

**INTERNATIONAL PACIFIC SALMON
FISHERIES COMMISSION**

PROGRESS REPORT.

No. 10

**THE HISTORY OF THE
EARLY STUART SOCKEYE RUN**

By

A. C. COOPER and K. A. HENRY

COMMISSIONERS

SENATOR THOMAS REID

A. J. WHITMORE

W. R. HOURSTON

GEORGE C. STARLUND

CLARENCE F. PAUTZKE

DeWITT GILBERT

NEW WESTMINSTER, B.C.

CANADA

1962

INTERNATIONAL PACIFIC SALMON
FISHERIES COMMISSION

Appointed under a Convention
Between Canada and the United States for the
Protection, Preservation and Extension of
the Sockeye and Pink Salmon Fisheries in
the Fraser River System

PROGRESS REPORT

No.10

THE HISTORY OF THE
EARLY STUART SOCKEYE RUN

by

A.C. COOPER and K.A. HENRY

COMMISSIONERS

Senator Thomas Reid
A.J. Whitmore
W.R. Hourston

DeWitt Gilbert
George C. Starlund
Clarence F. Pautzke

DIRECTOR OF INVESTIGATIONS

Loyd A. Royal

New Westminster, B.C.
Canada
1962

ABSTRACT

Historical evidence as far back as 1820 indicates that the Early Stuart sockeye run to the Fraser River never has been large and was subject to significant variations in abundance caused primarily by obstructions to its upriver migration in the Fraser Canyon. The construction of fishways at Hell's Gate, which had been an obstruction even prior to the Hell's Gate block in 1913, coupled with certain regulatory protection in the commercial fishery increased the average size of the Early Stuart run about seven times during the period 1949 to 1961. The increased size of the run and the occurrence of high river levels in recent years during the upriver migration of the Early Stuart sockeye have led to the discovery of several points that are still obstructions or present difficult passage. Recommendations are made for the removal of the remaining known obstructions, which are estimated to have already caused a loss of nearly one million dollars in the catch of sockeye, and which could cause further and more serious losses in future years under similar river flow conditions.

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
TIMING OF THE STUART SOCKEYE RUNS	1
ANNUAL ABUNDANCE OF EARLY STUART SOCKEYE	3
DISCOVERY OF THE EARLY STUART OBSTRUCTIONS	10
POINTS OF POSSIBLE OBSTRUCTION	14
EFFECTS OF THESE OBSTRUCTIONS ON INDIVIDUAL RUNS	17
The 1914 Early Stuart Run	17
The 1933 Early Stuart Run	18
The 1954 Early Stuart Run	20
The 1955 Early Stuart Run	23
The 1960 Early Stuart Run	26
CONCLUSIONS	36
RECOMMENDATIONS	44
LITERATURE CITED	48

THE HISTORY OF THE EARLY STUART SOCKEYE RUN

INTRODUCTION

The Early Stuart sockeye run, on occasion, has shown very abrupt drops in run size from one cycle year to the next. Although Early Stuart escapements were apparently adequate in some years to have produced large runs, historically, production was much lower than at present.

Data collected in recent years, particularly since 1955, indicate very strongly that the probable reason for the inconsistency in run size and for the comparatively poor historical production from the Early Stuart run was that it periodically encountered natural obstructions to its upstream migration to the spawning grounds. The purpose of this report is to locate the obstructions, define the periodicity of their occurrence, assess their effect on the reproduction of the Early Stuart run and determine what corrective measures need to be taken.

TIMING OF THE STUART SOCKEYE RUNS

There are two separate sockeye runs to the Stuart Lake system. The Early Stuart run spawns in the tributaries of Takla Lake and Middle River, while the Late Stuart run primarily spawns in Middle River, between Takla Lake and Trembleur Lake, and in the Tachie River, between Trembleur Lake and Stuart Lake (FIGURE 1). The comparative time of migration for these two races at three separate locations, (New Westminster, Hell's Gate and Fort St. James at the outlet of Stuart Lake) are shown graphically in FIGURE 2. These migration curves are a composite of the data from 1953 through 1958 and are based on Indian catches, test fishing and scale analyses (Henry, 1961). They do not represent any single year but show the range in the migration time of these two races that has occurred in the six years. Since a very early run, 1953, and a very late run, 1958, have occurred during this period it is quite possible that the ranges in migration time shown in FIGURE 2 would include the time of migration of most of the historical runs for these two races.

