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An Impact Assessment of the 1973 Quesnel-Cariboo Log Drive on the Aquatic Environment

by
R. E. Elvidge and G. S. Wickerson

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DEPARTMENT OF THE ENVIRONMENT
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FISHERIES OPERATIONS
SOUTHERN OPERATIONS BRANCH
HABITAT PROTECTION UNIT

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ACKNOWLEDGMENTS

Co-operation of Weldwood of Canada Ltd. is greatly appreciated in providing information on the log drive and supplying river transportation.

District Fisheries Staff assisted with the program and provided valuable information on salmon escapements and distribution.

Flow information (Fig. 7) supplied by Water Survey of Canada, Inland Waters Branch. Gauge located at the Gravelle Ferry Crossing, Station # 08KH006.

INTRODUCTION

Since 1963, Weldwood of Canada Ltd. have annually utilized the Cariboo-Quesnel Rivers for the transport of logs from upstream sites (landings) to a sawmill located on the left bank of the Fraser River, two miles below the Quesnel River confluence. The number of pieces transported on the rivers has increased from 20,000 in 1963 to 431,048 in 1973 (Table 1). Both Federal and Provincial Agencies including the B.C. Fish and Wildlife Branch, B.C. Forest Service, the International Pacific Salmon Fisheries Commission and the Department of the Environment, Fisheries Service, have, since the commencement of log driving on the Quesnel-Cariboo Rivers, generated guidelines restricting the timing and volume of logs transported. In 1973, as a result of the marked increase in number of logs to be watered, the Fisheries Service initiated a monitoring program to document impacts of log drive activities on the aquatic environment. This information would then be used in the formulation of more precise guidelines to minimize log drive effects and thus ensure the protection and maintenance of the Fisheries Resource.

This report, prepared by the Habitat Protection Unit, Southern Operations Branch of the Fisheries Services, presents the procedures, results and conclusions of the monitoring program.

TABLE # 1

Approximate Volume and Number of Logs
Transported in Cariboo-Quesnel Rivers
1963 - 73

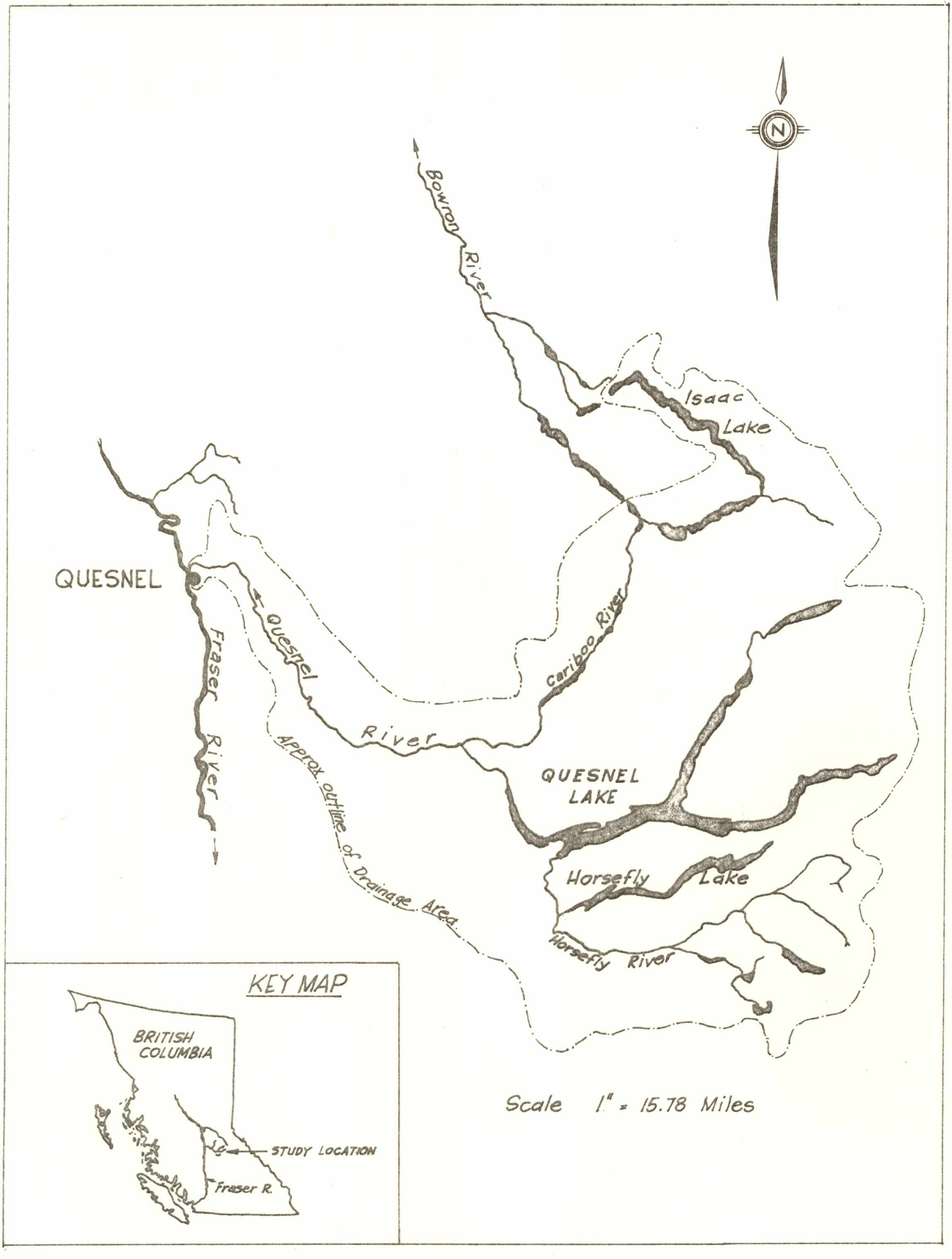
Year	Volume (Mcf)	No. of Logs
1963	500	20,000
1964	1700	60,000
1965	2500	100,000
1966	3000	130,000
1967	4700	260,000
1968	4300	245,000
1969	4600	255,000
1970	5080	297,000
1971	5828	340,000
1972	5647	330,000
1973	6500	429,731

BASIN DESCRIPTION AND SALMON ESCAPEMENTS

The Quesnel River, 67 miles in length, flows west from Quesnel Lake to confluence with the Fraser River at the present townsite of Quesnel in South Central British Columbia. Two major drainages are tributary to the Quesnel, the Horsefly River flowing north to Quesnel Lake and the Cariboo River flowing South West joining the Quesnel River at Quesnel Forks, 6 miles downstream from Quesnel Lake (Figure 1).

The Quesnel, Cariboo and Horsefly Rivers support escapements of Chinook, Sockeye and Pink Salmon as well as indigenous populations of kokanee, rainbow trout, dolly varden char, lake trout, mountain white fish and burbot. Sockeye, the numerically dominant anadromous species, pass through the Quesnel River and Lake to the Horsefly drainage where peak of spawning occurs between August 15 to September 12. Annual escapements average 75,878 (1957 - 1972) with a maximum recorded during the period of 364,567 in 1965. Chinook spawn principally in the Quesnel River immediately downstream from Quesnel Lake with some spawning documented in the lower Quesnel mainstem, the upper Cariboo River and the Horsefly River. Peak of spawning occurs from mid-September to the middle of October with the number of adults averaging 966 for the period of 1957 to 1972. Pink salmon were first documented in the Quesnel River in 1965 and principally spawn in the lower four miles of river, although scattered spawning has been observed upstream to mile 15. Escapements frequent the system only during odd years with an estimated maximum of 5,000 adults recorded in 1971.

