Biophysical Inventory and Resource Maintenance Flow Requirements of Salmon in Norrish Creek, B.C.

T.R. Cleugh, L.R. Russell and A.G. Sewid

Habitat Protection Division
Department of Fisheries and Oceans
Vancouver, B.C. V6E 2P1

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BIOPHYSICAL INVENTORY AND RESOURCE MAINTENANCE FLOW REQUIREMENTS OF SALMON IN NORRISH CREEK, B.C.

By

T.R. Cleugh, L.R. Russell

and

A.G. Sewid

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ABSTRACT

This study examines the history of the Norrish Creek watershed, evaluates the biophysical habitat afforded salmon by the creek and provides an estimate of stream flows necessary for spawning, incubating and rearing of coho and chum salmon. In addition, data are presented on the limit of upstream spawning migration, incubation periods and timing of emergence from the gravel of juvenile salmon. Rearing distribution of juvenile coho salmon in the creek is given in relation to various stream flows.

Key words: Salmon, biophysical parameters, resource maintenance flow, Norrish Creek, B.C.

RESUME

La présente étude comprend une analyse rétrospective du bassin hydrographique du ruisseau Norrish, l'évaluation du milieu biophysique qu'il constitue pour le saumon et des cours d'eau nécessaires à la fraie, à l'incubation et à la croissance de jeunes saumons coho et kéta. Elle renferme aussi des données sur la limite extréme de la migration de fraie en amont, sur les périodes d'incubation et le moment de la sortie des jeunes saumons dans le gravier. La répartition des jeunes saumons coho est faite en fonction des divers cours d'eau du bassin.

Mots clefs: Saumon; paramétres biophysiques; courant minimal; ruisseau Norrish; C.-B.

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I. INTRODUCTION

1.1 Preface

In 1975 the Fisheries and Marine Service received notice of a water licence application on Norrish Creek. A subsequent review of escapement records revealed substantial populations of chum (*Oncorhynchus keta*) and coho (*Oncorhynchus kisutch*) salmon (Table 1). A bio-engineering study was therefore established to help resolve any potential water use conflict. This report represents the current state of biological knowledge of the system.

Norrish Creek (which drains 114 sq. kilometers) flows for ten miles through steep-walled canyons in the coastal mountains before entering the Fraser River via Nicomen Slough (Figure 1). It deposits large amounts of rock and gravel in its lower reaches in the shape of an alluvial fan. This gravel is essential for continued successful spawning of Norrish Creek's salmonid populations.

Discharge in the creek is dependent on snowmelt, ground water, precipitation (Table 2) and water storage in Dickson Lake. Norrish Creek has a mean annual daily peak flow of 3900 cfs with a maximum recorded instantaneous peak flow of 14100 cfs (13 year record). Highly variable runoff patterns result from extended periods of heavy precipitation causing flooding (winter - spring) or from prolonged periods of drought (summer - fall).

Both flooding and drought have serious detrimental effects on anadromous salmonids. Floods may prevent or delay adult migration, reduce success of egg fertilization or deposition by spawning fish or scour out and destroy redds during egg or alevin incubation (Neuman and Newcombe, 1977; Orsborn and Dean, 1976; and Stalnaker and Arnette, 1976). Droughts and resulting low levels of discharge may leave incubating eggs and rearing juveniles with a water supply insufficient to maintain adequate amounts of oxygen or essential temperature regimes (Anon, 1973; Giger, 1973; Hamilton and Buell, 1976; Neuman and Newcombe, 1977; Orsborn and Allman, 1976; Orsborn and Dean, 1976; Smith, 1975 and Stalnaker and Arnette, 1976). Low flows may also prevent spawning adults from utilizing large areas of good spawning gravel.

TABLE 1: TEN YEAR AVERAGE ESCAPEMENT OF COHO AND CHUM SALMON FOR NORRISH CREEK, 1969-1978, FROM FISHERIES OFFICERS' RECORDS

	Coho	Chum
1969	500	5,000
1970	300	2,000
1971	2,000	1,000
1972	300	2,000
1973	500	1,000
1974	500	2,000
1975	500	10,000
1976	200	1,500
1977	400	4,000
1978	500	4,000
10 year average	570	3,250

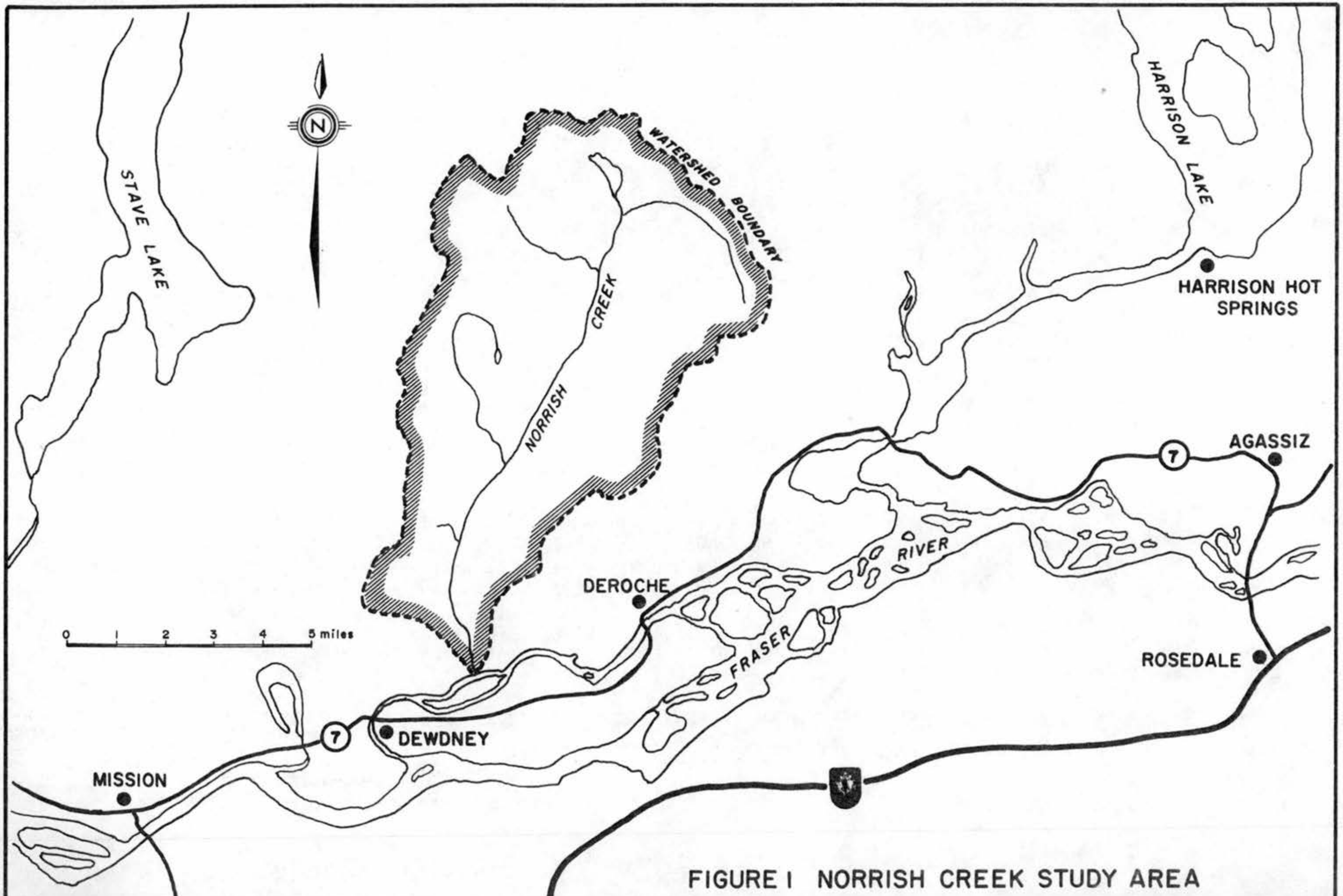


FIGURE I NORRISH CREEK STUDY AREA

TABLE 2: TEMPERATURE AND PRECIPITATION FOR MISSION, B.C., 1941-1970. (from Atmospheric Environment Service).

Latitude 49 08 N Longitude 122 18 W Elevation 185 Ft. ASL

	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Daily Temperature (Deg.F)	35.6	40.9	43.0	48.1	54.8	59.9	63.8	63.3	59.0	51.4	43.3	38.6	50.1
Mean Daily Maximum Temperature	40.1	46.4	50.1	56.2	64.0	68.5	74.0	73.3	68.0	58.3	48.4	43.0	57.5
Mean Daily Minimum Temperature	31.1	35.4	35.9	40.1	45.6	51.3	53.5	53.3	49.9	44.4	38.1	34.0	42.7
Extreme Maximum Temperature	60	69	71	79	90	93	100	96	88	78	66	60	100
No. of Years of Record	17	17	17	18	18	18	18	18	18	18	18	18	
Extreme Minimum Temperature	6	7	10	27	28	38	40	41	34	27	8	-3	-3
No. of Years of Record	17	17	17	18	18	18	18	18	18	18	18	18	
No. of Days with Frost	15	8	8	2	*	0	0	0	0	1	5	11	50
Mean Rainfall (Inches)	7.05	6.46	5.37	4.29	3.02	2.54	1.73	2.16	3.64	7.25	7.68	8.19	59.38
Mean Snowfall	10.8	2.8	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.5	7.2	25.4
Mean Total Precipitation	8.13	6.74	5.66	4.31	3.02	2.54	1.73	2.16	3.64	7.25	7.83	8.91	61.92
Greatest Rainfall in 24 hrs.	3.84	2.63	1.61	2.06	2.69	2.06	1.93	1.41	2.05	2.97	3.76	2.97	3.84
No. of Years of Record	17	17	16	18	18	18	18	17	18	18	18	18	
Greatest Snowfall in 24 hrs.	9.3	4.2	8.0	2.0	T	0.0	0.0	0.0	0.0	0.0	5.0	10.6	10.6
No. of Years of Record	17	17	17	18	18	18	18	18	18	18	18	18	
Greatest Precipitation in 24 hrs.	3.84	2.63	1.61	2.06	2.69	2.06	1.93	1.41	2.05	2.97	3.76	2.97	3.84
No. of Years of Record	17	17	16	18	18	18	18	17	18	18	18	18	
No. of Days with Measurable Rain	16	16	15	16	12	12	7	10	11	17	18	19	169
No. of Days with Measurable Snow	5	2	2	*	0	0	0	0	0	0	1	4	14
No. of Days with M. Precipitation	20	17	16	16	12	12	7	10	11	17	19	22	179

While natural causes alone contribute significantly to Norrish Creek's variable flow patterns, human activity in the watershed has tended to increase the instability of the creek's flow regime. Intensive logging practices, gravel removal and flood protection measures have all contributed to increased occurrence of winter flooding, siltation and erosion of the streambed. All of these factors are highly detrimental to the successful survival of salmon (see references listed previously) and probably contributed to the elimination of pink salmon from this system after 1961.

The City of Mission presently holds a water licence on Norrish Creek to divert 2.5 million gallons of water per day (5 cfs). A further water licence application by the recently formed Central Fraser Valley Water Commission to divert an additional 16 cfs has prompted this Service to investigate the fisheries resource maintenance flow requirements of Norrish Creek.

This study was designed to provide the following information about Norrish Creek salmon:

1. Extent of upstream migration, timing and distribution of coho and chum salmon spawners.

2. Extent of utilization by coho juveniles of side channels for rearing purposes prior to smolting.

3. Timing of emergence from the gravel and seaward migration of chum and coho salmon juveniles.

Data gathered in this investigation, when combined with what is already known about the ecology of the salmonid populations in Norrish Creek, should provide a basis on which to judge the potential problems associated with the proposed water diversion.

As with most studies there are some basic limitations and data gaps. In this study we were unable to investigate in detail the temperature budget or the salmon food and benthos or invertebrate drift relationships. Nor were we able to assess the relationship of channel instability to fish food production.

1.2 Recent History of Norrish Creek

The Norrish Creek watershed has undergone significant alteration since Department of Fisheries and Environment records began in 1929. The creek has always been subject to severe fluctuations in discharge because of heavy precipitation and watershed response characteristics.

In 1951 the Belgian Consul constructed a dyke along the lower part of Norrish Creek to protect their property below the CPR bridge to Nicomen Slough from winter floods. This involved the removal of a considerable amount of spawning gravel in the vicinity of the dyke and altered the flow regime of the creek during construction.

During 1966 the Canadian Pacific Railway began stream maintenance operations on Norrish Creek which were designed to prevent flood damage to their railway bridge. A dyke was installed along the centre of the stream beginning 1,800 yds. above the bridge and extending to within approximately 1,200 yds. of the bridge. This dyke diverted most of the water in the creek into an eastern channel deepened by the removal of 500,000 cubic yds. of gravel. Following dyke construction, the western channel of the creek (hitherto an important coho salmon spawning and rearing area) was abruptly closed as part of the flood control program causing the death of an undetermined number of coho salmon present in the channel.

In 1967, the Department of Highways removed gravel from 100 yds. of streambed for use in road construction. In the same year, the CPR continued to grade the streambed and remove gravel above the railway bridge as part of their flood control program. They also installed two culverts in the dyke along the north end of the western channel (at the request of the Department of Fisheries and Environment) in order to supply enough water to the channel to support the coho salmon there.

The following year the CPR breached the upper dyke to increase the flow in the western channel but also continued to remove gravel from the area of the creek directly above the railway bridge. Existing dykes in the creek were fortified with rock and gravel removed from the adjacent streambed. In addition, a number of permits for placer mining operations in the area surrounding Norrish Creek were granted to private citizens.

In 1969 the CPR removed further large quantities of gravel from Norrish Creek. By 1970 the streambed had eroded to such an extent that original engineering plans for creekbed stabilization had to be revised by CPR consultants. Although the CPR constructed two rock cribs in the creek to prevent further erosion, they also removed large amounts of gravel from the streambed above their railway bridge and diverted 2 cfs of water from Norrish Creek to wash the gravel crushed at their on-site gravel processing operation.

During 1971 additional rock cribs were constructed in the eastern channel of the creek and larger culverts were placed in the dyke at the head of the western channel by the CPR. The railway also removed an undetermined amount of gravel from the creekbed directly above the bridge.

In 1972, following a wash out of the culverts placed in the creek in 1971, the Department of Fisheries and Environment requested the reopening of the western channel by the CPR. This proposal was rejected by the railway on the grounds that it would jeopardize their flood control program. In addition, despite lack of government approval, the CPR thereafter removed an additional amount of gravel from Norrish Creek.

During 1973 the CPR again graded the creekbed and armoured its dykes. Large rocks were placed in the streambed to prevent further erosion.

No streambed maintenance occurred in Norrish Creek after September, 1973 when negotiations between the Department of Fisheries and Environment and the CPR broke down over the proposed reopening of the western channel. The railway has since been prevented from entering the creekbed to armour their dykes or remove gravel deposited above the bridge.

In 1975, the District of Mission expressed renewed interest in developing their water licence. Their engineering consultants, Dayton and Knight, suggested that a storage dam be placed on Dickson Lake and a water diversion structure be located in the vicinity of the confluence of Norrish and Rose creeks. Further progress towards development of the District of Mission's water licence has been stayed because of the formation of the Central Fraser Valley Water Commission who applied for a licence for 16 cfs on September 14, 1978.

2. METHODS

2.1 Biophysical Inventory of Norrish Creek

The survey was conducted from 3-6 October 1976 for reaches 1-14 and from 24-25 November 1976 for reaches 15-18 (Figure 2). Reaches were then combined into three areas based on similar physical characteristics. The inventory extended from Nicomen Slough to Rose Creek, the maximum potential upper limit of migration for salmon. Immature fish were sampled using beach seine nets or "Gee" traps. The rationale for selecting physical features were based on studies by Orsborn and Deane, and Neuman and Newcombe.

The following categories of information were recorded: length of reach, substrate material, stream bank interface material, mean stream wetted width, pool - riffle ratio, obstructions, secondary and flood channels, rearing habitat, unstable areas, stream bank vegetation, and bank height.