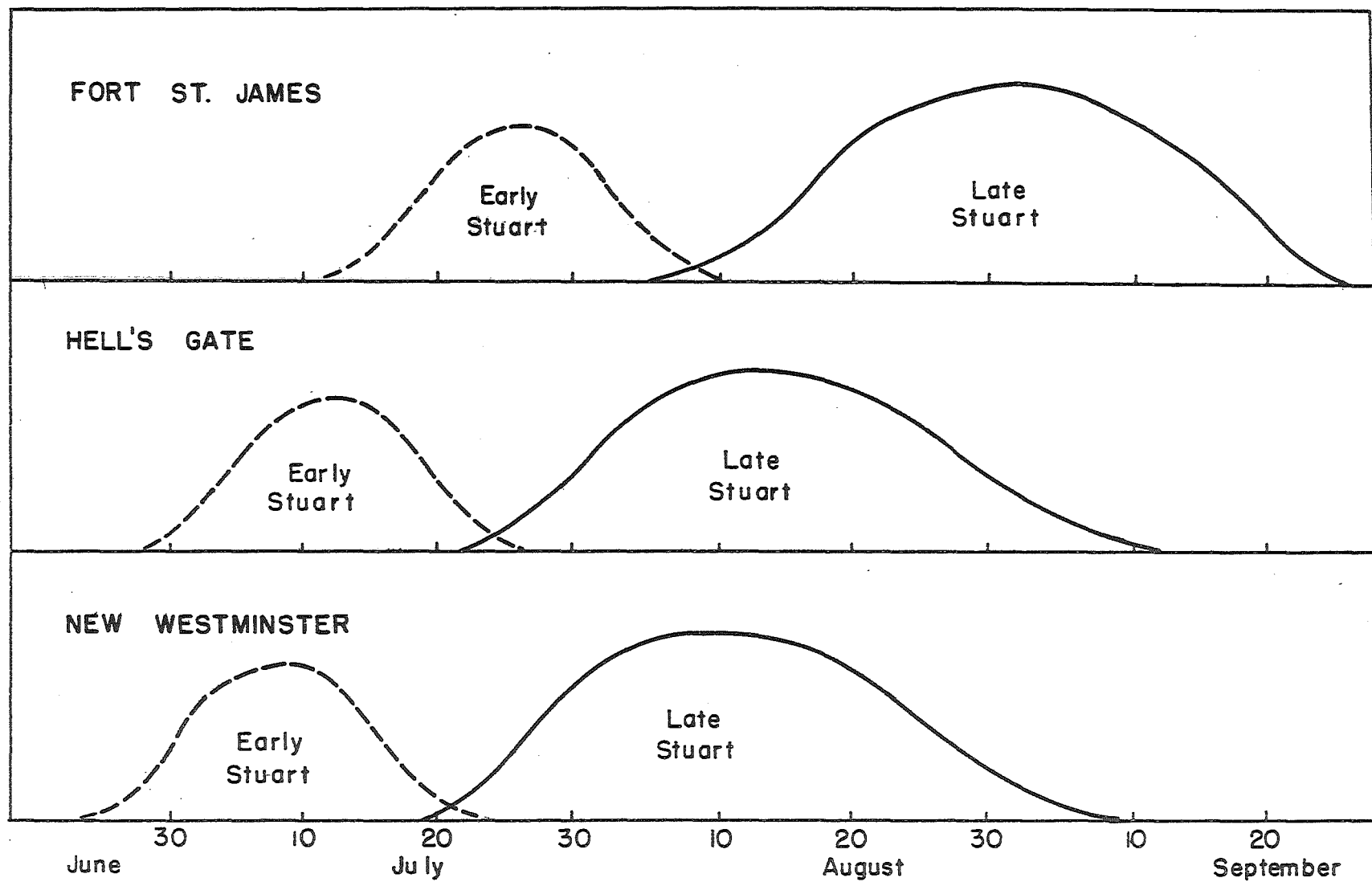


FIGURE 2 - Time of passage of the Early Stuart and Late Stuart sockeye runs at New Westminster, Hell's Gate and Fort St. James based on the years 1953 - 1959.

FIGURE 2 shows that the Early Stuart runs, even in the year with a late migration, would be almost entirely past New Westminster by July 20 and would be past Hell's Gate by July 24. FIGURE 2 also shows that Early Stuart fish could be present at Fort St. James between July 10 and August 10, although there would be relatively few after August 5.

The extended range shown for the Late Stuart data is due primarily to the very late appearance of the 1958 run. For the other 5 years, 1953-1957, the Late Stuart run was past New Westminster by August 20, past Hell's Gate by August 24 and past Fort St. James by September 9. However, the 1958 Late Stuart run was present at New Westminster from about August 11 until September 10 and the peak of abundance in 1958 did not occur at Fort St. James until September 15 with the run extending until about September 30 at that location.

ANNUAL ABUNDANCE OF EARLY STUART SOCKEYE

It is possible to trace the history of the Early Stuart sockeye run from 1820 to 1900 through the records kept by the Hudson's Bay Company at Fort St. James. These records, as far as salmon are concerned, primarily document the appearance and catch of salmon by the Indians in that area. Unfortunately records for all the years are no longer available. A further consideration is that, even though the Indians were starving, they apparently did not always fish when the fish first appeared and undoubtedly there had to be a fair number of fish present before any were caught. Even with these shortcomings, considerable information can be obtained from these records.

For the 1961 cycle, records were available for many of the years from 1825 to 1897. It is apparent from the information listed that the abundant run on this cycle was the Late Stuart run. In fact, there is no definite indication of any Early Stuart run until 1853 and then it was obviously small. It was not until 1897 that Early Stuart fish were again noted. There is a possibility of Early Stuart fish in 1825 since there was an entry dated August 8, 1825 which stated that,

"...the river is thick with them...". Strangely enough, there was no mention of any fish being present prior to that date. According to FIGURE 2, August 8 would be quite late for a normal appearance of a large number of Early Stuart sockeye at Fort St. James. On the other hand, however, it would also appear to be quite early for the appearance of a large number of Late Stuart fish.

For the 1960 cycle, records were available, with some exceptions, from 1820 to 1900. This was generally a cycle of failure during these years, and there is no evidence of any Early Stuart run in these years. The Late Stuart run was apparently good in 1820, 1848 and 1852.

For the 1959 cycle, records were available for many of the years between 1823 and 1899. Here again it was the Late Stuart run that was the abundant race whenever there were any salmon. The most abundant years were 1823 and 1847. It was not until 1847 that there were any fish that could be considered as Early Stuart and there were very few of them. There appeared to be a fair-sized Early Stuart run in 1895, but virtually none appeared in 1899.

For the 1958 cycle, records were available from 1822 to 1898, again with several years missing. The Late Stuart run was obviously abundant in 1842, 1850, 1854 and 1894 and probably in 1846. The first definite mention of a possible Early Stuart run occurred in 1850. Possible Early Stuart runs were mentioned again in 1854 and 1894.

To summarize these data, Early Stuart fish were not mentioned prior to 1847, with the possible exception of 1825. They were then mentioned on three of the four cycles within a relatively few years (1847, 1850 and 1853), but only in small numbers. The Early Stuart run was not mentioned on the 1960 cycle up through 1900, and on none of the cycles was it mentioned as being significant prior to 1894.

Also from these data it appears that in at least two of these years, 1899 and 1900, the Early Stuart escapement failed to reach the spawning grounds. In 1899 catch records show a total of approximately 220,000 sockeye caught in the United States fishery by July 14, and these would have been primarily Early Stuart fish.

An estimate of fishing intensities at that time indicates that there should have been an escapement of over 100,000 Early Stuart fish. However, the records from the Hudson's Bay Company for that year indicate that no fish had arrived at Fort St. James by August 12 and later in the year the records show the run for the season was "almost a total failure".

Again in 1900, based on catches and estimated fishing intensities, there was estimated to have been an escapement of about 40,000 Early Stuart fish and yet at Fort St. James it was reported on September 20, 1900, "There are no salmon here this year and we are looking forward to a hard winter."

On the basis of catch statistics, calculated fishing intensities and scale analyses it is possible to compile a summary of the abundance of the Early Stuart run from 1900 to 1961. These data clearly indicate three general levels of relative abundance of the Early Stuart run during these years: from 1900 to 1914 poor abundance, from 1915 to 1948 mediocre abundance, and from 1949 to 1961 good abundance.

The calculated annual total runs of Early Stuart sockeye for each year back to 1900, grouped by cycle year, are listed in TABLE 1. It is obvious from these data that the production for each cycle has increased significantly in recent years - particularly since about 1949.

The average annual total run for the three periods mentioned (1900 to 1914, 1915 to 1948, 1949 to 1961), for each cycle, are listed in TABLE 2.

The increased production on all cycles since 1948 is very apparent. For the 1961 cycle the average annual total run size from 1949 to 1961, i.e. the 1949, 1953, 1957 and 1961 runs, has been 770,433 fish compared with an average run size of 166,063 fish from 1915 to 1948, and 30,650 fish from 1900 to 1914. For all cycles combined, the average annual run size for the 13 years from 1949 has increased by 287,765 fish over the period from 1900 to 1914 and by 279,802 fish over the period of 1915 to 1948.