FIGURE 1.


N
Bowron River
Isaac Lake
QUESNEL
Quesnel River
Cariboo River
Fraser River
Approx outline of Drainage Area
QUESNEL LAKE
Horsefly Lake
Horsefly River
KEY MAP
BRITISH COLUMBIA
STUDY LOCATION
Fraser R.
Scale 1" = 15.78 Miles

LOG DRIVE DESCRIPTION

Throughout the summer and winter harvesting season, logs were trucked to the respective landings (sites adjacent to the river) where they were unloaded, bucked, trimmed and stored until commencement of the log drive. Watering of logs was by means of rubber tired or tracked front end load (grapple) machines. (Plate 2). There were eight landings from which logs were watered and these sites were located in the upper twenty miles of the 77 river miles covered by the drive. Landing dimensions ranged from 1/4 to 1/2 mile in length, and 100 to 200 yards in width. Of the eight landings, seven were on the Cariboo River, the upper (C7) being one half mile below the outlet of Cariboo Lake (Figure 2), the lowermost (Q1) being on the Quesnel River six miles downstream of Quesnel Forks.

The 1973 log drive commenced on May 19 with watering progressing from upstream landings to downstream sites. The pre-drive log inventory of 434,731 pieces included 409,312 logs stockpiled on the landings and 25,419 logs stranded on the river from previous years' activities.

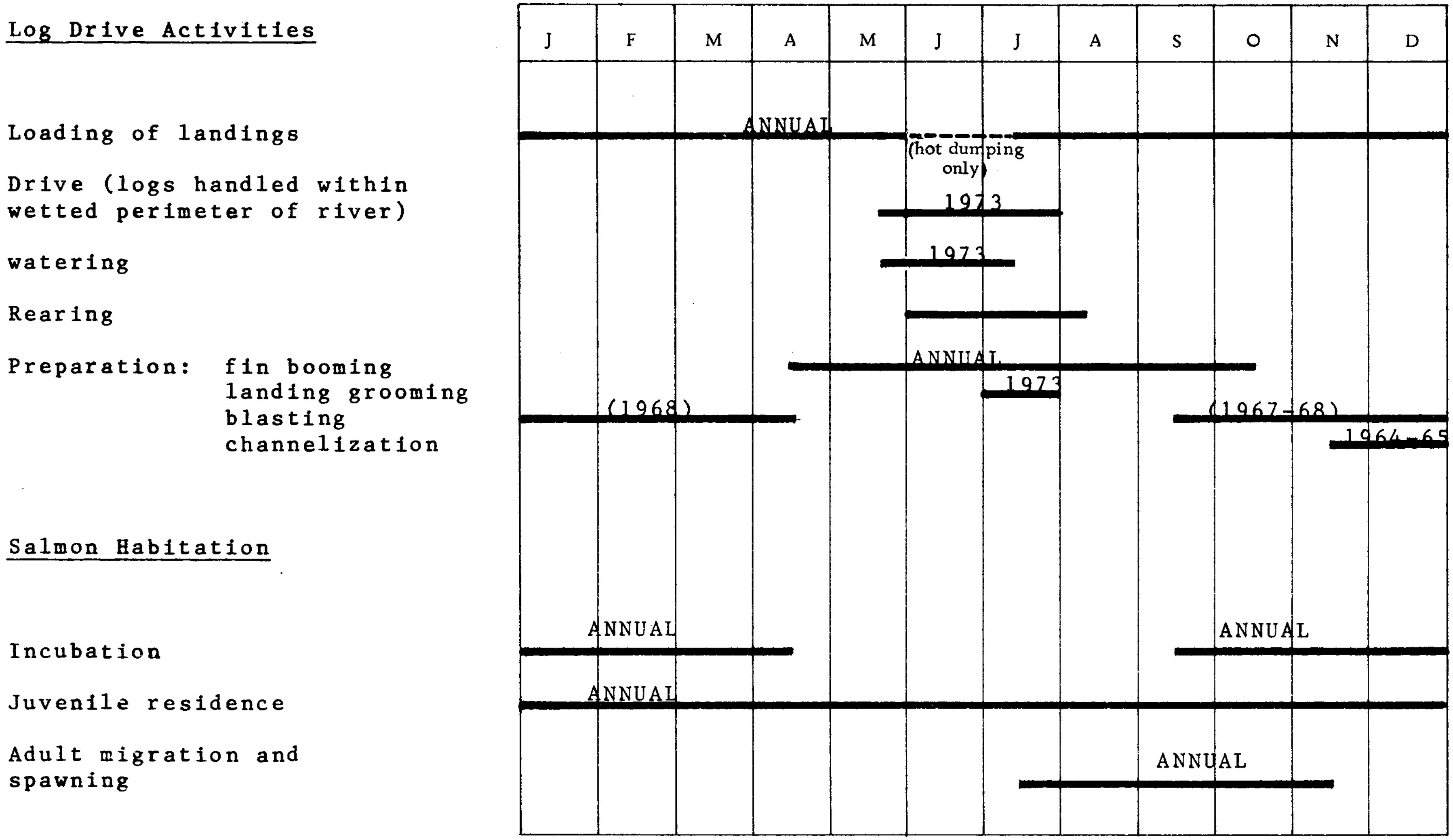
Rearing (the freeing of stranded or arrested logs) began at a limited level of activity, almost simultaneously with watering. Full rearing operations commenced with completion of watering (June 21) and continued through to the completion of the drive on July 18 (Figure 3).

There are three major techniques involved in rearing. The first method, confined to the navigable limits of the river, was the most efficient operationally and appeared to have the least effect on the aquatic environment. Utilization of this method involved the clearing of the log jam from the downstream end (Plate 5). This is done by choosing a point in the jam which can

SAMPLE SITE No.	FUNCTIONS	WATER QUALITY	BARK
1	CONTROL	✓	✓
2	RIVER LOAD	✓	
3	RIVER LOAD	✓	
4	CONTROL RIVER LOAD LANDING CONTRIBUTIONS	✓ ✓ ✓	✓ ✓ ✓
5	CONTROL	✓	
6	CONTROL RIVER LOAD LANDING CONTRIBUTIONS	✓ ✓ ✓	✓ ✓ ✓
7	RIVER LOAD		✓
8	RIVER LOAD		✓
9	RIVER LOAD		✓
10	RIVER LOAD		✓
11	RIVER LOAD	✓	
12	RIVER LOAD	✓	✓
13	RIVER LOAD	✓	✓
14	RIVER LOAD	✓	✓
15	RIVER LOAD	✓	✓
16	RIVER LOAD	✓	✓
17	CONTROL CONTACT	✓	
18	RIVER LOAD	✓	✓
19	RIVER LOAD	✓	✓
20	RIVER LOAD		✓
21	RIVER LOAD	✓	
22	RIVER LOAD	✓	✓
23	RIVER LOAD	✓	
24	RIVER LOAD	✓	✓

FIG. 2

Figure 3. CALENDAR OF LOG DRIVE ACTIVITIES AND SALMON HABITATION ON THE QUESNEL AND CARIBOO RIVERS.



be broken through by towing logs free with a jet boat, bulldozing them out or, if necessary, a combination of both. In most cases a log jam, with the establishment of a breach, will break up and float free with no further assistance than that supplied by the jetboat. (Plate 6).

Another rearing method used within the navigable limits of the river involves the use of a "raker log", tractor and jet boat. The tractor is anchored on the bank, with its winch cable attached to the log. The jetboat then tows the log around the upstream end of the jam to a point where the current lodges the log against the jam. The log is then winched back toward the tractor, raking logs free of the jam. This process is repeated until the jam is cleared.