2.2 Fisheries Resource

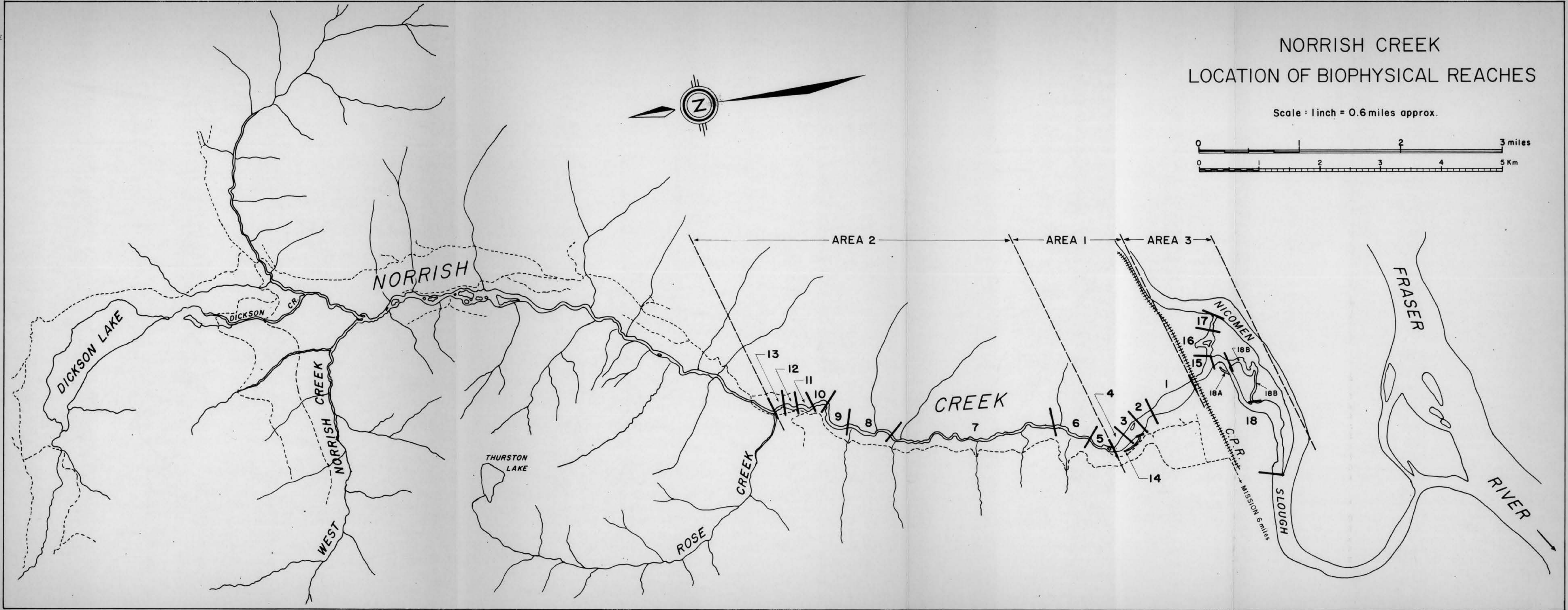
2.2.1 Spawning Distribution

Stream surveys were conducted by walking the lower reaches of Norrish Creek approximately twice per month during the spawning seasons in 1976 and 1977. Locations of active spawning, numbers of fish, numbers of carcasses, and locations of redds were recorded for both coho and chum salmon. Upper limits of migration within the creek were determined by walking upstream until spawning fish were no longer evident or until impassable barriers to migration were encountered.

2.2.2 Habitat Requirements During Incubation

Habitat requirements specific to incubating eggs and alevins in Norrish Creek were not determined. Recommendations of adequate streamflows, oxygen supply and temperatures were derived from extensive studies carried out by other investigations (see Results).

FIGURE 2


NORRISH CREEK
LOCATION OF BIOPHYSICAL REACHES
Scale : 1 inch = 0.6 miles approx.
0
1
2
3 miles
0
1
2
3
4
5 Km
Z
AREA 2
AREA 1
AREA 3
NORRISH
CREEK
DICKSON LAKE
DICKSON
CR.
WEST
NORRISH
CREEK
THURSTON
LAKE
ROSE
CREEK
NICOMEN
SLOUGH
FRASER
RIVER
C.P.R.
MISSION 6 miles
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
18A
18B
18B

2.2.3 Timing of Emergence and Rearing Requirements of Salmon Juveniles

Surveys of juvenile salmon distribution were conducted bimonthly during late 1976, 1977 and early 1978 throughout the entire lower portion of the stream from the upper extent of the western channel to the mouth of the creek (Figure 2). Numbers, species and approximate age of all fish sighted were recorded. Scale samples from 20 juvenile coho, in each reach, were analysed for age structure to determine freshwater residence period.

3. RESULTS

3.1 Biophysical Inventory (Table 3)

3.1.1 Stream Banks

Throughout Area 1 (except reach 14) unstable banks are extensive and some bank slumping and soil mass-wasting is evident. Streambank interface consists mostly of gravel and larger rocks, less than 10 percent of the bank consists of sand. Bank vegetation consists of trace deciduous in the lower reach (1) to continuous deciduous in the upper reach (4).

Area 2 has stable banks throughout, the majority of the banks were composed of bedrock with large boulders and gravel occurring to a lesser degree. The vegetation was continuous coniferous and deciduous trees and shrubs. Bank height in most reaches of Area 2 were generally greater than 100 feet.

Area 3 is generally described as a braided channel, with bank height generally less than twenty feet. Bank composition was mostly gravel in the upper reach (15), progressively getting smaller (sand to clay) in the lower (near Nicomen Slough) reaches (17 and 18). Bank cover was generally continuous deciduous vegetation.

3.1.2 Streambed Characteristics

The stream substrate material in Area 1 was mainly comprised of large boulders and coarse gravel. Stream width in the main channel varied from 10-22 yards (9-20 meters) with no obstructions. The pool - riffle

TABLE 3: SUMMARY OF BIOPHYSICAL INVENTORY DATA FOR NORRISH CREEK

PARAMETERS MEASURED	REACH 1	REACH 2	REACH 3	REACH 4
Length of Reach	900 yds.	250 yds.	375 yds.	300 yds.
Substrate Material(%)	boulder(30)large clean gravel(30) med.clean gravel(30)sm.cl.grav(10)	boulders(30)lg.cl.gravel(40) med.cl.gravel(15)sm.cl.gravel (10) sand(5)	bedrock(1)boulder(39)lg.cl.gravel(25) med.cl.grav.(15)sm.cl.grav.(15) sand (5)	bedrock(1)boulder(49)lg.cl.gravel(15) med.cl.grav.(15)sm.cl.grav.(15) sand(5)
Stream Bank Interface(%)	boulder(30)gravel(60)sand(10)	boulder(10)grav.(85)sand(5)	bedrock(1)boulder(50)gravel(45) sand(4)	bedrock(15)boulder(60)gravel(20) sand(5)
$\bar{X}$ wetted stream width	22yds.	10 yds.	20 yds.	10 yds.
Pool riffle ratio	5 - 95	30 - 70	30 - 70	30 - 70
Obstructions	None	None	None	None
Secondary & Flood Channels	None	Extensive	None	None
Rearing Habitat	Limited	Moderate	Limited	Limited
Unstable Areas	Extensive - both banks	Extensive	Extensive sloping boulder & gravel	Some
Bank Vegetation Type/Height	trace/deciduous shrubs/15-20'	intermittent/deciduous shrubs & trees/15-20'	continuous/deciduous trees/10'	continuous/deciduous trees/ east shore 10' - west shore 100'

TABLE 3: (cont'd.)

REACH 5	REACH 6	REACH 7	REACH 8	REACH 9
400 yds.	680 yds.	2,900 yds.	810 yds.	627 yds.
boulder(50)lg.cl.gravel(20) med.cl.gravel(29)sm.cl.grav.(10)	bedrock(15)boulder(40)lg.cl.gravel(25) med.cl.grav.(10)sm.cl.grav.(10)	bedrock(60)boulder and gravel(40)	bedrock(45)boulder(50) cl.gravel & sand(5)	bedrock(15) boulder and gravel(85)
bedrock(100)	bedrock(30)boulder(40)gravel(25)	bedrock(80)boulder and gravel(20)	bedrock(75)boulder and gravel(25)	bedrock(25)boulder and gravel(75)
30 yds.	22 yds.	20 yds.	22 yds.	20 yds.
40 - 60	20 - 80	20 - 80	20 - 80	20 - 80
None	None	None	None	None
None	None	None	None	None
Limited	Limited	Limited	Limited	Limited
Stable	Stable	Stable	Stable	Stable
continuous/coniferous-deciduous trees/150'	continuous/conifers-deciduous trees and shrubs/50'-150'	continuous/conifers/ deciduous/50'-150'	continuous/conifers/ deciduous/50'-150'	continuous/conifers and deciduous shrubs/50'-150'

TABLE 3: (cont'd.)

REACH 10	REACH 11	REACH 12	REACH 13	REACH 14 west channel
262 yds.	275 yds.	185 yds.	180 yds.	110 yds.
lg.cl.boulder and gravel	bedrock(50)boulder and lg.cl. gravel(50)	bedrock(40)boulder(40) lg.cl.gravel(20)	bedrock(15)gravel(85)	sm.cl.gravel(80)sand(20)
lg.cl.boulder and gravel	bedrock(100)	bedrock(60)boulder(20) gravel(20)	bedrock(30)boulder(50) gravel(20)	boulder(5)gravel(85)sand(10)
20 yds.	20 yds.	20 yds.	21 yds.	2 - 3 yds.
10 - 90	40 - 60	10 - 90	40 - 60	40 - 60
None	Non-Passable Falls	40' Falls	None	Isolated Channel
None	None	None	None	Flood channel & ground-water
Limited	Limited	Limited	Moderate	Extensive
Stable	Stable	Stable	Stable	
intermittent/conifers-deciduous shrubs/50'-150'	continuous/conifers-deciduous trees and shrubs/50'-150'	continuous/conifers-deciduous trees and shrubs/30'-50'	continuous/conifers-deciduous trees and shrubs/10'-30'	intermittent/deciduous trees/4'

TABLE 3: (cont'd.

REACH 15 Bridge to Fork	REACH 16 East Fork	REACH 17 Lower End East Fork	REACH 18 West Fork
240 yds.	200 yds.	1000 - 1200 yds.	2,700 yds.
lg.gravel(30)sm.gravel(60)sand(10)	lg.gravel(10)sm.gravel(70) sand(20)	sm.gravel(60)sand-clay-mud(40)	upper-(50%)gravel(50) fines, lower-mostly fines (clay,sand)
gravel(80)sand-clay(20)	sand-clay(100)	gravel(10)sand(10)clay(80)	mostly fines - (clay)
30 yds.	25 yds.	25 yds.	20-25 yds.
0 - 100	No pools	20-80	No pools
None	None	None	None
Limited	Numerous	Numerous	Numerous
None	Extensive	Extensive	Extensive
None	None	None	None
continuous/mixed/10-20'	continuous/deciduous/10'	intermittent/deciduous	continuous/deciduous

ratio varied from a low of 5-95 (5 percent pool - 95 percent riffle) in reach 1 to 30-70 in the rest of this area. No secondary channels were evident except in reach 2 where there was extensive braiding and numerous side area channels. Fish rearing habitat is limited to the main stem except in reach 2 where a side channel is available as limited rearing area.

Area 2 stream substrate materials were comprised exclusively of bedrock and boulders. No spawning gravels were observed. Wetted stream width averaged 20 yards (18 meters) and two impassable (to fish) obstructions (18 meter waterfalls) were located in reach 12. Pool - riffle ratios varied from 10-90 to 40-60, no side channels were observed, and fish rearing habitat was limited.

Area 3 stream substrate material ranged from gravel in the upper reach (15) to sand and silt in reaches 17 and the lower end of 18. Stream width ranged from 20-30 yards, with no obstructions to fish passage. Pool - riffle ratio ranged from no pools to 20-80. Extensive rearing areas were evident in the numerous side channels.

3.1.3 Reach 14

Reach 14 in Area 1 was examined separately because of its special characteristics.

1. The channel is fed by a ground water source, and was consistently 0.5°C warmer on temperature spot checks (compared to Norrish Creek) during winter and 0.5°C cooler during summer months.

2. The channel is presently 1-3 meters higher in elevation than the main-stem Norrish Creek.

3. The channel is man-made and between two protective dykes. Ground water immerses into the gravel at approximately mid-length, and at low flows (less than 10 cfs) does not visibly enter Norrish Creek. At higher flows it functions as a flood channel. The banks, normally stable under average (ground water) flows, become unstable during flood flows. The banks consist mainly of gravel with intermittent deciduous trees and shrubs.

The stream substrate is mainly clean, small gravel with a 40-60 pool - riffle ratio. Extensive fish rearing habitat is available within the approximately 300 square yards of wetted stream area. A major obstruction fo fish passage occurs at low flows when this channel is effectively isolated from Norrish Creek.

3.1.4 Streamflow Records

Hydrological records have been continuously maintained on Norrish Creek (Water Survey of Canada station 08MH058) from 1960 to the present. Monthly summaries from 1960 to the 1977 are presented in Table 4. Daily discharge data for 1976 and 1977 (the study period) is presented in Table 5, and a historical annual extremes in discharge plus the annual total discharge is given in Table 6. A graph of the mean monthly flows and the extreme historical low monthly flows are shown in Figure 3.

These figures show that for the 17 year period, 1960-1977, Norrish Creek had a mean annual discharge of 447 cfs. The low flow month is August with a mean of 126 cfs. Recorded extremes in daily discharge are 7,560 cfs on 26 November 1963 and 27.4 cfs on 16 September 1973. The lowest recorded mean monthly flows for the critical period of June to October are 113 cfs for June (1963); 83 cfs for July (1960); 48.4 cfs for August (1973); 51.3 cfs for September (1973) and 56.5 cfs for October (1974).

3.2 Fisheries Resource

3.2.1 Spawning Distribution and Habitat Conditions

Maps showing the location of coho and chum spawning areas in Norrish Creek during 1976 and 1977 appear in Figures 4 and 5. Numbers of spawners observed during the study were:

	Coho	Chum
1976	200	1,500
1977	350	3,500

TABLE 4: ANNUAL EXTREMES OF DISCHARGE IN CFS AND ANNUAL TOTAL DISCHARGE IN ACRE-FEET FOR 1960 - 1977, NORRISH CREEK

Year	Maximum Instantaneous Discharge	Maximum Daily Discharge	Minimum Daily Discharge	Total Discharge
1960	5580 CFS at 2210 PST on Feb. 6	2880 CFS on May 30	28.0 CFS on Aug. 13	383000 AC-FT
1961	9800 CFS at 1030 PST on Jan. 15	6810 CFS on Jan. 15	---	---
1962	9140 CFS at 1600 PST on Nov. 19	2900 CFS on Nov. 19	76.0 CFS on Aug. 2	312000 AC-FT
1963	14100 CFS at 0300 PST on Nov. 26*	7560 CFS on Nov. 26*	44.0 CFS on Sep. 13	255000 AC-FT
1964	4930 CFS at 1100 PST on Nov. 30	3760 CFS on Nov. 30	125 CFS on Sep. 14	358000 AC-FT
1965	5570 CFS at 1900 PST on Feb. 4	2330 CFS on Feb. 5	82.0 CFS on Jul. 24	295000 AC-FT
1966	12000 CFS at 1245 PST on Dec. 13	5510 CFS on Dec. 13	95.0 CFS on Sep. 3	377000 AC-FT
1967	8670 CFS at 1400 PST on Dec. 10	4450 CFS on Dec. 10	84.0 CFS on Jul. 25	356000 AC-FT
1968	11700 CFS at 1315 PST on Jan. 20	5310 CFS on Jan. 20	51.4 CFS on Aug. 20	380000 AC-FT
1969	12500 CFS at 1015 PST on Jan. 5	5450 CFS on Jan. 5	---	---
1970	3870 CFS at 1053 PST on Apr. 9	2210 CFS on Apr. 9	49.9 CFS on Aug. 31	215000 AC-FT
1971	4440 CFS at 0242 PST on Jan. 19	2670 CFS on Jan. 19	52.9 CFS on Aug. 30	350000 AC-FT
1972	6040 CFS at 1858 PST on Mar. 5	3090 CFS on Jul. 12	53.4 CFS on Sep. 4	434000 AC-FT
1973	3430 CFS at 0518 PST on Oct. 13	2200 CFS on Nov. 28	27.4 CFS on Sep. 16*	226000 AC-FT
1974	5760 CFS at 0300 PST on Dec. 21	2940 CFS on Jan. 14	34.2 CFS on Oct. 19	356000 AC-FT
1975	7550 CFS at 1254 PST on Dec. 2	5390 CFS on Dec. 2	36.4 CFS on Aug. 21	334000 AC-FT
1976	3280 CFS at 0847 PST on Dec. 26	2380 CFS on Dec. 26	51.1 CFS on Oct. 23	299000 AC-FT
1977	---	2820 CFS on Jan. 18	43.2 CFS on Aug. 21	253000 AC-FT
				324000 AC-FT MEAN

*Extreme recorded for the period of record.