TABLE 1 - Calculated Annual Total Runs of Early Stuart Sockeye, in Convention Waters, by Cycle, 1900 - 1961,

1961 Cycle		1960 Cycle		1959 Cycle		1958 Cycle		4-Year Total
1961	1,000,000	1960	91,505	1959	8,173	1958	112,107	1,211,785
1957	516,659	1956	86,707	1955	133,193	1954	221,797	958,356
1953	965,073	1952	191,450	1951	275,000	1950	65,000	1,492,523
1949	600,000	1948	20,000	1947	15,000	1946	10,000	645,000
1945	115,000	1944	2,500	1943	4,100	1942	64,000	185,600
1941	44,000	1940	700	1939	1,400	1938	20,000	66,100
1937	7,500	1936	6,500	1935	3,000	1934	60,000	77,000
1933	600,000	1932	10,000	1931	12,000	1930	9,000	631,000
1929	320,000	1928	2,000	1927	6,700	1926	17,000	345,700
1925	130,000	1924	10,000	1923	3,000	1922	6,500	149,500
1921	56,000	1920	13,300	1919	2,300	1918	5,000	76,600
1917	56,000	1916	6,600	1915	6,600	1914	93,000	162,200
1913	58,000	1912	17,000	1911	8,000	1910	43,000	126,000
1909	16,000	1908	18,000	1907	18,000	1906	62,000	114,000
1905	8,600	1904	10,000	1903	20,000	1902	75,000	113,600
1901	40,000	1900	120,000	-	-	-	-	-

TABLE 2 - Average Annual Total Runs of Early Stuart Sockeye by Cycle

	1961 Cycle	1960 Cycle	1959 Cycle	1958 Cycle	Combined
1949 to 1961	770,433	123,221	138,789	132,968	328,205
1915 to 1948	166,063	7,956	6,011	23,938	48,403
1900 to 1914	30,650	41,250	15,333	68,250	40,440

This increased production has been reflected by increased catches in the fishery. For all cycles combined, the average annual catch for the 13 years from 1949 has increased by 179,261 fish over the period from 1900 to 1914 and by 166,011 fish over the period from 1915 to 1948. Based on 1961 wholesale prices for canned salmon the catch has increased in value by about \$700,000 annually, or a total increase in value of approximately \$9 million during this 13 year period.

It can be seen by examining the relationship between the estimated escapements past the fishery for the various years and the sizes of the returning runs that the inconsistencies in production through the history of the Early Stuart run were caused by some factor other than overfishing. The calculated yearly Early Stuart escapements, by cycle, are shown in TABLE 3 and are the gross escapements past the fishery.

TABLE 3 - Calculated Annual Gross Escapements of Early Stuart Sockeye, by Cycle, 1900 - 1961.

1961 Cycle	1960 Cycle	1959 Cycle	1958 Cycle
1961 228,439	1960 39,506	1959 3,182	1958 39,100
1957 258,987	1956 21,764	1955 21,000	1954 43,959
1953 181,549	1952 36,679	1951 65,000	1950 65,000
1949 600,000	1948 20,000	1947 15,000	1946 10,000
1945 35,000	1944 1,000	1943 3,000	1942 9,000
1941 15,000	1940 300	1939 1,000	1938 8,000
1937 1,500	1936 1,200	1935 1,000	1934 21,700
1933 53,000	1932 4,800	1931 6,150	1930 3,800
1929 30,000	1928 1,000	1927 4,200	1926 7,500
1925 29,000	1924 5,500	1923 1,700	1922 2,650
1921 10,000	1920 8,650	1919 1,600	1918 2,350
1917 6,000	1916 3,000	1915 3,000	1914 16,000
1913 9,000	1912 5,000	1911 6,000	1910 25,000
1909 10,400	1908 13,000	1907 10,000	1906 12,000
1905 1,000	1904 5,000	1903 15,000	1902 30,000
1901 24,000	1900 42,000		

In examining TABLE 1 for the period from 1900 to 1948, which includes several years prior to the occurrence of the Hell's Gate slide and is prior to the period of recent increased production, very abrupt drops in run size occurred in 1918 on the 1958 cycle; in 1904 on the 1960 cycle; and in 1937 on the 1961 cycle. However, the escapements (TABLE 3) for the three brood years which produced these runs (1914, 1900 and 1933) were certainly sufficient, at least past the fishery, to have produced much better runs.

Brood Year	Estimated	Run Produced
	Gross Escapement	
1900	42,000	10,000
1914	16,000	5,000
1933	53,000	7,500

These data indicate that these particular escapements, especially when compared with the size of the cycle escapements in other years, did not produce as they should have. The failure of at least the major portion of the 1900 escapement to reach the spawning grounds has already been noted.

In examining that part of TABLE 1 covering the more recent period from 1948 to 1961 it will be noticed that in spite of the increased production in this later period the run size also has suffered some setbacks. In order to determine whether these decreases in total run size are due to poorer returns from a given escapement or are merely the result of changes in the size of the different escapements, the escapements for these various years must also be considered. This is done in FIGURE 3 where the number of fish returning each year per fish from the brood year gross escapement are shown graphically for the years 1952 through 1961. The gross escapement includes fish that are subsequently caught in the Indian fishery or which may fail to reach the spawning grounds for some other reason and is not necessarily the actual number of fish spawning successfully.

In examining FIGURE 3, the two years which had the poorest returns were 1953 with 1.6 fish returned per sockeye from the gross escapement in 1949 and 1959