A modification of the "raker log" technique is used in the more canyonous and unnavigable areas of the river. A second tractor replaces the jet boat and is anchored on the opposite bank of the river. This operation requires considerable stream side cover removal to allow clearance for the winch lines (Plate 7).

The rearing process was conducted from the upstream limit of the drive, to the millsite on the Fraser River.

On completion of watering, an extensive grooming of the landings was undertaken to clear accumulated debris (Plate 4). This material was moved to the off river side of the landing and burned. Reloading of the landings for the following year's log drive began immediately following grooming.

STUDY METHODS

Water quality sampling and physical measurements were made possible by utilization of specialized jet river boats supplied by Weldwood of Canada Ltd. Other means of transportation included light aircraft, helicopter and four-wheel-drive vehicles.

Field Study Timetable

Assessment of the 1973 log drive activities was conducted during the following periods:

a) May 16: An aerial inventory of the Cariboo/Quesnel Rivers was undertaken prior to the 1973 watering to note flow conditions, landing locations, areas of potential difficulties, and logs stranded from past years' activities.

b) May 24 - 27: On the ground observations, sampling and photography to note landing condition, log watering activities and impacts, and log drive route assessment was made. A preliminary assessment of log bark loss was conducted at the mill-site and the landings.

c) June 12 - 21: An intensive sampling series for suspended sediment and coarse particle material was initiated. Documentation of landing cleanup and rearing activities in the Cariboo River was conducted.

In addition, a study of sensitive bank interface was undertaken to determine the degree of erosion caused by log contact and natural hydraulic activity. Assessment of post-drive bark loss on logs at the mill-site continued.

d) July 4 - 6: An isolated study of rearing effects was possible during this period as all log watering from landings had been completed. Water quality sampling was continued; final observations on rearing activities were made. The assessment of post-drive bark loss was concluded.

Recognizing timing and logistical restraints, the water quality program was designed to measure those stream components that have been previously documented as altered by log driving activities[2]. Components sampled included suspended sediments and microdebris, macrodebris, total dissolved solids, and alteration of stream bank and substrate. Procedures used included:

a) Suspended sediments and microdebris are defined as all materials capable of entering the mouth (dia. 30 mm) of a pint bottle. Sampling was by the standard integrated depth technique. This procedure was used to accommodate the larger particles which would clog the orifice of the U.S.D.H. 48 sampler, normally used for this type of sampling.

b) Macrodebris being defined as that material retained by 1/4 inch mesh marquisette netting, was sampled using a dip net with an 18 inch diameter frame, screening a measured volume of water. Sampling stations were established in cross sections of river that were considered representative of the draining and influenced by log drive activities. A surface and subsurface sample was collected at each station.

Water quality samples were taken at 24 sites along the drive route throughout the drive period (Fig. 2). The samples included one series for measuring distribution of suspended microdebris throughout the river (table 2) and a series for measuring depth distribution of macro debris. Sampling series included subsamples from high recruitment areas (i.e. landings) (Tables 3,4). The suspended microdebris series also included random sampling of log/bank contacts.

In conjunction with water quality samples, further suspended sediment samples were collected at a site approximately 300 yards from the mouth of the Quesnel River. The sampling period extended from peak drive activity to 10 days after drive completion (June 16 - July 27). These samples were, when possible, taken daily at random times for use as an index of total organic/ inorganic load passing through the Quesnel River during and after the drive.

Spawning Substrate:

Areas of difficult log passage were identified and mapped with particular emphasis on those areas of known and potential spawning locations (fig. 5). Some of these areas were observed during rearing operations to determine disturbance, sedimentation and degree of bark infiltration into the substrate.

Bank Interface Sensitivity:

Points of known sensitivity (i.e. outside curves combined with active sloughage) were chosen to identify the magnitude of erosion caused by log/bank contact. A total log count was taken at a cross section within the sensitive areas over a 30 minute period. Within this time period,

TABLE # 2 DISTRIBUTION OF SUSPENDED SEDIMENT IN SECTIONS OF THE DRIVE ROUTE

LEVELS AND COMPOSITION OF RIVER LOAD SILT SAMPLES

Mileage Point	Date	Total P.P.M.(1)	% Inorganics	% Organics
77.6	June 13	2.65	65.0	35.0
66.0	June 13	15.92	48.0	52.0
61.5	June 13	1.65	27.0	73.0
55.6	June 19	54.93	88.5	11.5
25.7	June 4-5	77.08	84.0	16.0
22.5	June 20	104.0	67.3	32.7
17.3	June 20	91.4	82.06	17.94
15.3	June 20	92.9	93.65	6.35
14.0	June 20	91.0	85.55	14.45
13.0	June 20	100.3	86.69	13.31
12.6 (2)	June 20	653.0	85.87	14.13
10.5	June 21	91.7	85.06	14.94
9.4	June 21	91.7	83.97	16.03
6.5	June 21	89.6	89.29	10.71
4.1	June 21	97.4	86.24	13.66
2.8	June 16-July 27	141.35	89.44	10.66
2.6	June 21	84.0	90.48	9.62

(1) Where more than one sample exists an average of control samples was taken.

