta Junction

This alternative would involve an 864 mm (34 in.) diameter pipeline extending from Delta Junction, Alaska and would follow the Alaska Highway Gas Pipeline route to Squanga Lake, Yukon and from there continue by a route identical to that of the Skagway system, to Keg River, Alberta (Fig. 1). Due to the presence of permafrost, some 137 km of pipeline would be constructed in the aboveground mode. (Application page E-12). Total length of the pipeline is 1828 km (1135 mi).

c. Skagway to Edmonton

This alternative would be identical to the Skagway to Keg River route, up to Kledo Creek. At this point (Fig. 1), the pipeline route would continue to follow the Alaska Highway Gas Pipeline route southeast through British Columbia, passing to the northeast of Prophet River. The route would then turn easterly, crossing the Sikanni Chief River 5.6 km south of its confluence with Trutch Creek. The Beatton River would be crossed next and then the British Columbia/Alberta border. From the provincial boundary, the route would continue to follow the Alaska Highway Gas Pipeline route, passing approximately 9.7 km south of the community of Spirit River. The route would then diverge from the gas line route, head east, join and follow Highway 43 to the point where the highway turns south. From there the alternative route would continue east, passing to the north of both Volmer and Nanamo before turning south to Edmonton. The total length of the pipeline is 1755 Km (1091 mi.).

B. THE PROBLEM

The three corridors traverse heterogeneous areas with widely varying environmental sensitivities. The Trans Mountain route is mainly in the Fraser River drainage which is predominately located in south-central British Columbia, with extensive mountain ranges forming its eastern and western limits. The route traverses the Cascade Mountains in the lower coast, then the interior plateau in the Merritt-Kamloops-North Thompson areas followed by the Selkirk Mountains and the Rocky Mountain Foothills in the Athabasca River drainage.

The proposed Kitimat pipeline route traverses five distinct major physiographic units between Kitimat and Edmonton; the coastal zone, the interior plateau, the Rocky Mountain trench, the Rocky Mountains, and the foothills/plains. Four major drainage basins are involved. The Kitimat, Skeena and Fraser River systems drain into the Pacific Ocean, the Athabasca system drains, via the Slave/Mackenzie River system, into the Beaufort Sea. The Athabasca River system, for the most part, drains prairie, boreal and tundra landscapes, while the other three drain mostly mountainous terrain.