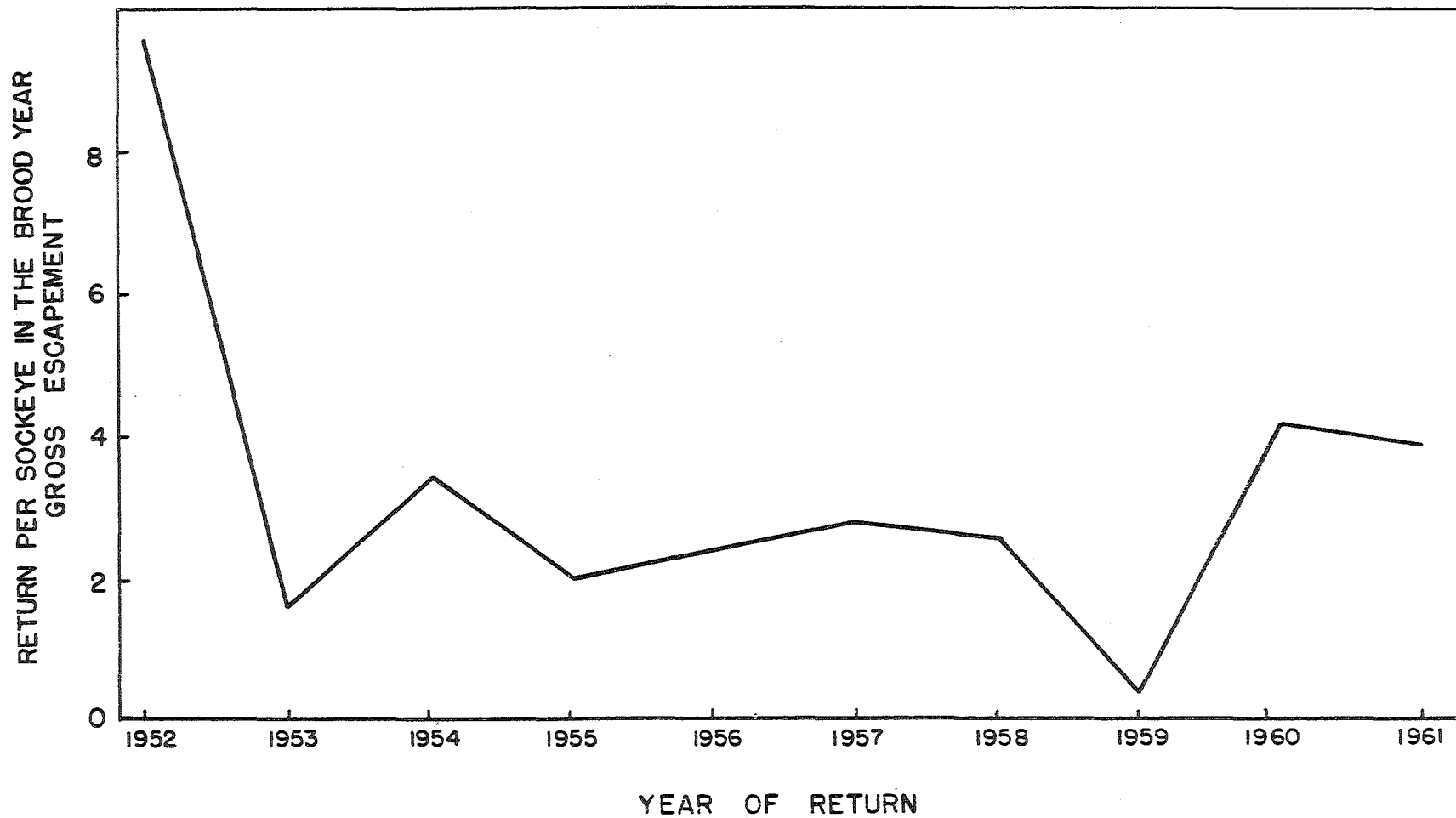


FIGURE 3 - Return per sockeye from the brood year gross escapement for Convention waters, Early Stuart 1952 - 1961.

with only 0.4 fish returned per sockeye from the 1955 gross escapement. The poor return in 1953 can undoubtedly be attributed to the overcrowded conditions on the Early Stuart spawning grounds in 1949 (Internat. Pacific Salmon Fish. Comm., 1954, page 19). As will be pointed out later, the 1955 Early Stuart escapement was almost decimated by block conditions in the Fraser Canyon during its upriver migration. Out of an escapement of about 21,000 fish, only 2,170 reached the spawning grounds and this accounts for the severe drop in the run returning in 1959.

DISCOVERY OF THE EARLY STUART OBSTRUCTIONS

The best known obstruction occurring in the main Fraser River is at Hell's Gate. Railroad construction in 1911 and 1912 had dumped large quantities of rock into the Fraser River at this location causing a block (Thompson, 1945) and this block, combined with a slide which occurred in 1914, contributed to the poor production from 1915 to 1948. However, there are indications that Hell's Gate may have been a block to the Early Stuart spawning migration, at least at the higher water levels, even before this railroad construction and slide. As mentioned earlier, Early Stuart fish were quite scarce prior to 1894. There appeared to be a fair-sized Early Stuart run in 1895 and 1899. Early Stuart abundance was termed poor from 1900 to 1914, mediocre from 1915 to 1948 and good from 1949 to 1961. (TABLES 1 and 2). The increased abundance from 1949 is obviously associated with the construction of the Hell's Gate fishways. If there had been no obstruction at Hell's Gate prior to the railroad construction and slide and the fishways had merely corrected a condition which resulted from this construction, then the abundance prior to that time theoretically should have been as great as the abundance after the fishways were constructed. However, it is apparent from the data in TABLES 1 and 2 that the abundance of Early Stuart sockeye was not as great from 1900 to 1914 as it was after the construction of the fishways.

Indications that Hell's Gate was a block at certain water levels even prior to the railroad construction are also forthcoming from engineering data. On

the basis of model studies and certain engineering reports (Jackson, 1950, Pretious and Hiltner, 1942, Internat. Pacific Salmon Fish. Comm., 1944) passage conditions at Hell's Gate prior to 1911 have been summarized as follows (Milo Bell, private communication), "The left bank under natural conditions was not passable at least above gauge 50. The right bank under natural conditions provided only limited passageway between gauges 50 and 65. The right bank profile at gauge 65.5 is such that it would indicate that no fish passed above this gauge level." These data indicate very strongly that Hell's Gate has always been an obstruction to Early Stuart sockeye at certain water levels and that fishways not only corrected the adverse affect of the railroad construction and the slide, but also corrected any adverse conditions which had existed before that time.

One of the initial studies by the Salmon Commission (Thompson, 1945) demonstrated that Hell's Gate after the 1914 slide was a serious block to all upriver sockeye runs at certain water levels. Regarding the water levels which could be considered as obstructions, Thompson stated (page 160), "These are between 26 and 40 feet inclusive and above except for brief openings at 40 and 50 feet." Unfortunately, during the years of this study, 1938-1942, there were very few Early Stuart fish present and, furthermore, the river level had always fallen below gauge 56 by the time the Early Stuart fish were present in early July, so there was no opportunity to observe the passage of fish at higher water levels.

On the basis of these studies fishways were constructed on both banks at Hell's Gate with a designed operating range of between gauge 23 to 54. These fishways were completed in May, 1946. A high water level fishway was constructed on the right bank during the winter of 1946-1947 to be operative up to gauge 70. However, fish seem to experience great difficulty reaching this high level fishway even when it is operative, and as a result this fishway does not appear to be very effective for passing fish at higher water levels. Because of extreme turbulence along the right bank outside the fishway, passage of sockeye at high river levels

would be very limited and possibly blocked. In 1950, when the right bank high level fishway was in operation, sockeye were blocked on both banks between July 5 and 15 when the gauge ranged from 73 to 58. At gauge 57 fish were able to use the right bank high level fishway in limited numbers and the left bank fishway in large numbers even though this fishway was designed to operate only up to gauge 54.

On the basis of these blocked fish in 1950, an effective high level fishway on the left bank was constructed. This fishway was only partially completed in time for the 1951 run but was finished in December, 1951. The left bank high level fishway also is designed to operate up to gauge 70 but is known to have passed fish up to gauge 71.6. The 10.5 foot drop in water surface on the left bank would prevent any migration up this bank at higher river levels.

Although construction of the Hell's Gate fishways eliminated blocks over certain water levels, it subsequently became apparent that Hell's Gate was still a block above the operating levels of the fishway, and that there were other locations below Hell's Gate which also were obstructions to the upriver migration of the Early Stuart run.

The serious effect of these blocks below Hell's Gate on the Early Stuart escapement became evident during the 1955 season. That year, the escapements of the early migrating races, Early Stuart and Bowron, failed to appear at Hell's Gate at the expected time. An investigation was started immediately to determine the cause of the delayed appearance of these fish and led to the discovery of an obstruction at a point about 15 miles downstream from Hell's Gate or 3 miles upstream from the Village of Yale.