TABLE 5a: DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1976

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	385	410	142	394	1210	510	736	96.7	197	67.2	536	145
2	310	363	120 B	311	1390	413	500	91.9	173	98.8	316	134
3	283	313	117 B	284	869	363	395	88.5	157	93.2	243	125
4	520	260	113 B	296	779	334	676	81.7	295	70.3	203	118
5	545	234	112 B	370	739	352	485	78.9	2000	76.7	179	110
6	371	211	110 B	645	652	459	449	77.1	870	74.7	156	149
7	304	195	108 A	530	818	560	423	77.3	527	66.4	145	1680
8	357	182	106	682	1130	668	579	97.8	353	61.7	145	1790
9	372	169	104	737	1190	618	442	90.3	276	59.2	126	944
10	359	245	363	707	1410	856	358	76.1	232	142	114	933
11	341	479	294	886	1120	569	319	70.3	200	225	106	1770
12	280	494	201	692	725	649	282	64.6	248	113	97.8	882
13	233	340	170	502	715	438	251	72.8	185	86.2	91.5	616
14	499	445	153	453	657	395	239	77.1	225	75.4	88.3	422
15	1610	346	146	415	638	1160	252	68.9	192	69.6	121	1040
16	1700	477	145	342	830	1260	249	362	162	66.3	950	792
17	1230	424	422	308	841	837	227	493	144	63.1	1340	1090
18	957	399	1160	299	533	813	199	206	133	59.7	541	988
19	564	288	541	276	458	719	183	500	121	57.0	328	505
20	430	231	376	379	446	535	186	752	112	55.2	252	372
21	393	201	327	321	431	486	164	303	105	53.9	218	330
22	501	187	586	276	471	448	146	223	101	52.4	194	279
23	480	227	438	260	416	423	144	194	98.0	51.1	169	259
24	348	234	481	443	576	550	150	207	92.4	87.7	473	226
25	293	215	472	387	670	501	139	205	87.2	303	530	290

TABLE 5a: (cont'd.)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
26	309	191	358	343	999	363	128	467	81.4	229	279	2380
27	1650	176	334	455	1250	346	116	365	78.4	163	219	1090
28	780	166	287	661	727	407	113	1120	75.6	851	191	553
29	856	153	245	739	611	431	135	419	72.4	357	172	387
30	624	--	314	910	679	383	113	293	69.8	232	158	314
31	466	--	666	--	510	--	104	234	--	970	--	264
TOTAL	18359	8255	9511	14303	24490	16846	8882	7553.0	7663.2	5030.8	8681.6	20977
MEAN	592	285	307	477	790	562	287	244	255	162	289	677
AC-FT	36400	16400	18900	28400	48600	33400	17600	15000	15200	9980	17200	41600
MAX	1700	494	1160	910	1410	1260	736	1120	2000	970	1340	2380
MIN	233	153	104	260	416	334	104	64.6	69.8	51.1	88.3	110

SUMMARY FOR THE YEAR 1976

MEAN DISCHARGE, 411 CFS
TOTAL DISCHARGE, 299000 AC-FT
MAXIMUM DAILY DISCHARGE, 2380 CFS ON DEC. 26
MINIMUM DAILY DISCHARGE, 51.1 CFS ON OCT. 23

MAXIMUM INSTANTEOUS DISCHARGE
3280 CFS AT 0847 PST ON DEC. 26

TYPE OF GAUGE - RECORDING
LOCATION -LAT 49 10 54 N
LONG 122 09 06 W
DRAINAGE AREA 45.2 SQ. MILES

A-MANUAL GAUGE
B-ICE CONDITIONS

NATURAL FLOW

TABLE 5b: (PRELIMINARY) DAILY DISCHARGE IN CUBIC FEET PER SECOND FOR 1977

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	245	115	234	203	528	961	83.1	63.4	64.5	96.4	2160	848
2	217	106	205	190	604	475	128	61.3	67.4	93.3	1310	2290
3	189	100	187	178	611	358	123	59.4	182	84.2	639	1710
4	163	98.1	172	201	432	383	127	57.4	124	79.0	427	798
5	146	95.8	161	356	331	349	95.7	55.6	137	75.0	339	513
6	136	93.2	205	592	296	334	87.9	54.3	90.7	75.1	557	553
7	126	92.2	648	799	316	299	83.1	53.4	82.0	99.5	719	529
8	119	91.2	553	826	335	246	79.3	52.3	81.7	412	375	360
9	115	180	543	601	345	200	76.2	52.0	73.6	239	511	295
10	108	740	355	438	348	183	74.2	51.0	70.0	157	1310	1080
11	105	659	268	419	337	172	104	50.0	66.3	128	795	2210
12	133	1610	301	331	244	157	99.6	49.4	63.4	165	696	1710
13	123	730	234	541	239	143	87.8	48.7	61.1	320	752	1410
14	145	415	199	376	271	134	80.3	47.7	61.8	172	1450	2460
15	255	308	176	396	263	125	75.4	46.7	61.4	135	672	1460
16	481	291	156	553	285	120	221	45.5	60.7	157	520	1010
17	2070	685	144	359	266	117	250	44.7	58.3	125	399	611
18	2820	554	137	319	278	111	132	43.8	56.2	110	302	459
19	944	364	131	276	268	103	106	43.7	75.7	107	243	371
20	533	312	137	243	251	96.8	95.6	43.3	647	98.4	204	303
21	381	318	805	228	386	119	93.1	43.2	391	99.4	175	266
22	301	725	751	337	266	275	87.9	43.5	183	95.5	154	234
23	252	439	824	697	273	117	83.7	77.9	205	261	135	203
24	215	303	562	989	649	115	79.7	140	263	379	140	170
25	188	266	416	972	370	124	76.2	151	176	521	1080	155
26	164	237	599	1130	559	99.7	73.1	147	138	669	1120	145
27	147	249	632	673	404	92.5	70.9	92.5	117	382	923	135
28	134	264	351	554	310	95.7	75.9	99.8	104	272	1820	125
29	122	--	276	501	265	91.4	83.5	109	95.8	619	1590	200
30	115	--	237	487	240	86.1	71.5	78.4	91.4	1510	711	170
31	115	--	225	--	621	--	66.5	68.9	--	802	--	130
TOTAL	11307	10440.5	10824	14765	11191	6282.2	3071.2	2074.8	3949.0	8537.8	22228	22913

TABLE 5b: (cont'd.)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
MEAN	365	373	349	492	361	209	99.1	66.9	132	275	741	739
AC-FT	22400	20700	21500	29300	22200	12500	6090	4120	7830	16900	44100	45400
MAX	2820	1610	824	1130	649	961	250	151	647	1510	2160	2460
MIN	105	91.2	131	178	239	86.1	66.5	43.2	56.2	75.0	135	125

SUMMARY FOR THE YEAR 1977

MEAN DISCHARGE, 350 CFS
TOTAL DISCHARGE, 253000 AC-FT
MAXIMUM DAILY DISCHARGE, 2820 CFS ON JAN 18
MINIMUM DAILY DISCHARGE, 43.2 CFS ON AUG 21

TABLE 6: HISTORICAL STREAMFLOW SUMMARY, IN CUBIC FEET PER SECOND, 1959 - 1977
From Water Survey of Canada)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	MEAN
1959	---	---	---	---	---	---	---	117	504	---	---	---	---
1960	357	508	403	699	850	1190	83.0	166	237	655	628	575	528
1961	1030	1100	584	684	626	---	---	---	207	574	473	706	---
1962	654	432	142	631	372	284	119	250	204	432	736	925	432
1963	353	505	173	343	241	113	214	71.3	59.6	428	1080	666	352
1964	561	387	348	517	719	792	416	281	421	377	608	496	493
1965	527	779	310	516	489	254	96.2	118	104	476	668	582	407
1966	570	313	473	639	639	427	283	120	123	575	680	1380	521
1967	961	673	348	223	659	543	112	85.4	101	918	496	786	492
1968	1090	874	527	384	405	350	140	107	444	681	691	606	524
1969	---	---	---	---	---	---	---	131	368	394	429	441	---
1970	429	459	324	471	246	153	98.8	61.1	187	234	523	402	297
1971	844	754	375	456	800	605	281	70.7	163	493	690	299	484
1972	450	702	1210	945	924	634	479	85.9	305	113	418	908	597
1973	301	279	285	318	474	285	103	48.4	51.3	423	428	735	312
1974	920	424	617	603	695	851	375	98.7	55.8	56.5	542	653	491
1975	449	221	320	262	670	481	144	154	91.3	671	968	1080	462
1976	592	285	307	477	790	562	287	244	255	162	289	677	411
1977	365	373	349	492	361	209	99.1	66.9	132	275	741	739	350
MEAN	615	533	417	509	586	483	208	126	211	441	616	703	447

LOCATION - LAT 49 10 54 N
- LONG 122 09 06 W

DRAINAGE AREA 44.1 SQ. MILES
NATURAL FLOW

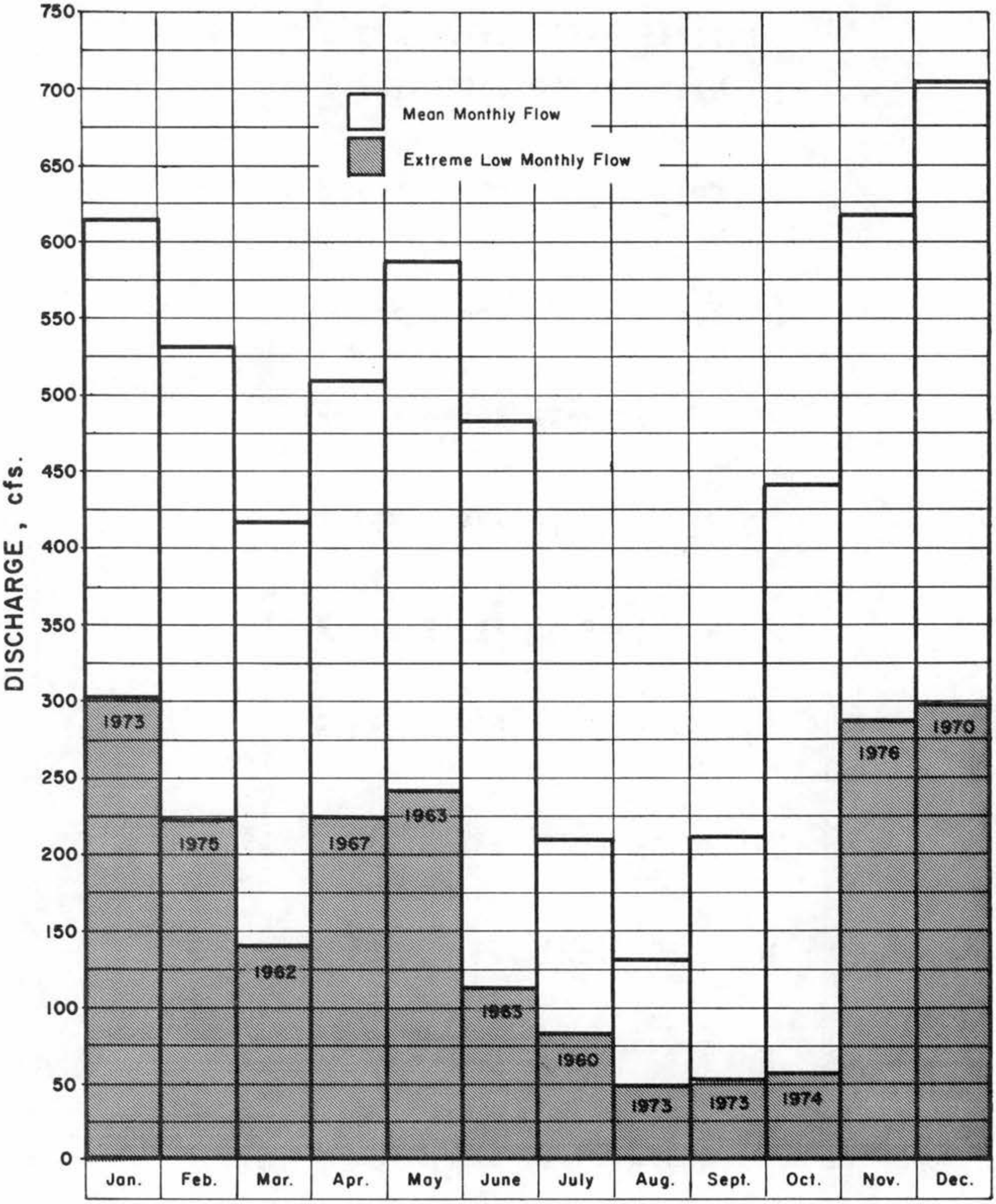


FIGURE 3: NORRISH CREEK, MEAN MONTHLY and EXTREME LOW HISTORICAL MONTHLY FLOWS 1960 TO 1977

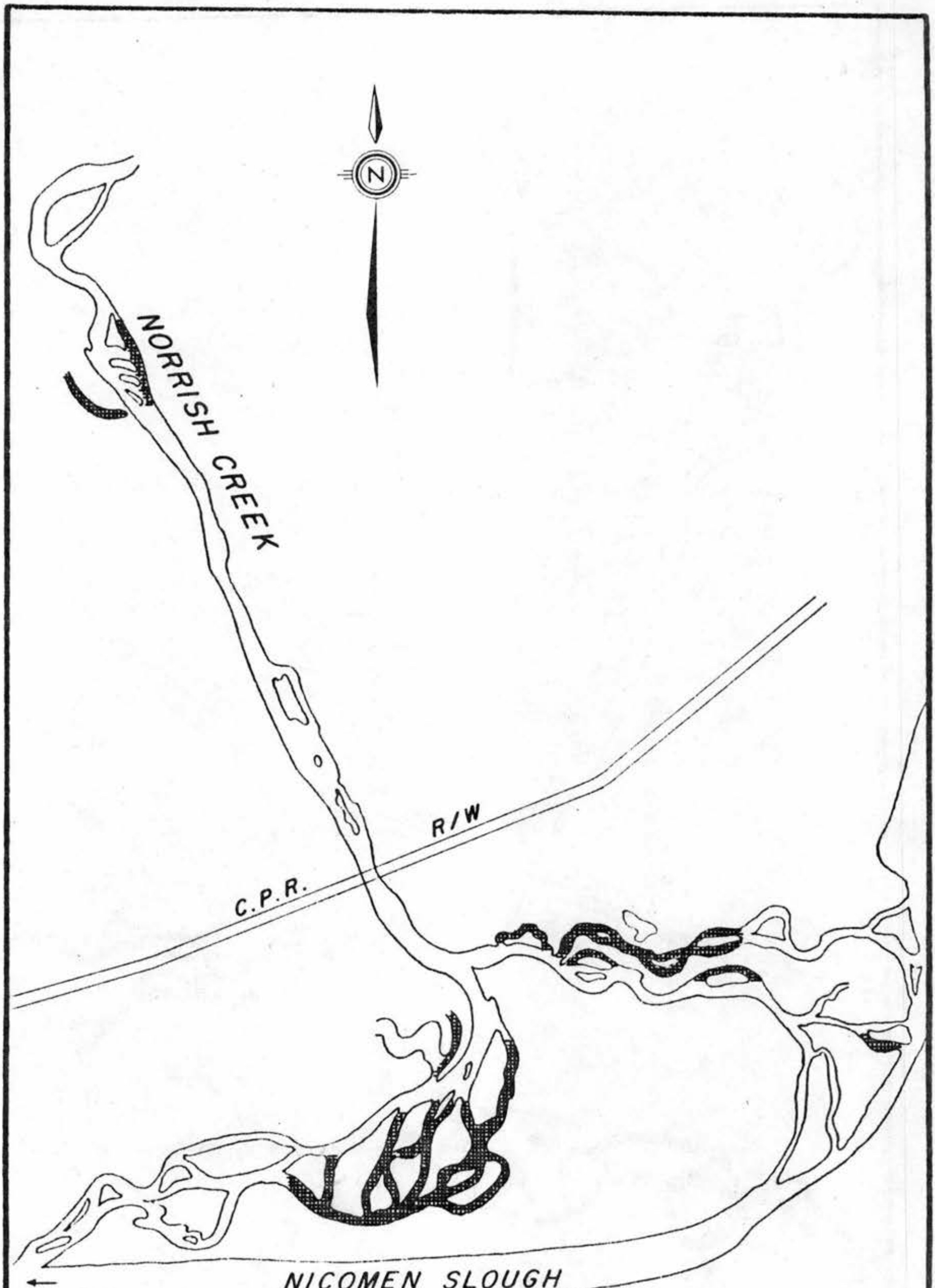


FIGURE 4: COHO SPAWNING AREAS – NORRISH CREEK 1976-77.

