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Impressions on the construction of the Pointed Mountain Gas Pipeline

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Northern Operations Branch
Pacific Region



IMPRESSIONS ON THE CONSTRUCTION
OF THE POINTED MOUNTAIN GAS PIPELINE

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1. Abstract

Environmental problems related to pipeline construction in a sub-arctic region are discussed. Both overland and river crossing phases are discussed. Various construction situations creating environmental concern, such as permafrost, bank instability and siltation to rivers are mentioned. An attempt was made to sample the extent of siltation resulting from the dredging activity. It appears that the trenching introduces more silt than the bank filling operation. Specific results and theoretical calculations are presented and compared. Problems of winter sampling and proposals for future research needs are outlined. This report attempts to familiarize the reader with pipeline construction and problems evident to the researcher during pipeline construction. Appendix IV includes the editor's corrections of literature citing this report as a source. The collection of additional data to assess the levels of siltation during winter construction should be stressed.

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2. Introduction

The gas pipeline detailed in this report is a 20 inch diameter pipe, 34.2 miles long, connecting the existing dehydration plant at Beaver River, British Columbia, with its counterpart at Pointed Mountain, Northwest Territories. The route crosses areas of British Columbia, the Yukon and Northwest Territories in a south-westerly direction from Pointed Mountain (Plate 1). The line was constructed for Westcoast Transmission Ltd., Vancouver, B. C., by Marine Pipeline Ltd., Calgary, Alberta.

During the periods of February 12th to 14th and March 5th to 9th, 1972, field studies were conducted by the Fisheries Service to gather information on the techniques and problems of laying pipelines in a sub-arctic region. Aquatic surveys were conducted on the La Biche and Kotaneelee Rivers in an attempt to determine the magnitude of disturbance caused to these rivers by pipeline crossings.

3. Overland Construction

3.1 Foreword

The Pointed Mountain pipeline, which is now completed at a cost of 5 million dollars is as yet inoperative (March, 1972). It is a buried pipeline and will carry natural gas at a temperature of 120°F and at a pressure of 1350 psi. The 34.2 mile route follows a southwesterly direction running parallel to the Liard River and the Kotaneelee and La Biche Mountain ranges (southern extensions of the Mackenzie Mountains). The pipeline traverses the rugged foothills of these mountains between the 1,000 and 1,800 foot contour lines (Plate 1).

The vegetation in the area is dense northern forest consisting of approximately 60% coniferous and 40% deciduous growth (Plate 2). The southern terminal linking the new pipeline into the system is Beaver River Dehydration Plant (Plate 3).

3.2 Initial Construction

During 1971, various routes had been considered by Westcoast Transmission Ltd. The initial construction of the selected route began on January 24, 1972, with the surveying and clearing of the 80 foot wide right of way.

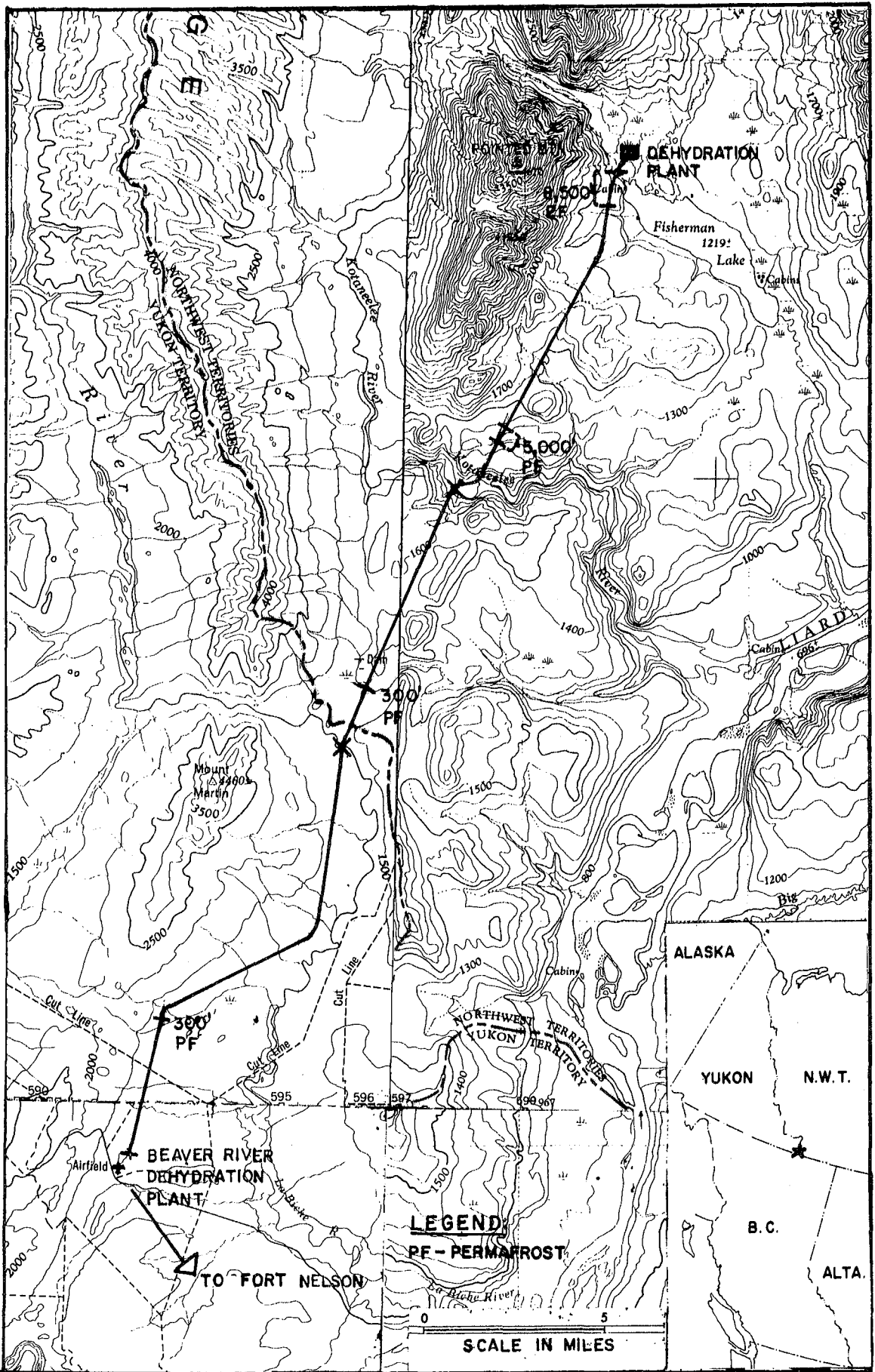


PLATE I: POINTED MOUNTAIN-BEAVER RIVER PIPELINE ROUTE WITH RIVER CROSSINGS (X) AND PERMAFROST (PF) LOCATIONS

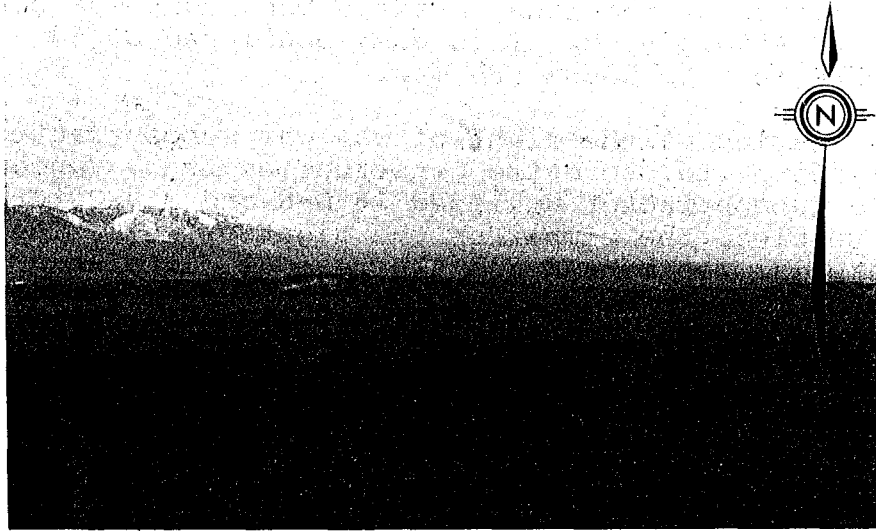


PLATE 2. Topography and vegetation encountered by the pipeline. Note the La Biche and Kotaneelee Mountains.

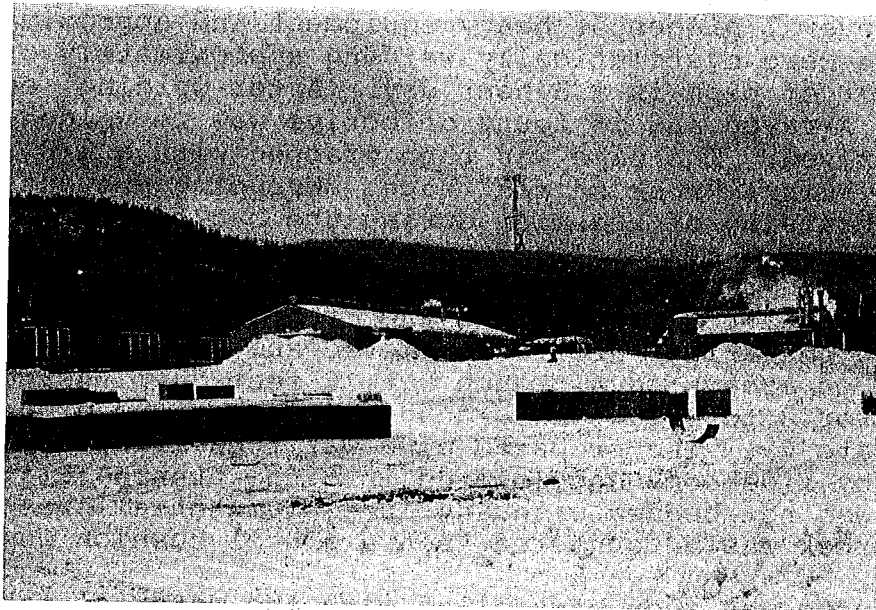


PLATE 3. Dehydration plant at Beaver River.

To accommodate and service the men and equipment for the construction of the line, a field base camp was established at Beaver River, B. C. This camp consisted of 63 portable trailers to house 480 men.

The clearing of the right of way was subcontracted from Marine Pipeline Ltd. to Catre Construction Ltd., Vancouver, B. C. The subcontractor utilized 16 D-8 and D-9 Caterpillar Tractors to clear the timber on the right of way. The larger material was burned and the residue was placed in a windrow over the proposed trench for the pipe. This procedure insulates the area to be trenched and clears that portion of the right of way to be used as a road. This allows far greater frost penetration on the road. Small summer runoff streams, crossing the roadway, were temporarily filled. Upon completion of the pipeline these streams were cleared. Moderate side slopes encountered on the right of way were cut and graded to make a level path for the pipe.

3.3 Laying of Pipe

Following the clearing operation the pipe was laid out or "strung" along the right of way (Plate 4) on 4 X 4 inch supports or "Sleepers" to await the bending and welding processes. Sections of pipe were cold bent to follow the contour of the ground and the direction of the right of way. The 60 foot lengths of pipe were then butted and welded in place. Several pieces of heavy equipment and approximately 20 welders were systematically welding approximately 10,000 feet of pipe in a 5 hour day. After welding, each joint was X-rayed and if found defective was re-welded and re-X-rayed. The pipe was then wrapped with a 1/8 inch thick poly-vinyl "rock shield" tape. Wrapping prevents possible bruising of the pipe during the backfilling operation and it also helps to insulate the pipe (Plate 5).

In preparation for digging the trench, the windrow insulating the trench area was removed and graded. The ditcher then excavated a trench 5 to 6 feet deep thereby allowing for 3 to 4 feet of ground cover when the pipe is in place (Plate 6). The prepared pipe was then lifted off the sleepers by sidebooms and lowered into the trench (Plate 7). The pipe was not bedded with any special material except where bedrock was encountered then a gravel cushion was used.

The pipe was then backfilled with the material taken from the trench, and compacted by "walking" heavy equipment over it. In addition, a large berm 4 to 6 feet high was placed over the line to allow for any settling of the backfill material. Additional smaller berms or "Breakers"



PLATE 4. The pipe "strung" along the right of way.

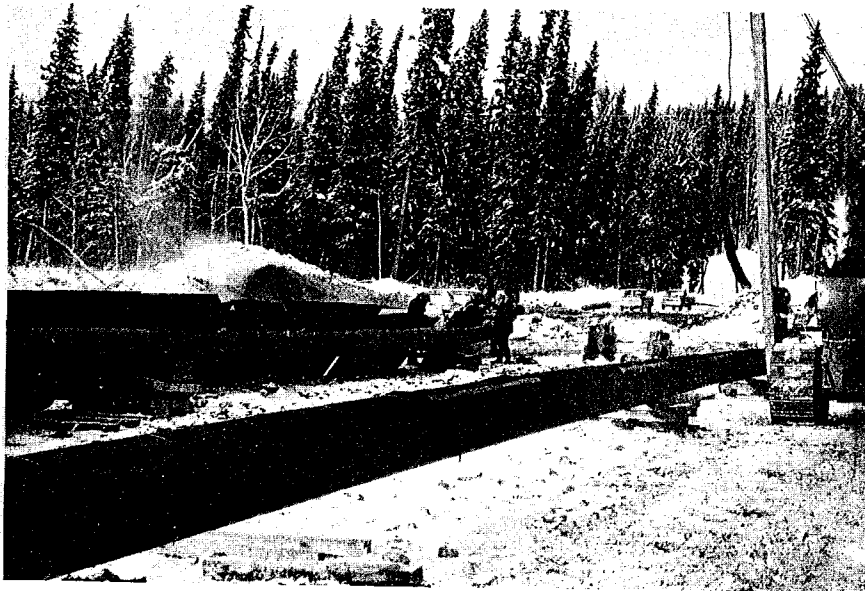


PLATE 5. Welded and wrapped section of pipe. Note the additional wrapping for river crossings.

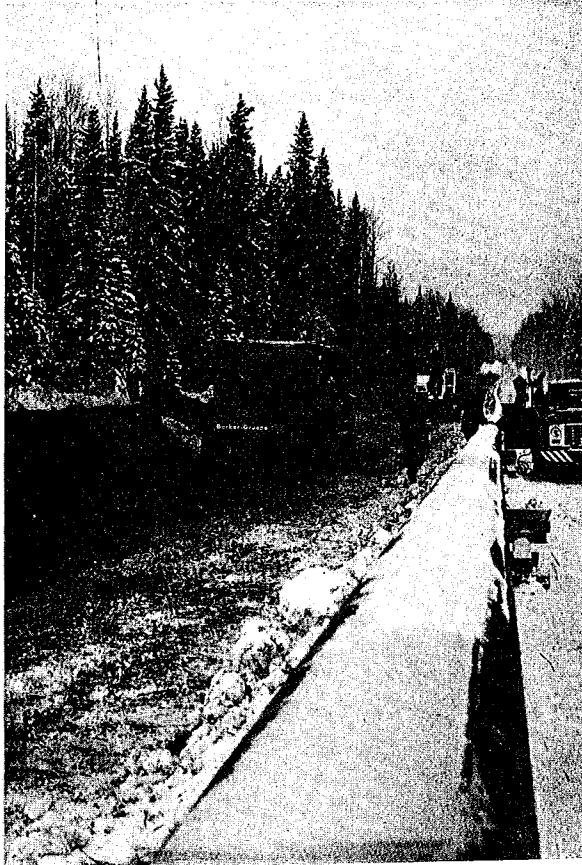


PLATE 6. Excavating the pipeline ditch.