(2) Mixmaster eddy

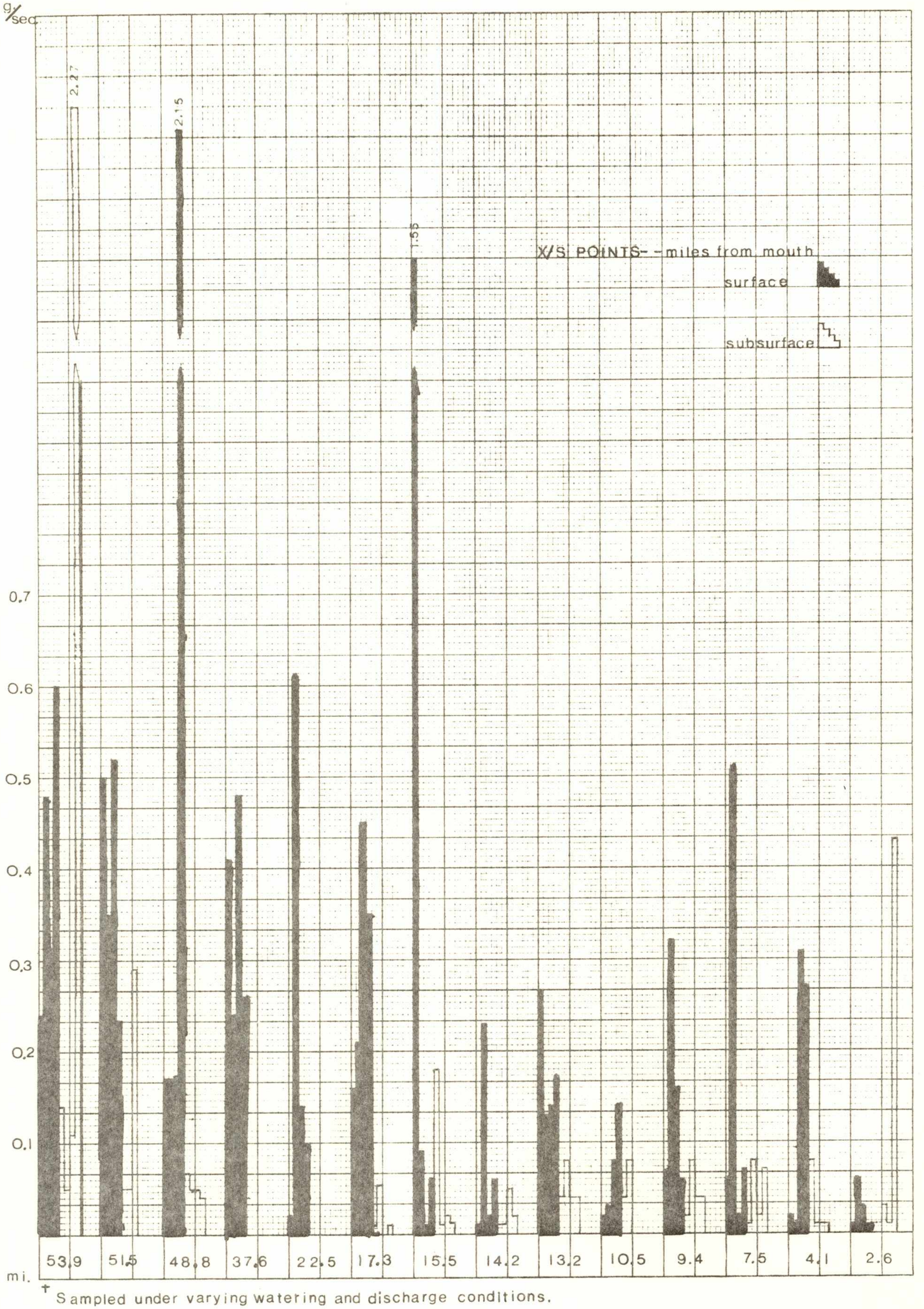
TABLE # 3

BARK DISTRIBUTION IN TOP ONE-THIRD OF QUESNEL RIVER

MILEAGE POINTS	AMOUNT ON SURFACE AS % OF TOTAL AVERAGE SAMPLE
53.9	38.81*
51.5	78.76
48.8	93.29
17.3	92.77
15.5	88.48
14.2	78.91
13.0	77.39
9.4	77.44
7.5	84.37
4.1	84.47
2.6	70.57

* 78.37 would be a more representative figure as an unusually large subsurface sample was taken at one point along the cross-section

FIG. 4 QUESNEL RIVER – DEPTH DISTRIBUTION OF COARSE PARTICLES†



† Sampled under varying watering and discharge conditions.

SILT CONTRIBUTIONS FROM LANDINGS

CARIBOO # 2 JUNE 13, 1973 TABLE # 4

	Organics		Inorganics	
	Control (P.P.M.)	Downstream	Control (P.P.M.)	Downstream
1.	2.7	140.1	2.6	124.0
2.	7.0	90.8	5.8	119.0
3.	7.0	45.2	10.0	73.0
4.	20.0	71.9	17.0	89.0
5.	0.5	91.4	0.2	151.0
6.	12.2	99.8	13.0	82.0
7.	11.6	146.3	13.0	115.0
8.	9.3	150.1	11.0	161.0
9.	11.3	80.2	7.1	117.0
10.	6.8	115.0	8.4	116.0
11.	7.2	83.0	9.2	154.0
12.	5.8	341.9	2.4	347.0
13.	10.5	105.5	4.7	136.0
14.	8.1	94.2	4.5	122.0
15.	4.1	113.0	5.8	117.0
Average	8.27	124.7	7.65	134.9

GESKIES JUNE 19, 1973

1.	6.7	68.7	39.3	517
2.	5.4	129.0	48.0	624
3.	6.4	115.0	59.0	722

TABLE # 3A

SILT CONTRIBUTION AT MIXMASTER EDDY (MILE 12.6) JUNE 20, 1973

Background Control (P.P.M.)		Control (P.P.M.)	Contact (P.P.M.)
Mile 13	275	339	584
Mile 10.5	91.7	500	1320
		1500	1440
Average		780	834

the number of log/bank contacts on the defined sensitive area were counted and tabulated (Table 6). For comparative value, another area representing a typical curve, without active sloughage was assessed in the same manner.

A sensitive area at mile 12.6 was assessed for sediment introduction by taking water samples, as previously described, to determine the result of log/bank contacts. Accompanying background control samples were taken simultaneously, immediately upstream from the contact.

A helicopter flight of the log drive route supplied information on the protection afforded by finbooms (bank shear logs) and the identification of protected and unprotected areas with degree of sensitivity noted (Fig. 5).

Bark Deposition:

For an estimate of the volume and rate of accumulation of peripheral bark deposits, measurements of deposits at specific sites were taken at various stages during the log drive (Appendix 4).

Sample Analysis

Procedures followed in analysis for suspended sediments, T.D.S. and organic, inorganic constituents are outlined in Standard Methods, 1971 edition. Macrodebris samples were dried at 105°C to obtain a constant weight.

Using an electronic digitizer, bark loss was calculated from photographs (Plates 12 & 13) of pre- and post-driven logs (Appendix 1 - 3).

BOOM #	BOOMSTICKS
1 —	80 -- 3000' 1" cable, 4000' 3/4"
2 —	9
3 —	12
4 —	20
5 —	19
6 —	19
7 —	26 -- 500' 3/4" cable
8 —	8
9 —	27
10 —	18
11 —	18
12 —	15
13 —	21
14 —	5
15 —	17
16 —	7
17 —	12
18 —	13
19 —	9
20 —	6
21 —	16
22 —	12
23 —	10
24 —	16
25 —	14
26 —	39 -- 1000' 3/4" cable
27 —	9
28 —	20
29 —	16
30 —	27 -- 500' 3/4" cable
31 —	5
32 —	14
33 —	9

BOOM #	BOOMSTICKS
34 —	18
35 —	9
36 —	9
37 —	13
38 —	14
39 —	8
40 —	28 -- 500' 3/4" cable
41 —	28 -- 500' 3/4" cable
42 —	12
43 —	13
44 —	22
45 —	22
46 —	13
47 —	14
48 —	14
49 —	12
50 —	14
51 —	15
52 —	14
53 —	23
54 —	6
55 —	9
56 —	15
57 —	15
58 —	13
59 —	20
60 —	10
61 —	17
62 —	17
63 —	14
64 —	14
65 —	11
66 —	22

BOOM #	BOOMSTICKS
67 —	11
68 —	7
69 —	7
70 —	10
71 —	12
72 —	16
73 —	14
74 —	20
75 —	9
76 —	19
77 —	31
78 —	10
79 —	4
80 —	10
81 —	25
82 —	12
83 —	12
84 —	6
85 —	7
86 —	7
87 —	9
88 —	16 -- 1000' 3/4" cable
89 —	7
90 —	12
91 —	10
92 —	7
93 —	8
94 —	12
95 —	6
96 —	3
97 —	9 -- "stiff leg"
98 —	12
99 —	15 -- "stiff leg"

TOTAL - QUESNEL TOWNSITE TO CARIBOO LAKE

SHEAR BOOMS	99 (SHEAR BOOMS PROTECTING SENSITIVE INTERFACE- 35)
BOOMSTICKS	1441
1" CABLE	3000'
3/4" CABLE	8000'

FIG. 5

TABLE # 6

PERCENTAGE LOG/BANK CONTACT PER HALF HOUR WATERING INTERVALS AT POINTS OF HIGH SENSITIVITY

Date	Time	Location (1)	#Logs	#Contacts	%Contacts
May 25	1200-1230	58.5	242	27	11.0
June 15 (2)	1800-1830	2.5	324	5	1.5
June 17	0915-0945	52.2	128	33	25.8
June 17	0955-1025	52.8	171	35	20.5
June 17	1110-1140	48.2	178	13	7.3
June 17	1115-1145	46.5	210	20	9.5
June 17	1155-1225	46.5	192	25	13.0

Average % - Contact

Average % - Contact excluding June 15 entry

(1) River Miles upstream from millsite

(2) No sloughage on this curve

RESULTS AND DISCUSSION

Observations and sample analysis (Tables 4 and 5) indicate the following log watering activities contribute a significant quantity of sediment and debris to the aquatic environment.

a) the dumping of logs from banks consequently dislodging bank material and bark as logs tumble into the river (Plate 1).

b) driving machines into the river at shallow sites to facilitate log watering (Plate 2).

c) Bucking debris and sediment intermingled with logs that have been raked together to form a watering load.