It was concluded from observations conducted throughout the early 1955 runs that the migrating sockeye were partially or totally blocked at this obstruction point near Yale when river levels at Hell's Gate varied between gauge 73 and 70, which is considered a high water level block. More extensive surveys were made of this obstruction and it was found that, actually, four separate points of obstruction

were involved - two on each bank. Fishways were planned which would provide passage on the right bank over a range of river levels corresponding to gauge 78 to 62 at Hell's Gate. The construction of these fishways was recommended by the Commission and the structures were completed in May, 1957 in time for the escapement of the dominant cycle Early Stuart run that year. Observations had shown that, although some delay was involved, fish which were blocked on the left bank at Yale Rapids would cross the river and migrate up the right bank. Furthermore, it was determined that the right bank fishway had sufficient capacity to handle the magnitude of Early Stuart escapement expected to be present under current levels of production. For these reasons, the construction of fishways at the left bank obstructions were left to be undertaken in succeeding years at a pace consistent with any expansion in the production of the early sockeye runs.

The river levels were quite low during the Early Stuart spawning migrations in 1957, 1958 and 1959 and, since the obstructions near Yale were high water level obstructions, the right bank fishways were not required in these years.

Observations during the Early Stuart upriver migration in 1960 showed that the Yale fishways were operating properly and fish were observed passing through them. However, on July 14, some red-colored sockeye, indicating an unusually advanced stage of maturity, were observed at Hell's Gate and investigations were made to locate the cause. By this time the river had dropped below the operating range of the Yale Fishways, but some pink and red-colored sockeye were accumulated below the fishways and between the upper fishway and another drop about 1,000 feet upstream from the fishway. No evidence of a large accumulation of fish could be found in the vicinity of the fishways themselves. Subsequent reports from the Early Stuart spawning grounds showed that the first sockeye arrived there 15 days later than expected and in poor condition. These fish commenced spawning immediately upon arrival and a large percentage died unspawned. Dead, unspawned fish were also observed at various points in the Tachie River and Stuart Lake and River downstream from the spawning grounds. Based on test fishing and scale analyses (Henry, 1961) *21*

estimated 39,506 Early Stuart fish [REDACTED] escaped from the fishery in 1960. However, only 14,572 fish reached the spawning grounds. Subtracting an Indian catch of 4,134 fish, this left 20,800 sockeye which never reached the spawning grounds and could not be accounted for. Obviously, an obstruction to the migration of these fish still existed somewhere below Hell's Gate. It was therefore decided that the whole problem of upriver passage of the Early Stuart run be re-examined. In order to avoid the confusion of using different gauges at different obstructions, all gauge levels used are Hell's Gate gauge levels and will not be further identified in this report.

POINTS OF POSSIBLE OBSTRUCTION

The section of river from Yale to Hell's Gate contains at least four locations at which the size of the local drops in water surface indicate a potential obstruction or point of difficult passage. These four locations are listed in TABLE 4.

TABLE 4 - Possible Obstructions to the Upriver Migration of the Early Runs of Fraser River Sockeye.

Location	Drop in Water Surface
1. Yale Rapids, site of fishways	Left Bank: 4.5' and 6.5' at gauge 70 Right Bank: 3.0' and 5.7' at gauge 70
2. Indian Fishing Station, right bank 3.3 miles above Yale	4.7' at gauge 70 5.1' at gauge 72
3. Indian Fishing Station, right bank 3.5 miles above Yale	8.2' at gauge 70 6.3' at gauge 70.6
4. Hell's Gate	Left Bank: 10.5' at gauge 71 Right Bank: 10.5' at gauge 71

Considering all available evidence from earlier years and all the evidence presented in this report, the deduced periods of blockage or difficult passage at these potential high water level obstructions, prior to any improvements or construction of any fishways, are shown in FIGURE 4.

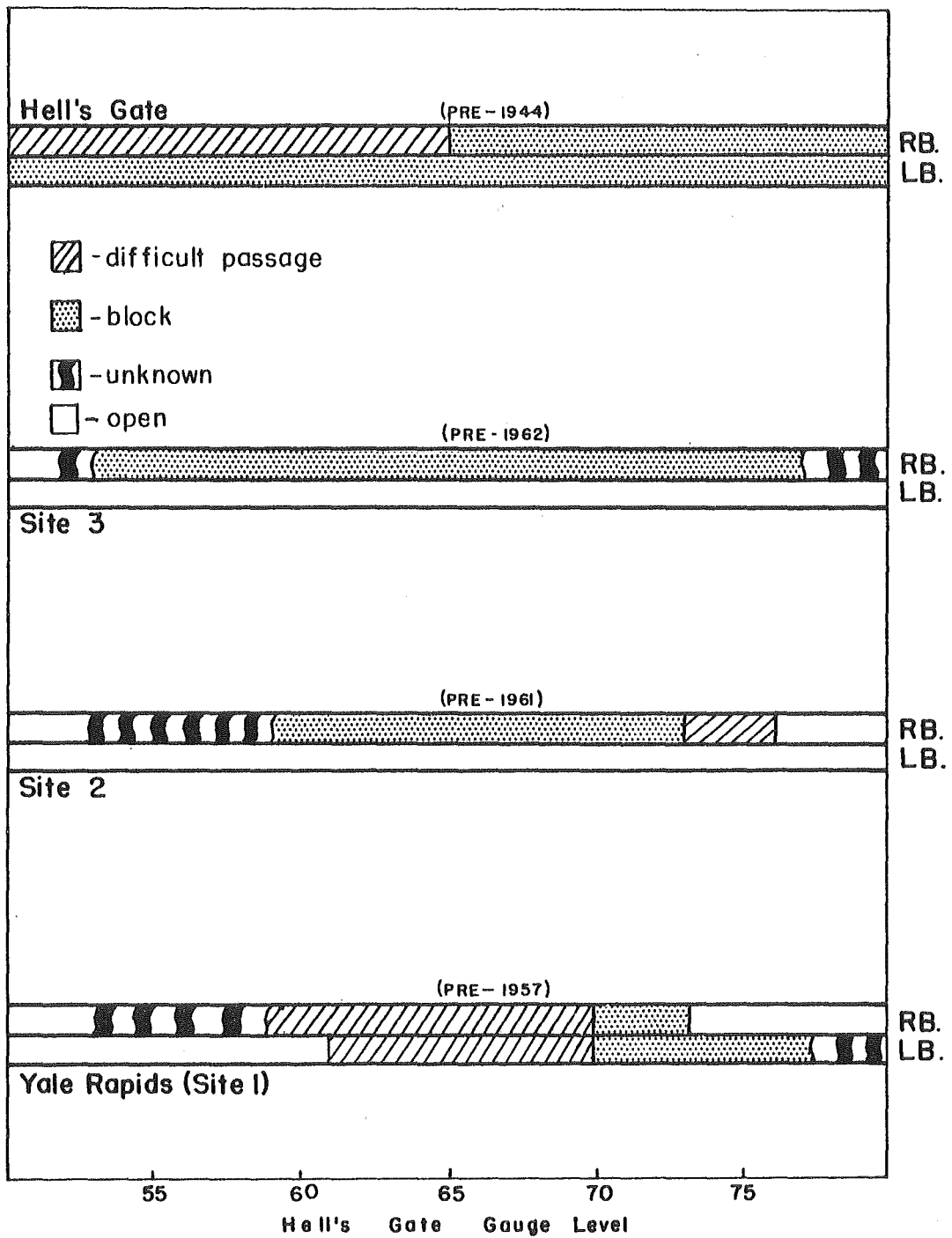


FIGURE 4 - Block levels of certain Fraser Canyon obstructions prior to improvements.