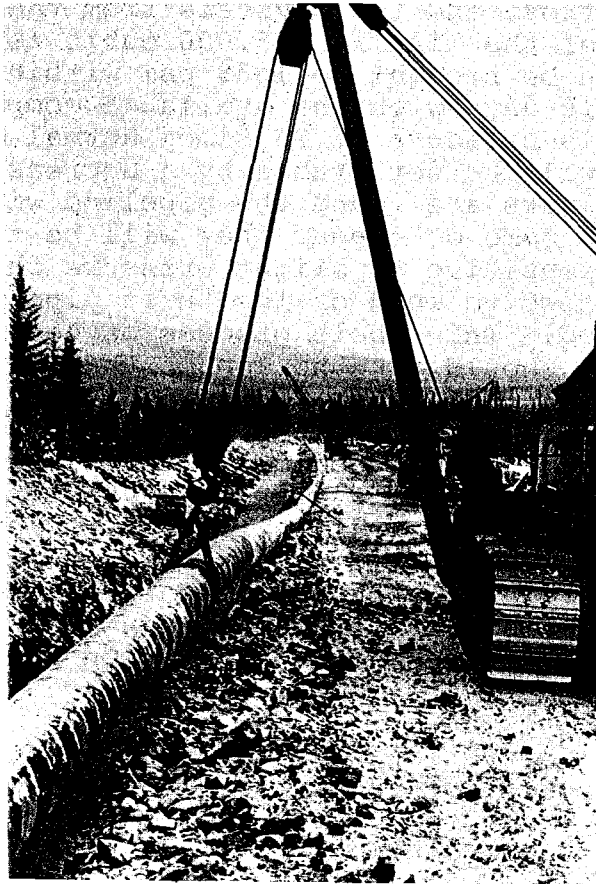


PLATE 7. Pipe being lowered into trench. Note the water in the trench from the surrounding swamp.

were then placed at intervals along the right of way, paralleling the natural drainage pattern of the route. This procedure routes water away from the trench to minimize erosion during spring runoff (Plate 8).

3.4 Testing and Clean-up

When construction of the pipeline is completed and connections have been made at both plants it will then be "pigged" with several hundred gallons of methyl hydrate. This removes all frost and ice crystals from the inside of the pipe (volume of the line is 345,000 cubic feet). Air pressure will then be brought to 1688 psi within the pipe, a process taking 10 days with the available compressing equipment. At this pressure (1.25 times normal operational pressure), leaks will be detectable by a decrease in pressure. If no leaks are found the pipeline will be ready for operation. If some do appear they will be traced by means of a "pig" sensitive to slight pressure changes within the line. The defective weld or length of pipe will then be dug up and replaced. This whole process of testing and repairing the line should take no longer than two weeks.

When the snow melts near the end of April the right of way is to be fertilized and seeded. For this purpose a variety of 15 different native grasses have been selected, and the seeds purchased from a distributor in Fort St. John, B. C. Two or three applications of seeds and fertilizer from a "crop duster" aircraft for the entire length of the right of way is proposed. Plans have been made by Westcoast Transmission Ltd. to study this revegetation programme at intervals during the first summer.

During normal operation seasonal aerial patrols will be carried out to inspect for leaks and areas of concern.

3.5 Problems and Solutions

This sub-section deals with some of the solutions to problems that were encountered during the overland construction phase of the pipeline.

3.5.1 Permafrost

Two main areas of permafrost each approximately one mile in length as well as several small ice lenses of only a few hundred feet were encountered during the construction of this pipeline (Plate 1). In all cases the permafrost occurred immediately below the seasonal frost levels in the ground. The largest permafrost area occurred in the ancient

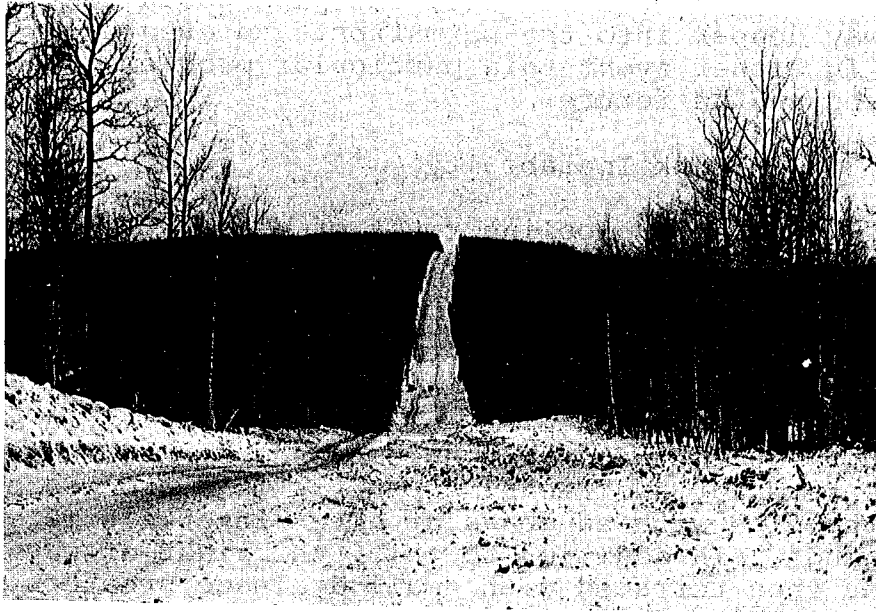


PLATE 8. Completed section of pipeline depicting roadway, berm and drainage breakers.

bed of Fisherman Lake, a low swampy region covered by dwarf birch. The other areas occur in relatively high plateaus covered by dense timber.

In areas of permafrost, the pipe was weighted at calculated intervals with "saddle weights" (concrete saddles weighing 2 tons) (Plate 9). The weights and the ground cover supposedly give the pipe a neutral buoyancy when the heat from the natural gas melts the permafrost in the area immediately surrounding the pipe. It is the writers' opinion however, that this method of dealing with permafrost is probably unsatisfactory. If the pipe is found to have too much buoyancy for the existing weight, it is inevitable that the pipeline will eventually "melt" its way to the surface. If the reverse is true, the pipe would continue to melt its way deeper into the permafrost and eventually rupture. In either event this particular problem should be re-evaluated in the future.

3.5.2 Bank Instability

One slope on the pipeline right of way that might have possible erosion and support problems is situated where the pipeline ascends the west side of the Kotaneelee River valley. This bank drops a distance of about 150 feet at an angle of approximately 40 degrees. The right of way ascending this bank is bordered on both sides by naturally unstable "cut-banks". The pipe at this particular ascent was layed at a depth of 8 to 10 feet and then encompassed by sandbags at 15 foot centers for additional support. This process of wrapping the pipe with sandbags at given intervals is called "sand logging". In addition to this, the right of way surface was then terraced with small drainage breakers which will help channel spring runoff away from the ditch line and decrease erosion on the bank (Plate 10). It is also hoped that the proposed spring seeding programme will provide further stability to this section and prevent erosion in future years. If the grass cover does not germinate a serious instability problem may arise as the bank is of soft erodable silt and sand.

4. River Crossings

4.1 Foreword

The 34.2 mile route from Pointed Mountain to Beaver River crosses two major rivers, the Kotaneelee and La Biche Rivers. Both rivers are tributaries of the Liard River

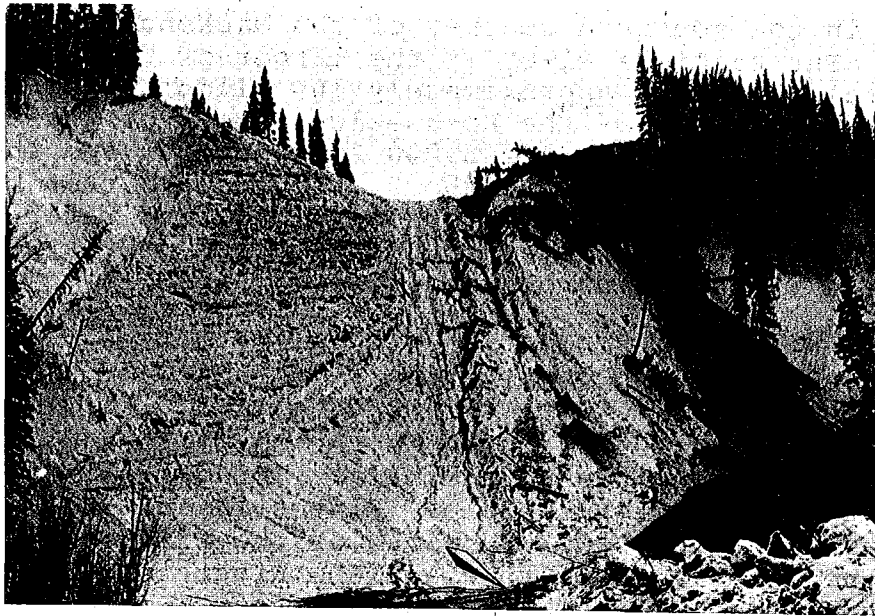


PLATE 9. Concrete "Saddle weights" weighing 2 tons are fastened around pipe in an attempt to achieve neutral buoyancy in permafrost and negative buoyancy in river crossings.



PLATE 10. Close-up of the pipeline ascending the west side of the Kotaneelee River. Note the berm and drainage breakers.

(headwaters in the southern reaches of the Mackenzie Mountains). The La Biche River is the larger of the two having a total length of approximately 100 miles as compared with the 60 mile length of the Kotaneelee. Both of these rivers originate from about the 5,000 foot contour and their drainage distance is relatively short. It appears that both rivers will be subject to high discharges and fast water during the spring thaw. Large amounts of flood debris were evident on the flood plains of both rivers (Plate 11).

4.2 La Biche River Crossing

The construction methods used on the La Biche and Kotaneelee Rivers crossings were similar. Draglines were used to dig the trench for the pipe (Plates 12 and 13). The principal difference was the width of the flood plain as part of the crossing. On the La Biche River the overall length of the flood plain approached 1000 feet (Plate 14). One problem evident from the backfilling operation in the mainstream was the partial stream blockage resulting in overflowing and freezing downstream. (Plates 15 and 16).

4.3 Kotaneelee River Crossing

In preparation for the river crossing the required amount of pipe is welded together (Plate 17) and dressed for the crossing. The dressing for the pipe consists of bolting 2 ton concrete collars around the pipe at 15 foot intervals to insure a negative buoyancy to the pipe and a layer of 2 X 4 inch boards strapped between the collars to guard against possible damage to the pipe during the backfilling operation.

The trench was dug to a depth of 14 feet which will allow 12 feet of cover for the pipe. This insures protection from possible ice scour during spring breakup. The strapped and dressed pipe is then pulled across the river channel, slung into the trench and welded to the existing pipe on both sides of the river (Plates 18, 19 and 20). The approaches to the trench are backfilled and the river banks are restored to their approximate original slope and shape (Plate 21). The remaining trench in the actual river channel is then usually backfilled to normal river bed level.

In the Kotaneelee River however it was felt that because of the small channel width (approximately 40 feet), much of this task was better left to the natural siltation that would occur during high water in the spring. There-

fore only the midstream section was backfilled. Backfilling would likely restore a large fraction of course material to the 12 feet deep trench which would not occur under natural filling by siltation. Backfilling, then, would presumably make for a more stable river bottom.

This raises the question of whether it is better to suffer the short term high level of siltation from backfilling or to have the possibility of a permanent source of river silt from the naturally filled trench.

4.4 Ice Bridges

A related topic to river crossing and one that bears mention is the construction of ice bridges. The ice bridge over the La Biche River was constructed by laying 8 to 30 foot limbed logs, cabled together, on the ice surface parallel to the current flow. These logs were then covered with compacted snow and then this whole structure was flooded with several applications of water and allowed to freeze.

When solidly frozen this ice bridge increased the ice cover over the river by $1\frac{1}{2}$ to 2 feet. When use of this ice bridge is no longer required the logs will be removed leaving only the natural snow and ice cover.

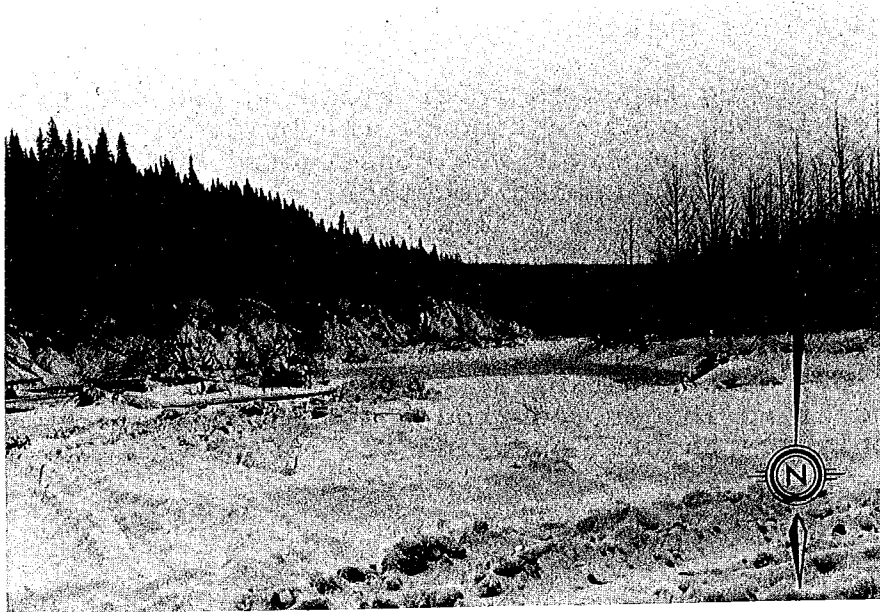


PLATE 11. Downstream of the La Biche River pipeline crossing depicting the flood plain, debris and unstable east bank.

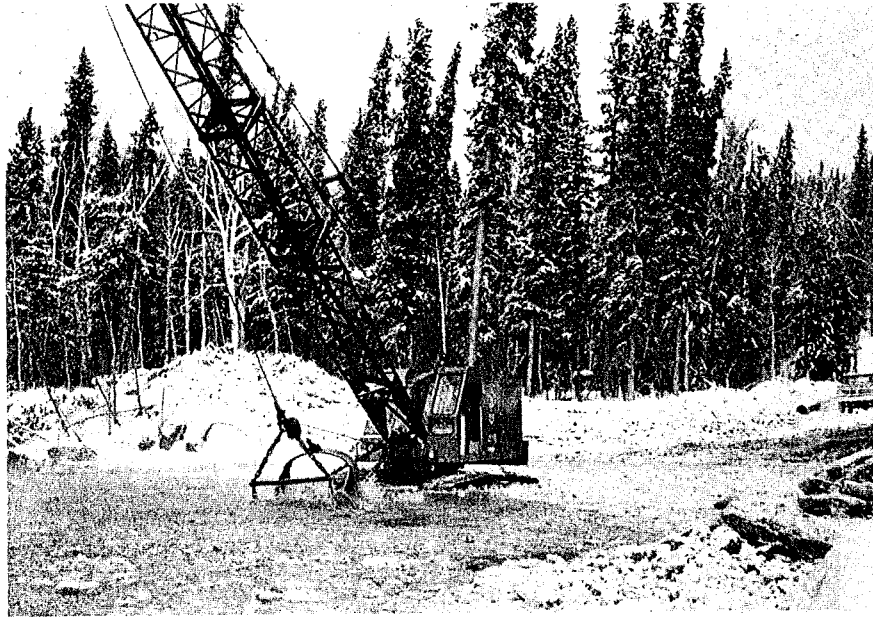


PLATE 12. Heavy equipment trenching for the pipeline in the La Biche River.