It has been estimated that approximately 35,000 loads were required to complete watering of the 1973 landing log inventory. In that watering procedures involved at least one of the above activities, and giving consideration to the data as per Tables 4 and 5, the contribution of debris and sediment to the aquatic environment during this log drive phase was indeed significant.

a) Macro-Debris

In addition to the material contributed to the river during log watering, bark dislodgement was observed during the log drive and rearing phases. Surface and subsurface sampling indicate that of the estimated 7,850 tons of bark (Appendix 3) contributed to the Quesnel-Cariboo Rivers, 70 - 93 percent was within 1 foot of the surface.

TABLE # 5

BARK CONTRIBUTIONS FROM LANDINGS

CARIBOO # 2 JUNE 14, 1973

	CONTROL (g. per. sec.)	DOWNSTREAM (g. per. sec.)	CONTRIBUTIONS (g. per. sec.)
1.	0.27	2.39	2.12
2.	0.32	0.58	.26
3.	0.21	1.60	1.39
4.	0.33	2.22	1.89
5.	0.68	6.40	5.72
6.	0.18	6.08	5.90
7.	0.10	3.44	3.34
8.	0.05	1.37	1.32
9.	0.47	2.73	2.26
10.	0.13	1.76	1.63
Average			
	0.27	2.62	2.58

GESKIES (Q1) JUNE 19, 1973

1.	0.02	9.32	9.30
2.	0.02	9.23	9.21
3.	0.01	2.80	2.79
4.	0.01	27.58	27.57
Average			
	0.015	12.27	12.21

Extensive bark deposits were noted along the river periphery, owing to receding water levels (Figure 7, Plate 3). Estimates of the amount range from 20 - 29% of the total bark loss; however, this material would probably gain water access the following spring as water levels again increased.

Information supplied by Weldwood of Canada Ltd. indicates that transport of logs over the 77 miles of river requires 12 - 14 hours. Although complete data on bark sinkage rates is not available, Schaumberg (3) notes that 10% of a total bark sample can be expected to sink within the first 24 hours. Giving consideration to this information, observations and surface/subsurface sampling, the amount of bark flushed into the Fraser River, either immediately or during the following spring freshet, represents a high percentage of the total bark loss. Notable exceptions of deposition in low velocity areas such as back channels, eddies and deep pools were observed, but were limited in extent. It is anticipated a reduction in benthic productivity would result in these areas, however, determination of degree would require further intensive study. Accordingly, to comment on the impact of this bark on the Fraser River would be speculative, without a knowledge of deposition location.

b) Suspended Sediments and Micro-Debris

The analysis of water samples for suspended sediment verified visual observations; viz. that watering procedures were a source of heavy siltation. On Cariboo # 2 landing where the most extensive sampling was done, the average downstream sample of inorganic content was 134.9 ppm as compared to a control reading of 7.65 ppm. Furthermore, each sample represented the relative contribution of one forklift load of logs and at 12 logs per load there would be approximately 7500 such loads from Cariboo # 2 alone (Table 4).

Owing to low background suspended sediment levels of the Cariboo River, it is possible to see that the composition of the downstream samples closely corresponded to the composition of the sediment entering the river at the landings. These figures were found to be a reasonable index of composition comparing controls to downstream samples and percentages determined. The average of all downstream samples from Cariboo # 2 were inorganic 52% and organic 48%. Subtracting the weight of the control samples from those taken downstream, the constituent percentages remain the same.

The Cariboo # 2 control samples, moreover, because log watering was occurring above C2 at the time of sampling, appear to reflect the influence of time and river distance to the introduced sediment. It is thus possible to derive a pattern of sinkage from these two sets of samples. Organics and inorganics mixed with the river at the landings on the Cariboo at a 48 - 52% ratio and at levels above 100 ppm. Both settled out fairly rapidly but the inorganics did so at a slightly faster rate leaving a higher organic constituent and a river load of less than 30 ppm. When large quantities of debris were again added at a lower landing, higher levels were reasserted.

The data suggests that suspended sediments introduced to the Cariboo are deposited locally for an undetermined period of time and/or significantly and quickly diluted.

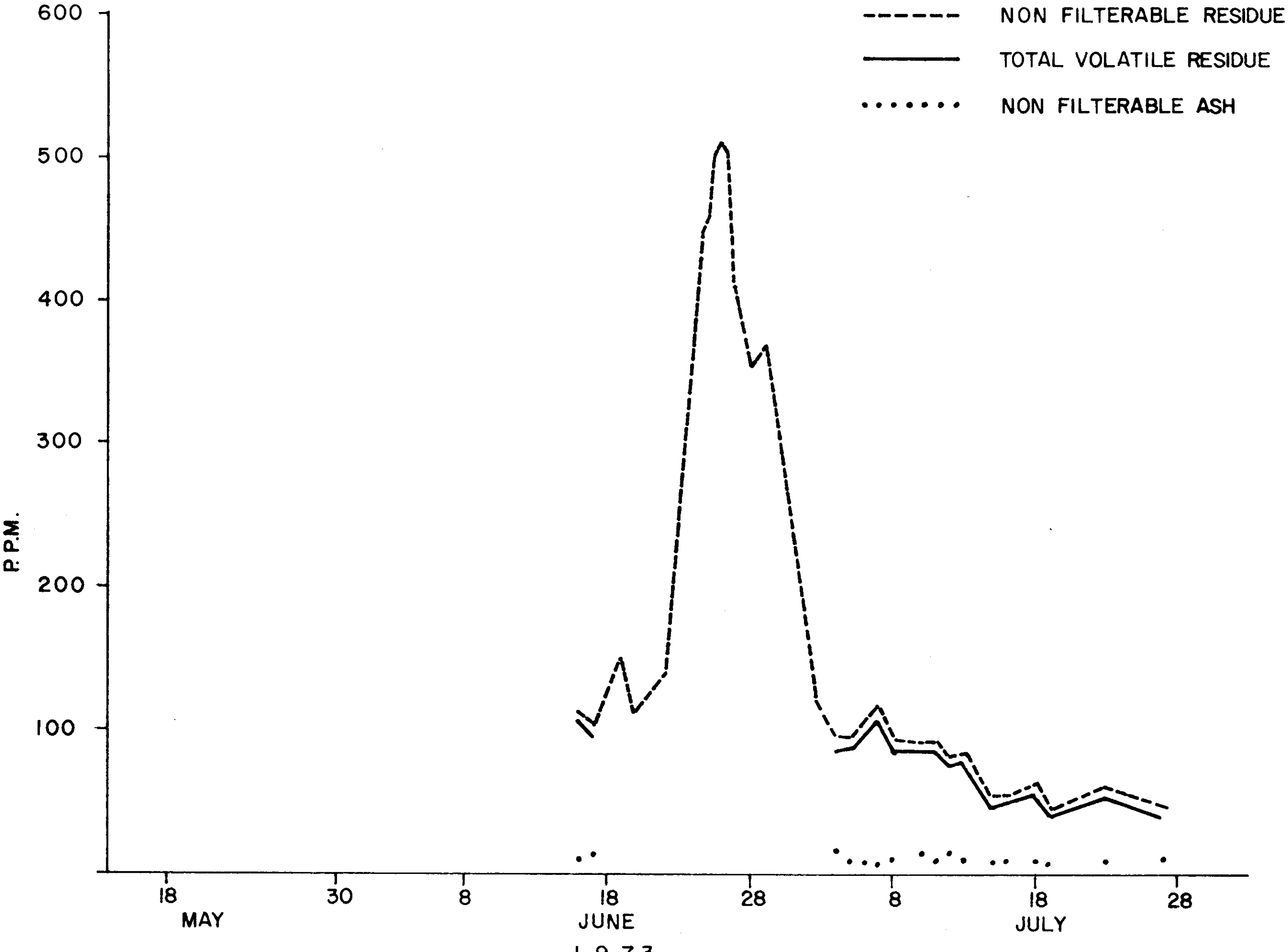
The low readings of the Cariboo-Quesnel forks samples support this. In addition, the impact of heavy siltation from the landings on either the Quesnel or Cariboo did not influence the pattern of suspended sediment levels taken at the Quesnel footbridge. High siltation levels here were directly related to high discharge levels and this relationship was not significantly altered by watering (Figures 6 & 7).