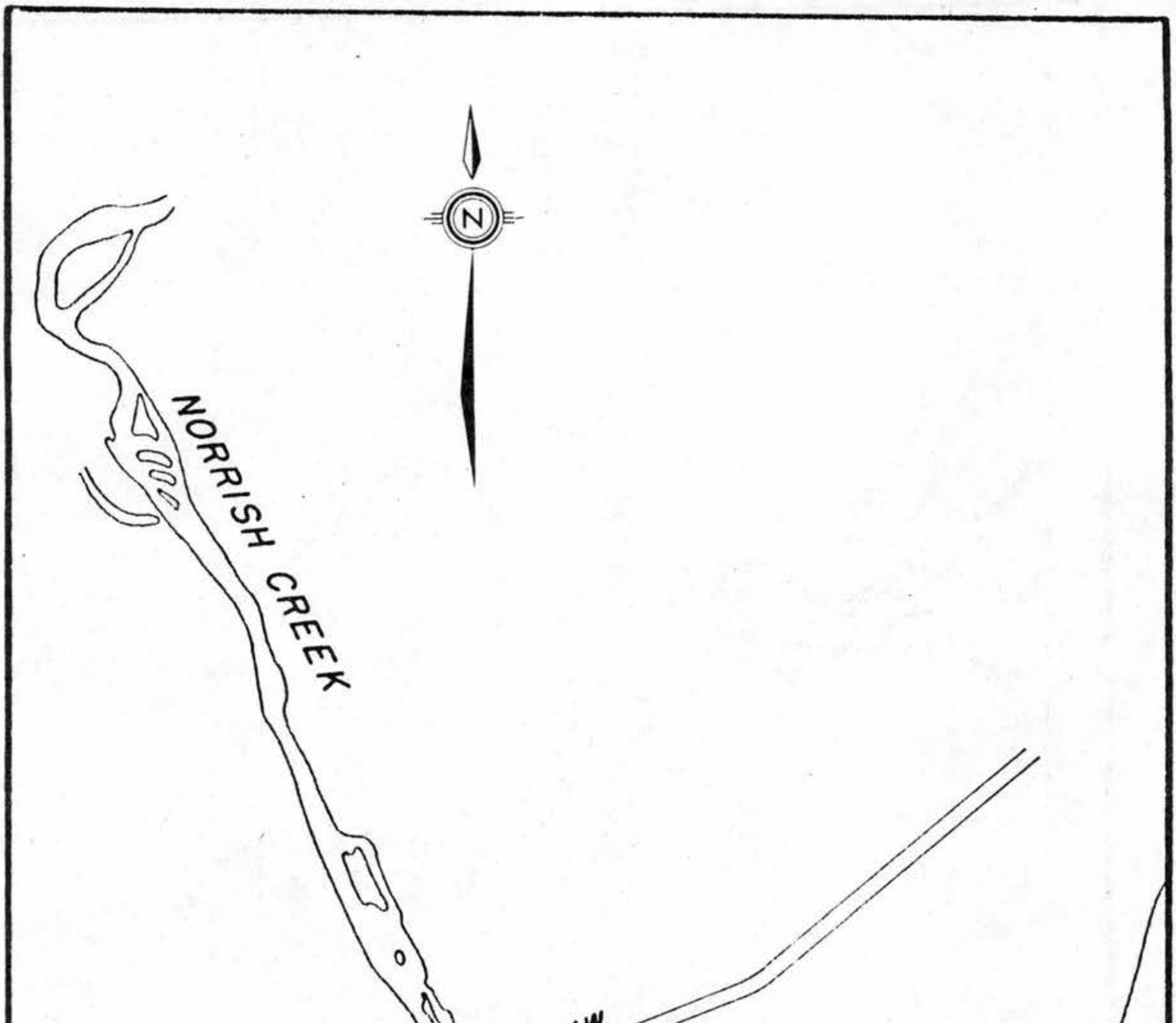


FIGURE 5: CHUM SPAWNING AREAS - NORRISH CREEK 1976-77.

Timing of the coho and chum runs in 1976 and 1977 were:

1976

Spawning Time	Coho	Chum Early	Chum Late
arrival on grounds	mid-Nov.	late Oct.	mid-Dec.
first spawning	mid-Nov.	late Oct.	mid-Dec.
peak spawning	Dec.	mid-Nov.	mid-Dec.
end of spawning	early Jan.	early Dec.	late Dec.

1977

Spawning Time	Coho	Chum Early	Chum Late
arrival on grounds	mid-Nov.	mid-Oct.	mid-Dec.
first spawning	late Nov.	early Nov.	mid-Dec.
peak spawning	late Dec.	late Nov.	late Dec.
end of spawning	early Feb.	mid-Dec.	early Jan.

A summary of relevant habitat requirements of spawning salmon is presented in Table 7.

TABLE 7: WATER DEPTH, VELOCITY AND PREFERRED GRAVEL SIZE OF SPAWNING COHO AND CHUM SALMON

Reference	COHO Depth (ft.)	COHO Velocity (f.p.s.)	COHO Gravel Size (in.)	CHUM Depth (ft.)	CHUM Velocity (f.p.s.)	CHUM Gravel Size (in.)
Thompson, 1972	0.6	1.0 -3.0		0.6	1.5 -3.2	
Briggs, 1953	0.9 -2.3	0.3 -0.6				
Sams and Pearson, 1963	0.5 -2.7	0.3 -1.8				
Chambers, et al. 1955	1.00-1.50	0.25-2.00	0.5 -4.0			
	1.00-1.25	1.20-1.80				
Burner, 1951	0.25-1.67		0.5 -6.0	0.25-1.5		0.5 -4.0
				0.5 -1.8	0.7 -3.3	
Lucas, 1960			0.75-4.0			
Bams and Simpson, 1977			0.75-1.5			0.75-1.5
Smith, 1973	0.73	0.63-2.27		0.98+	1.48-3.29	
	0.49	0.69-2.30		0.59*	1.51-3.31	

* minimum depth
\+ mean depth

Surveys of spawning coho and chum salmon in Norrish Creek revealed the following:

a. Coho preferred shallow (15 - 30 cm deep), low velocity (1.0 - 2.0 fps) side channels with a ground water or other stable flow source. Gravel size ranged between 1.5 to 10 cm.

b. Chum salmon spawned in deeper (22 - 60 cm), faster (1.0 - 3.0 fps) water than coho and occupied sections of the main stream which were subject to severe fluctuations in discharge. These fish spawned over substrates ranging in size from 0.6 to 12 cm gravel.

c. Estimated streamflow necessary for submersion of all gravelled streambed is 350 cfs.

3.2.2 Habitat Conditions During Incubation

Coho and chum salmon require approximately two months to hatch and an additional month as alevins prior to emergence from the gravel (Scott and Crossman, 1973). Minimum incubation flows are therefore essential to the normal development of the young fish for at least three months after spawning has been completed (October 1976 until April 1977 for the 1976 spawning run and October 1977 to May 1978 for the run in 1977).

The extreme variations in the hydrograph of Norrish Creek is very evident during the fall and winter of the year. Unfortunately, this is during the critical period of spawning and incubation of salmon. Ideally flows should be similar during spawning and incubation in order to prevent dehydration within the redds. However, streamflow less than those necessary for spawning but which are still sufficient to prevent exposure of redds, may be less desirable since lower stream velocities and shallower water may substantially reduce water percolation and therefore oxygen supply to incubating eggs.

During the present study on several occasions fish were observed spawning at high flows. Plate 21 shows a chum salmon digging a redd on November 17, 1976 at 1,340 cfs. In the following months the flow increased to over 2,000 cfs on several daily occasions; on December 21 a maximum discharge of 2,660 cfs was registered. This high discharge also resulted in a large amount of siltation as shown in Plate 22. On February 9, 1977 this same redd was examined, (see Plate 22) at 180 cfs, and the redd was completely dewatered. Likewise a coho redd, (see Plates 23 and 24) was dewatered between spawning on December 26, 1976 (270 cfs) and February 9, 1977 (180 cfs). A large amount of debris had also been transported. This information suggests that the variations in flow characteristics in Norrish Creek may be responsible for considerable loss of incubating eggs as a result of scouring and siltation or exposure to freezing and dessication.

3.2.3 Timing of Emergence and Rearing Requirements of Juvenile Salmon

No chum fry were seen in Norrish Creek at any time during the study. This was probably due to their immediate migration out of the river following nocturnal emergence.

Maps showing distribution of rearing coho juveniles at streamflows varying from 50 to 2,460 cfs are given in Figures 6 to 12. A general distribution pattern for young coho in Norrish Creek is also presented (Figure 13).

Visual surveys revealed the following points about populations of coho rearing in the creek:

a. Fry first begin to emerge from the gravel in mid-February.

b. Rearing fish occupy sheltered areas under cutbanks, fallen trees, streamside vegetation and pools.

c. During periods of high discharge, side channels, backeddies and sheltered pools only are utilized by rearing fish (Figures 9 - 12).

d. During periods of low discharge (Figures 6 - 8) juvenile coho utilize the whole of the wetted streambed for rearing; shelter is afforded by rubble, deep pools and uprooted vegetation.

e. Numbers of coho juveniles observed rearing in the creek increase through the spring and summer months and decrease with the onset of cooler temperatures and high winter flows (November - February).

The lengths and ages of 34 juvenile coho trapped in reaches 16 and 18b of Norrish Creek are given in Table 8. While the majority (26) of the fish were 1^+ (had spent one full year in fresh water), 4 of those sampled had spent 2 years (age 2^+) rearing in fresh water. At the time when scale sampling was in progress, newly emergent coho fry were also observed. Thus, three age classes of fish occupied the creek at the same time.

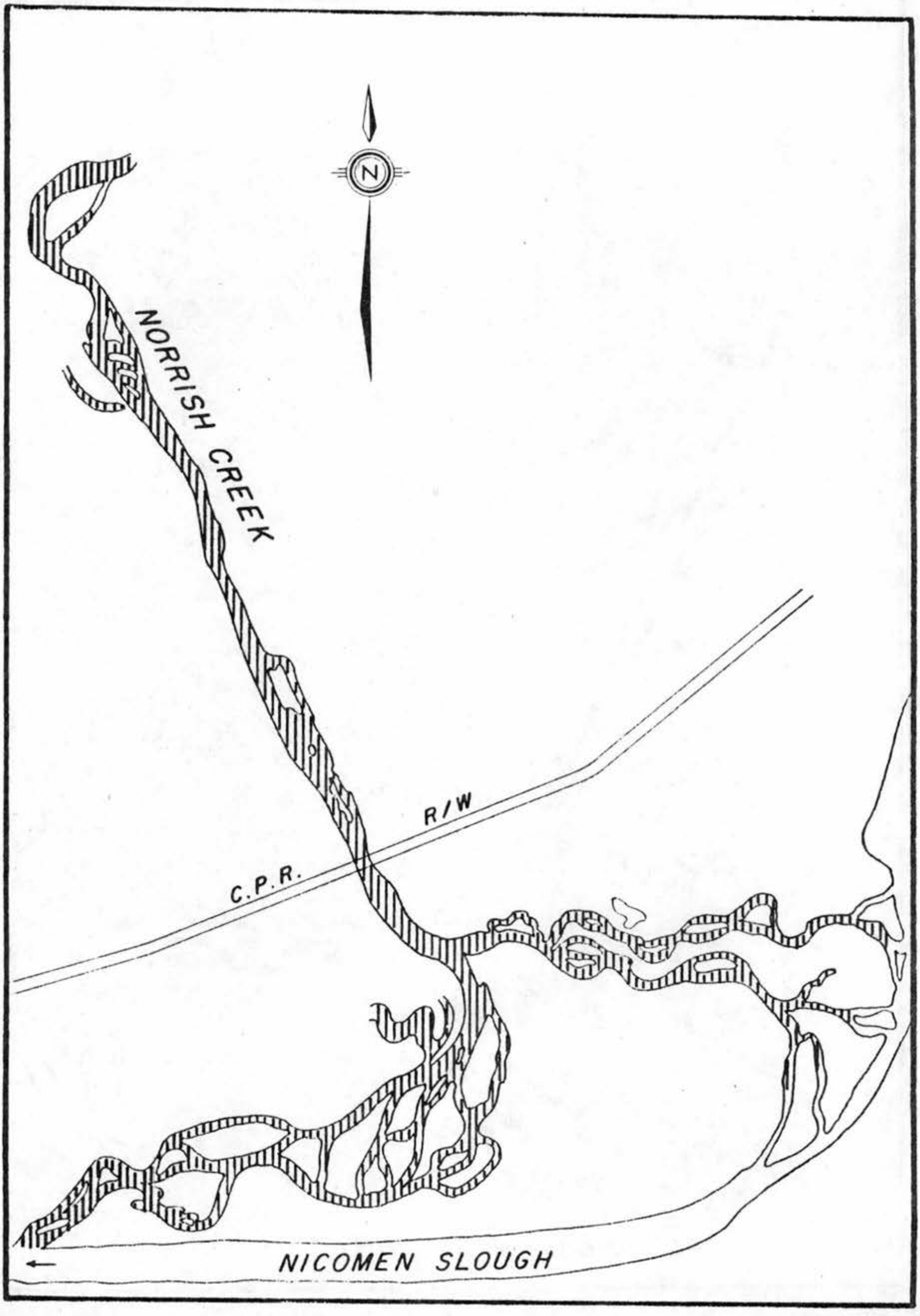


FIGURE 6: COHO REARING DISTRIBUTION — NORRISH CREEK, AUG. 11, 1977; 50 cfs.

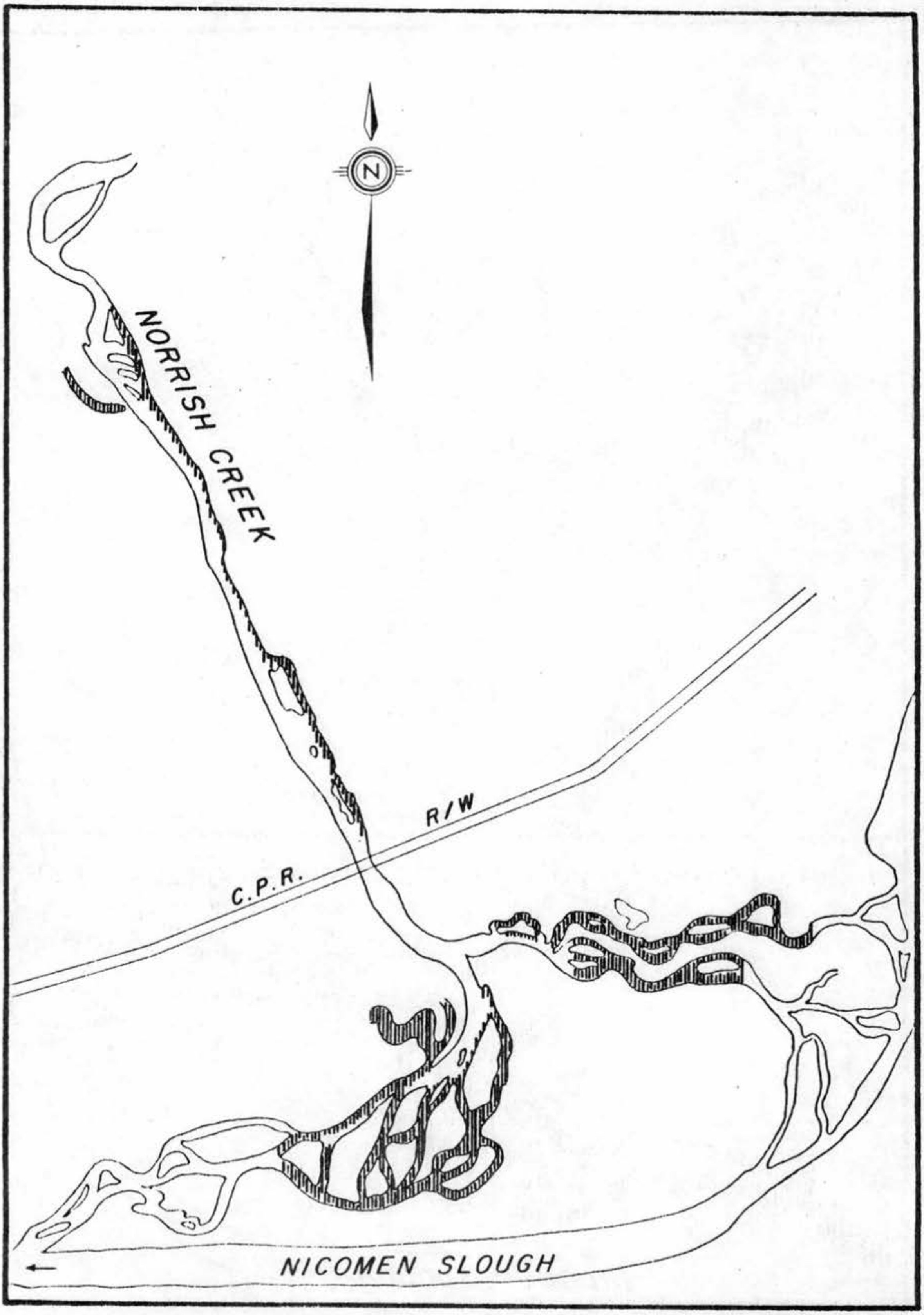


FIGURE 7: COHO REARING DISTRIBUTION – NORRISH CREEK, OCT. 4, 1977; 79 cfs.