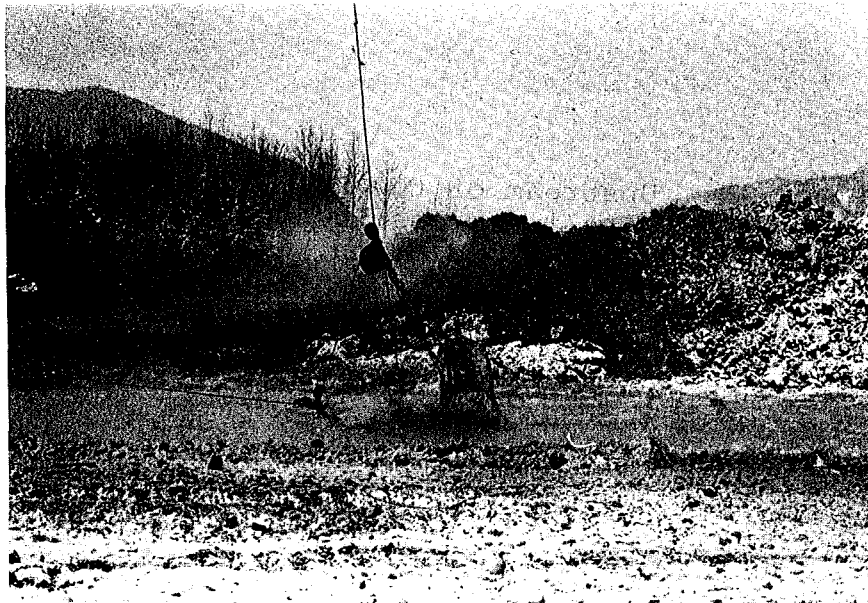


PLATE 13. Dragline digging of the trench for the La Biche River crossing.

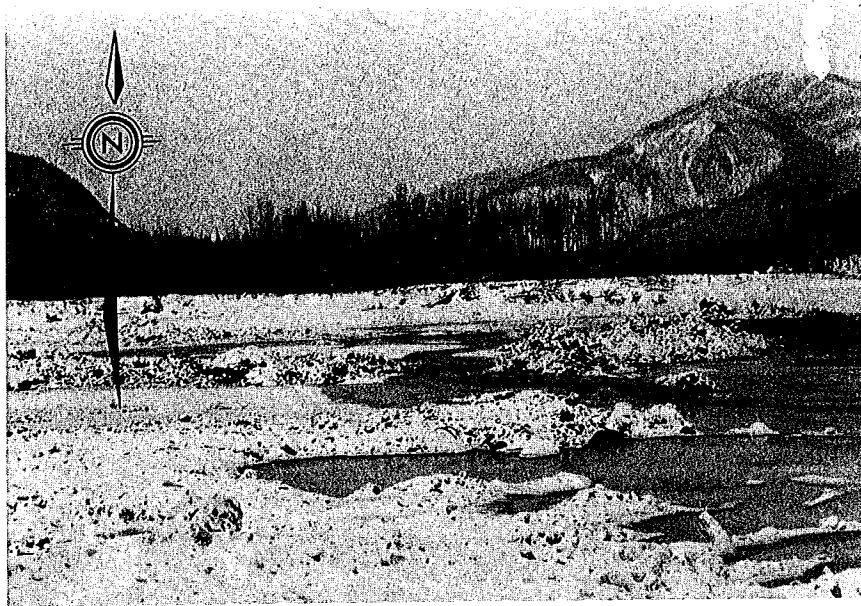


PLATE 14. Upstream of the La Biche River pipeline crossing depicting the large flood plain.

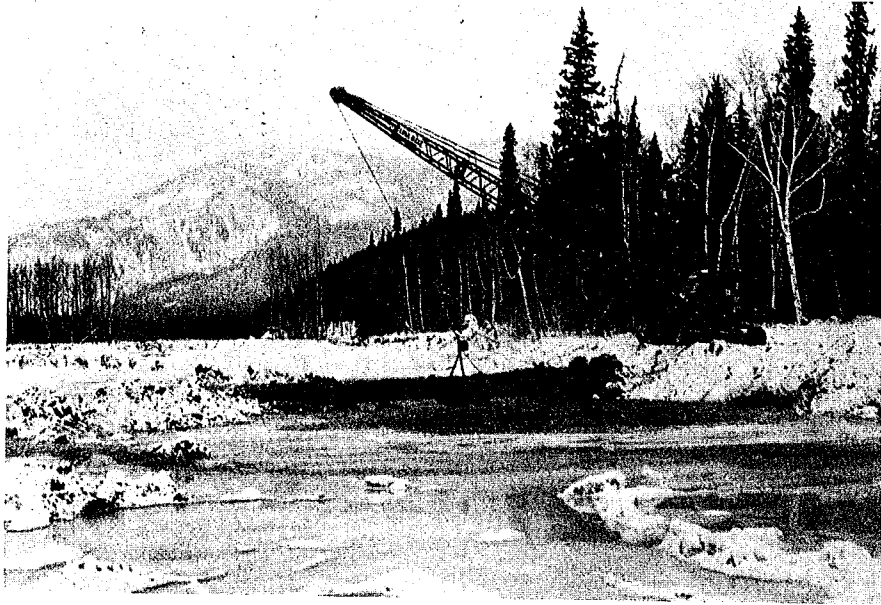


PLATE 15. Removal of excessive backfill
La Biche River.



PLATE 16. Overflow of water and partial
blockage resulting from the back-
filling operation.

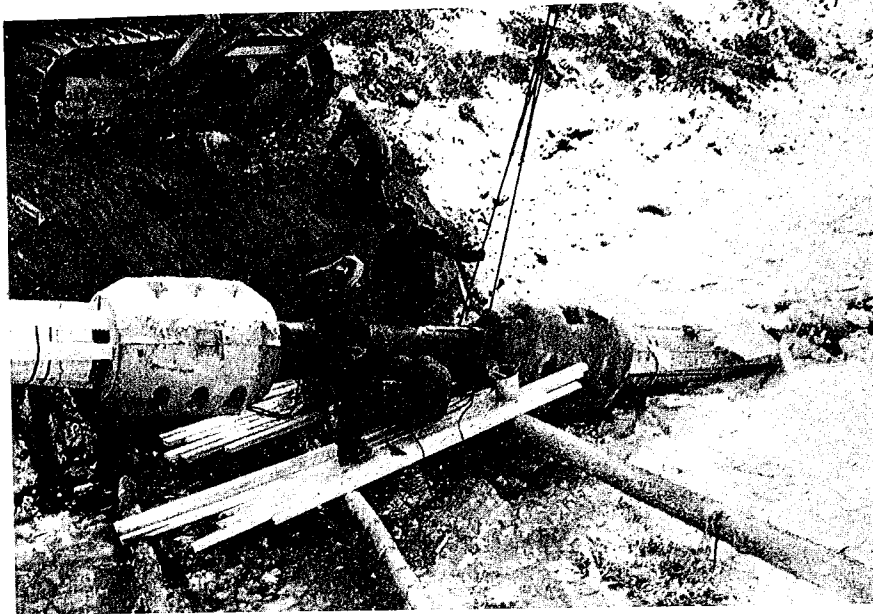


PLATE 17. Welding pipe together on the Kotaneelee River pipeline crossing.



PLATE 18. Pulling the strapped and dressed pipe across the Kotaneelee River. Note the size of the crossing.

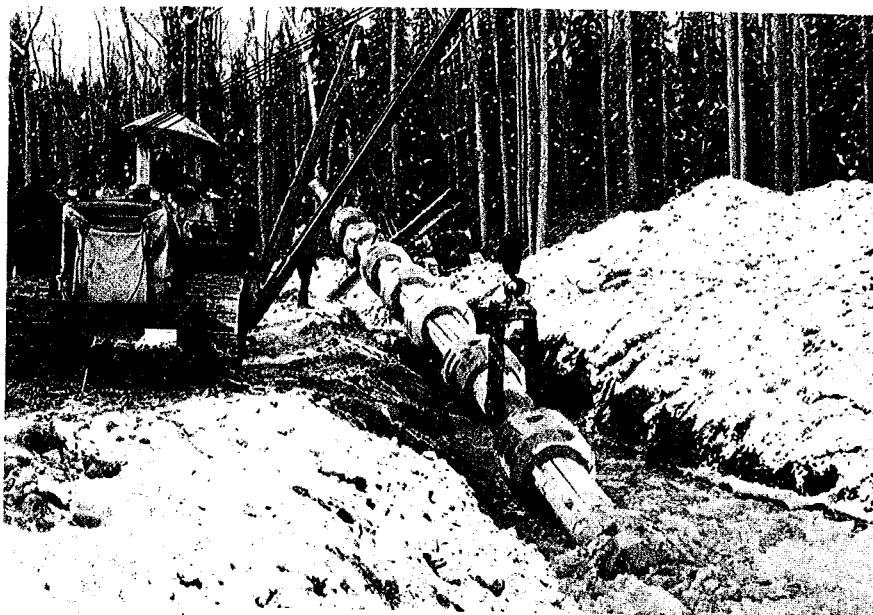


PLATE 19. Slinging the strapped and dressed pipe into the trench beneath the river bed.



PLATE 20. Welding the strapped and weighted section of the pipeline to the existing pipe. Note the concrete collars to prevent floatation.



PLATE 21. Backfilling the river banks to their original slope and shape.

5. Analysis of Disturbance to the Aquatic Environment as a Result of Pipeline Construction

Objectives

The Principal purpose of the survey was to determine the extent and effects of dredging activity in a river bed for a pipeline crossing. In particular:

To determine the magnitude of suspended sediment and its movements.

To compare the total dissolved solids above and below the dredging site.

To determine if an increase in Total Dissolved Solids occurs with increase in suspended sediment.

To determine what fraction of the dredged material is being washed downstream.

To determine what aquatic fauna are resident in the stream bed above and below the pipeline crossing.

To determine the magnitude of the bedload and suspended load movement downstream of the crossing, thereby indicating the changed conditions during the dredging operation.

To relate the results obtained to other published literature in order to estimate the damage, if any, to the aquatic environment.

6. Sampling Methods and Data Collection Planned and Attempted Procedure

6.1 River velocities

Velocity measurements were attempted upstream of the dredging operation on the La Biche River in an undisturbed area (cross-section A, Figure 1), using a Gurley 622 current meter. This method was unsuccessful as the moving cup-wheel of the meter froze up immediately when removed from the water. It is suggested that in future under low temperature conditions (-10 to -30°F) a small gas heater-blower be used on site to thaw and dry the instrument after each reading. Average velocity was estimated to be 3 ft/sec. Using cross-section A (Figure 2) gives a discharge of