Yale Rapids (Site 1), an obstruction on both banks, was considered to be completely blocked from gauge 70-73, inclusive, on the basis of evidence obtained in 1955. The right bank was open above gauge 73, but the left bank was blocked up to at least gauge 77. Below gauge 70 the left bank was open but the right bank now appears to provide difficult passage down to some level between 53 and 60. Fish apparently could get by this obstruction when only one bank was blocked by crossing the river to the other bank.

Site 2, a right bank obstruction only, was considered to be open above gauge 76. This site provided difficult passage from gauge 76-74 and was a block down to at least gauge 59. Fish migrating up the right bank do not appear able to cross the river during a block at Site 2 because of the closeness of this site to Yale Rapids. Fish apparently can drop downstream below Yale Rapids and then migrate up the left bank, providing it is not blocked.

Site 3 is also a right bank obstruction only. The available data is not sufficient to distinguish the effect of the drop at this point from the effect of drops downstream. Physical measurements indicate very strongly that this drop would block the movement of sockeye along the right bank over a wide range of river levels from at least gauge 77 down to possibly as low as gauge 53. However, if there is a block at this location, records of past runs indicate that the sockeye are able to get past by crossing the river to the other side and migrating up the left bank. There has not been any opportunity to observe sockeye at this point, and evidence of the existence of a block is speculative, involving at most a delay of 1 or 2 days for fish to cross to the other bank of the river.

At Hell's Gate, prior to the construction of any fishways and after the Hell's Gate slide, both banks were blocked between gauges 26-40 and above with brief openings at gauges 40 and 50. Above gauge 50 the left bank was always blocked while the right bank had limited passage from gauges 50-65 and was blocked above gauge 65. The construction of the fishways in 1946 and 1950 changed the block pattern at Hell's Gate so that after 1950 the right bank was open below gauge 58 and the left bank was open below gauge 71.6.

As mentioned previously, fishways were constructed on the right bank of Yale Rapids and these changed the block pattern so that, after 1956, the right bank was open above gauge 62 and the left bank block was unchanged.

EFFECT OF THESE OBSTRUCTIONS ON INDIVIDUAL RUNS

On the basis of this newly acquired information on obstructions, the history of the upstream passage of the Early Stuart run in previous years has been re-examined. As mentioned previously, the annual Early Stuart escapements since 1900 which gave definite indications of having been adversely affected by block conditions were 1914, 1933, 1954, 1955 and 1960. These five years will be examined individually.

The 1914 Early Stuart Run

The 1914 Early Stuart escapement would have encountered river levels of from gauge 56 to 66. It is not possible to state exactly what block conditions existed during the 1914 run since block conditions at Hell's Gate were still undergoing change. As stated by Jackson (1950, page 92): "At 10:00 p.m. on February 23, 1914, the already impassable channel at Hell's Gate was further obstructed by the collapse of a huge rock cliff through which the Canadian Northern Railway had driven a cut and tunnel. An estimated 100,000 cubic yards of massive granite rock now filled the eddy existing immediately above the left bank bedrock outcrop which formed Hell's Gate. The channel was narrowed to 75 feet and the river was partially dammed so that it had a fall of 15 feet in a length of 75 feet along the face of the slide."

Although tremendous effort was made to try to eliminate this rubble prior to the appearance of sockeye, it is obvious that the Early Stuart escapement must have encountered extremely difficult passage conditions. McHugh (1915, page 270) reported, "On Friday, July 3, salmon were first observed in the rough Hell's Gate passage struggling and fighting to get through Actual proof of salmon successfully negotiating the fall was not forthcoming until July 15 when three

sockeye were caught with a dip net above the obstruction. This showed that some of the stronger fish were able to get by safely, but the majority were certainly being thrown back and were taking shelter behind the point of the 'Gate' in the smooth waters." There seems little doubt that this block at Hell's Gate to the 1914 escapement was the primary cause of the poor Early Stuart run in 1918.

The 1933 Early Stuart Run

FIGURE 5 illustrates the passage of the 1933 run in relation to conditions at the block points as deduced from the evidence considered in this report. The escapement which should have arrived at Yale Rapids on July 5 and 6 would have encountered river levels of gauge 80-81. The left bank of Yale Rapids would have been blocked, but the right bank should have been open. Site 2 would have been open but the fish would have had to cross over to the left bank to avoid the block at Site 3. No definite conclusion can be drawn as to the exact point of blockade of these fish, but they would certainly have been blocked at Hell's Gate if they had reached there. In any event, these fish did not reach the spawning ground.

The escapement arriving at Yale Rapids on July 12 and 13 would have encountered a river level of gauge 73 and would have been blocked on both banks until July 23. These fish also never reached the spawning grounds.

The escapement arriving at Yale Rapids on July 19 and 20 would have been blocked on both banks since the river level was at gauge 70. On the basis of block levels established in 1955, Yale Rapids would have opened on July 23 at gauge 66, and some of these fish presumably reached Hell's Gate on July 24 at which time the river was at gauge 65. Based on the arrival date of the first fish on the spawning grounds on August 9, evidently some of these latter fish were able to pass Hell's Gate on the right bank either on July 24 when the gauge was at 65 or on July 25 when the gauge was at 62. However, these fish were reported to be in very poor condition when they arrived on the spawning grounds.