c) Spawning Substrate

The highest incidence of log jamming occurred in shallow riffle areas which also exhibited actual or potential spawning substrate values. Although log jamming could initiate gravel scouring by restricting flow thereby increasing velocities, rearing activities were noted to commence almost immediately upon jam formation, thus minimizing anticipated impacts on the substrate. Observations of rearing activities noted further bark loss; however, increased flows and jet boat activity served to scarify or clean the adjacent gravels of silt and organic material. Rearing, an activity essential to the success of the log drive, with exception of the modified raker log method incorporating removal of streamside vegetation and damage to stream bank interface, appeared to have little adverse effect on the aquatic environment, jam removal and log drive timing. It should be noted, however, rearing activities would interfere with spawning populations should the drive coincide with spawning activity.

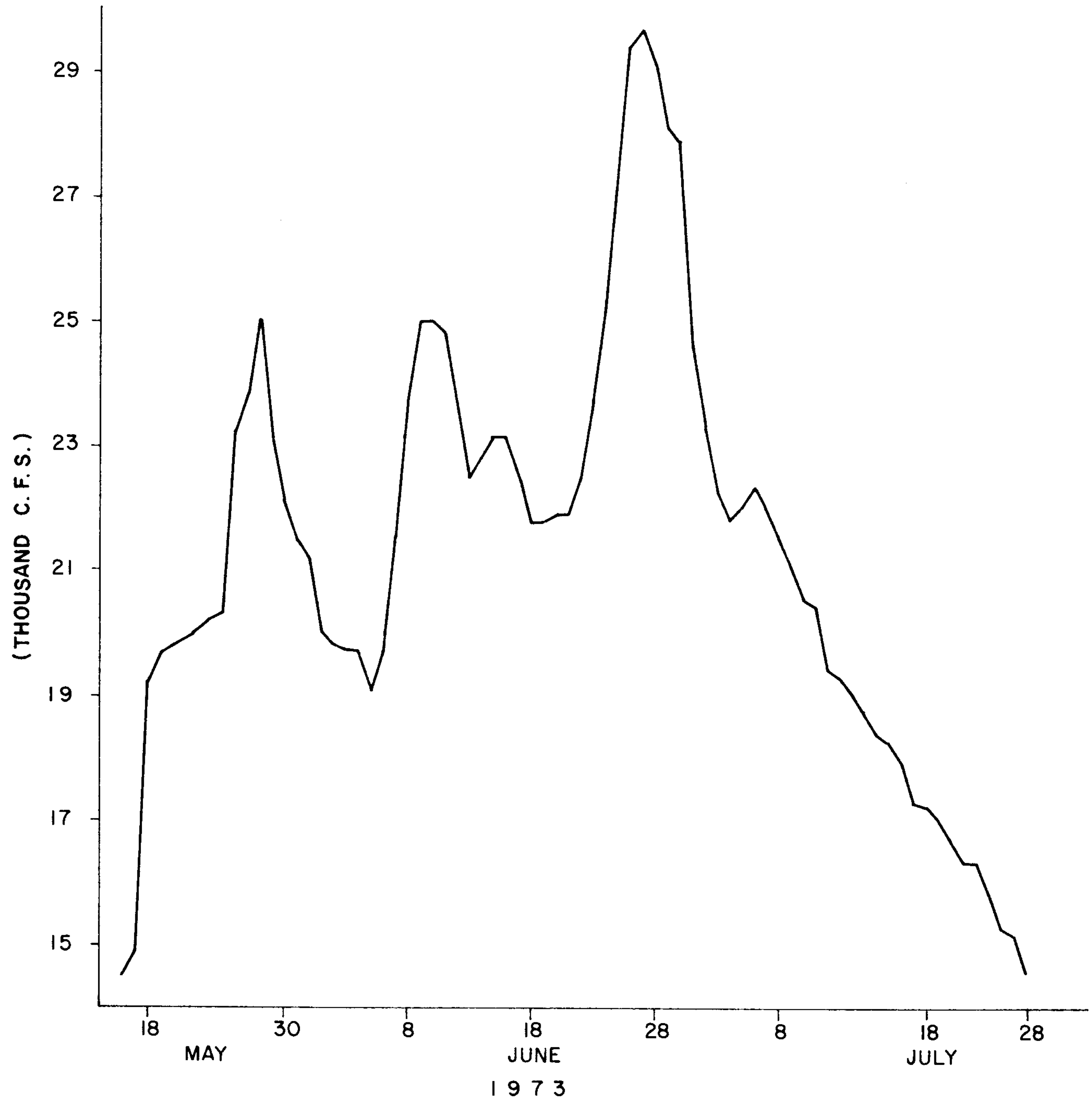
d) Stream Bank Interface Sensitivity

The Quesnel River has many highly sensitive bank interfaces within the log drive route (Plate 8). This appears to be