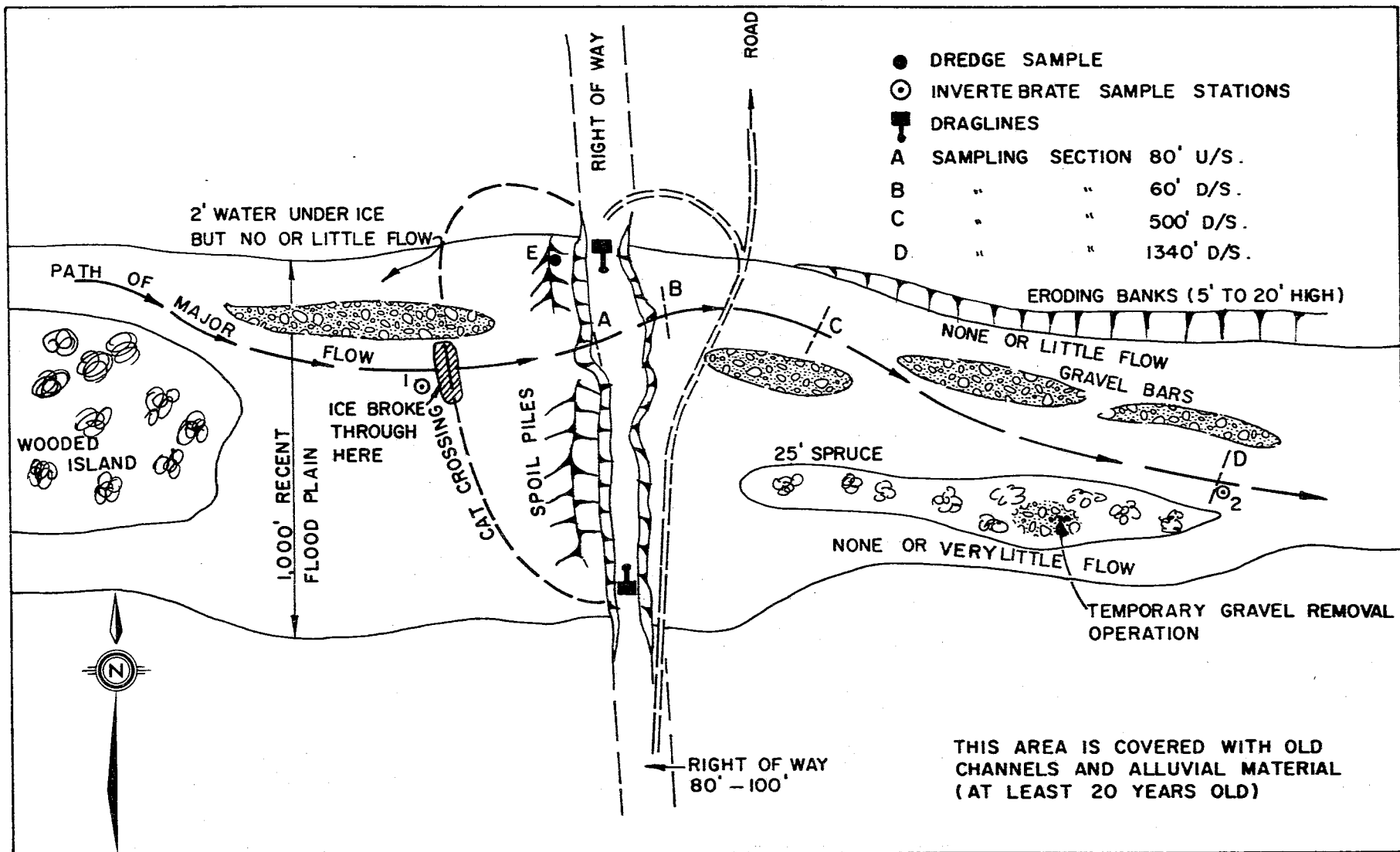


FIGURE 1: LA BICHE RIVER CROSSING

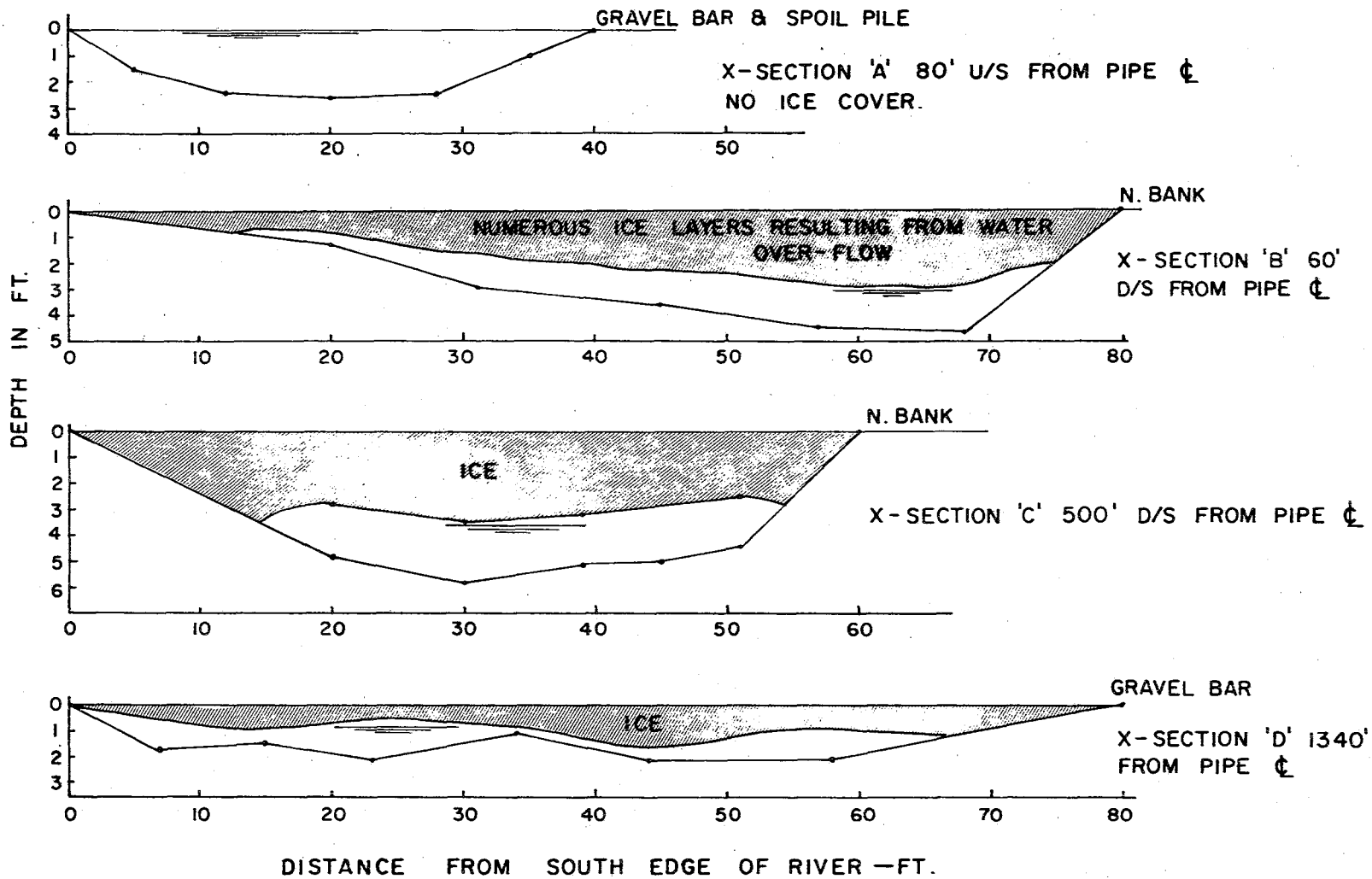


FIGURE 2: SAMPLING CROSS-SECTIONS ON LA BICHE RIVER

approximately 200 c.f.s. (from $Q=AV$) on Feb. 13/72 on the La Biche River. Discharge of the Kotaneelee River on Mar. 16/72 in the area of the pipeline crossing was estimated at 124 c.f.s. immediately above the trench (Figure 4, cross-section A). These estimates are questionable as open water areas were limited to portions of river in the immediate vicinity of the trenching.

6.2 Sampling Transects

Transects were done at all stations used for either suspended sediment sampling or discharge measurement. Ice depth and water depth was recorded at 4 or 5 points in each cross-section. In addition, the total iced width of the stream was measured. Locations of transects are shown for the La Biche River (Figure 1) and the Kotaneelee River (Figure 3). The cross-sections are drawn for the La Biche River (Figure 2) and the Kotaneelee River (Figure 4). The survey data is summarized in Appendix Tables I and II.

6.3 Suspended Sediments and Total Dissolved Solids

Suspended sediment sampling was attempted with the use of a US-DH 48 sampler. This method failed as the sampler froze upon removal from the water. Here, too, a gas heater-blower could be used to keep the sampler operational. A method for obtaining water samples was then improvised; a 500 ml plastic bottle attached by a string was pushed slowly to the bottom using a $\frac{1}{2}$ inch steel rod and then raised to the top by pulling the string (Plate 22).

On the La Biche River 3 samples were collected from each of 5 holes on each transect, during the trenching operation in the river. Locations of the four transects are shown in Figure 1. On the Kotaneelee River 2 samples were collected from each of 4 holes per transect once 24 hours after the trenching was completed, and once during the backfilling operation. Locations of the 4 transects are shown in Figure 3. The method of sampling was very crude and has the following drawbacks:

1. Turbulence at the mouth of the bottle probably reduced the amount of sediment entering the bottle.
2. The closest the mouth of the bottle samples to the river bed was 5 inches, thus excluding the region where suspended sediments are likely to be highest. This is also the region where the heavier particles will be found and it is these that are most likely to settle in the vicinity of the crossing.

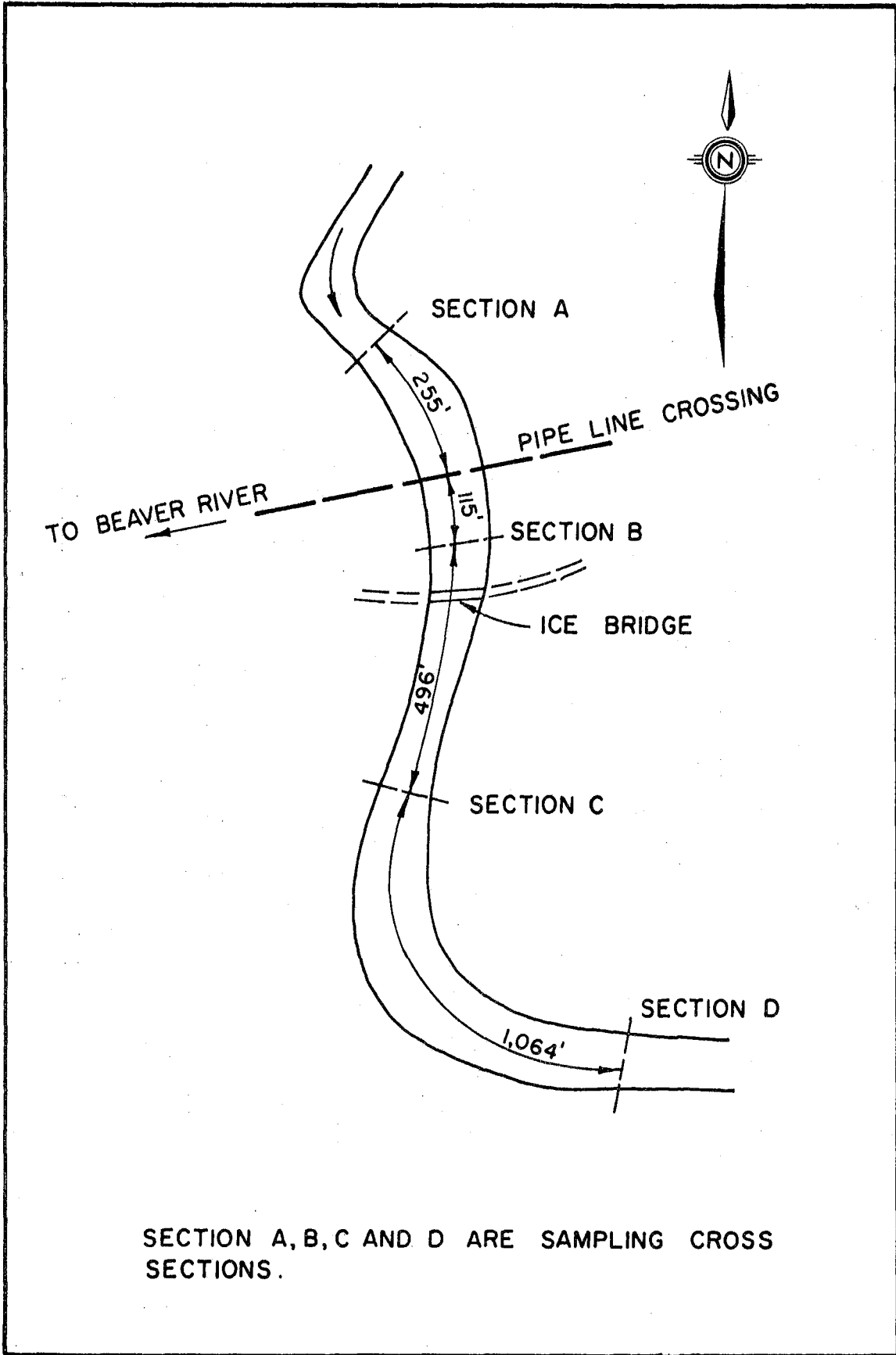


FIGURE 3: KOTANEELEE RIVER CROSSING.

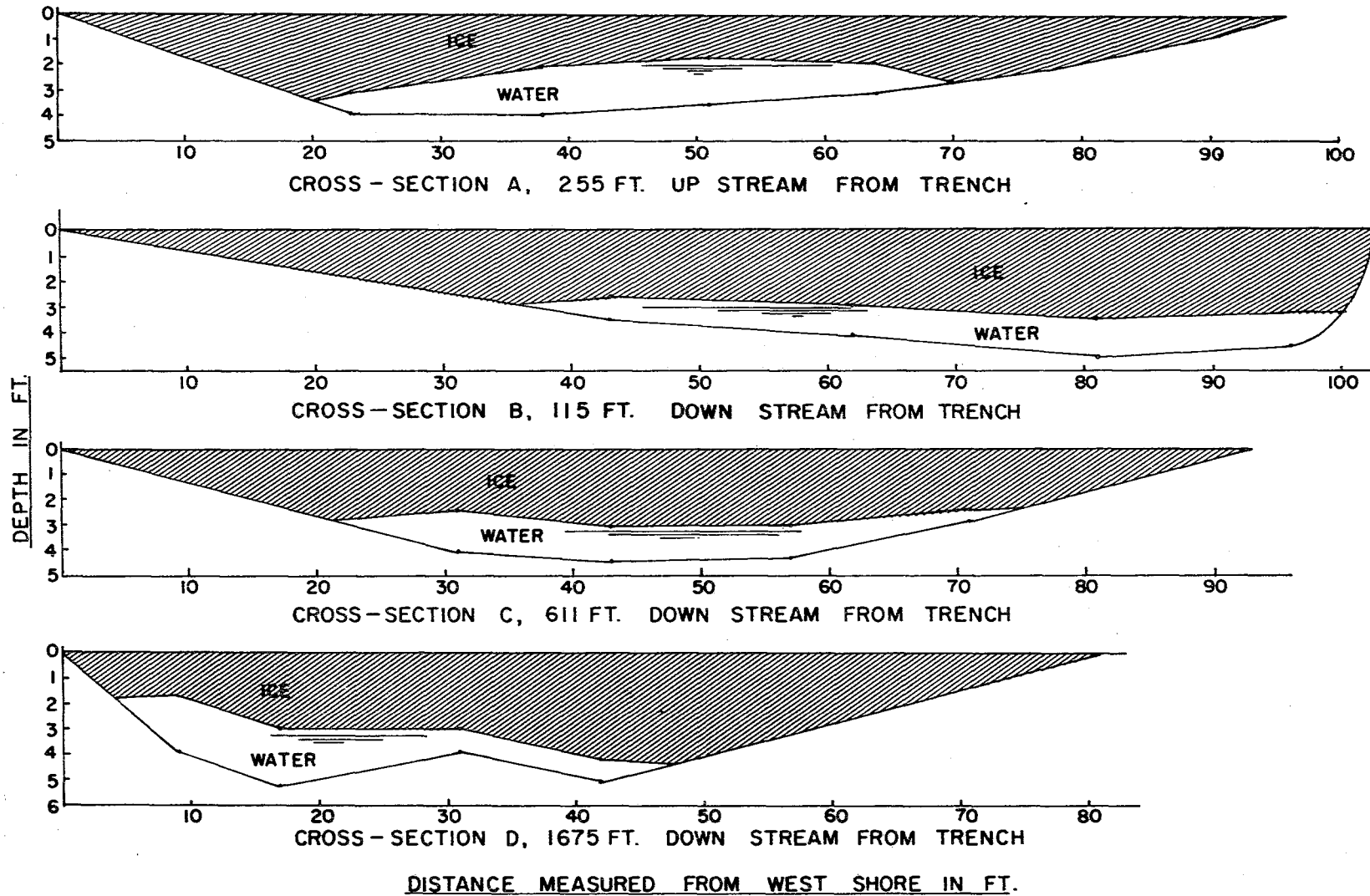


FIGURE 4: SAMPLING CROSS SECTIONS ON KOTANEELEE RIVER



PLATE 22. Improvised suspended sediment sampling apparatus.

3. Part of the sample is unavoidably collected from the static water pushed up the hole in the ice by the flowing water beneath. This would also tend to reduce the sediment concentration. This particular problem was corrected to a great extent on the Kotaneelee River by using a cap which could be placed and removed under the ice.

6.4 Turbidity

Samples collected on the La Biche were analyzed with a Beckman Turbidity Meter.

6.5 Bottom Samples

Bed material samples were obtained on the La Biche River at stations A and D (Figure 1) using a bucket sampler. A sample of the material being dredged from a depth of 15 to 20 feet below the river bed was obtained from the spoil pile at E in Figure 1. The sampler was a reinforced 2 gallon galvanized bucket (mouth opening, 10 inch diameter and depth 12 inches, tapered to an 8 inch diameter) attached to a 1/2 inch pipe handle. Leverage for sampling was achieved by connecting a rope to the bucket handle.

The disadvantage of such a sampling method is that in disturbing the bed many of the smaller particles are washed downstream. Better sampling methods are the freeze sampler developed by Fisheries Service, Vancouver, and the McNeil sampler (McNeil *et al* 1964). Both of these samplers are restricted to shallow water areas (1-2 feet).

6.6 Benthic Invertebrate Samples

Bottom fauna samples were obtained on the La Biche River at points 1 and 2 shown in Figure 1, with the use of a Kussat sampler (R. Kussat, 1969, pers. comm.). As the river bed was composed of large boulders 6 to 10 inches diameter, working the sampler into the gravel without disturbing the bottom fauna was difficult.

7. Analysis and Results

7.1 Suspended Sediments

All suspended sediment samples were filtered through GSC glass fiber paper and the sediment retained was dried and weighed. The results of this analysis appear in Tables I, II and III for the La Biche and Kotaneelee Rivers.

TABLE I. Suspended sediment sampling in La Biche River.

Transect	Site	Sample No.	Filterable Solids (mg/l)	Turbidity - JTU	
			Avg.		
A 80 Ft. (24 m) Upstream of trench	1	1	<10	<10	None detectable
		2	<10		
		3	<10		
	2	1	<10	<10	None detectable
		2	<10		
		3	<10		
	3	1	<10	<10	None detectable
		2	<10		
		3	<10		
	4	1	<10	<10	None detectable
		2	<10		
		3	<10		
	5	1	<10	<10	None detectable
		2	<10		
		3	<10		
B 60 Ft. (18 m) Downstream of trench	1	1	79	81	35
		2	79		
		3	85		
	2	1	97	97	25
		2	120		
		3	74		
	3	1	90	85	40
		2	81		
		3	84		
	4	1	100	102.5	19
		2	97		
		3	111		
	5	1	150	144	55
		2	138		
		3	143		
C 500 Ft. (153 m) Downstream of trench	1	1	93	105	55
		2	121		
		3	100		
	2	1	179	124	45
		2	88		
		3	106		
	3	1	117	99	25
		2	77		
		3	102		
	4	1	508	453	70
		2	543		
		3	309		
	5	1	170	172	70
		2	164		
		3	183		
D 1340 Ft. (410 m) Downstream of trench	1	1	135	111	65
		2	124		
		3	75		
	2	1	160	166	50
		2	188		
		3	148		
	3	1	129	146	40
		2	133		
		3	176		
	4	1	154	159	50
		2	165		
		3	158		
	5	1	123	159	50
		2	157		
		3	107		

TABLE II. Suspended sediment samples, from the Kotanelee River 24 hours after the trenching operation had ceased.