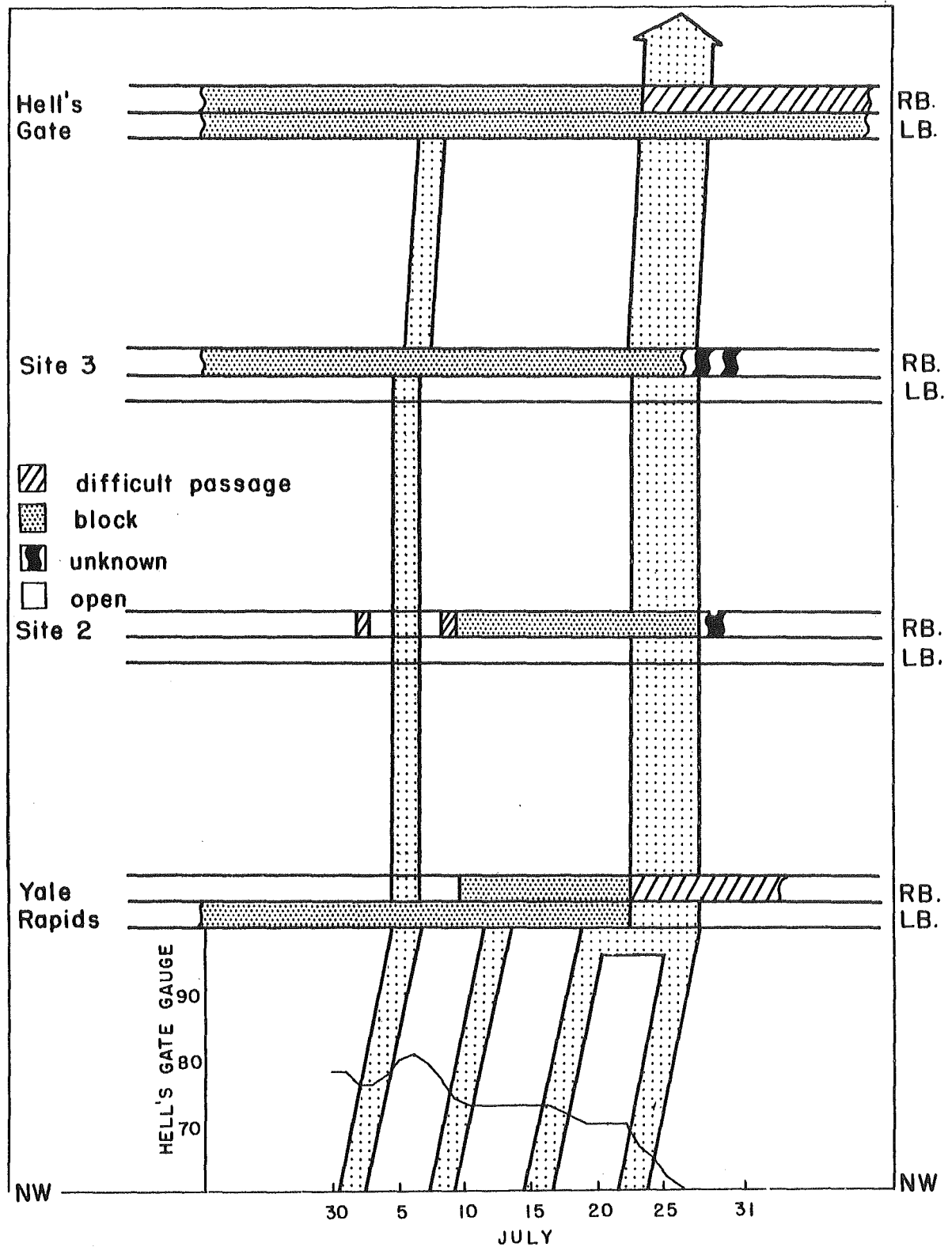


FIGURE 5 - Passage of the 1933 Early Stuart sockeye run in relation to certain Fraser Canyon obstructions.

From these data it can be concluded that the Early Stuart run of 1933 was blocked somewhere at river levels ranging from gauge 81.5 to between 65 and 70, and that it was able to migrate past Hell's Gate, at least in part, at a river level between gauge 62-65.

The 1954 Early Stuart Run

The first sockeye was reported at Hell's Gate on June 29 and would have been from the small escapement prior to June 28. Fish were again noted at Hell's Gate on July 4 and July 8 and a large number of sockeye arrived on July 13, continued until July 16 and then declined until July 20. The first sockeye was not observed at Forfar Creek until July 29 and the peak of the arrival of the first large group of fish was on August 1. FIGURE 6 illustrates the passage of the 1954 Early Stuart run up the Fraser River in relation to the conditions at the various blocks.

The escapement prior to June 28 would have contained only about 200 fish and these would have appeared primarily in the last few days of the closure. The June 27 escapement should have reached Yale Rapids on July 1 at gauge 71.6 and would have been blocked on both banks so there would have been very few fish from this escapement which were able to reach the spawning grounds.

The escapement from the July 2, 3 and 4 closure, which contained an estimated 24,000 fish, should have reached Yale Rapids on July 6-8 and would have encountered river levels of gauge 76 to 75. The left bank would have been blocked but fish should have been able to pass the right bank and some obviously did since they arrived at Hell's Gate on July 8. However, these fish apparently did not arrive at Hell's Gate in the numbers that they should have indicating an obstruction downstream which limited the passage of fish.

FIGURE 7 diagrammatically portrays the possible migration route of this July 2-4 escapement. As already mentioned, the left bank at Yale Rapids was blocked to these fish so any that got by this site would have had to use the right bank.

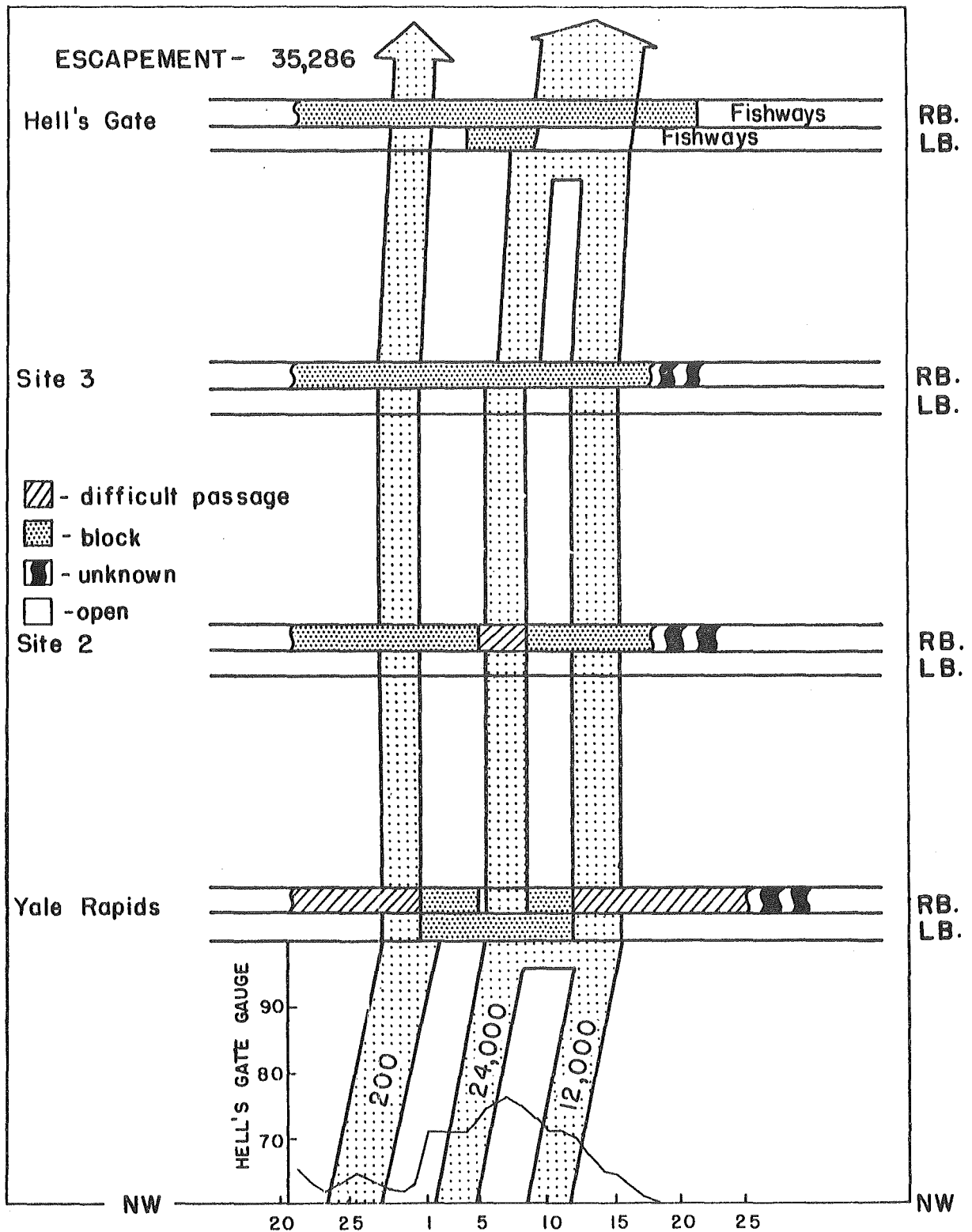


FIGURE 6 - Passage of the 1954 Early Stuart sockeye run in relation to certain Fraser Canyon obstructions.