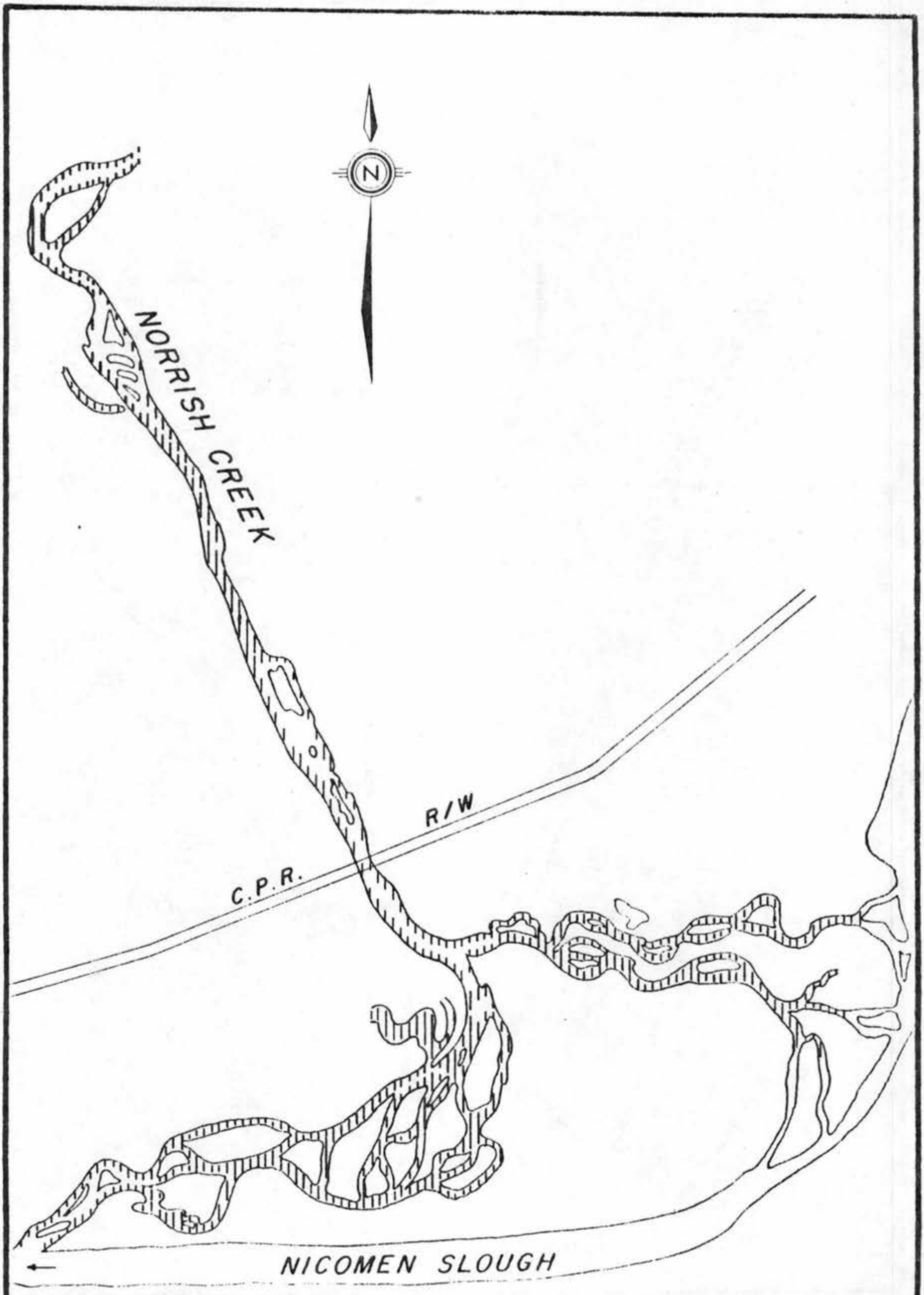


FIGURE 8: COHO REARING DISTRIBUTION – NORRISH CREEK, OCT. 3, 1976; 93 cfs.

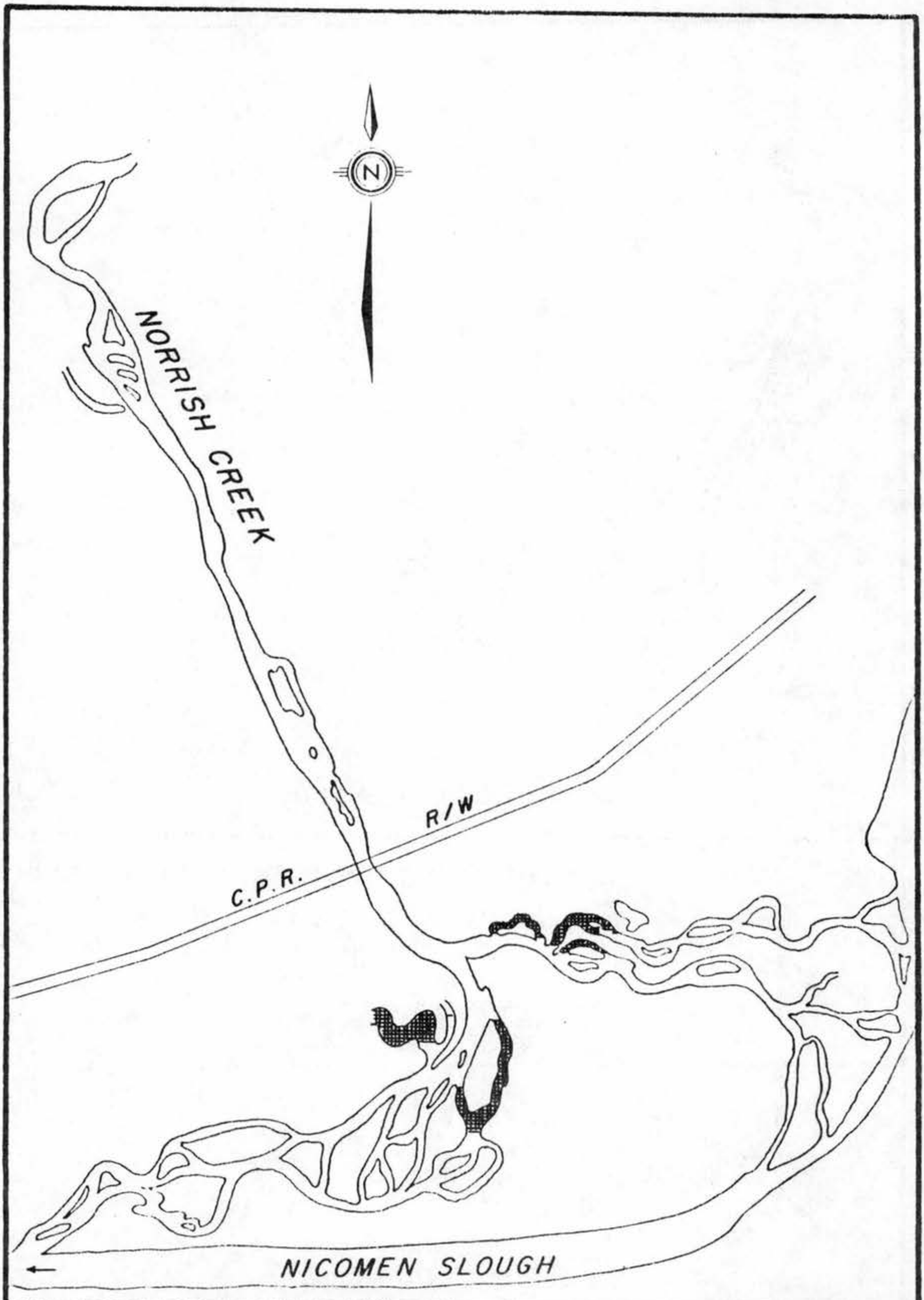


FIGURE 9: COHO REARING DISTRIBUTION – NORRISH CREEK, FEB. 13, 1978; 227 cfs.

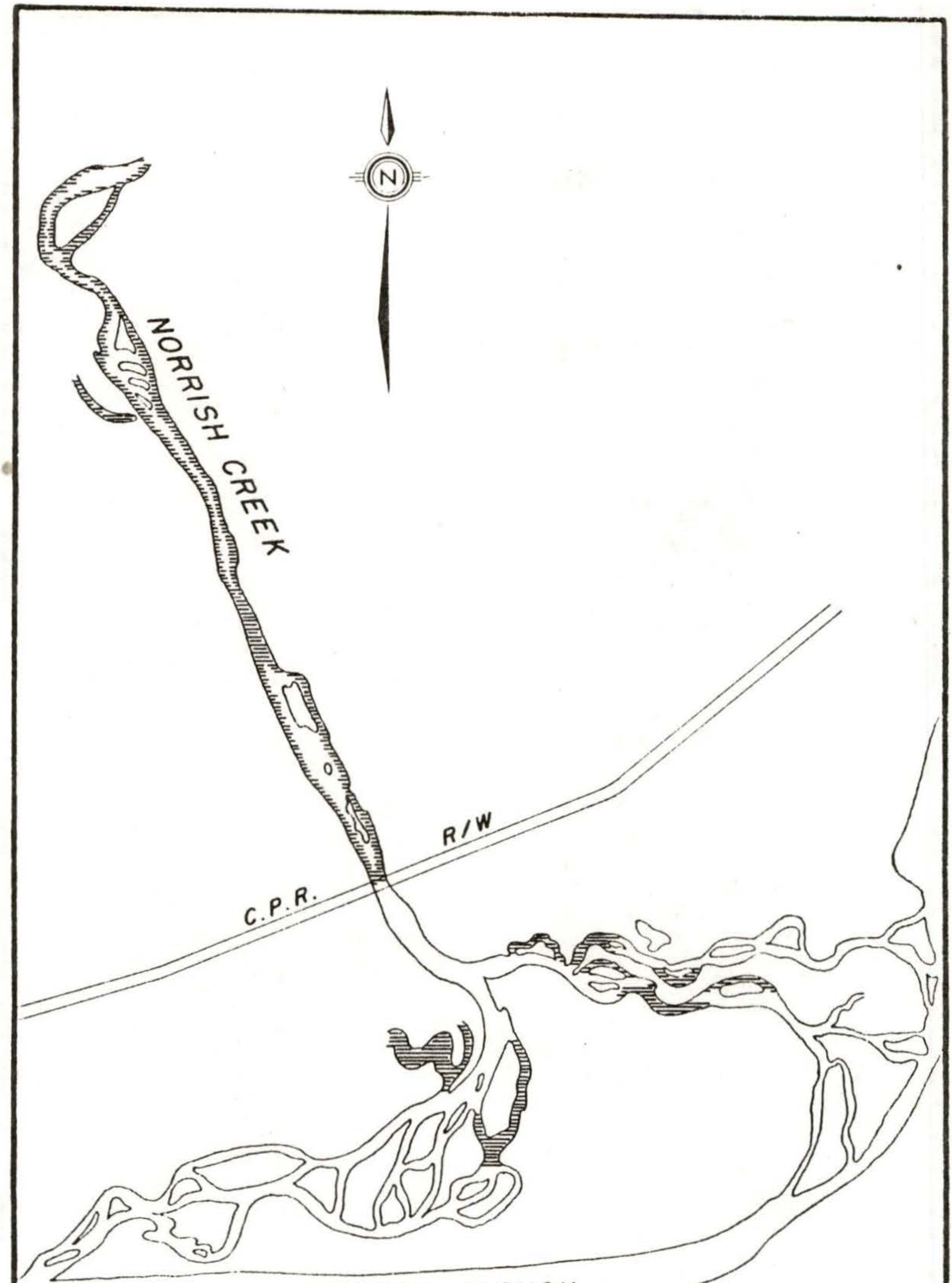


FIGURE 10 : COHO REARING DISTRIBUTION – NORRISH CREEK, APRIL 22, 1977 ; 337 cfs.

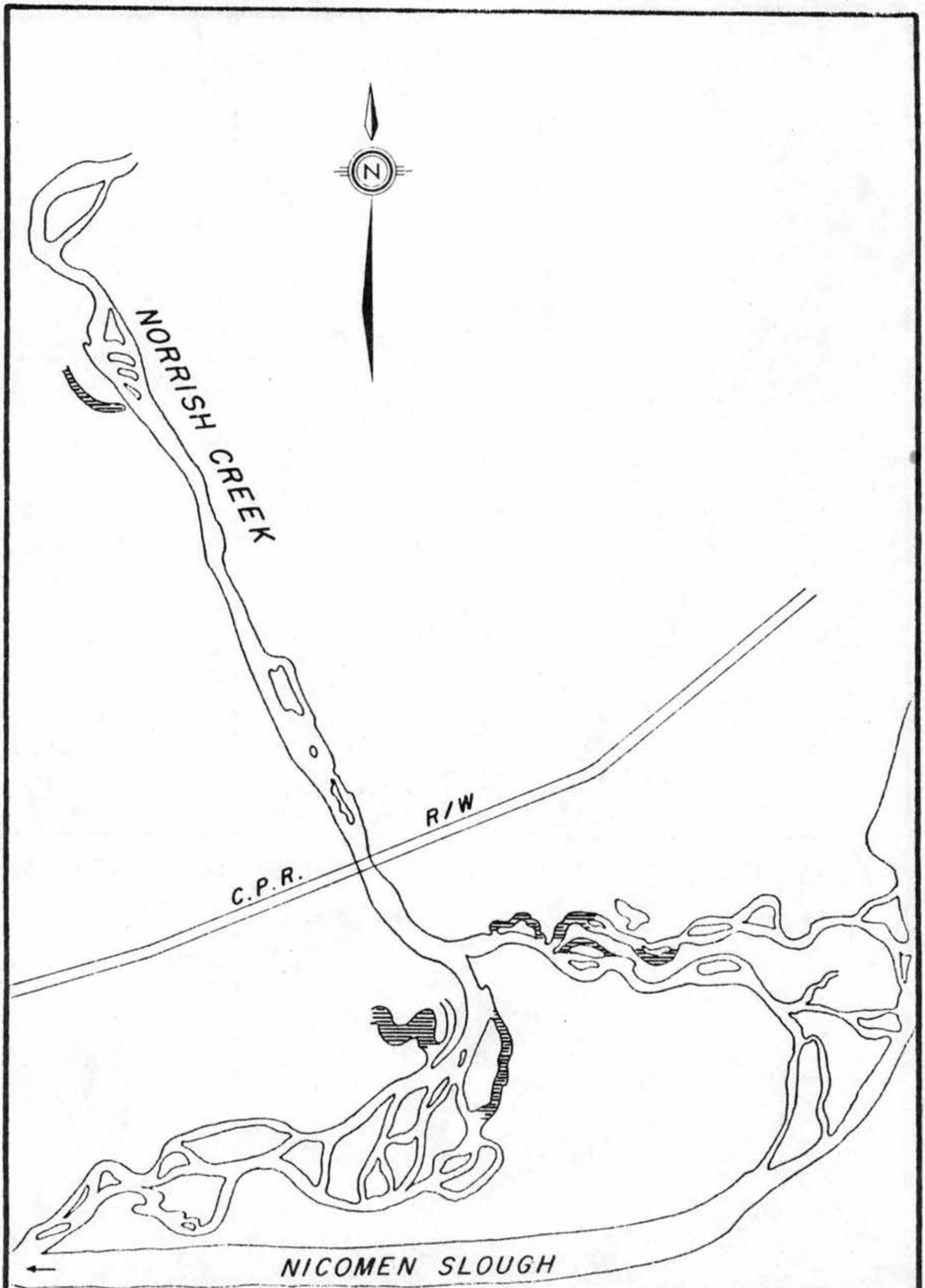


FIGURE 11 : COHO REARING DISTRIBUTION – NORRISH CREEK, FEB. 28, 1978; 350 cfs.

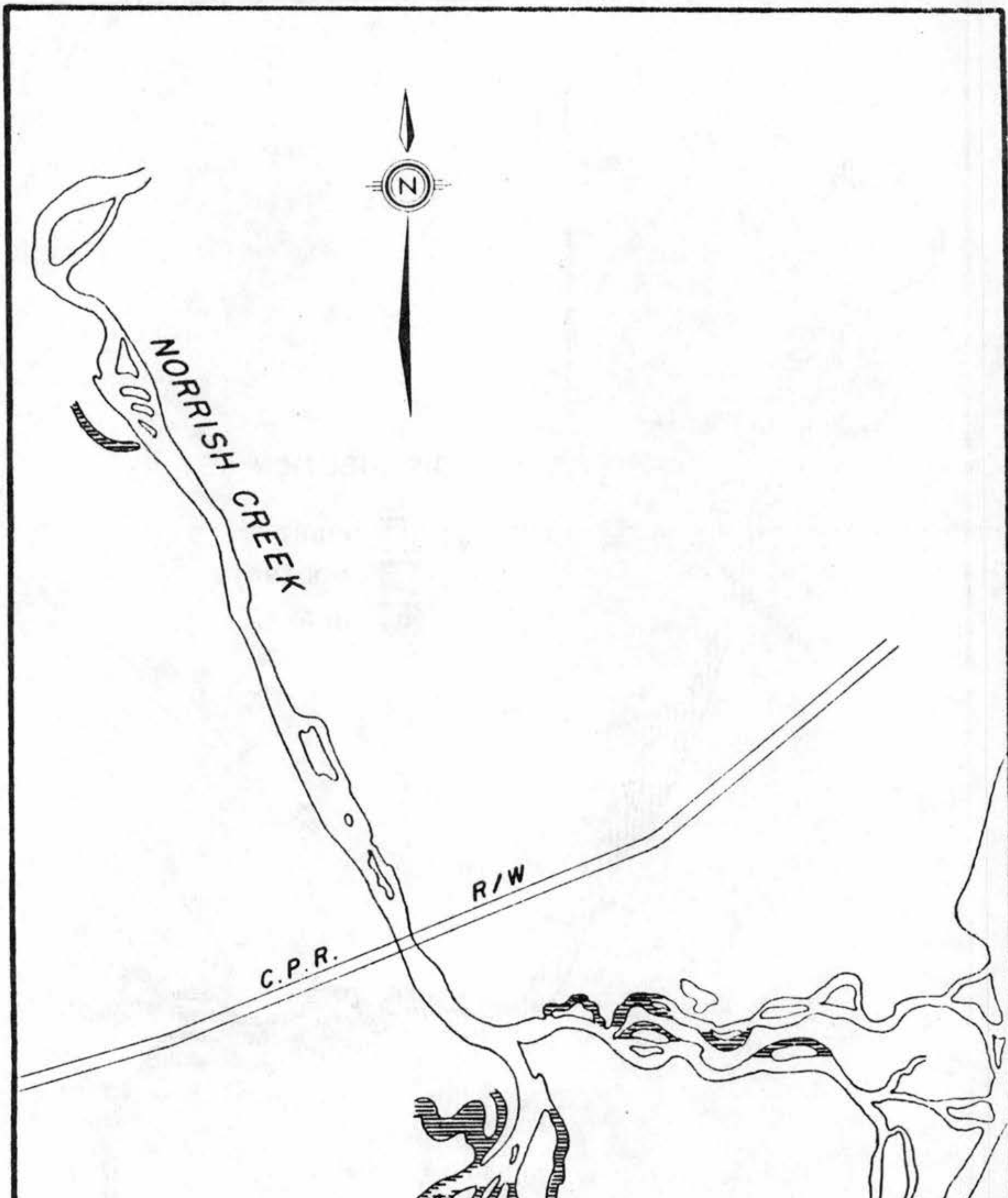


FIGURE 12: COHO REARING DISTRIBUTION – NORRISH CREEK, NOV. 24, 1976; 473 cfs.