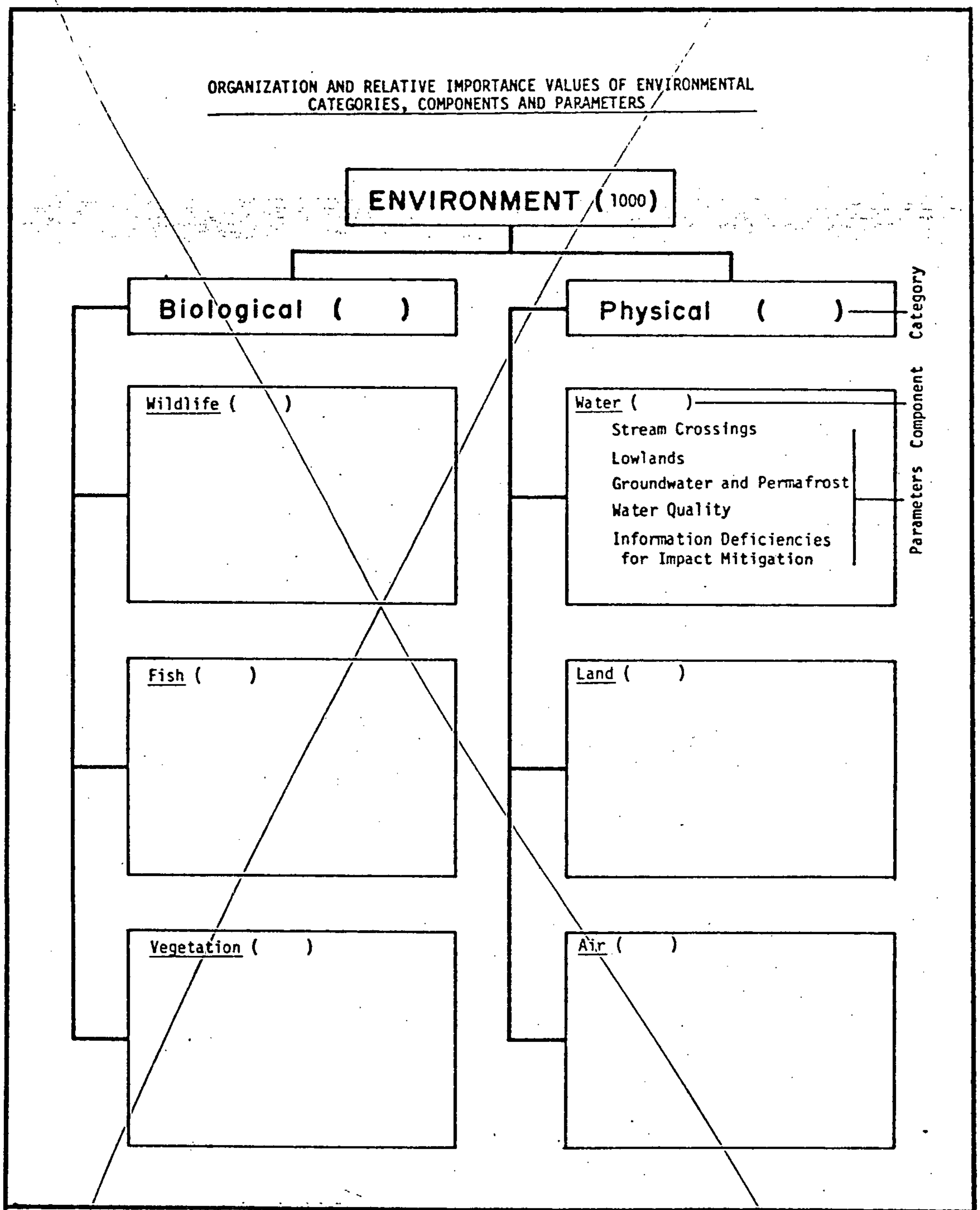
The Skagway to Keg River alternative of the proposed Alaska Highway pipeline corridor traverses four small drainages within the Upper Yukon River system with a combined drainage approximating 325,000 km^2. The four drainages that will be crossed by pipeline construction include the Tutshi Lake basin, the Bennett Lake basin, the Tagish Lake basin and the Little Atlin Lake basin. These drainages are interconnected through a series of streams and narrow lake channels and originate in a low lying wetland area east of the proposed route. Water sources for these basins lie within both glaciated and non-glaciated regions. The majority of stream crossings are tributaries to major lakes and rivers. Generally these tributaries exhibit mountain stream characteristics such as steep gradients, flash floods and a wide range in size and type of bed material. Several poorly drained marsh areas are also crossed by the pipeline route.

East of Squanga Lake, the Alaska Highway pipeline corridor traverses the Teslin and Liard Rivers, each of which has a major drainage basin in southern Yukon. Watercourses crossed by the pipeline corridor vary from small, intermittent high-energy streams to relatively large rivers. Between Kledo Creek and Keg River the proposed pipeline traverses the Liard and Hay River drainages, which are major tributaries within the Upper Mackenzie River system. Drainage conditions along this portion of the pipeline route are generally poor as approximately 240 km of the alignment traverses the Fort Nelson Lowlands, an extensive muskeg region. Lakes in the area are shallow. The water courses crossed by the pipeline route pass through boreal forest bogs and muskegs and have meandering channels. The exception is the Kuskwa River which has a braided channel pattern.

In the Skagway to Edmonton alternative the route after Kledo Creek would generally cross the Alberta Plateau. The most significant hydrologic feature here is that rivers are subject to exceptionally large floods.

The Delta Junction alternative substitutes Upper Yukon drainage in the Skagway-Keg River corridor with the North Yukon Plateau and the Shakwak Trench drainages. Notable concerns here are muskeg, permafrost and the ephemeral streams along the west shore of Kluane Lake.

FIGURE 2


ORGANIZATION AND RELATIVE IMPORTANCE VALUES OF ENVIRONMENTAL CATEGORIES, COMPONENTS AND PARAMETERS
ENVIRONMENT (1000)
Biological ( )
Physical ( )
Category
Wildlife ( )
Water ( )
Component
Stream Crossings
Lowlands
Groundwater and Permafrost
Water Quality
Information Deficiencies for Impact Mitigation
Parameters
Fish ( )
Land ( )
Vegetation ( )
Air ( )

Impact Value Scale

TABLE 1

Impact	Scale	Comments
low	0	low to insignificant effect
moderate	1	no special risks i.e. low velocities, generally incised channels with high bed and bank stability, short sediment effect length, low groundwater and water quality degradation potential.
high	2	serious effect i.e. a few design problems have been identified, although serious if not solved are considered to have short term impact potential.
extreme	4	very serious effect i.e. many or major environmental design problems have been identified which may result in long term damage to the environment if not solved.