SUSPENDED SEDIMENT CONSTITUENT - QUESNEL RIVER FOOTBRIDGE

FIG. 6



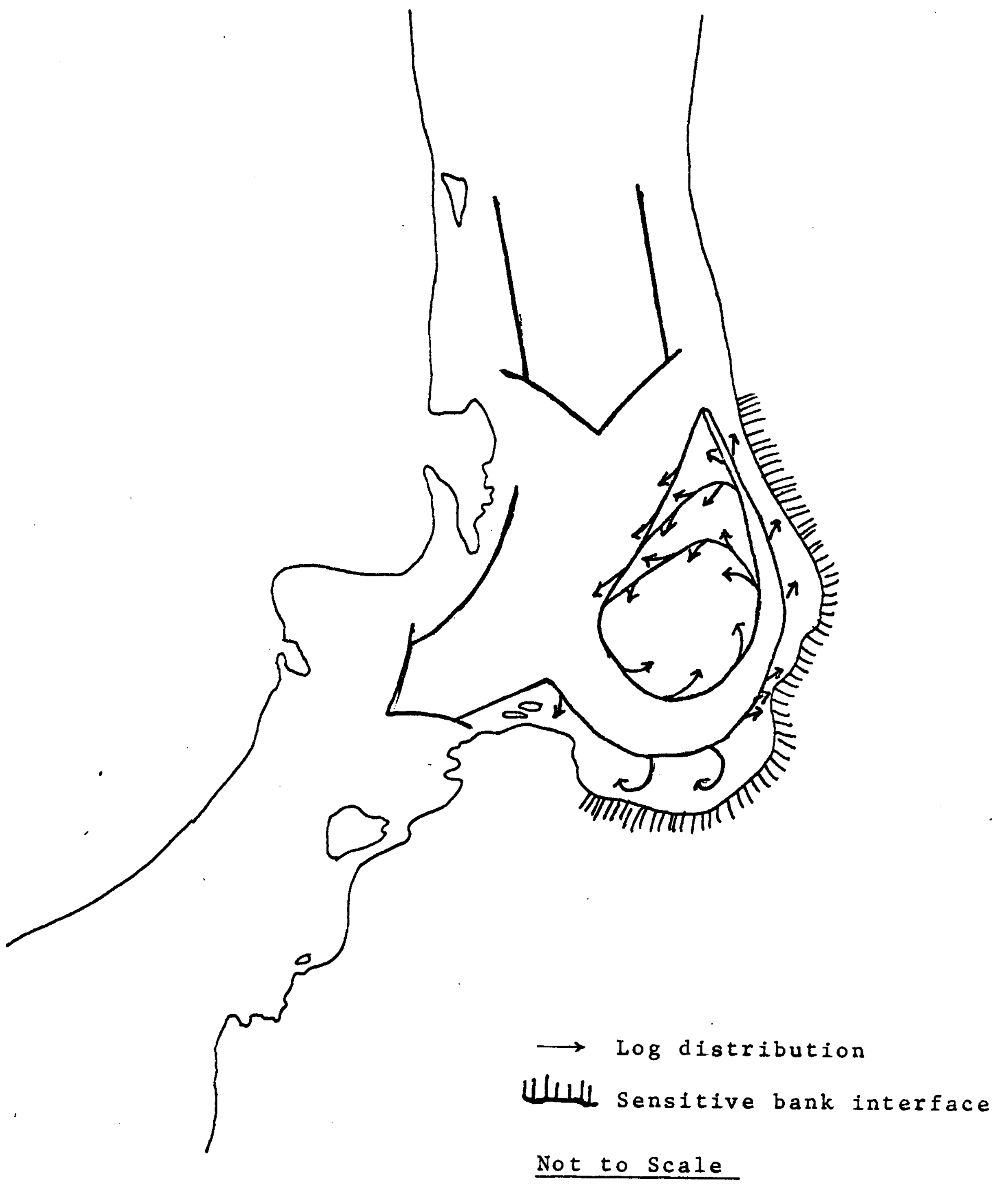
QUESNEL RIVER DISCHARGE

FIG. 7

a result of sloughage of the adjoining slopes which are almost constantly saturated with groundwater seepage. During high flows, sloughage is accelerated by the increased hydraulic action of the river. This not only produces a high clay, gravel and silt recruitment (Plate 9) from these areas, but also a high incidence of forest debris, including whole trees. The latter, referred to as "sweepers", produce severe scouring as their root mass effects a ploughing action. Sloughage was mitigated to a degree by the incidental bank protection afforded by the 22.3 miles of finbooms placed along the river to expedite log passage (Fig. 5, Plate 9). The majority of these booms were in place several weeks before the drive and remained there well into the fall, thus providing extended protection from naturally deposited logs and trees. Boat patrols also fell incipient "sweepers", leaving root masses intact in the bank, thus slowing the rate of erosion and decreasing the number of "sweepers" in the river.

The area of sensitive bank interface at mile 12.6 was considered unique in that it encompassed a large eddy in which the most extreme examples of log/bank contact erosion were observed (Plate 10, 11; Fig. 8). Also, as indicated by the analysis of sediment samples, it was the location of the most severe hydraulic erosion along the river. Instantaneous log/bank contact samples taken here identified the magnitude of this erosion. The average of the control samples taken in the eddy were at least four times greater than the average of two background river load samples taken one half mile above, and two miles below the eddy (Table 3A).

Fig. 8 - Mile 12.6 - Mixmaster Eddy
Log Distribution



CONCLUSIONS

1) An estimated 7,850 tons of bark and debris were contributed to the Quesnel-Cariboo rivers as a consequence of activities associated with the 1973 log drive.

2) Log watering was the major source of the bark and debris contributed to the aquatic environment.

3) Of the estimated 7,850 tons of bark contributed to the Quesnel-Cariboo river, 70 - 93 percent remained within one foot of the river surface and passed from the Quesnel-Cariboo drainage to the Fraser River.

4) Log rearing activities, involved in removal of midstream and peripheral log accumulations, do not appear to have a marked deleterious effect on the fisheries resource owing to:
   a) Efficiency and expediency of log jam removal noted during the 1973 log rearing operations.
   b) Log rearing activities were conducted during a period when no salmon spawning takes place within the Cariboo-Quesnel drainages.

5) The location and efficiency of log guiding facilities (finbooms) effectively reduced the degree and incidence of logs striking sensitive stream banks.

6) Adherence to existing timing and stream flow restrictions will minimize potential log drive impact on salmon stocks utilizing the Cariboo-Quesnel System.

RECOMMENDATIONS

It is recommended that:

1) The driving of logs on the Quesnel-Cariboo rivers be phased out over a three year period commencing in 1975.

2) The watering, driving and rearing of logs in the Quesnel-Cariboo rivers, during the phase out period, be subject to the following conditions:

a) Increased debris controls be undertaken at the log watering sites (landings):-

i. all log bucking and limbing operations be conducted above the high water mark at the respective landings.

ii. landing clean up operations be conducted frequently to minimize water access of accumulated debris.

b) Elimination of those log watering practices which are characterized by:-

i. driving of machines into the river at shallow sites.

ii. dumping of logs from stream banks consequently dislodging bank material.

c) Maintenance of existing finboom installations on the log drive route and addition of new facilities at mile 12.6, Quesnel River.

3) Early discussions be undertaken between respresentatives of the appropriate resource agencies and Weldwood of Canada Ltd. to develop specific protective procedures and formalize the phase out sequence.

4) On completion of log driving activities on the Quesnel-Cariboo rivers, Weldwood of Canada Ltd. undertake habitat restoration measures involving re-establishment of ground and forest cover on landings, removal of stranded logs and debris accumulations in low velocity rearing areas, as required to ensure a viable aquatic habitat.

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2. International Pacific Salmon Fisheries Commission. Effects of Log Driving on the Salmon and Trout Populations in the Stellako River. Progress Report No. 14, Vancouver, B.C., 1966.

3. Schaumberg, F.D. The Influence of Log Handling on Water Quality, Annual Report 1969 - 70. Department of Civil Engineering, Oregon State University, 1970.