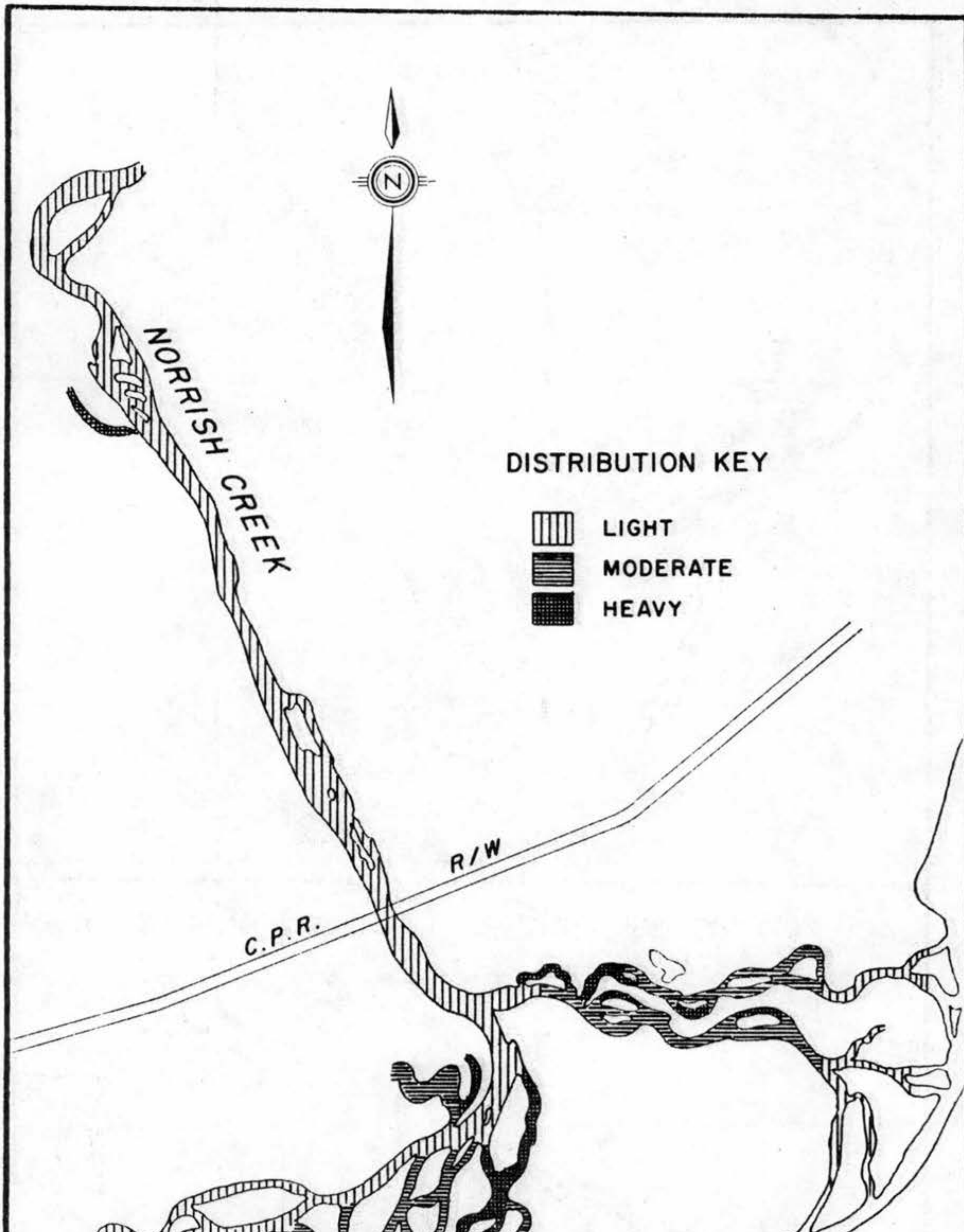


FIGURE 13: GENERAL COHO REARING DISTRIBUTION — NORRISH CREEK, OCT. 1976 – FEB. 1978.

TABLE 8: AGES OF JUVENILE COHO SALMON TRAPPED IN NORRISH CREEK, FEBRUARY 28, 1978

Reach	Length(cm)	Age	Comments	Reach	Length(cm)	Age	Comments
16	6.1	1+	Slow Growth	18b	7.5	1+	Normal
	7.5	"	" "		8.2	"	"
	6.6	"	" "		7.3	"	"
	8.5	"	Normal		6.9	"	"
	7.1	"	"		5.6	"	Slow Growth
	6.4	"	Slow Growth		7.0	"	" "
	8.9	"	Normal		7.5	2+	" "
	7.8	"	"		7.7	1+	Fast Growth
	8.2	"	"		6.4	--	
	6.1	"	"		6.9	--	
	9.4	2+	"		8.9	2+	Normal
	10.4	1+	Fast Growth		8.1	2+	"
	7.0	"	Slow Growth		5.9	1+	"
	6.3	"	" "		6.4	--	
					5.7	1+	Slow Growth
					5.3	"	" "
					5.3	"	" "
					8.1	"	Fast Growth
					6.7	--	
					7.5	1+	Slow Growth

Scale reading also revealed some information about the relative growth of juvenile coho in the creek. Many of the larger fry, originally thought to be age 2+ were fast-growing 1+ fish. Also, some of the 2+ coho showed indications of very slow growth.

4. DISCUSSION

4.1 Recommended Spawning Flows

Numbers of coho spawners utilizing Norrish Creek appear to be marginally declining compared with the ten year spawning average reported in Table 1. This may be a reflection of fishing pressure, a more accurate estimation of the numbers of salmon in the creek during this study than has been made previously, or it may be a result of extremely low streamflows preventing adult coho from entering the small side channels in which they prefer to spawn. The latter explanation probably best describes the situation in the western spawning channel located approximately 825 meters north of the CPR railway bridge (Figure 2). The main channel in this area has eroded to such an extent that flows in excess of 400 cfs are required in the creek before the channel becomes accessible to spawning coho. Streamflow records for Norrish Creek during the years when this study was conducted (Table 5) indicate that there were only 6 days in November, and 16 days in December in 1976, and 20 days in November and 16 days in December and January of 1977 when flows exceeded 400 cfs. Thus, insufficient streamflow conditions for this reach (14) were prevalent during more than half the time when adult fish were in the creek.

The number of chum spawners in Norrish Creek have remained fairly stable during the last 12 years (Table 1). Since these salmon utilize the creek below the railway bridge they appear to spawn over a wider range of water velocities and depths and have different spawning gravel preferences than coho. It is therefore possible that the variable flows common in Norrish Creek affect spawning success of chum salmon to a much lesser degree than coho. Also, the presence of two distinct runs, one early and one late, probably provides a measure of insurance for the Norrish chum run since unfavourable flow conditions resulting in poor spawning for one run may be offset by better conditions and a successful spawn by the other.

Spawning habitat preferences of coho and chum salmon observed in Norrish Creek appeared similar to those found by other investigators (Table 7). Both species of salmon apparently select redd sites within these flow and gravel substrate criteria and by the presence of upwelling water in the gravel beds near the spawning site (Burner, 1951; Chambers et al., 1955; Hamilton and Buell, 1976, and Stalnaker and Arnette, 1976). In this manner, areas of the streambed most suitable for incubation of their young are chosen by the spawning fish.

4.2 Optimum Incubation Conditions

While no intragravel streamflows were measured in this investigation, an estimate of flows required for incubation may be made on the basis of those required for spawning (Bishop and Scott, 1973; Stalnaker and Arnette, 1976). Thus, if 2/3 of the spawning flow (350 cfs recommended in Section 3.2.1) is used as an approximation of the flow required for incubation (Thompson, 1972), 231 cfs would be the recommended incubation optimum streamflow in Norrish Creek.

Successful incubation of salmon eggs and alevins is dependent on steady intragravel percolation of cold, clean well-oxygenated water. Gangmark and Bakkala (1958) related velocities of 122 cm/hr. through redds and dissolved oxygen contents of 8 ppm with the highest salmon egg survival. Sams and Pearson (1963) observed chinook salmon fry survival of 30 percent in a spawning channel with a mean permeability of 60,200 cm/hr. but only 11 percent in the same channel the following year when permeability was 9,400 cm/hr. More successful spawning was found at oxygen concentrations of 5.7 - 9.1 ppm than at 0.1 - 6.8 ppm by Chambers et al.(1955).

4.3 Emergence and Rearing Requirements of Juvenile Salmon

Chum salmon emergence and downstream migration timing was not determined in this study. A detailed trapping program would be necessary if information regarding the specific timing of this species was required.

Rearing distribution of coho salmon indicates that this species utilizes the lower reaches of Norrish Creek extensively throughout the year and especially during the spring and summer months. High streamflows cause the young fish to seek shelter in quiet side channels and pools along the periphery of the stream. Low flows dry up these sheltered areas and force the salmon into pools and backeddies in the main channel. At very low streamflows (50 cfs, Figure 6) rearing fish are often stranded in pools and are subject to high predation and the harmful effects of warm, poorly-oxygenated water. Hamilton and Buell (1976) found similar relationships between flows and the ability of the Campbell River to support rearing coho salmon.

Numbers of salmon rearing in the creek probably increase steadily throughout the spring and summer due to recruitment of 0+ fish from Norrish and possibly the Fraser River or other nearby coho producing systems. Evidence for recruitment from other streams can be found in the scale analysis report presented in Table 8. Those fish with a lot of steady growth during their first year are probably from a more stable and productive system, whereas 1+ and 2+ fish displaying poor, intermittent growth are likely native to Norrish Creek (Yole, per. comm.).

The decline in the number of rearing salmon in the creek during the late fall and winter months may also be dependent on streamflows. Severe flooding often occurs as a result of heavy winter rains in the Norrish Creek watershed (Tables 4, 5 and 6) and the deep, swiftly moving water probably displaces large numbers of rearing fish, forcing them along with the current until they reach Nicomen Slough or the Fraser River. In addition, lower temperatures, reduced streambank cover and the variable nature of winter flows likely result in lower invertebrate production and hence, less food for the rearing salmon.

The above discussion indicates that the numbers, distribution and growth of juvenile coho salmon in Norrish Creek are primarily dependent upon streamflows. Similar conclusions regarding rearing salmonids have been drawn by Giger (1973), Hamilton and Buell (1976), and Stalnaker and Arnette (1976). These and other authors have cited the preferred depth and velocity characteristics for stream-rearing of juvenile salmon and trout presented in Table 9.

Of secondary importance to a stream's ability to support rearing salmon are: the amount of protective cover present (Giger, 1973; Hamilton and Buell, 1976; Stalnaker and Arnette, 1976), adequate streamflow for production of aquatic invertebrates (depth 0.25 - 3.0 ft.; velocity 1.2 - 2.0 fps; Hooper, 1973; Kennedy, 1967; Needham and Usinger, 1956; Pearson et al., 1970; Surber, 1951) and the pool to riffle ratio in the stream (50:50 recommended by Thompson, 1972).

4.4 Optimum Rearing Flows

The Oregon Department of Fish and Wildlife utilize the following criteria to determine rearing flows: 1) adequate depth over riffles (minimum of 0.25 ft. necessary for adequate production of food organisms; Kennedy, 1967); 2) pool to riffle ratio 50:50; 3) 60 percent of riffle area covered by flow; 4) riffle velocities 1.0 - 1.5 fps; 5) pool velocities 0.3 - 0.8 fps; 6) stream cover available (Thompson, 1972).

Using a combination of Oregon's flow criteria and comparing the rearing distribution of coho observed in this study (Figures 6 - 13) to the flow, an approximate optimum rearing flow for Norrish Creek of 100 - 150 cfs was determined.

4.5 Maintenance Rearing Flows

The optimum flow from a fisheries point of view is that flow which will provide the maximum wetted streambed for fish usage. This optimum flow accounts for many physical criteria like velocity, depth, cover, and streambed. Since it is usually impractical to

TABLE 9: DEPTH AND VELOCITY CHARACTERISTICS OF SALMONID MICROHABITATS (FROM GIGER, 1973

Species	Age	Length (mm)	Depth (m)	Velocity (m/sec.)	References
Steelhead	0	32	<0.15	<0.15	Everest & Chapman, 1972
Trout	1	95	0.60-0.75	0.15-0.30	Everest & Chapman, 1972
	0,1	Varied	0.18-0.67	0.06-0.49	Thompson, 1972
	0,1	--	0.43-1.1	0.25-0.82	Hamilton & Buell, 1976
Chinook	0	62	0.15-0.30	<0.15	Everest & Chapman, 1972
Salmon	0	--	0.30-1.22	0.06-0.24	Thompson, 1972
Coho	0	66-89	--	0.09-0.21	Pearson *et al.*, 1970
Salmon	0	--	0.30-1.22	0.06-0.24	Thompson, 1972
	0,1	--	0.11-0.89	0.05-0.4	Hamilton & Buell, 1976
Cutthroat Trout	0,1,2	Varied	0.40-1.22	0.06-0.49	Thompson, 1972

maintain this optimum flow due to the variability of streamflows, a maintained flow must also be presented. In streams with a braided delta optimum and maintenance flows will usually be considerably different. This is the case with Norrish Creek. An estimate of maintenance flows may be derived from the on-site visual assessments of rearing coho juveniles presented in Figures 6 - 12. These figures show than an efficient utilization of available mainstem streambed occurred at flows ranging from 50 to 93 cfs. Where higher streamflows were encountered fish tended to rear only in low velocity side channels and pools. At flows as low as 50 cfs, numerous isolated pools formed in side channel areas as well as the main stem below the bridge crossings, trapping rearing fish and exposing them to predation and to increased temperatures. A flow of 75 cfs (Figure 7) was also acceptable for rearing coho fry and smolts. Thus the maintenance flow should fall between 50 and 75 cfs if the stream remains in its present configuration. A detailed analysis of streambed stability and morphology should be undertaken to refine more precisely the resource maintenance flow requirement. Such a study may also indicate acceptable alternative approaches to the release of these water quantities.