SUMMARY SCORE SHEET

ALL ROUTE ALTERNATIVES

WATER COMPONENT - TOTAL VALUE 100

TABLE 2

Parameters	Approximate Route Length (km)	Stream Crossings	Lowlands	Groundwater & Permafrost	Water Quality	Mitigation Potential	Total	Rank
Relative Importance Values		32	12	15	21	20	100	
		Impact Magnitude Rating						
TRANS MOUNTAIN (Table ~~2~~ 4)	1089	224	12	30	105	100	471	1
KITIMAT 4 (Table 3)	1211	224	12	15	105	140	496	2
FOOTHILLS								
Skagway - Keg River (Table ~~4~~) 7	1120	384	48	45	84	200	761	4
Delta Jtn. - Keg River. (Table 6) 7	1828	448	48	60	105	240	901	5
Skagway - Edmonton (Table 5) 6	1755	384	24	45	84	200	737	3

TABLE 3

PARAMETER CHECKLIST AND SCORE SHEET

KITIMAT ALTERNATIVE

Parameters - elements	Physiographic Units, Pipeline Kilometers & Impact Value* Coast (0 - 170)	Interior Plateau (170 - 549)	Rocky Mtn. Trench (549 - 727)	Rocky Mtns. (727 - 886)	Alberta Foothills & Plateau (886 - 1221)	Overall (0 - 1221)	
Stream Crossings							
- drainage areas less than 250 km^2	86 (2)	113 (1)	50 (2)	50 (2)	118 (2)	417 (2)	-Wedeene River -Little Wedeene River -Zymoetz River -Athabasca River & flashy tributaries (e.g. Fiddle Cr.)
- drainage areas greater than 2500 km^2	1 (2)	8 (2)	1 (2)	0 (0)	4 (2)	14 (2)	
- near mouth	65 (1)	40 (1)	33 (1)	47 (1)	34 (1)	219 (1)	-Alluvial floodplains & fans of Fraser R. tributaries upstream of McBride.
- high scour and/or erosion potential (braided, high energy, meandering)	3 (2)	0 (0)	0 (0)	3 (2)	0 (0)	6 (2)	-slide potential near Lakelse & Telkwa
					Total Score	7	
Lowlands (marsh, bog, etc.) - kilometers	5 (1)	5 (1)	3 (1)	21 (1)	10 (1)	44 (1)	
					Total Score	1	
Permafrost and Groundwater							
- incidence of permafrost or ice-rich silts	(0)	(0)	(0)	(0)	(0)	(0)	
- incidence of groundwater problems (see pages 8 & 9 of text)						(1)	
					Total Score	1	
Water Quality							
- streams/total length paralleled by pipeline (km)	6/130 (1)	10/224 (1)	5/183 (1)	5/169 (1)	5/163 (1)	31/869 (1)	
- streams crossed in headwaters	14 (1)	54 (2)	10 (1)	1 (0)	34 (2)	113 (2)	
- lakes paralleled by pipeline	1 (1)	3 (1)	2 (1)	8 (2)	11 (2)	25 (2)	
- winter D.O. levels	(0)	(0)	(0)	(0)	(0)	(0)	
					Total Score	5	
Information Deficiencies for Impact Mitigation							
- % route length along existing linear developments (highway and/or pipeline)	9 (2)	66 (2)	53 (2)	87 (1)	100 (1)	69 (2)	-moderate past experience -much more studies needed
- number of gauging stations							
- drainage area less than 250 km^2	9 (2)	7 (2)	3 (4)	1 (4)	17 (2)	37 (2)	
- drainage area greater than 250 km^2	15 (2)	2 (1)	10 (1)	17 (2)	22 (2)	56 (2)	
- total number of streams & lakes monitored for water quality						29 (1)	
					Total Score	7	

*Impact magnitude values are shown in brackets; they were determined from scale 0 to 4 defined in the text.