Transect	Site	Sample F. No.	Filterable Solids (mg/l)		Total Dissolved Solids	
				Avg.		
A 255 Ft. (78 m) Upstream	1	1	<10	<10	406	
		2	<10		386	
	2	1	<10	<10	382	
		2	<10		392	
	3	1	<10	<10	386	
		2	<10		-	
	4	1	<10	<10	2089*	
		2	<10		366	
						Avg. - 386
	B 115 Ft. (35 m) Downstream	1	1	12	15	391
			2	18		377
		2	1	<10	<10	-
2			<10		397	
3		1	<10	<10	382	
		2	<10		378	
4		1	<10	<10	383	
		2	<10		363	
					Avg. - 381	
C 611 Ft. (186 m) Downstream		1	1	<10	<10	391
			2	<10		389
		2	1	<10	<10	350
	2		<10		385	
	3	1	<10	<10	383	
		2	<10		371	
	4	1	<10	<10	405	
		2	<10		397	
						Avg. - 384
	D 1675 Ft. (510 m) Downstream	1	1	<10	<10	391
			2	<10		400
		2	1	<10	<10	398
2			<10		396	
3		1?	<10		400	
		2	13		402	
4		1	<10	<10	399	
		2	<10		395	
					Avg. - 398	

*Questionable value excluded from average.

TABLE III. Suspended sediment samples during the backfilling operation on the Kotaneelee River.

Transect	Site	Sample F. No.	Filterable Solids (mg/l)		Total Dissolved Solids	
				Avg.		
B 115 Ft. (35 m) Downstream		1'	140	131.5	400	
		2'	123		408	
		1'	38	55	399	
		2'	72		392	
		1'	13	13	398	
		2'	-		-	
		1'	10	10	398	
		2'	10		421	
					Avg. - 402	
	C 611 Ft. (186 m) Downstream		1'	54	57	396
			2'	60		396
			1'	99	66.5	397
		2'	34		397	
		1'	37	23.5	385	
		2'	10		399	
		1'	10	10	390	
		2'	10		394	
					Avg. - 394	
D 1675 Ft. (510 m) Downstream			1'	48	47.5	377
			2'	47		384
			1'	26	25.5	406
		2'	25		372	
		1'	50	34.5	382	
		2'	19		393	
		1'	17	15	368	
		2'	13		394	
					Avg. - 384	

The lateral variation in the distribution of suspended sediment in the La Biche River (Figure 5) ranges generally between 100 and 200 mg/l with a peak of 453 mg/l on transect C.

The lateral distribution of suspended material during the backfilling on the Kotaneelee (Figure 6) is skewed to one bank.

Longitudinal distribution of suspended sediment during the trenching at La Biche (Figure 7) rises abruptly downstream of the trench, and then diminishes somewhat to a value of 142 mg/l 1340 feet (410 m) downstream of the trench. The longitudinal distribution on the Kotaneelee River (and during the backfill operation) 24 hours after the trenching operation ceased is shown in Figure 8. (The samples taken 24 hours after trenching on the Kotaneelee crossing show little (10 mg/l) or no sediment being taken into suspension.) Here again, during the backfill operation the suspended sediment concentration rises abruptly from a non-measurable value upstream of the trench to a significant value downstream of the trench.

7.2 Total Dissolved Solids

Total dissolved solids recorded for all Kotaneelee River water samples are tabulated (Table II). All transects average between 380 and 400 mg/l.

7.3 Turbidity

A plot of filterable solids vs. turbidity for the water samples obtained from the La Biche River appear in Figure 9. The most likely relationship between turbidity and filterable solids is indicated by the dashed line.

7.4 Bed-Material Samples in La Biche River

The two bed-material samples were mistakenly combined and sieved together. The resulting curve is shown in Figure 10.

The analysis should have included some larger sieve sizes to give a better indication of size distribution. The sample of dredged material from the spoil site was soaked and wet sieved as it was in large, compacted, frozen chunks. The

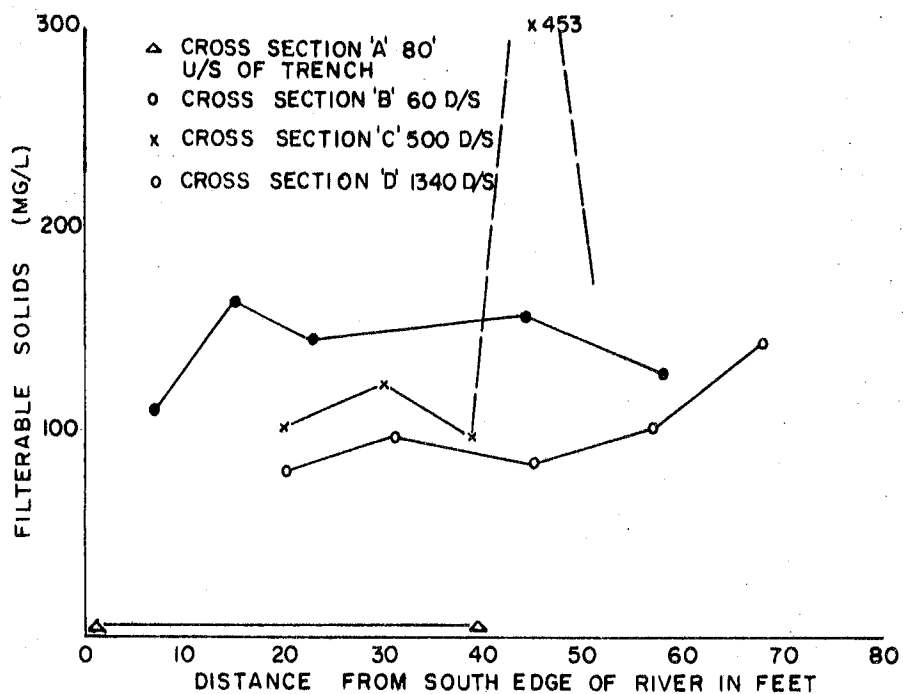


FIGURE 5: LATERAL DISTRIBUTION OF SUSPENDED SEDIMENTS AT FOUR CROSS SECTIONS ON THE LA BICHE RIVER.

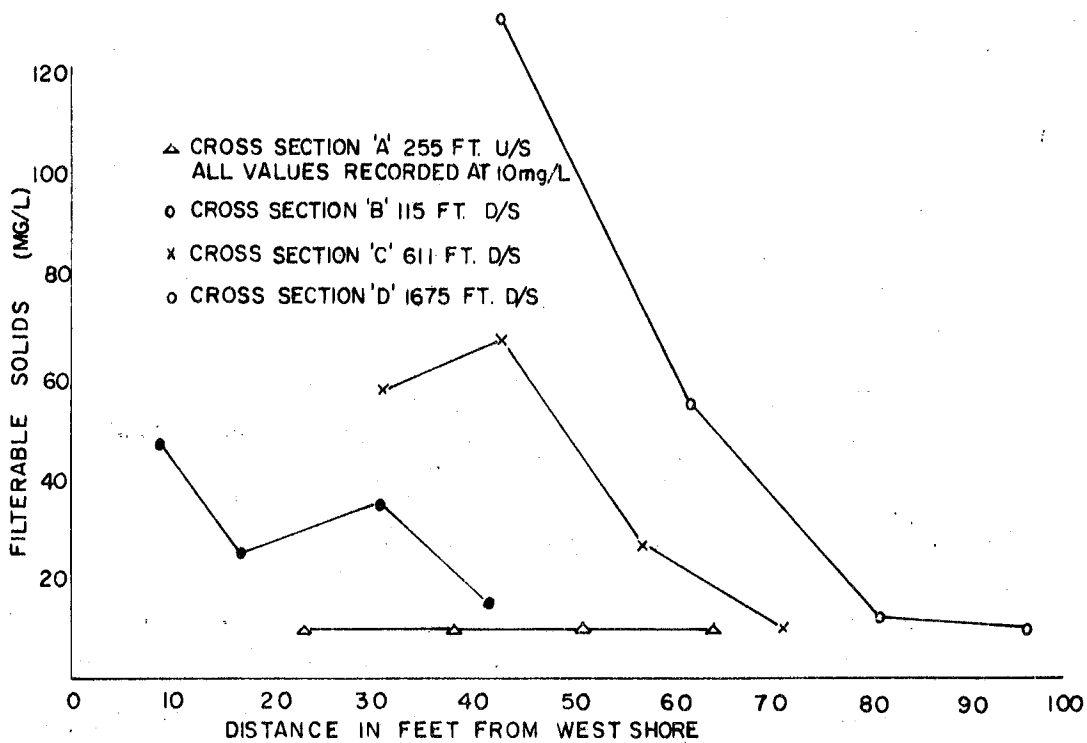


FIGURE 6: LATERAL DISTRIBUTION OF SUSPENDED SEDIMENTS DURING BACKFILL OPERATION ON KOTANEELEE RIVER.

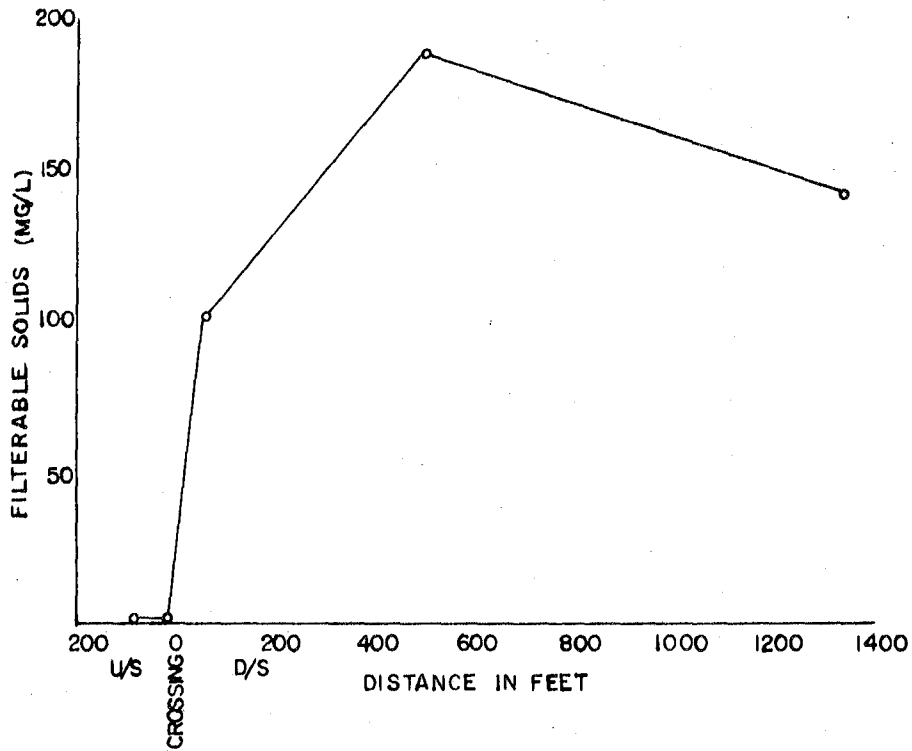


FIGURE 7: LONGITUDINAL DISTRIBUTION OF SUSPENDED MATERIAL LA BICHE RIVER.

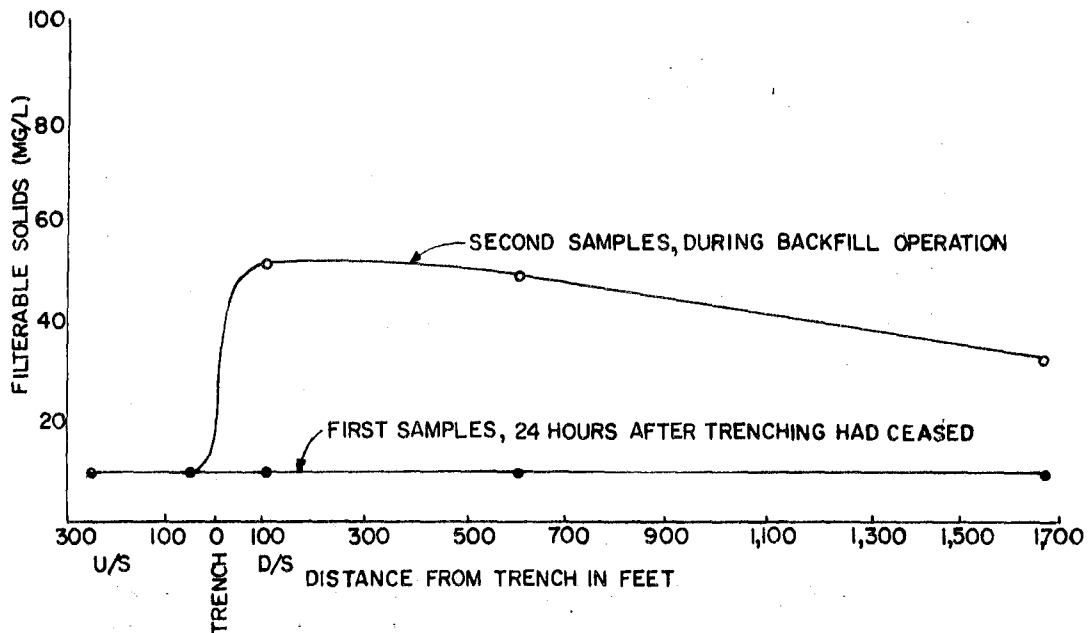


FIGURE 8: LONGITUDINAL DISTRIBUTION OF SUSPENDED SEDIMENT ON KOTANEELEE RIVER.