5. SUMMARY

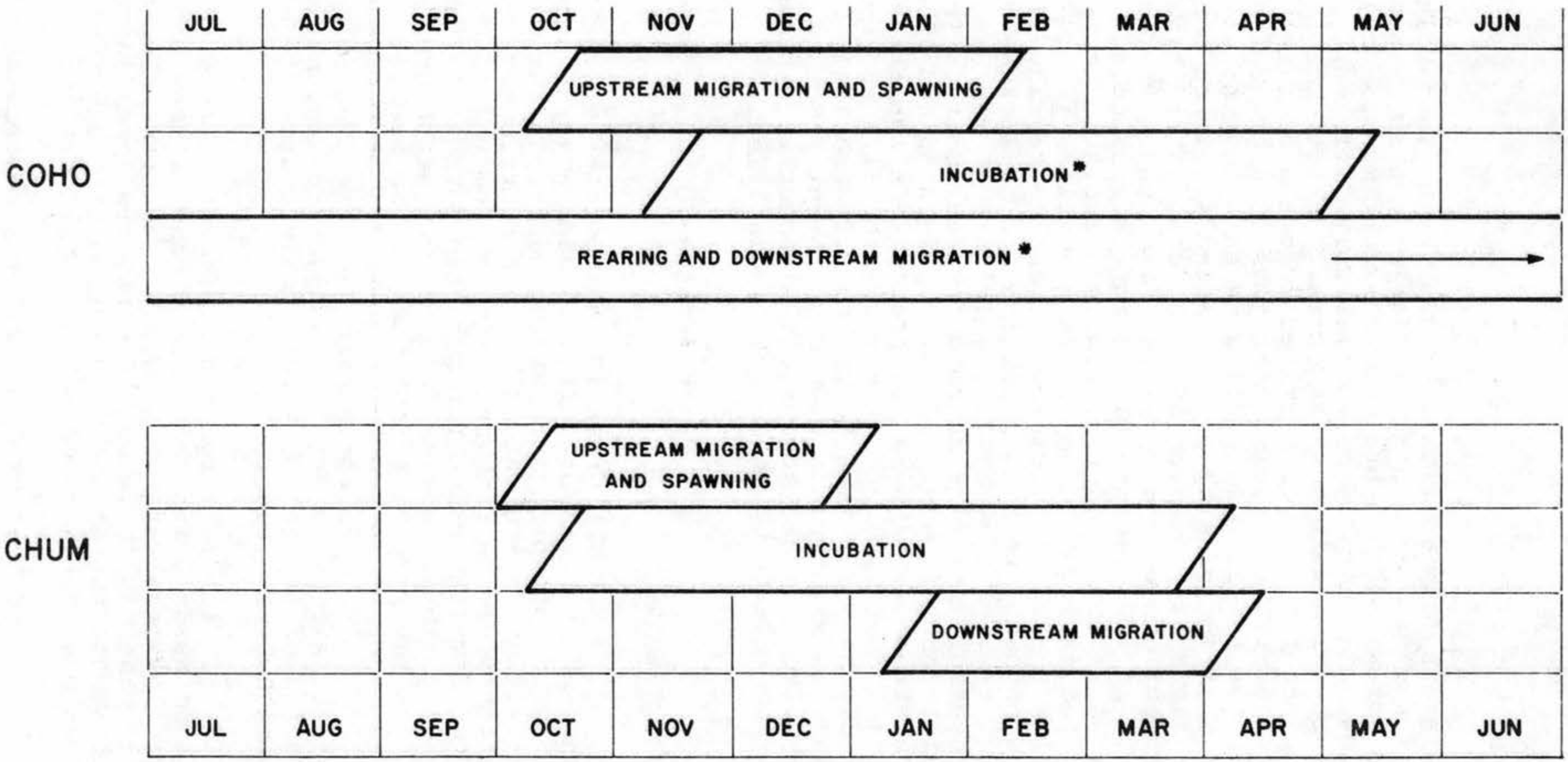
Norrish Creek is an important producer of coho and chum salmon. It possesses a large amount of potential spawning and rearing habitat. Various activities in the watershed have contributed to the extinction of a pink salmon run. Removal of additional water from the creek for domestic purposes without accompanying storage and/or flow control structures will affect the present salmon runs in the system.

This investigation has attempted to determine the streamflows essential to spawning, incubation and rearing of the salmon species which currently utilize Norrish Creek (Figure 14).

If discharge flows of greater than 50 cfs can be assured for the rearing coho (June - October) and flows adequate to maintain a constant flow in the side channels (between 100 - 150 cfs depending upon stream configuration) from November to May, the number of salmon in the creek should remain stable.

Further examination of streambed stability and morphology is recommended to refine the fisheries resource maintenance flow requirements.

FIGURE 14: FRESHWATER LIFE CYCLES OF NORRISH CREEK SALMON.



* EXACT PERIOD OF INCUBATION AND DOWNSTREAM MIGRATION IS NOT KNOWN.

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PHOTOGRAPHIC PLATES

<u>PLATE</u>

1	Norrish Creek, reach 1, 3 October 1976 Note extensive slumping; 90 cfs
2	Norrish Creek, reach 3, 3 October 1976
3	Norrish Creek, reach 4, 3 October 1976, 90 cfs, immediately below Water Survey of Canada gauging station 08MH058
4	Norrish Creek, reach 5, 3 October 1976 Typical streambed in this reach
5	Norrish Creek, reach 6, 3 October 1976
6	Norrish Creek, reach 8, 3 October 1976
7	Norrish Creek, reach 10, 3 October 1976
8	Norrish Creek, reach 14, 3 October 1976 Ground water side channel which flows intermittently into reach 1
9	Norrish Creek, 11 August 1977, 50 cfs; looking downstream through reaches 4 to 1
10	Norrish Creek, 11 August 1977, reach 4 looking upstream
11	Norrish Creek, 11 August 1977, reach 2, riffle-pool area
12	Norrish Creek, 11 August 1977, reach 2, typical dried side channel, 50 cfs in main stem
13	Norrish Creek, 11 August 1977, 50 cfs; bifurcation of reaches 18 and 16 from reach 15
14	Norrish Creek, 11 August 1977, 50 cfs; isolated pools in reach 16 with trapped coho fry
15	Norrish Creek, 11 August 1977, reach 16

PHOTOGRAPHIC PLATES (cont'd.)


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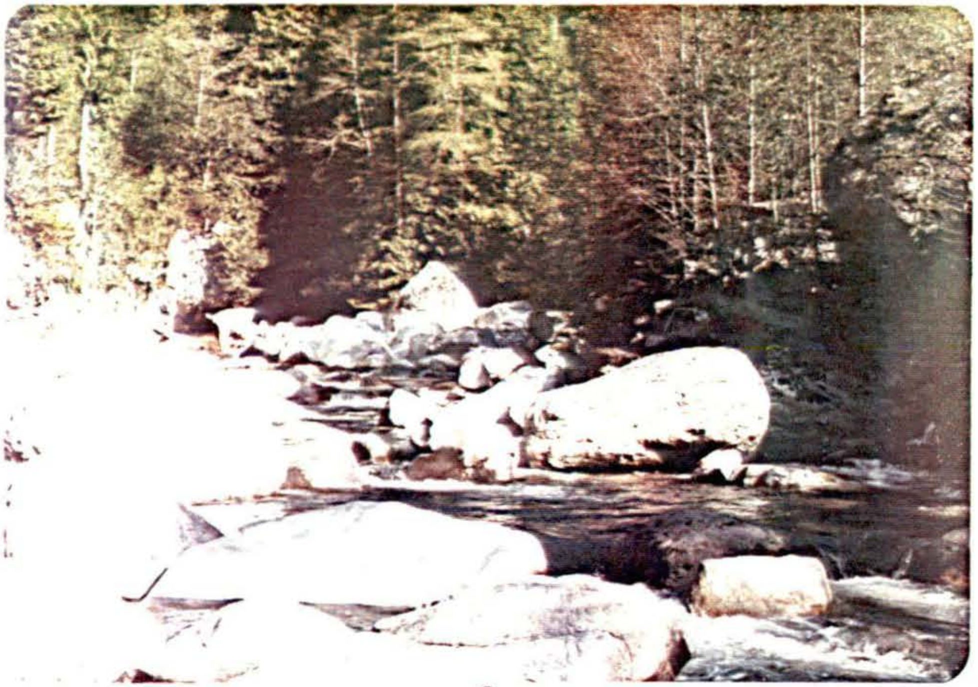
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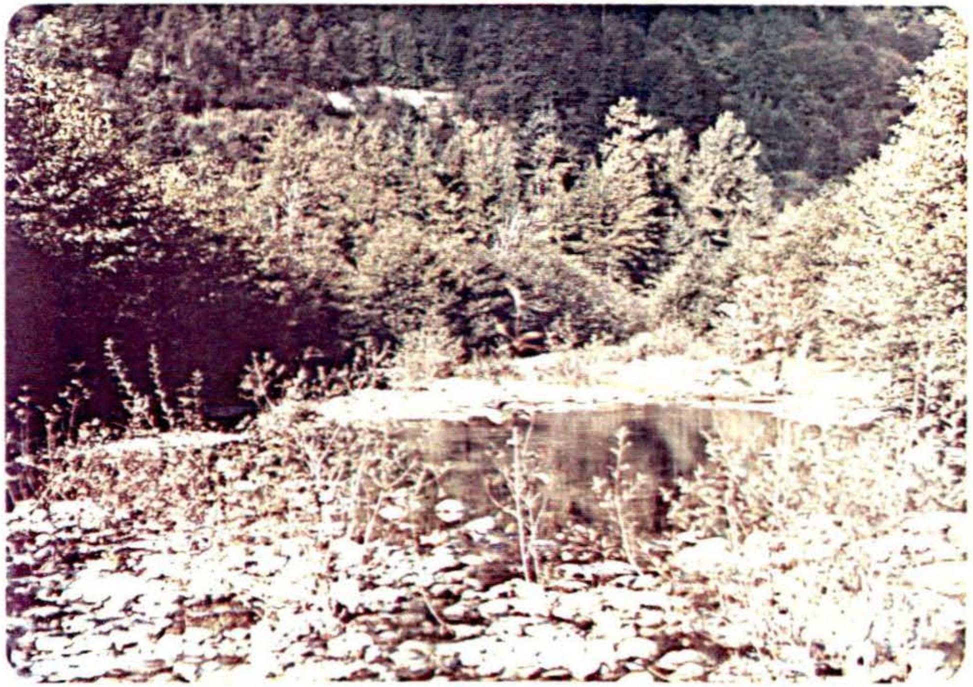
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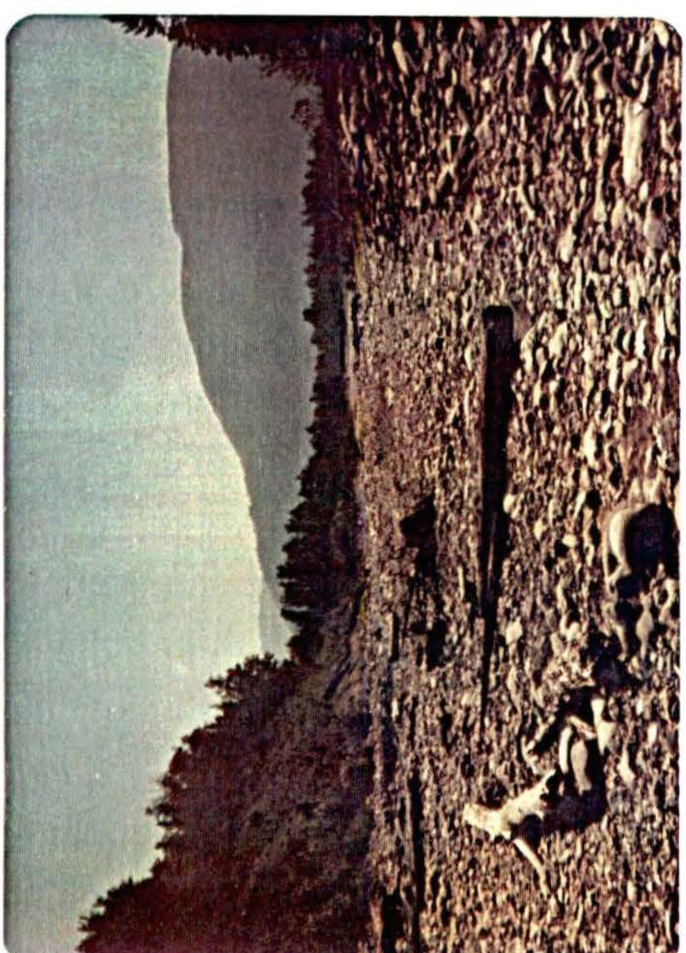

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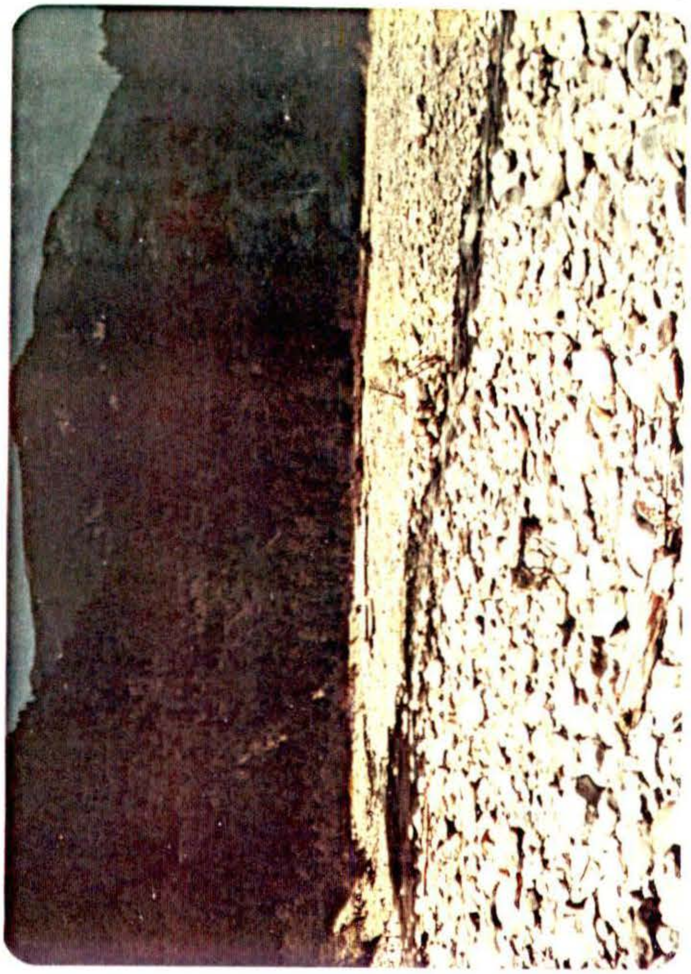

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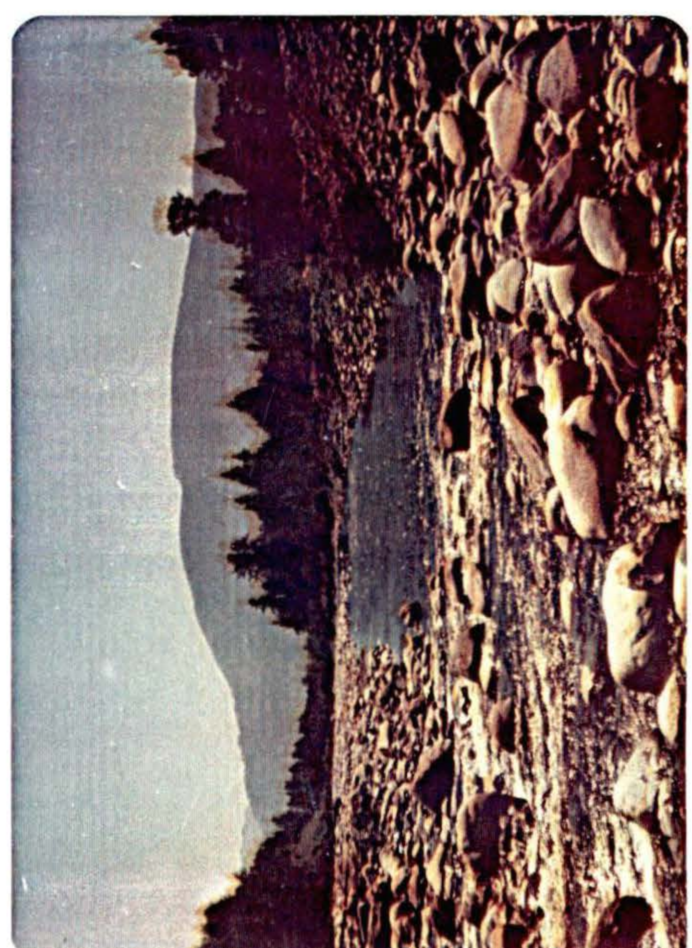

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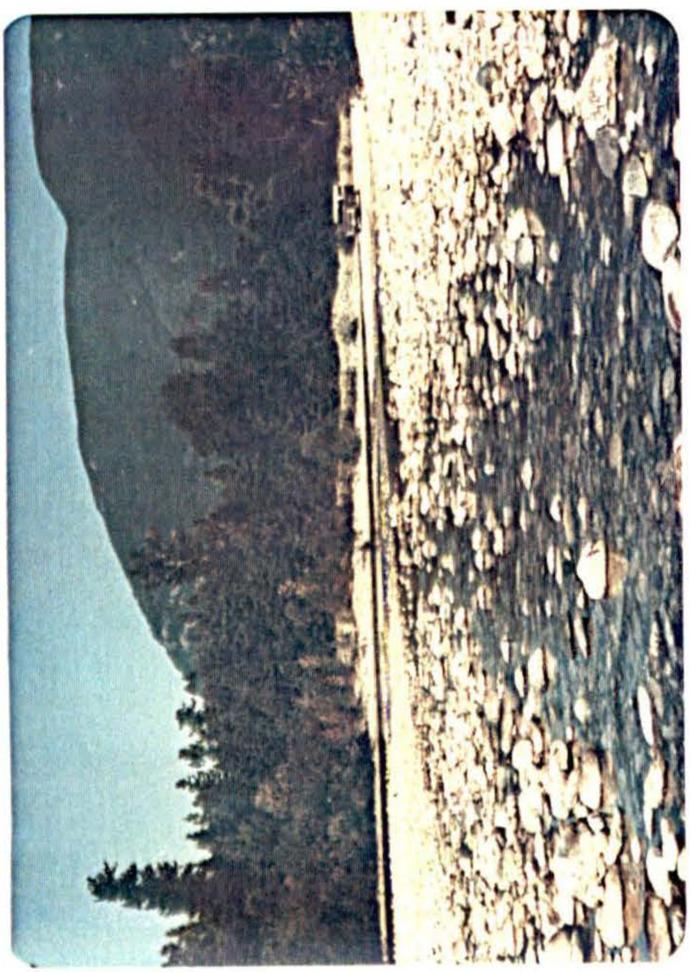