TABLE 4

PARAMETER CHECKLIST AND SCORE SHEET

TRANS MOUNTAIN ALTERNATIVE

Parameters - elements	Physiographic Units, Pipeline Kilometers & Impact Value*				
	Cascade 1089 - 959	Interior Plateau 959 - 531	Rocky Mtn.Foothills & Alberta Plain 531 - 0	Overall 0 - 1089	
Stream Crossings					
- drainage areas less than 250 km^2	34 (1)	155 (1)	138 (2)	327 (2)	
- drainage areas greater than 2500 km^2	0 (0)	5 (1)	5 (2)	10 (2)	
- near mouth	27 (1)	97 (1)	87 (1)	211 (1)	
- high scour and/or erosion potential (braided, high energy, meandering)	1 (2)	0 (0)	3 (2)	4 (2)	- Coquihalla River (approx. 6 crossings) - McLeod River - Flashy tributaries to Athabasca R.(e.g. Fiddle Cr.) - Alluvial floodplains and fans along the Fraser River upstream of Tete Jaune.
			Total Score	7	
Lowlands (marsh, bog, etc.)					
- kilometers	0 (0)	11 (1)	21 (1)	32 (1)	
			Total Score	1	
Permafrost and Groundwater					
- incidence of permafrost or ice-rich silts	(0)	(0)	(0)	(0)	
- incidence of groundwater problems (see pages 8 & 9 of text)				(2)	
			Total Score	2	
Water Quality					
- streams/total length paralleled by pipeline (km)	5/130 (1)	10/227 (1)	18/151 (0)	33/508 (1)	
- streams crossed in headwaters	4 (0)	23 (1)	55 (2)	82 (2)	
- lakes paralleled by pipeline	1 (0)	7 (1)	19 (2)	27 (2)	
- winter D.O. levels	(0)	(0)	(0)	(0)	
			Total Score	5	
Information Deficiencies for Impact Mitigation					
- % route length along existing linear developments (highway and/or pipeline)	100 (1)	100 (1)	100 (1)	100 (1)	- within existing pipeline corridor and in close proximity of highway at many areas, therefore much environmental experience exists; however, some additional studies are needed.
- number of gauging stations					
-drainage area less than 250 km^2	4 (2)	16 (2)	2 (4)	22 (2)	
-drainage area greater than 250 km^2	4 (1)	10 (1)	11 (2)	25 (1)	
- total number of streams & lakes monitored for water quality				29 (1)	
			Total Score	5	

*Impact magnitude values are shown in brackets; they were determined from scale 0 to 4 defined in the text.

TABLE 5

PARAMETER CHECKLIST AND SCORE SHEET

ALASKA HIGHWAY ALTERNATIVE - SKAGWAY TO EDMONTON (Canadian Section)