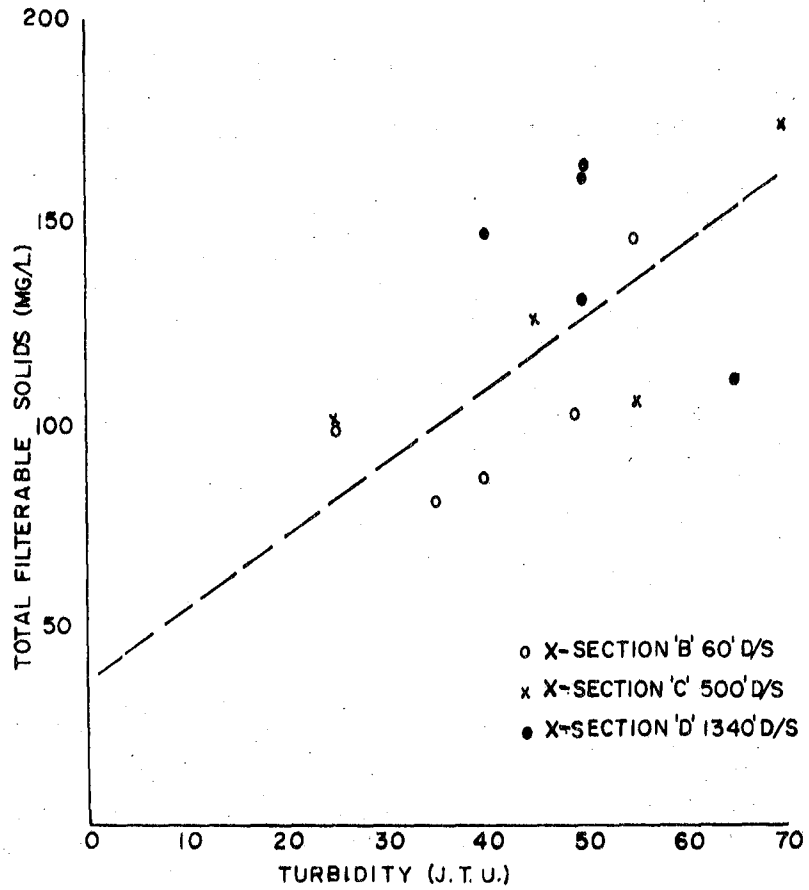


FIGURE 9: TURBIDITY FILTERABLE SOLIDS
 LA BICHE RIVER

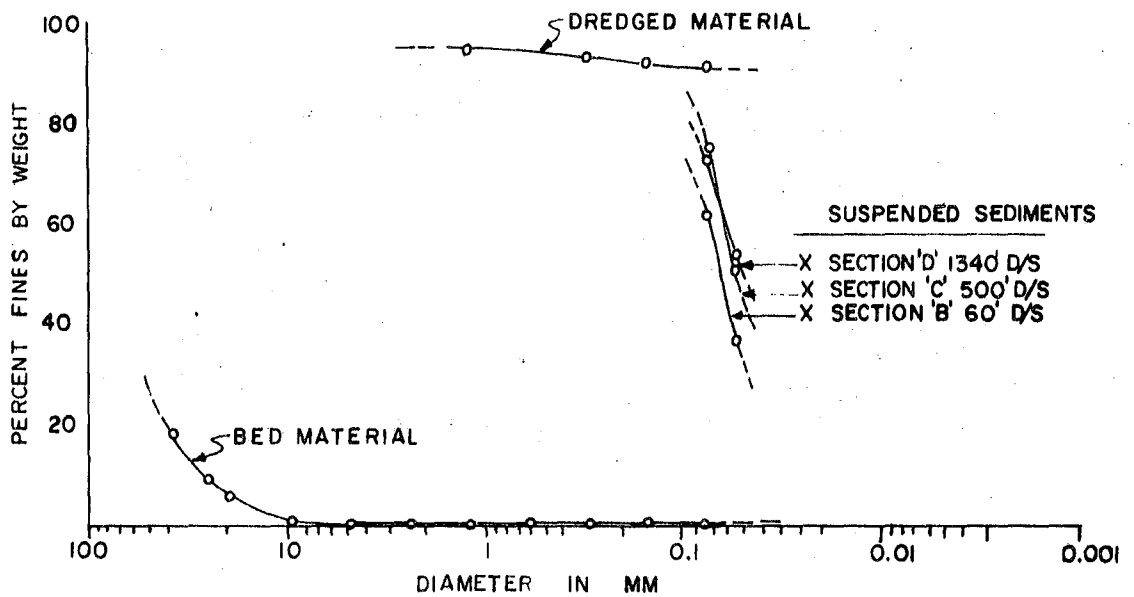


FIGURE 10: LA BICHE RIVER GRAIN SIZE ANALYSIS

resulting curve is shown in Figure 10. The analyst notes that further soaking would very likely have resulted in all the material passing through the 0.074 mm sieve.

The size distribution of the suspended material from cross-sections B, C, and D are also shown in Figure 10. All the above data is tabulated in Appendix Table III.

7.5 Benthic Invertebrate Samples

The analysis of the aquatic invertebrates collected on the La Biche River appear in Table IV. No conclusions can be drawn from only 2 samples of this type. It is therefore impossible to postulate the effect the disturbance had on aquatic benthos downstream.

8. Discussion of Results of Sampling Project

8.1 Suspended Sediment

Except for one point on cross-section C (Figure 5), the lateral variation of suspended sediment on the La Biche River is not excessive. The very high value of 453 mg/l on cross-section C seems questionable although all three samples from that hole were found to have suspended sediment concentrations in that range.

Lateral distribution of suspended material during the backfill operation on the Kotaneelee River (Figure 6) is skewed to one bank, very likely as a result of the position of the backfilling at that time, and of the river bend tending to keep the sediment on that same bank.

Longitudinal distribution of suspended sediment during the trenching operation in the La Biche (Figure 7) rises abruptly downstream of the trench and then falls somewhat to a value of 142 mg/l 1340 feet (410 m) downstream of the trench. This is true if the high value in cross-section C is included. If this value is excluded, the longitudinal distribution rises gradually from 102 mg/l 60 feet (18 m) downstream to 142 mg/l 1340 feet (410 m) downstream.

This, however, is not what would be expected. It would seem reasonable if the greatest amounts of suspended sediment were found closest to the source - namely, the river bed disruption. Higher levels of suspended sediments might be

TABLE IV. Invertebrate samples from the La Biche River.

Fauna 300 Ft. (91 m) Upstream from Trench

Ephemeroptera	11
Diptera: Chironomidae	12
Unknown	1

Fauna 1340 Ft. (410 m) Downstream from Trench

Ephemeroptera	40
Plecoptera	12
Diptera: Simuliidae	1
Tipulidae	1
Emphididae	2
Chironomidae	48
Unknown	4

found farther downstream, after the disturbance had ceased, during periods of fluctuating discharge, or turbulence when fine particles could re-enter the water column.

Therefore, the only conclusion that can be drawn is that the suspended sediment concentration in La Biche River resulting from the trenching operation is between 100 and 200 mg/l persisting downstream a distance of at least 1340 feet (410 m) from the trench.

In the Kotaneelee River during the backfilling operation, again the suspended sediment concentrations rise abruptly from a non-measurable value upstream of the trench to a significant value downstream. The concentration of suspended sediment seems to fall off in a downstream direction to some extent from 52 mg/l 100 feet (30 m) downstream to 32 mg/l 1670 feet (509 m) downstream. The samples taken 24 hours after trenching had ceased show very little (<10 mg/l) or no sediments were being taken into suspension as a result of the trenching operation. It was assumed, but not confirmed, that the suspended sediment levels would soon return to natural levels after the backfilling as well. Therefore it is likely that the total effect of dredging in a river bed of material similar to that of the Kotaneelee River during a period of flow of approximately 125 s.f.s. is very temporary (less than 24 hours).

Comparing levels of suspended sediment concentration during the trenching of the La Biche River and during the backfilling of the Kotaneelee River indicate that the trenching operation produces a higher concentration of suspended sediment than does the backfill operation (100 to 200 mg/l compared to 30 to 60 mg/l). This would seem logical as the backfill material is generally large frozen chunks of silt, clay and gravel, whereas the material from the trench contains less frozen material. Even though this conclusion seems reasonable it should not be accepted at this point because the samples were taken from two different rivers with, likely, different bed material and flow conditions.

8.2 Total Dissolved Solids

Total dissolved solids recorded for all Kotaneelee River water samples are tabulated in Table II. All cross-sections average between 380 and 400 mg/l indicating that the pipeline operation in the Kotaneelee River has very little effect on the total dissolved solid concentration.

8.3 Turbidity - Filterable Solids Relationship

A paper presented by Duchrow and Everhart (1971) outlines studies done on the validity of using turbidity as a criterion for stream quality with regard to suspended matter. In order for turbidity to be used as an indirect method of measuring suspended solids certain prerequisites are outlined by the authors.

1. Total turbidity of a sample must be comprised mainly of settleable solids.
2. Non-filterable and total dissolved solids must have a negligible effect on the overall reading.
3. Percentage contribution of settleable solids must remain constant for determination of the appropriate factor to convert turbidity readings to settleable solids.

Duchrow's and Everhart's conclusion was that turbidity may be used as an index of suspended sediment concentrations if the source of sediment is constant. Each stream must be calibrated and the resulting curve can only be applied to that stream. This is due to the variability of sediment size, shape, colour, specific gravity and refractive index, from stream to stream.

A plot of filterable solids vs. turbidity for the water samples obtained from the La Biche River appears on Figure 9.

The data for filterable solids vs. turbidity are scattered and therefore only a crude relationship can be drawn for the two variables.

Two possible reasons can be given for the inconclusive results.

1. The total turbidity of the samples was not composed mainly of settleable solids. This is possibly due to the high percentage of very fine particles (<0.074 mm diameter) found in the material being dredged from the channel and being washed downstream by the river.
2. The data gathered is not sufficient to draw from it a rating curve for the river. Suspended sediment determinations should be made for turbidities

greater than 70 J.T.U. (up to 4000 J.T.U. if possible). Therefore Figure 9 shows only a limited portion of what should be a much larger rating curve. The most likely relationship between turbidity and filterable solids for the La Biche River is indicated by the dashed line in Figure 9. This line falls between that given for soil (steeper slope) and that given for Kaolin-clay material (gentler slope) by Duchrow and Everhart (1971).

Even though no conclusive results were gained from these data it is recommended that more work be initiated in this area when appropriate situations arise. The method would best be applied where a periodic monitoring of a particular stream is desired. If a turbidity-suspended relationship can be determined for the stream, quick turbidity measurements can be used as an index of suspended sediment concentration.

A Beckman turbidity meter was used to determine turbidity in the La Biche samples and has been found to be rather unreliable on some types of samples. This may be part of the reason for the large variability of the data (Figure 9).

8.4 Bed Material Samples from the La Biche River

The two bed material samples were mistakenly analyzed together. The analysis should have included some larger sieve sizes to give a better indication of size distribution.

The samples of dredged material were large chunks of frozen material. The analyst notes that if adequate thawing and soaking procedures were used likely all of the sample would have passed through the 0.074 mm sieve.

The bed material samples were obtained from the upper 15 cm of the river bed. The bulk of the material is larger than 10 mm in diameter (Figure 10). Finer material is undoubtedly flushed downstream during freshets. This is also evident from the large (150-200mm) boulders armouring the bed. The suspended sediments introduced by dredging may settle temporarily downstream during low stream discharges. However since most of the suspended sediment is much finer than the natural bed material, it would probably become suspended again and be flushed through the river system during the first freshet. The source of the suspended material is assumed to be the dredged material. If the suspended material curves are accurate only a small size range of the dredged material is being sampled as suspended load. The

larger particles are very likely to settle out in the immediate vicinity of the trench or are placed in the spoil pile. The smaller particles are very likely not broken down to their unit size but remain stuck together in larger particles. The unit size of the particles in the dredge sample appeared to be in the clay size range (0.0002mm to 0.002mm diameter). This possibly could have been confirmed if the dredge sample had been analyzed for smaller particle size. It is likely the suspended sediment consisted of finer particles as well. If these assumptions are true it would shift the curves for both the dredge material size and suspended sediment size farther to the right in Figure 10, into the silt-clay range (0.02mm to 0.0002mm diameter)

The conclusion which can be formed is that if any of the suspended material did settle in the bed in the sample reach it would be flushed out during the rising waters in the spring.

8.5 Aquatic Invertebrates

No conclusions can be drawn from this sampling programme except the presence of the few invertebrate taxa. A meaningful fauna programme must include adequate sampling before and after such disturbance. It would be more complete to include drift as well as benthic sampling.

8.6 Comparison of Field and Theoretical Values for Bedload Movement

If the suspended sediment sampling and analysis had been more accurate and extensive they could be compared with some theoretical constructs. In the future it is hoped that improved sampling plus the addition of some parameter measurements and estimates will provide such useful comparisons.

It is hoped that certain predictive value would be found in this procedure.

8.6.1 Theoretical bedload capacity in an undisturbed condition

- a) Using the Kalinske (1947) equation (Du Boys type) (Figure 12),

$$\frac{q_s}{u_* d} = fct \frac{(\tau_0) cr}{\tau_0}$$

q_s is the bedload rate in volume/unit time/unit width

where f_{ct} is given in Figure 12
 the value $(\tau_o)_{cr}$ is from Figure 11

τ_o is the tractive force or
 shear stress
 $(\tau_o)_{cr}$ is the critical shear
 stress
 u_* is the shear velocity

$$\tau_o = \gamma RS$$

γ is the specific weight of
 water (62.4 lbs/ft³)
 R is the hydraulic radius of
 the channel
 S is the slope of the river
 surface

$$q_s = f_{ct} \left[\frac{(\tau_o)_{cr}}{\tau_o} \right] u_* d$$

$$q_s = u_* d$$

$$u_* = \sqrt{\frac{g \tau_o}{\gamma}}$$

g is gravitational constant
 32.2 ft/sec²

$$dg_s = q_s$$

g_s is the bedload rate in
 weight/unit width/unit
 time

$$G_s = g_s B$$

G_s is the bedload rate in
 weight/unit time
 B is the channel width

The Kalinske equation should be used with caution at
 values of g_s over 6 kg/m/sec.

b) Using the Einstein (1950) equation

$$\phi = fct(\Psi)$$

ϕ is the intensity of bedload transport

Ψ is the intensity of shear stress on the particles

Assume $R_h = R_h'$ and $d_{50} = d_{35}$

R_h is the total hydraulic radius
 R_h' is the hydraulic radius due to particles

d_{50} is the median particle size of bed by weight

$$\text{then } \Psi = \frac{\rho_s - \rho}{\rho} \frac{d}{SR_h'}$$

ρ is the density of water (1)
 ρ_s is the density of particles in bed

S is the slope of river

$d = d_{50}$

Values for Ψ and ϕ are derived from Figure 13.

$$\phi = \frac{g_s}{\gamma_s} \sqrt{\frac{\rho}{\rho_s - \rho} \frac{1}{gd^3}}$$

g_s is the bedload rate in weight/unit width/unit time

g is a gravitational constant

Solve for g_s

$$G_s = g_s B$$

B is the channel width

G_s is bedload rate in weight/unit time

Results obtained from the Einstein equation and Kalinske equation should be compared to see if they are approximately within $\pm 20\%$. If they are not further investigation into methods of analysis should be made.

The theoretical point where appreciable bedload movement begins may be determined by using either of the above two equations and substituting in various values of R_h and S and B for changing river conditions.

The theoretical values represent the capacity of the river to transport bedload and will be obtained in actuality only if the variance in particle size on the stream bed is low so the d_{50} size is indeed representative of the whole bed (Figure 14). A more accurate method of predicting bedload movements is to solve the above equations for various particles in the bed (Figure 15).

This allows for the prediction when various sizes of bed-material will be moved in appreciable amounts. However, to produce a complete analysis of river particle transport we must consider the suspended sediment also. This is called the total load rate g_{st} and is obtained by the addition of the bedload rate g_s (from calculations (a) and (b)), and the suspended load rate g_{ss} . The methods for obtaining g_{ss} are not discussed here, but the reader is referred to Graf (1971) p. 161. There exist direct methods of determining the total load without the addition of two factors. In these cases, researchers establish a relationship which is immediately compared with measurements of total load. One of these approaches is from Einstein (1964) and is a revamping of an equation from Colby (1955, 1961), (Graf, 1971).

$$\frac{i_{st} g_{st}}{i_{ssm} g_{ssm}} = \frac{E^{z-1} (1 - A_E)^z (1 + P_E l_1 + l_2) A_E}{A_E (1 - E) (P_E l_1 + l_2) E}$$

where,

i_{st} is the fraction of total load of given gram size
 g_{st} is the total load rate in weight/unit time/unit width
 i_{ssm} is the measured fraction of suspended load of a given gram size

g_{ssm} is the measured suspended load rate/unit time/unit width

E is the ratio of unmeasured depth by suspended sediment sampler to total water depth

Z is the exponent for suspension distribution

$$Z = \frac{v_{ss}}{.4 u_*'}$$

where,

$$u_*' = gRh'S$$

g is the gravitational constant
 Rh' is the hydraulic radius due to particles

S is the river slope

ss is the settling velocity of a particular particle

$$A_E = \frac{a}{D}$$

D is the water depth

a is the bed layer = $2d$

d is the grain size diameter

I_1 is the integral value from Figure 16

I_2 is the integral value from Figure 17

$$P_E = 2.303 \log \left(\frac{30.2D}{\Delta} \right)$$

D is the water depth

$$\Delta = \frac{Ks}{x}$$

Ks is the roughness diameter d_{65}

$$x = fct \frac{Ks}{\delta} \quad \text{from Figure 18}$$

$$\delta = \frac{11.6\nu}{u_*}$$

ν is the Kinematic viscosity of water

$\Sigma_{ist}G_{st}$ is the bed-material rate
in weight/unit time for
all size fractions for
entire cross-section

[[For a complete explanation of the available techniques
the editor refers the reader to Graf, 1971.]]