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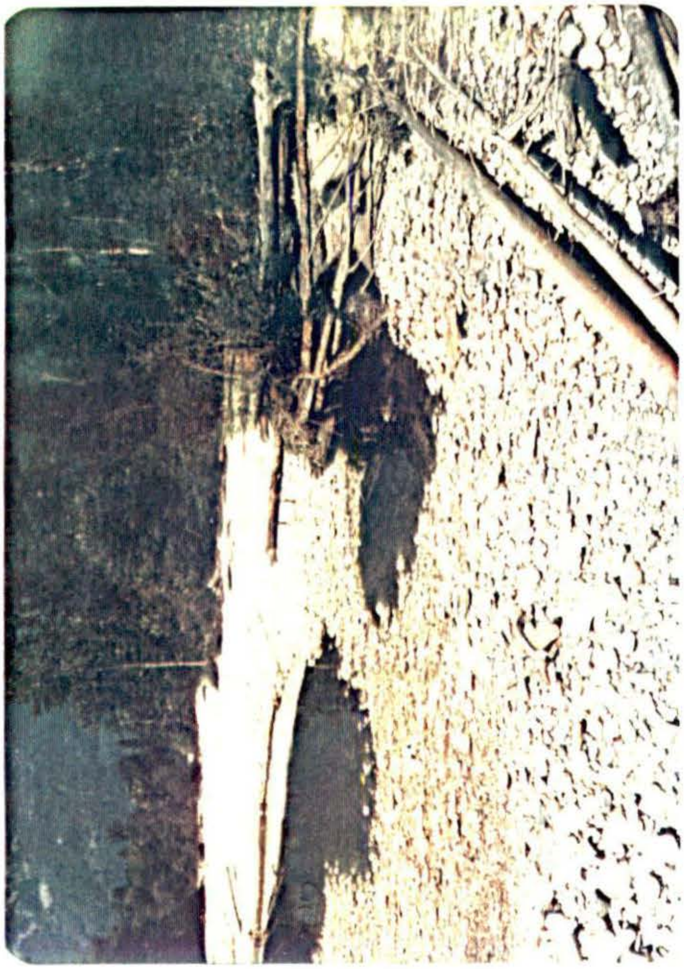

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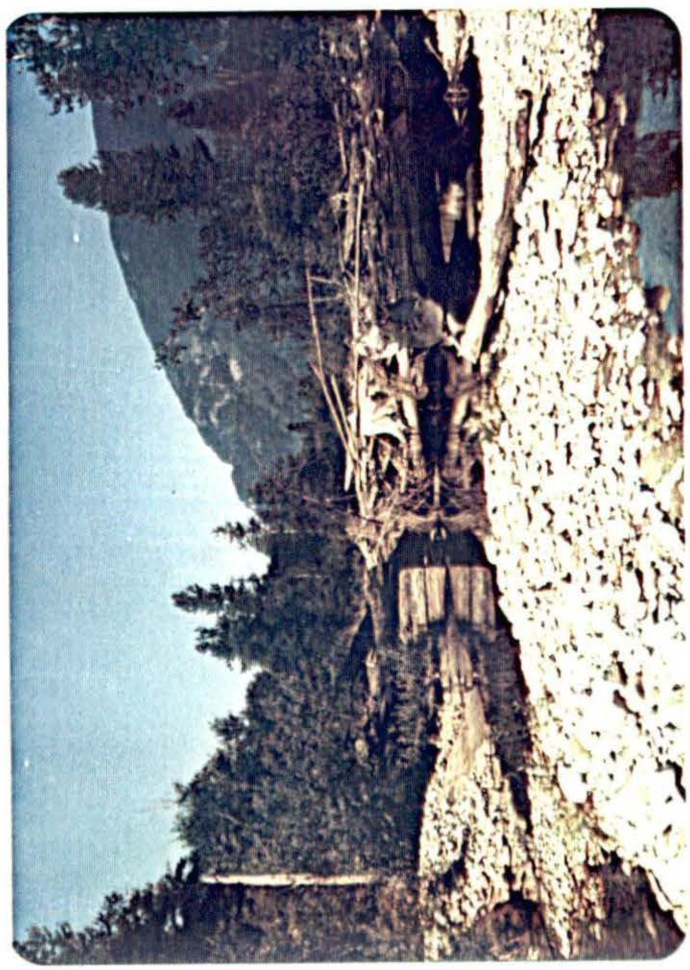

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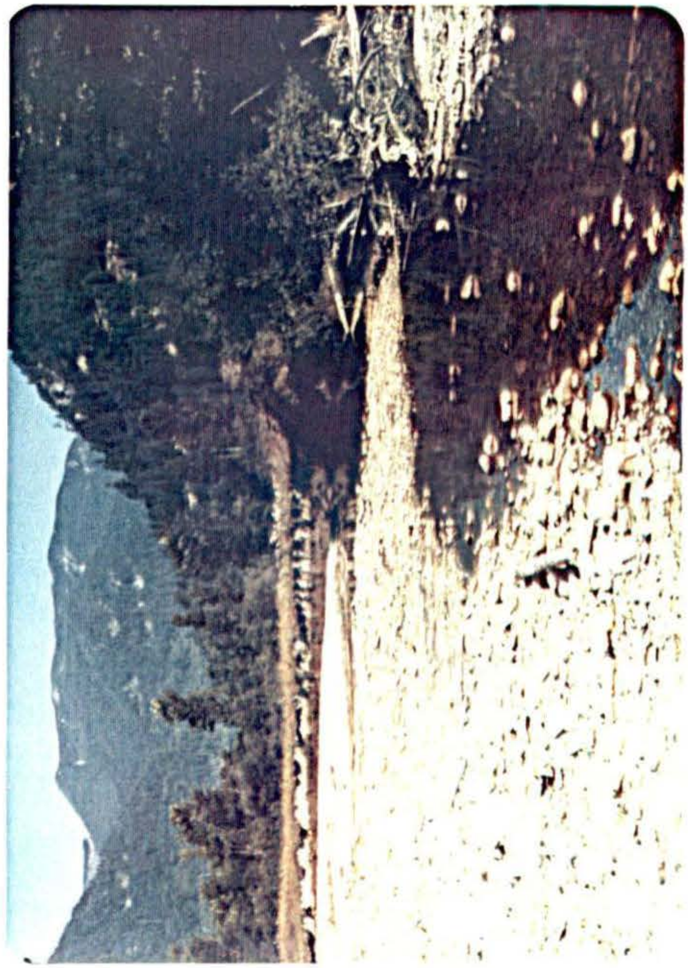

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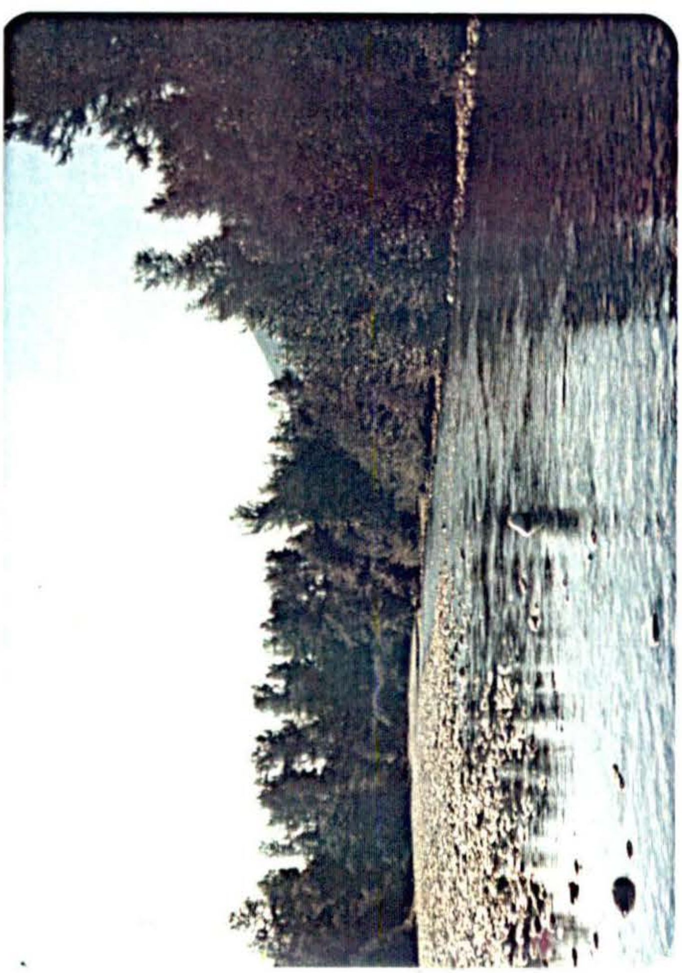

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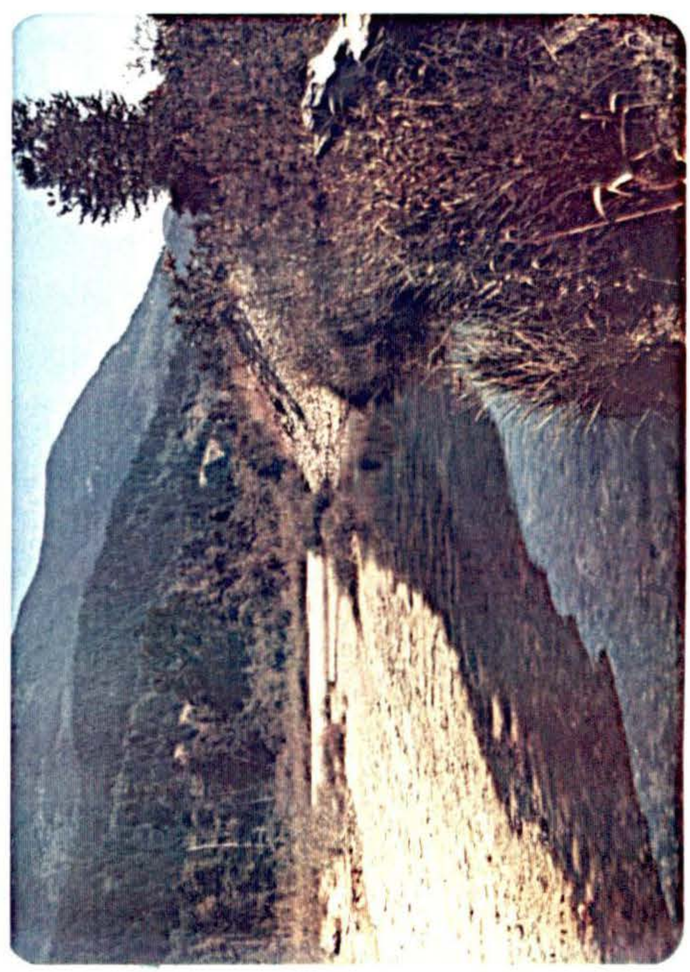

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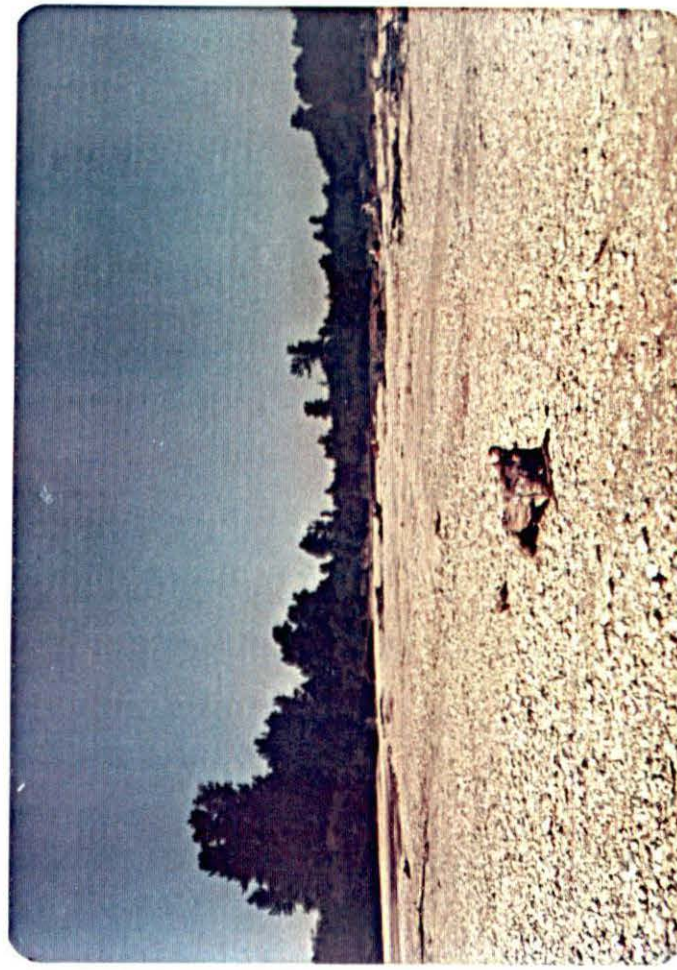

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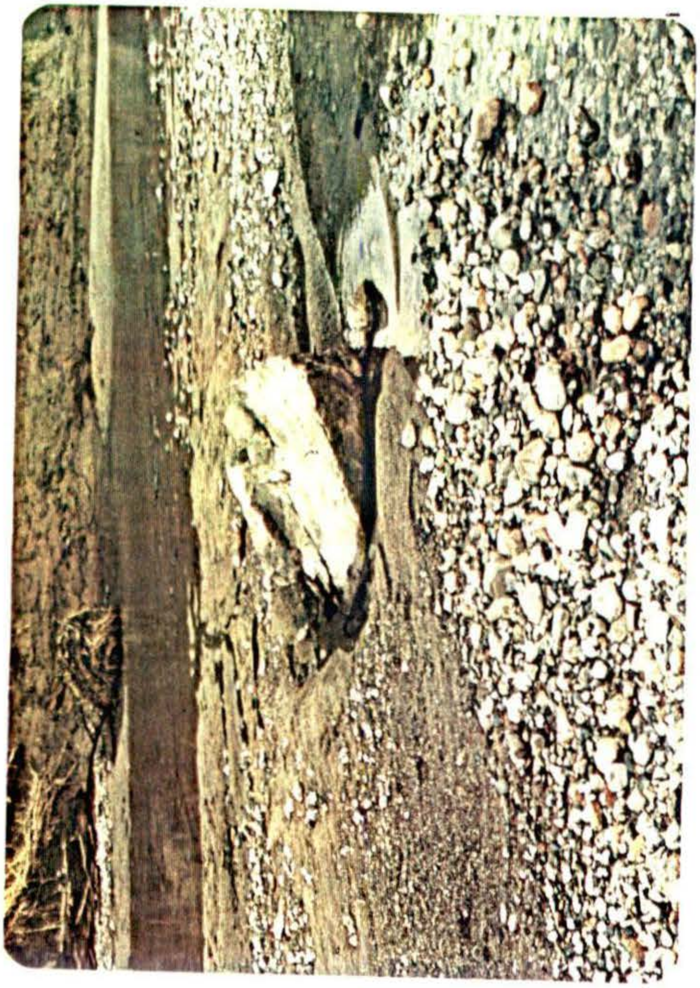

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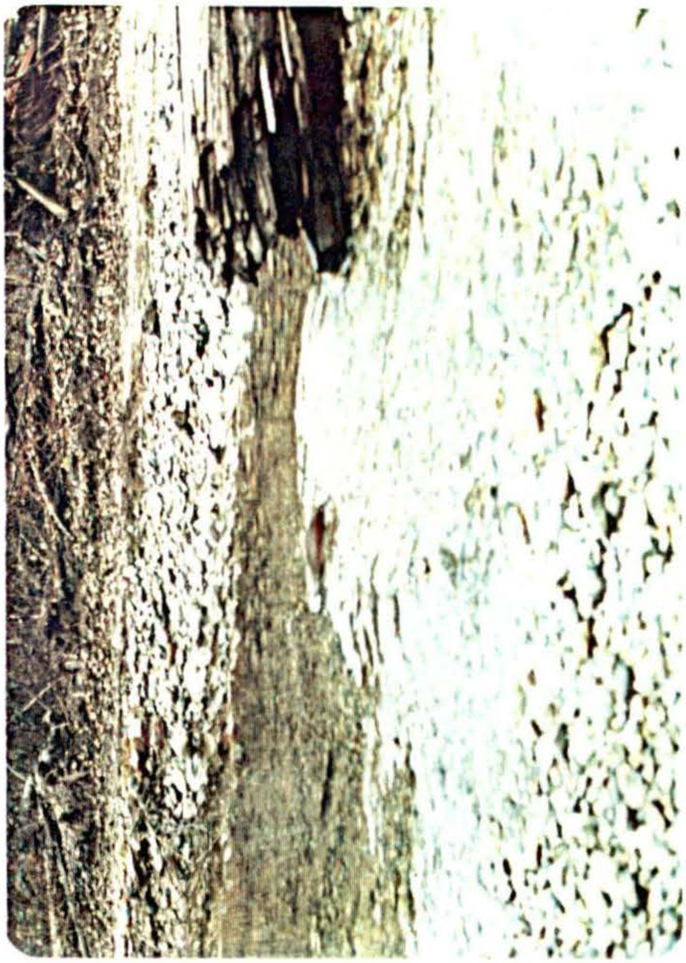

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