Parameters - elements	Physiographic Units, Pipeline Kilometers & Impact Value*						
	Coast	Yukon Plateau	Liard Plains & Plateau (320 - 575)	Rocky Mtn. Foothills	Alberta Plateau	Overall	
Stream Crossings							
- drainage areas less than 250 km^2	3 (2)	84 (4)	49 (2)	42 (4)	97 (2)	278 (4)	- Tutshi River - high energy tribs. to Crag & Bennett L. - 6 high energy tribs. to Teslin L. & Swift R.
- drainage areas greater than 2500 km^2	0 (0)	3 (4)	3 (1)	5 (4)	10 (2)	21 (2)	- Cormier, Coal, Smith, Brimstone, Liard, Toad, Snake, Dunedin, Muskwa, Prophet, Sikanni Chief, Beatton
- near mouth	0 (0)	76 (2)	35 (1)	21 (2)	26 (2)	158 (2)	- unstable tributaries between Cormier & Peace
- high scour and/or erosion potential (braided, high energy, meandering)	2 (2)	10 (4)	10 (1)	16 (4)	16 (1)	54 (4)	- Peace, Athabasca - several major & minor rivers crossed by pipeline in Rocky Mtn. Foothills & Rocky Mtns. have high erosion potential.
					Total Score	12	
Lowlands (marsh, bog, etc.) - kilometers	4 (4)	96 (4)	50 (2)	16 (2)	0 (0)	166 (2)	- moderate
					Total Score	2	
Permafrost and Groundwater							
- incidence of permafrost or ice-rich silts	(2)	(2)	(1)	(1)	(0)	(2)	- general presence of permafrost in the first 137 km from Alaska border.
- incidence of groundwater problems (see pages 8 & 9 of text)						(1)	- permafrost thickness, ice content & continuity decreases from north to south; confined mainly to poorly drained organic sites.
					Total Score	3	
Water Quality							
- streams/total length paralleled by pipeline (km)	2/8 (0)	12/213 (1)	6/61 (1)	2/169 (2)	11/191 (1)	645 (1)	
- streams crossed in headwaters	1 (1)	8 (1)	8 (1)	8 (1)	68 (2)	93 (1)	
- lakes paralleled by pipeline	1 (1)	6 (1)	2 (1)	0 (0)	2 (0)	11 (1)	
- winter D.O. levels	(1)	(2)	(0)	(0)	(0)	(1)	
					Total Score	4	
Information Deficiences for Impact Mitigation							
- % route length along existing linear developments (highway and/or pipeline)	100 (1)	100 (1)	1 (2)	1 (2)	32 (2)	37 (2)	- moderate past experience and some additional studies completed in Y.T. by proponent. Some data available from Provinces & Federal Govt.
- number of gauging stations - drainage area less than 250 km^2	0 (2)	5 (2)	3 (2)	0 (4)	17 (4)	25 (4)	- baseline data inadequate.
- drainage area greater than 250 km^2	0 (0)	13 (1)	3 (1)	21 (2)	31 (2)	68 (2)	
- total number of streams & lakes monitored for water quality						11 (2)	
					Total Score	10	

*Impact magnitude values are shown in brackets; they were determined from scale 0 to 4 defined in the text.

TABLE 6

PARAMETER CHECKLIST AND SCORE SHEET

ALASKA HIGHWAY ALTERNATIVE - DELTA JUNCTION TO KEG RIVER (Canadian Section)

Parameter - elements	Physiographic Units, Pipeline Kilometers & Impact Value*						
	Coast	Yukon Plateau	Liard Plains & Plateau (320 - 575)	Rocky Mtn. Foothills (575 - 787)	Alberta Plateau (787-1120.6)	Overall	
Stream Crossings							- White River, Donjek River, Duke River - unstable tributaries to Kluane Lake - 6 high energy tribs. to Teslin L. & Swift River - Cormier, Coal, Smith, Brimstone, Liard, Toad, Snake, Dunedin, Muskwa - unstable tribs. between Cormier & Muskwa - Fort Nelson River - many major & minor rivers in St. Elias Mtns., Rocky Mtn. Foothills & Rocky Mtns. have considerable erosion potential.
- drainage areas less than 250 km^2	82 (4)	60 (2)	49 (1)	42 (4)	55 (2)	288 (4)	
- drainage areas greater than 2500 km^2	6 (4)	2 (1)	3 (1)	5 (4)	3 (2)	19 (4)	
- near mouth	30 (2)	54 (2)	35 (1)	21 (2)	15 (2)	155 (2)	
- high scour and/or erosion potential (braided, high energy, meandering)	18 (4)	0 (0)	7 (1)	16 (4)	1 (2)	42 (4)	
					Total Score	14	
Lowlands (marsh, bog, etc.) - kilometers	10 (2)	0 (0)	50 (2)	16 (2)	292 (4)	368 (4)	- problems expected in the Nelson River-Hay River area.
					Total Score	4	
Permafrost and Groundwater							- general presence of permafrost in the first 137 km from Alaska border. - locating a hot oil pipeline in same corridor as chilled gas pipeline may result in an environmentally complex situation.
- incidence of permafrost or ice-rich cilts	(4)	(2)	(1)	(1)	(0)	(2)	
- incidence of groundwater problems (see pages 8 & (of text)						(2)	
					Total Score	4	
Water Quality							
- streams/total length paralleled by pipeline (km)	5/70 (2)	7/160 (2)	6/61 (1)	2/109 (2)	7/113 (1)	31/513 (2)	
- streams crossed in headwaters	6 (1)	4 (1)	8 (1)	8 (1)	30 (2)	56 (1)	
- lakes paralleled by pipeline	3 (1)	4 (1)	2 (1)	0 (0)	4 (1)	11 (1)	
- winter D.O. levels	(2)	(2)	(0)	(0)	(0)	(1)	
					Total Score	5	
Information Deficiencies for Impact Mitigation							- moderate past experience and some additional studies completed in Y.T. by proponent. Some data available from Provinces & Federal Govt. - baseline data inadequate.
- % route length along existing linear developments (highway and/or pipeline)	100 (2)	100 (1)	1 (2)	1 (2)	0 (4)	49 (2)	
- number of gauging stations - drainage area less than 250 km^2	9 (4)	3 (2)	3 (2)	0 (4)	0 (2)	15 (4)	
- drainage area greater than 250 km^2	10 (4)	4 (2)	3 (1)	21 (2)	5 (2)	53 (4)	
- total number of streams & lakes monitored for water quality						11 (2)	
					Total Score	12	