APPENDIX 1

Bark Loss on Landings

Location	Date	Sample #	Loss in Per Cent
Cariboo #7	May 24/73	1	8.16
		2	7.10
		3	3.96
		4	5.86
		5	6.68
		6	3.55
		7	12.89
		8	1.43
		9	9.35
		10	7.51

Average bark loss Cariboo #7 $\frac{66.49}{10}$ = 6.65%

Cariboo #2	June 14/73	11	1.05
		11a	0.00
		12	7.99
		13	47.26
		14	6.30
		15	17.69
		16	7.78
		17	14.52
		18	13.34
		19	29.18
		20	26.52
		21	4.87
		22	4.10

Average Bark Loss Cariboo #2 = $\frac{180.6}{13}$ = 13.89%

......Cont'd

APPENDIX 1 (Cont'd)

Average Bark Loss for Landings 2 + 7:

$$\text{Cariboo \#2} = \frac{180.6}{13}$$

$$\text{Cariboo \#7} = \frac{66.49}{10}$$

$$\text{Overall Average} = \frac{247.09}{23} = 10.74\%$$

APPENDIX 2

Bark Loss at Mill Pond (Plate 13)

During Watering Portion:

Date	Sample No.	% Bark Loss
May 26/73	23	11.65
May 26	24	77.79
May 26	25	20.03
May 26	26	3.98
May 26	27	57.78
June 21	28	100.00
June 21	29	35.20
June 21	30	13.60
June 21	31	24.91
June 21	32	77.60
June 21	33	26.95
June 21	34	15.10
June 21	35	63.95
June 21	36	29.03

Average bark loss during watering portion $\frac{557.57}{14} = 39.83\%$

During Rearing:

Date	Sample No.	% Bark Loss
July 6/73	37	24.34
July 6	38	46.57
July 6	39	19.40
July 6	40	42.19
July 6	41	35.65
July 6	42	88.43
July 6	43	70.55
July 6	44	84.00
July 6	45	60.32
July 6	46	15.49
July 6	47	22.27
July 6	48	30.20
July 6	49	34.17

Average bark loss for rearing stage: $\frac{573}{13} = 44.12\%$

APPENDIX 3

Determination of Bark Loss Weight

(A) Sample of model used[1]

Spruce:

1. Total volume of wood and bark in drive 6,500,000 cu. ft.[2]

2. Percent of spruce in drive = 64[3]
3. Spruce bark volume as a percentage of total log volume = 13[4]
4. Volume of spruce bark in drive =

(6,500,000) (64%) (13%) = 540,800 cu. ft.

5. Volume removed at mill pond:

   (a) Watering stage -[5]

   39.8% of 90% of 540,000 cu. ft. = 193,714.5 cu. ft.

   (b) Rearing stage -[6]

   44.1% of 10% of 540,800 cu. ft. = 23,849.3

   Total amount lost at mill pond 217,563.8 cu. ft.

6. Volume removed prior to watering[7]

   10.7% of 540,800 cu. ft. = 57,865.6 cu. ft.

7. Volume lost in river (217,563-57,865) = 159,698.0 cu. ft.

8. Density of dry spruce bark[8]

   (a) range - 22 - 34#/cu. ft.

   (b) average - 28#/cu. ft.

9. Spruce bark moisture content:

   Moisture factor 61[9]
   Moisture content

   (a) range 13-20#/cu. ft.

   (b) average 17#/cu. ft.

10. Density of wet bark[10] (dry bark and moisture content):

   (a) range 35-54#/cu. ft.

   (b) average 45#/cu. ft.

......Cont'd

APPENDIX 3 (Cont'd)

11. Weight of wet bark lost in river:

(a) range:

$$= \frac{35(159,698)}{2000} \text{ to } \frac{54(159,698)}{2000}$$

$$= 2,794.7 \text{ to } 4,311.8 \text{ tons}$$

(b) average:

$$\frac{45(159,698)}{2000} = 3,593.2 \text{ tons}$$

(B) Calculation factors

(a) General

(1) Total volume in log drive 6,500,000 cu. ft.

(2) Percent of bark removed at mill pond:

(a) for watering stage 39.8
(b) for rearing stage 44.1

(3) - Percent of logs subject to watering stage calculations = 90

- Percent of logs subject to rearing stage calculations = 10

(b) Specific species - (1) Balsam

(a) 15% of total volume in drive.

(b) bark volume 13.5% of total log volume

(c) dry bark density:

range - 25-35#/cu. ft.

average - 31#/cu. ft.

(d) moisture factor 118

(e) wet bark density:

range - 55-76#/cu. ft.

average - 67#/cu. ft.

.....Cont'd

APPENDIX 3 (Cont'd)

(2) Fir

(a) 11% of 6,500,000 cu. ft. in drive

(b) average bark volume is 23.3% of total log volume

(c) dry bark density:

range - 21-36#/cu. ft.

average - 31#/cu. ft.

(d) moisture factor 69

(e) wet bark density:

range - 35-61#/cu. ft.

average - 52#/cu. ft.

(3) Pine

(a) 10% of the total volume

(b) average bark volume is 10.1% of total log volume

(c) dry bark density:

range - 25-42#/cu. ft.

average - 33#/cu. ft.

(d) moisture factor - 55

(e) wet bark density:

range - 39-65#/cu. ft.

average - 51#/cu. ft.

Bark weight loss totals

Species	Range (tons)	Average (tons)
Spruce	2800-4300	3600
Balsam	1060-1475	1300
Fir	860-1500	1280
Pine	1280-2125	1670
TOTAL	6000-9400	7850

.....Cont'd

APPENDIX 3 (Cont'd)

NOTES:

(1) The model was used for all species.

(2) Information given by Weldwood

(3) Ibid

(4) Dobie, J. and D.M. Wright. Conversion Factors for the Forest Products Industry in Western Canada, D.O.E. Canadian Forest Service, Western Forest Products Laboratory, 1972, p. 17.

(5) Ninety per cent was applied because that many logs had been dewatered at the end of the watering stage.

(6) These logs, dewatered after watering had ceased, were subjected to more rearing than the others.

(7) See Appendix 1

(8) Dobie & Wright, op. cit. p. 19

(9) Ibid. P. 11. The figure given represents the weight of water compared to the weight of wood and bark present; i.e., if the wood weighed 100#/cu. ft. and the moisture factor was 61 then the moisture would weigh 61#/cu. ft. log. The weight of the log would be 161#/cu. ft.

(10) Dr. Kellogg, Western Forest Products Laboratory, U.B.C. aided in these calculations.

(11) Information provided here allows bark weight loss for any or all species to be made.

APPENDIX 4

VOLUME OF BARK DEPOSITED ON BANK

Estimated distance of bank covered - 35 - 45 river miles

Estimated average depth 1 inch
Estimated average width 2 feet
Volume range of bark on banks:

(a) $2(35) \times 5280 \times \frac{1}{12} \times 2 = 61{,}600$ cu. ft.

(b) $2(45) \times 5280 \times \frac{1}{12} \times 2 = 79{,}200$ cu. ft.

Total volume of bark lost during drive = 306,500 cu. ft.[(1)]

Percentage range of bark on banks:

(a) $\frac{61{,}600}{306{,}500} \times 100\% = 20\%$

(b) $\frac{79{,}200}{306{,}500} \times 100\% = 26\%$

(1) Total Bark Volume lost:

Spruce		160,000 cu. ft.
Balsam		53,000 cu. ft.
Fir		67,000 cu. ft.
Pine		26,500 cu. ft.
	TOTAL	306,500 cu. ft.

The figures were computed from the spruce model, Appendix 3.

PLATE 1 Log watering at landing C 2

PLATE 2 Log watering at landing C 2. Note machine locations.

PLATE 3 Accumulated bark and debris

PLATE 4 Landing C 3 on completion of log watering. Note debris.

PLATE 5 Log jam prior to breaching

PLATE 6 Breaching of log jam

PLATE 7 Stream side cover removal required for modified "raker log" rearing technique

PLATE 8 Active natural sloughage

PLATE 9 Fin booms and natural active sloughage

PLATE 10 Mixmaster Eddy - Mile 12.6

PLATE 11 Log-bank contact - Big Eddy

PLATE 12 Logs prior to watering - landing C 2

PLATE 13 Logs at mill pond-post log drive