This may be worked through for pre-construction, during
construction and post-construction periods to give an idea
of how intensive the disturbance is and for what length of
time the disturbance lasts due to pipeline trenching.

An estimation of when certain size fractions will be
eroded, transported and deposited under various hydraulic
conditions may be made from the Hjulström diagram (Figure
19). The various size fractions of the suspended load, bed
load and dredge material may be evaluated as to their con-
dition in various reaches of the river using Figure 11.

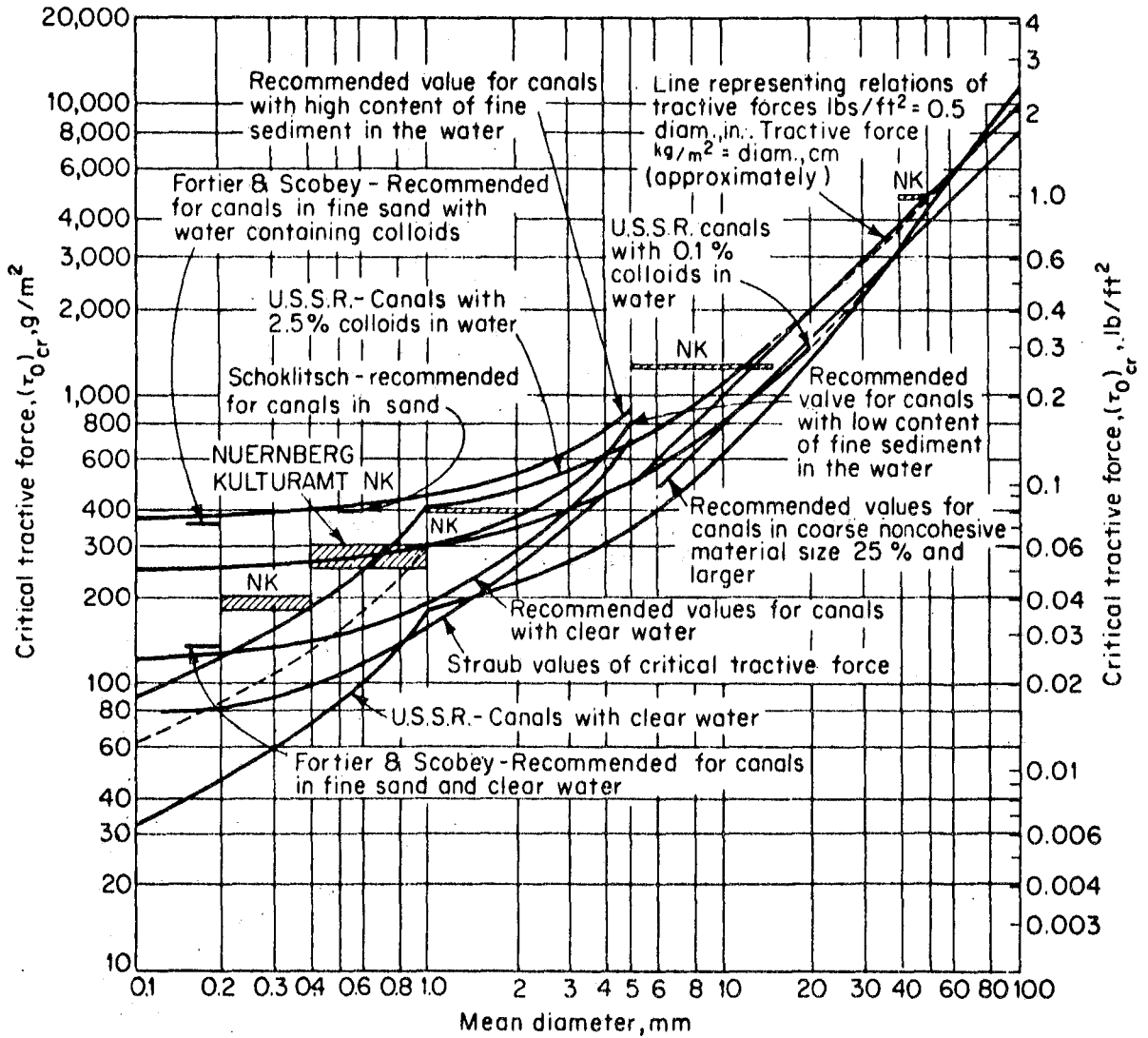


FIGURE II: CRITICAL SHEAR STRESS AS FUNCTION OF GRAIN DIAMETER (AFTER LANE (1953))

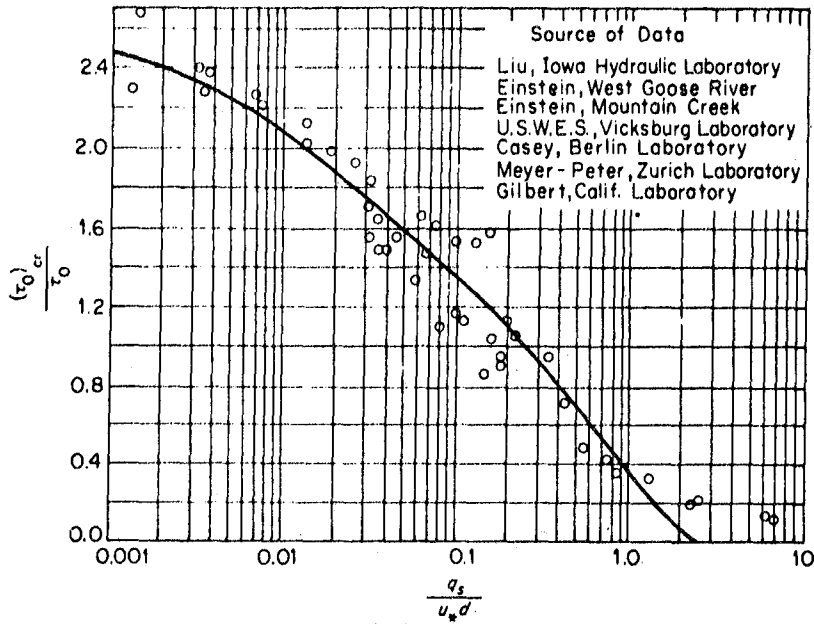


FIGURE 12: KALINSKE'S BEDLOAD EQUATION
(AFTER KALINSKE (1947))

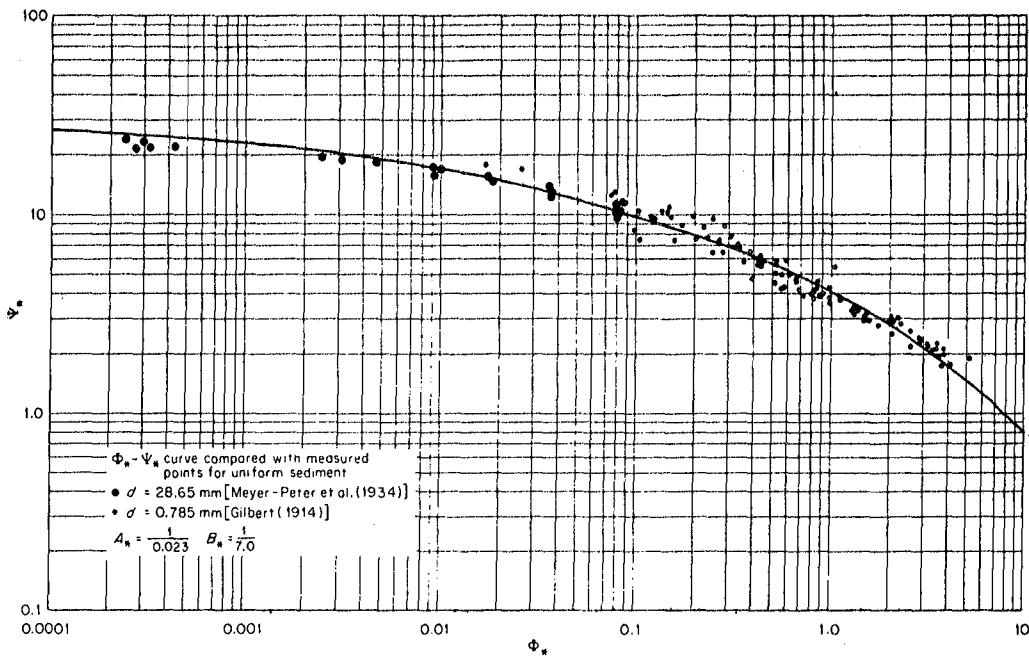


FIGURE 13: PLOT OF EINSTEIN'S FUNCTIONS ϕ vs ψ
(AFTER EINSTEIN (1950))

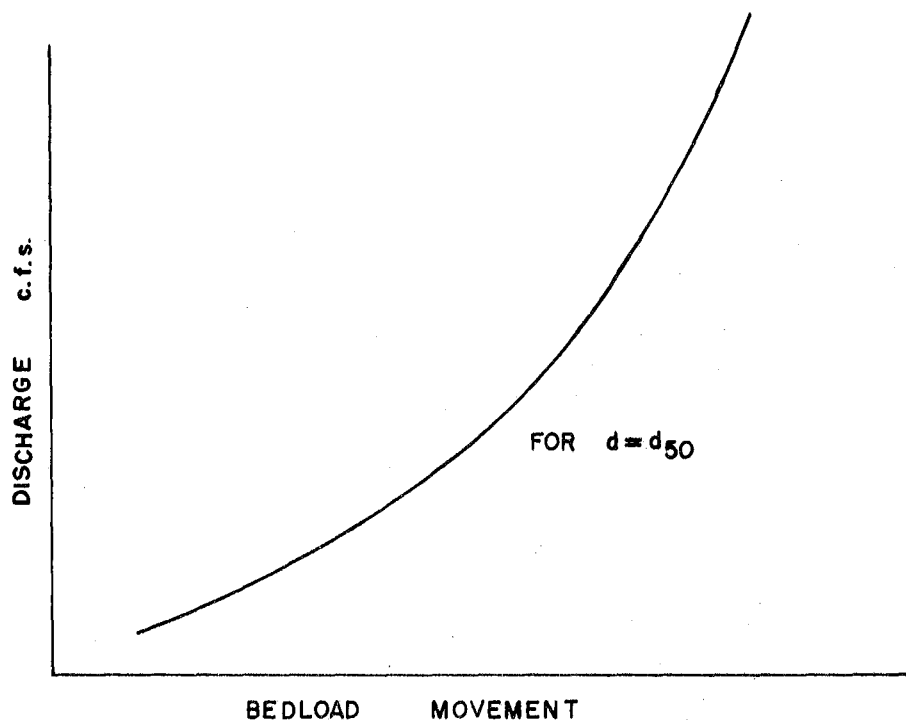


FIGURE 14: THEORETICAL BEDLOAD MOVEMENT AT VARYING DISCHARGES FOR d_{50} SIZE MATERIAL.

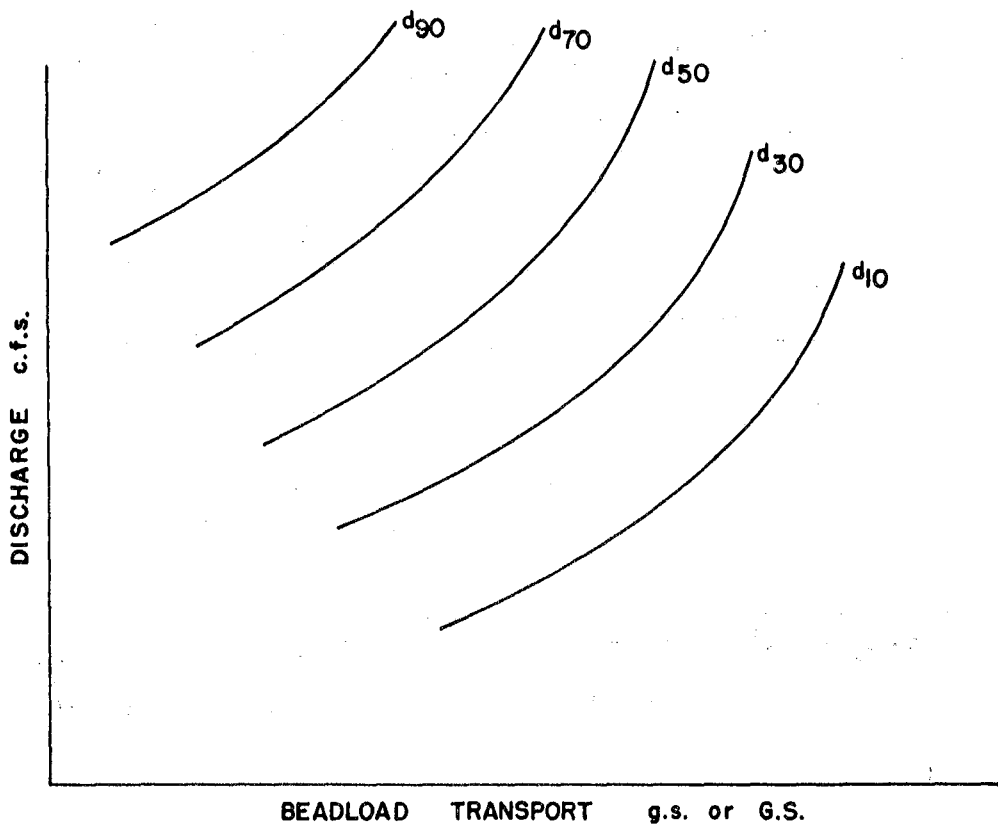


FIGURE 15: THEORETICAL BEDLOAD MOVEMENT FOR VARYING SIZES OF PARTICLES AT VARYING DISCHARGES (d_{10} , d_{30} , d_{50} , d_{70} , d_{90}).