*Impact magnitude values are shown in brackets; they were determined from scale 0 to 4 defined in the text.

TABLE 7

PARAMETER CHECKLIST AND SCORE SHEET

ALASKA HIGHWAY ALTERNATIVE - SKAGWAY TO KEG RIVER (Canadian Section)

Parameters - elements	Physiographic Units, Pipeline Kilometers & Impact Value*						
	Coast (0 - 17)	Yukon Plateau (17 - 320)	Liard Plains & Plateau (320 - 575)	Rocky Mtn. Foothills (575 - 787)	Alberta Plateau (787-1120.6)	Overall	
Stream Crossings							-Tutshi River -high energy tribs. to Crag & Bennett L. -6 high energy tribs. to Teslin L. & Swift R. -Cormier, Coal, Smith, Brimstone, Liard, Toad, Snake, Dunedin, Muskwa -unstable tribs. between Cormier & Muskwa -Fort Nelson River -several major & minor rivers crossed by pipeline in Rocky Mtn. Foothills & Rocky Mtns. have high erosion potential.
- drainage areas less than 250 km^2	3 (2)	84 (4)	49 (2)	42 (4)	55 (2)	233 (4)	
- drainage areas greater than 2500 km^2	0 (0)	3 (1)	3 (1)	5 (4)	3 (2)	14 (2)	
- near mouth	0 (0)	76 (2)	35 (1)	21 (2)	15 (2)	147 (2)	
- high scour and/or erosion potential (braided, high energy, meandering)	1 (2)	10 (4)	10 (1)	16 (4)	1 (2)	38 (4)	
					Total Score	12	
Lowlands (marsh, bog, etc.) - kilometers	4 (1)	96 (4)	50 (2)	16 (2)	292 (4)	458 (4)	- muskeg related problems expected in the Nelson River - Hay River area.
					Total Score	4	
Permafrost and Groundwater							
- incidence of permafrost or ice-rich silts	(2)	(2)	(1)	(1)	(0)	(2)	- sporadic discontinuous permafrost in Y.T. and B.C.
- incidence of groundwater problems (see pages 8 & 9 of text)						(1)	
					Total Score	3	
Water Quality							
- streams/total length paralleled by pipeline (km)	2/8 (0)	12/213 (1)	6/61 (1)	2/109 (2)	7/113 (1)	29/504 (1)	
- streams crossed in headwaters	1 (1)	8 (1)	8 (1)	8 (1)	30 (2)	55 (1)	
- lakes paralleled by pipeline	1 (1)	6 (1)	2 (1)	0 (0)	4 (1)	13 (1)	
- winter D.O. levels	(1)	(2)	(0)	(0)	(0)	(1)	
					Total Score	4	
Information Deficiencies for Impact Mitigation							-moderate past experience and some additional studies completed in Y.T. by proponent. Some data available from Provinces & Federal Govt. - baseline data inadequate.
- % route length along existing linear developments (highway and/or pipeline)	100 (1)	100 (1)	1 (2)	1 (2)	0 (4)	49 (2)	
- number of gauging stations							
- drainage area less than 250 km^2	0 (2)	5 (2)	3 (2)	0 (4)	0 (2)	8 (4)	
- drainage area greater than 250 km^2	0 (0)	13 (1)	3 (1)	21 (2)	5 (2)	42 (2)	
- total number of streams & lakes monitored for water quality						11 (2)	
					Total Score	10	

*Impact magnitude values are shown in brackets; they were determined from scale 0 to 4 defined in the text.

It is obvious therefore that environmental sensitivities vary widely among the three corridors; in addition the environmental elements within each corridor can be expected to be of unequal relative importance. The problem then was to devise a ranking system that would correlate these hydrologically dissimilar corridors on the basis of physiographic components and measure them on a common scale of numerical values. The general lack of currently available environmental data, particularly those related to water quality and small stream hydrology necessitated the comparison procedure to accommodate subjective evaluations. However, endeavour was made to maximize the credibility of results by adequately identifying and defining the judgements or assumptions used.

C. METHOD

1. General Approach

In a ranking system such as one adopted for this comparative review the total environment is broken down into categories such as physical, biological, etc.(Fig.2). The categories are then divided into major components and the components are separated into parameters, each with its group of identifiable elements. The water component (hydrology, hydraulics and wter quality), the subject of this report, falls in the physical category. Tables 3 to 7 list the selected parameters and elements.

2. Selection of Parameters

Parameters were first chosen independently by members of the study team. Subsequently they were compared and agreement reached on a final selection. Listed in section C following are descriptions of the elements considered to be relevant to the potential impact. Because of the reconnaissance nature of information provided in the applications, and paucity of baseline data, the concerns and mitigation for corridor alternatives were treated in a geographic context.

3. Nature of Parameter Elements

a. Stream Crossings

- number of water crossings; special attention was given to density of streams with drainage areas less than 250 km^2 and number of streams with drainage area greater than 2,500 km^2. Small streams are concerns relative to drainage alteration and culvert design; they can also be a major source of siltation.
- number of crossings near river mouth. A river's vertical and lateral activity is heightened by increased discharge or by an increased drainage basin.
- number of streams with scour and/or erosion potential. A braided stream has a high potential for lateral and vertical instability; also, sediment transport capability of a stream is a function of velocities and hydraulic gradient; consequently, high energy streams have a high environmental impact potential. Further, it is assumed that meandering streams have greater potential for meander cut-offs.

b. Lowlands (Marsh, Bog, etc.

- drainage interchange and damage to wetlands can be critical, therefore the proportion of route length through such areas is considered to be a relevant factor.

c. Groundwater

- groundwater problems may be: (a) geotechnical - caused by the influence of groundwater occurrence on the construction and operation of the pipeline, (b) resource related - caused by disruption of flow (e.g. compaction by a pipeline berm) or the introduction of pollutants (e.g. spills of contaminants during construction or oil spills during operation). The general unavailability of groundwater baseline data necessitated only a very qualitative estimate of potential impact. This was based on the length of route, total rise in elevation, total number of streams crossed, concentrations of population along the route, and the incidence of permafrost.

d. Water Quality

- number of streams and total kilometers paralleled by the pipeline.
- proportion of crossings in headwaters. For minimum siltation impact there should be a minimal length of downstream reach which will receive increased sediment transport rates. As in the case of "Stream Crossings", length of stream channel that will be affected by introduction of sediment will depend on velocity, available sediment, hydraulic gradient and the availability of low energy channel areas. (Also, headwaters represent recolonization sources for macro-invertebrate populations; destruction of biota in these areas has a more prolonged impact than in downstream areas.)
- number of lakes downstream of route. Lakes could be affected either because they are downstream from a river crossing or closely paralleled by the pipeline.
- ambient winter dissolved oxygen levels. In northern latitudes the release of organic substances (soils, sewage, oil, etc.) under ice cover can be expected to further increase biological oxygen demand leading to an accentuation of already stressed dissolved oxygen conditions.

e. Permafrost

- uncertainties and unpredictabilities involved when considering differential heaving, thaw erosion and solifluction in sloped terrain are the major risks associated with permafrost. Only the Alaska Highway corridor was considered to traverse permafrost zones. For this comparative review, an indicator of impact was the incidence of permafrost and ice-rich silts along the route.

f. Information Deficiencies for Impact Mitigation

This parameter was introduced to measure available data base, experience, etc. within a pipeline corridor for mitigative design.

- per cent of total corridor miles along existing linear development (highway and/or pipeline).
- number of streamflow gauging stations relative to number of streams in the two river-size categories identified under "Stream Crossings".
- per cent of streams monitored for water quality.

4. Impact Values

Pipeline route alternatives were divided into physiographic units and the parameters for each physiographic unit (Tables 3 to 7) were evaluated subjectively on the basis of information in the applications. Following this an appropriate impact magnitude value was assigned (Table 2). When information in the applications was considered to be inadequate to complete all parameter elements, reference was made to other sources including Water Survey of Canada, Water Quality Branch and Hydrology Research Division of Inland Waters Directorate, and B.C. Water Investigations Branch.