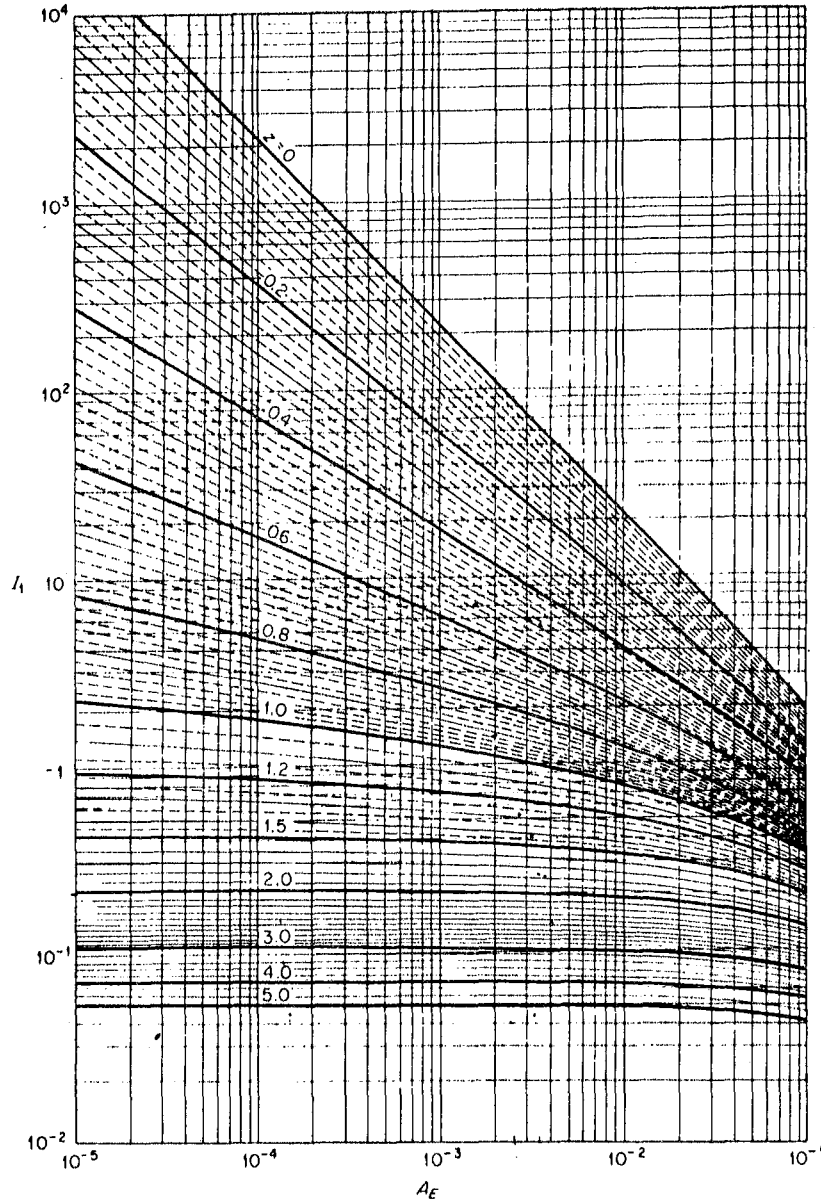


FIGURE 16: FUNCTION OF I_1 IN TERMS OF A_E FOR VALUES OF Z (AFTER EINSTEIN (1950))

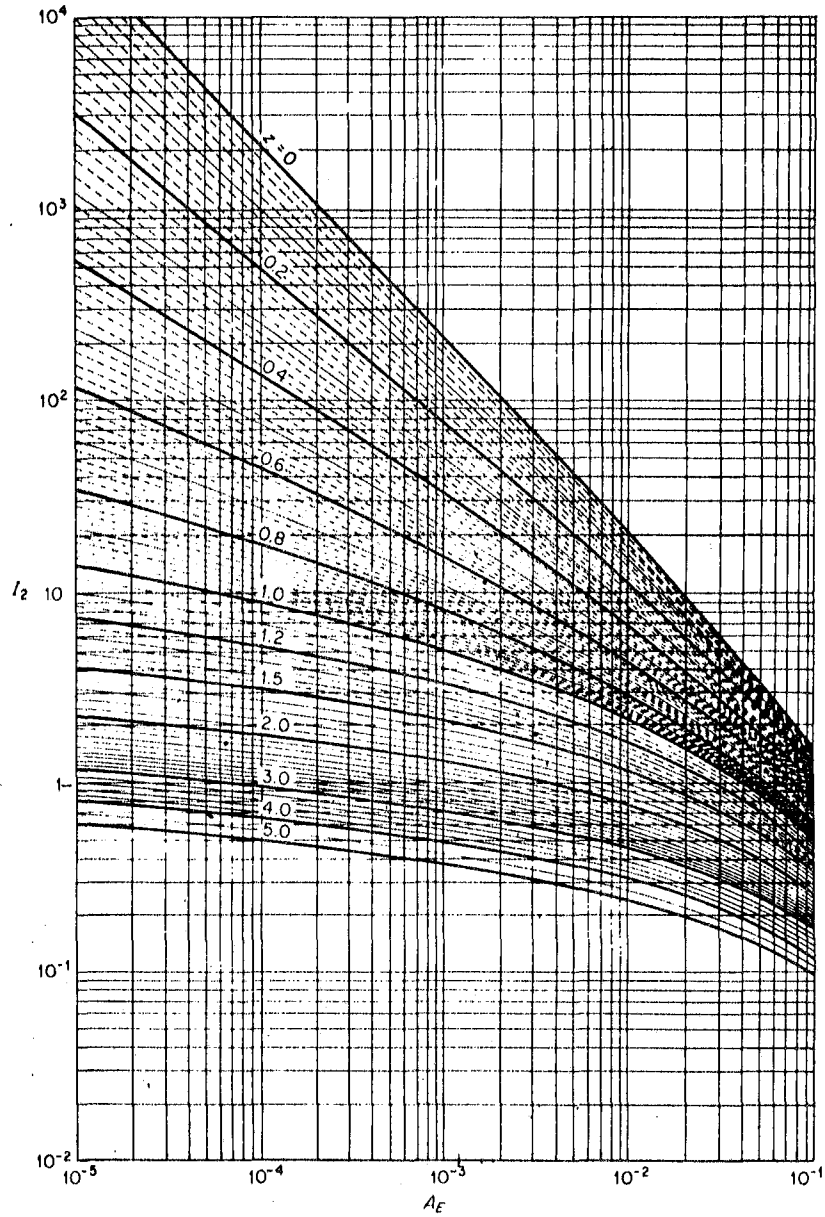


FIGURE 17: FUNCTION OF I_2 IN TERMS OF A_E FOR VALUES OF Z (AFTER EINSTEIN (1950))

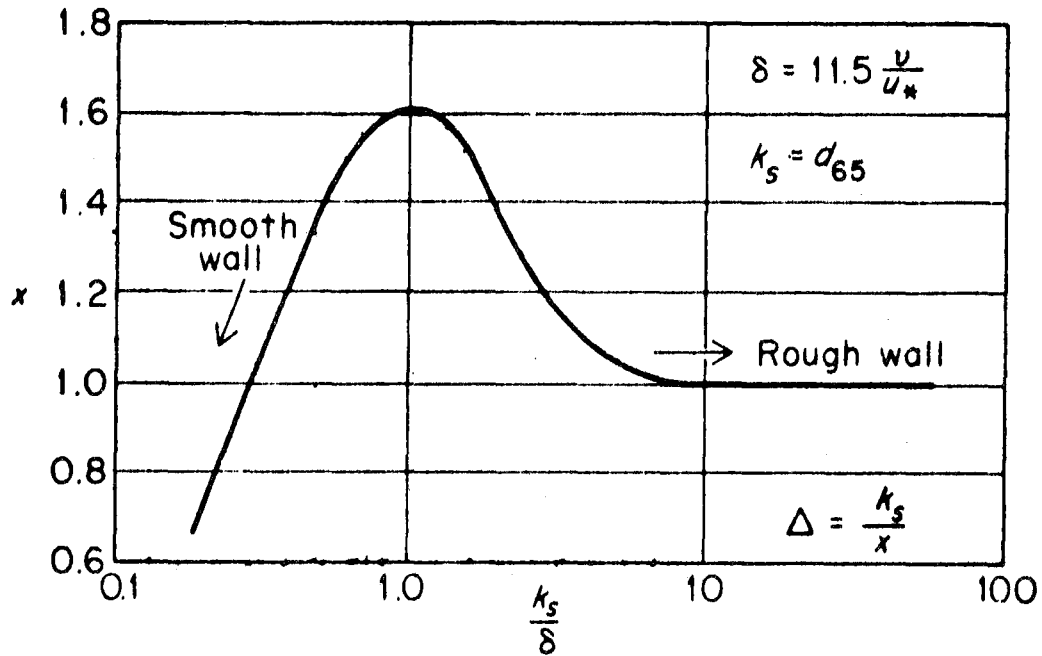


FIGURE 18: CORRECTION FACTOR IN THE LOGARITHMIC VELOCITY DISTRIBUTION (AFTER EINSTEIN (1950))

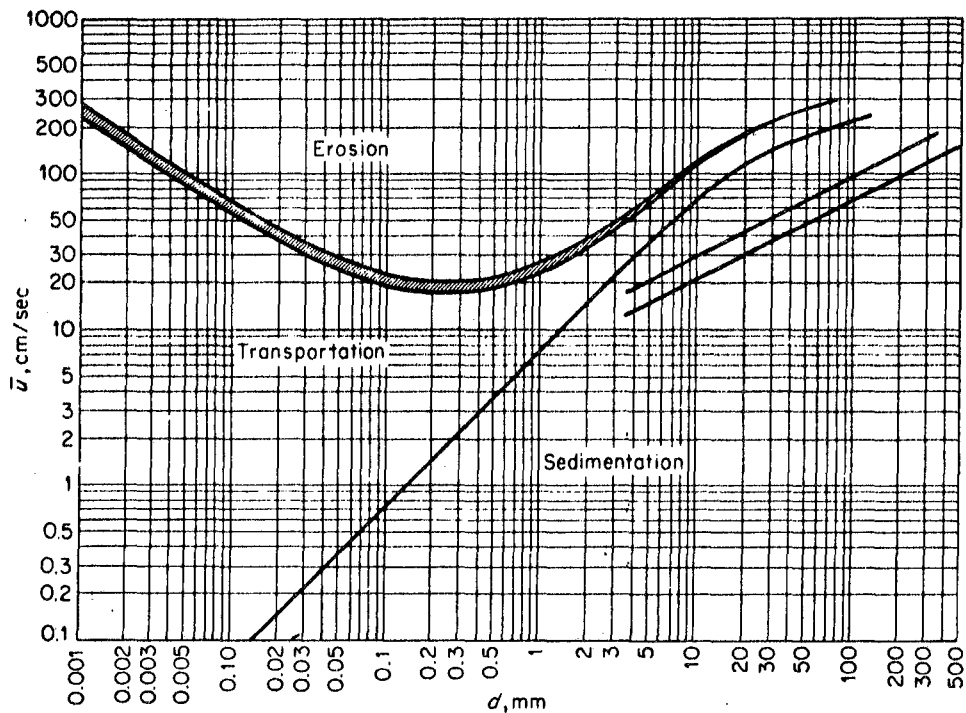


FIGURE 19: EROSION-DEPOSITION CRITERIA FOR UNIFORM PARTICLES (AFTER HJULSTRÖM (1935))

9. Recommendations

1. Better sampling methods be instituted during winter season.
2. More extensive sampling should be made downstream of trenching operations, e.g.,
 - sampling stations every 500 and 1000 ft for 1 to 3 mi downstream. Some stations may even be set up farther afield.
 - sampling at each station on a regular basis, for example, every 3 hours during construction, if possible, and every 6 to 12 hours after completion.

10. Conclusion

No conclusions can be drawn as to whether the pipeline crossings constructed on the La Biche and Kotaneelee Rivers resulted in temporary or permanent damage to the aquatic environment.

A general working knowledge of pipeline construction techniques was gained. The magnitude of the operation involved in river crossings was grasped. Most all ideas on how to improve upon sampling techniques and how to better monitor construction operations in a river were evolved.

This report represents the knowledge gained and lessons learned from the first actual experience with pipeline construction by the Fisheries' representatives involved.

11. References

American Society of Civil Engineers, Task Committee for Preparation of Sedimentation Manual, Committee on Sedimentation of the Hydraulics Division. Journal of Hydraulics Division A.S.C.E. vol. 97, No. HY4, 523567.

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APPENDIX TABLE I. Suspended sediment sampling stations
and ice depth in the La Biche River.

Cross-section	Cross-section distance from trench	Channel width	Sample distance from S. shore	Ice depth	Water depth
A	80 Ft. U/s	40 Ft.	5 Ft.	-	1.5 Ft.
			12 Ft.	-	2.4 Ft.
			20 Ft.	-	2.6 Ft.
			28 Ft.	-	2.4 Ft.
			35 Ft.	-	1.0 Ft.
B	60 Ft. d/s	80 Ft.	20 Ft.	0.8	0.6 Ft.
			31 "	1.6	1.4 "
			45 "	2.3	1.5 "
			57 "	2.8	1.7 "
			68 "	3.0	1.7 "
C	500 Ft. d/s	60 Ft.	20 Ft.	2.8	2.0 Ft.
			30 "	3.5	2.3 "
			39 "	3.2	2.0 "
			45 "	2.8	2.1 "
			51 "	2.5	2.0 "
D	1340 Ft. d/s	80 Ft.	7 Ft.	0.6	1.1 Ft.
			15 "	0.9	0.5 "
			23 "	0.6	1.5 "
			44 "	1.6	1.0 "
			58 "	0.9	1.1 "

APPENDIX TABLE II. Suspended sediment sampling stations and ice depth in the Kotaneelee River.

Cross-section	Cross-section distance from	Channel width	Sample distance from W. shore	Ice depth	Water depth
A	255 Ft. U/s	96 Ft.	23 Ft.	3.1 Ft.	0.7 Ft.
			38 Ft.	2.0 Ft.	1.8 Ft.
			51 Ft.	1.5 Ft.	1.9 Ft.
			64 Ft.	1.8 Ft.	1.3 Ft.
B	115 Ft. d/s	103 Ft.	43 Ft.	2.7 Ft.	0.8 Ft.
			62 "	2.9 "	1.2 "
			81 "	3.5 "	1.5 "
			96 "	3.3 "	1.3 "
C	611 Ft. d/s	93 Ft.	31 Ft.	2.5 Ft.	1.6 Ft.
			43 "	3.2 "	1.4 "
			57 "	3.0 "	1.3 "
			71 "	2.5 "	0.3 "
D	1675 Ft. d/s	83 Ft.	9 Ft.	1.7 Ft.	2.3 Ft.
			17 "	3.0 "	2.3 "
			31 "	3.0 "	0.8 "
			42 "	4.3 "	0.8 "

APPENDIX TABLE III. Particle size distribution of the La Biche River samples.

Sieve size (mm)	Weight retained by sieve (gm)		Suspended sediment			
	Bed sample	Dredge sample	A	B	C	D
38.2	9360.9					
25.4	1018.3					
19.1	385.7					
9.51	603.8					
4.76	66.8					
2.38	4.0					
1.19	1.5	36.0				
0.595	1.2					
0.297	0.9	10.8				
0.149	2.3	12.1				
0.074	3.9	1.4				
<0.074	8.0	622.7				
<u>>0.074</u>				0.3	0.3	0.2
0.053				0.2	0.2	0.2
<0.053				0.3	0.6	0.4
Total wt. of sample	11,457.3	683.0		0.8	1.1	0.8

NOT ENOUGH SEDIMENT IN SAMPLE TO ANALYSE

APPENDIX IV. Editor's corrections of literature citing this report as a source.

The editor wishes to correct some of the misinterpretations of this report that have come to his attention.

- (i) Bryan, 1973. "The Influence of Pipeline Development on Freshwater Fishery Resources of Northern Yukon Territory Aspects of Research Conducted in 1971 and 1972" Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development Report No. 73-6 63 p.

p. 17, last paragraph

"Twenty-four hours after backfilling the suspended sediment concentrations downstream of the trench were nearly equal to upstream values." This should read, "Twenty-four hours after trenching" etc. No samples were taken after the backfilling operation.

p. 18, Table 5.

The values for sites 1 to 5, 25 m upstream of the trenching on the La Biche River should all be changed from <1 ppm to <10 ppm. This represents a revaluation of detection levels at the Cypress Creek laboratories.

p. 19, Table 6.

"24 hours after backfilling ceased" should read, "24 hours after trenching ceased".

- (ii) Since Bryan, 1973, was cited in the Environment Statement by Canadian Arctic Gas Pipeline Limited, the previous corrections should be made in their statement as well. Readers should note the appropriate changes on p. 23, section 7-7.1 of the Environmental Statement.