5. Relative Importance Values

All parameters do not contribute equally to the long term stability and value of the total environment. Therefore, a weighting procedure was required in order to correlate the raw impact scores from Tables 3 to 7. These relative importance values were established by the study team on a concensus basis and were based as much as possible on scientific information gleaned during the review. Nevertheless, they are a function of the subjective judgements of the team members. The distribution of the importance values among the parameters is shown in Table 2.

6. Final Ranking

Information for each corridor was examined and impact magnitude values for the parameter elements were entered in Tables 3 to 7 for each physiographic unit. Subsequently parameter values for the total corridor were subjectively ascertained and summed to provide a "raw" score for each parameter. The parameter "raw" scores were then multiplied by the parameter importance value and entered in Table 2. Thus, on the basis of these scores the five pipeline alternatives were ranked. The bias that is normally inherent in this type of evaluation is reduced through use of the preselected impact values (Table 1). The water component (hydrology, hydraulics and water quality) ranking for each of the five corridor alternatives is shown in Table 2.

D. MAJOR ENVIRONMENTAL CONCERNS

Although most potential changes to surface water regimes can be mitigated by proper planning and design, the difficulty is knowing when designs are adequate. Long-term hydrologic data are generally not available, while such factors as flood peaks, ice jams and icings are difficult to anticipate. Furthermore, problems such as scour, local erosion, siltation and undersized culverts may not become apparent until well into the operation period, during or after peak floods.

The greatest hydrometric information gap is in flow data for drainage areas less than 250 km^2. The gap cannot be filled in a short time period. Years of data are required for an adequate analysis because of wide differences in local meteorological conditions (snow pack, thunderstorms, etc.) from year to year. It is felt that the level of hydrologic knowledge of small streams is insufficient for either river crossing design work or comprehensive environmental impact assessment.

Following are descriptions of major environmental concerns.

1. Skagway To Keg River Corridor

a. Upper Yukon Lakes

Four lake drainages in the Upper Yukon River system; Tutshi Lake, Bennett Lake, Tagish Lake and Little Atlin Lake are subject to:

- high siltation risk i.e. drainages into these lakes have steep gradients, particularly along the east shore of Bennett Lake and west shore of Crag Lake; streams here are subject to flash floods and shifting beds.
- drainage interchange in the poorly drained marsch-lake areas.
- high water table leading to difficulties in maintenance of access roads and work pads, which themselves may become barriers, through compaction, to surface and subsurface flow.
- icings in excavations across steep streams along Bennett and Crag Lakes.

Lack of hydrometric data particularly for assessment and mitigation of potential problems related to the steep drainages identified above is of concern.

b. Nelson River Lowlands

The extremely low relief and poorly defined muskeg drainage in the Fort Nelson River-Hay River lowlands from approximately Snake River (KP 890) to Keg River (KP 1120.6) is considered to be a potentially difficult section of the alignment alternative. The main concern is drainage interchange, complicated by the characteristic change in direction of flow, which depends on relative water levels among the channels. This may be further complicated by access roads creating permanent barriers through compaction and disrupting natural drainage patterns.

c. Rocky Mountain Foothills - Alberta Plateau

Serious flooding and erosive activity potential increases from Alberta Plateau, through the Rocky Mountain Foothills and into the Rocky Mountains themselves. The concern is that during such activity there is a great potential for the pipeline to be exposed and perhaps damaged, with consequent need for emergency repairs. A number of small unnamed streams are involved. Larger streams of greatest concern include Brimstone Creek, Toad River and Dunedin River.

This problem are is of about equal concern both in the Skagway-Keg River and Skagway to Edmonton corridors.

2. Delta Junction to Keg River Corridor

a. St. Elias Mountains

The alluvial deposits at the foot of St. Elias Mountains along the west shore of Kluane Lake are notable problem areas. The fan streams between Duke River and Silver Creek appear to be graded at present, but there is a possibility for serious degradation or slush avalanching to occur if a main stream begins to erode laterally into the base of the alluvial fan. Such fan activity could be destructive as it would threaten the safety of the pipeline. Kluane Lake is paralleled by the proposed pipeline for a relatively short distance.