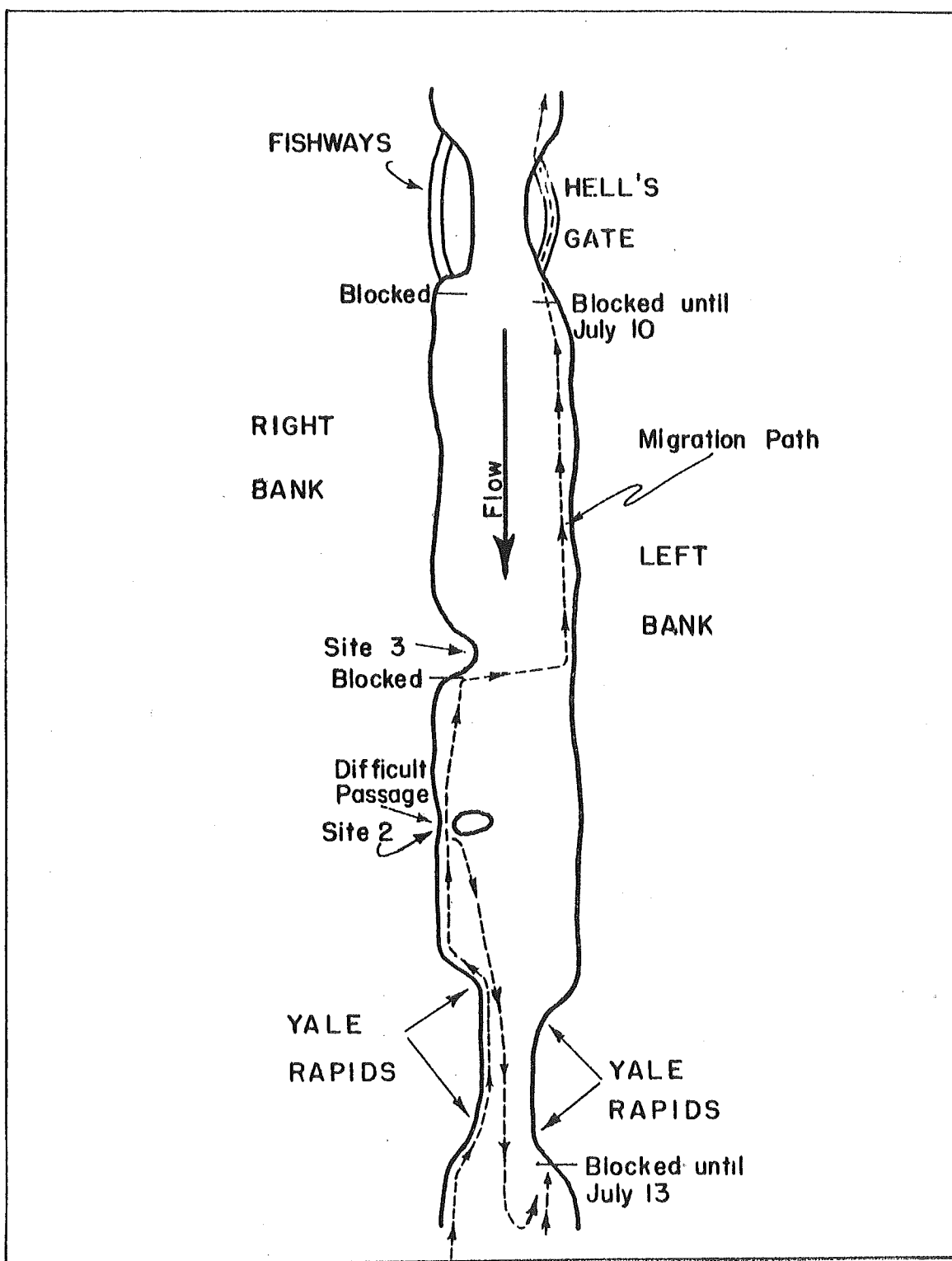


FIGURE 7 - Possible migration route from Yale Rapids to Hell's Gate of the July 2-4, 1954 Early Stuart sockeye escapement.

At Site 2, a right bank obstruction, these fish would have experienced difficult passage, but not a complete block. In view of the limited passage at Site 2 for this large number of fish, many of them undoubtedly would have dropped downstream below Yale Rapids and crossed over to the left bank. However, they still would have been blocked on the left bank at Yale Rapids until July 13. At Site 3, another right bank only obstruction, the fish would have been blocked on the right bank and they would have had to cross over and use the left bank to get by this obstruction.

These fish would have reached Hell's Gate about July 8, and with the river level at gauge 75, both banks would have been blocked. The left bank at Hell's Gate would have become passable on July 10 at gauge 71. Allowing the normal 20 days travel time from Hell's Gate to Forfar Creek, fish passing Hell's Gate on July 10 should have reached Forfar Creek on July 28; some were actually seen on July 29. This escapement appears to have been delayed 3 days before being able to get by Hell's Gate, one day in crossing the river at Site 3 and two days at Hell's Gate. The delay at Hell's Gate was caused by waiting until the high level left bank fishway came into operation. Evidently this delay did not affect the ability to spawn since the fish were 98 per cent spawned out on the spawning ground. However, there may have been possible adverse effects of this delay relative to normal energy consumption (Idler and Clemens, 1959).

The escapement from the July 9-11 closure, containing an estimated 12,000 Early Stuart sockeye, should have reached Yale Rapids on July 13, at which time the river level had dropped to gauge 67.6. There were no blocks on the left bank so these fish were able to reach Hell's Gate on July 13-14 and reach Forfar Creek on August 5, indicating a migration time of about 22 days from Hell's Gate. It is concluded that nothing obstructed the movement of this group of fish.

The 1955 Early Stuart Run

As already stated, an estimated escapement of about 21,000 sockeye was obtained from the Early Stuart run in 1955, but only 2,170 of these fish reached the

spawning grounds. FIGURE 8 illustrates the passage of this run up the river in relation to the various block points.

The escapement from the July 1-3 closure contained about 5,700 fish. These fish should have arrived at Yale Rapids on July 5 to 7 when gauge levels were 73, 70 and 67.6 respectively. Considering Yale Rapids to be blocked from gauge 73 to 70, the first two days escapement would have been blocked, but they should have been able to pass upstream on the left bank beginning July 7. However, if these fish took more than 1 day in reaching and passing Hell's Gate, they could have been blocked below Hell's Gate on July 9-10 when the river rose to gauge 70.6 and 73 respectively. The only evidence of this escapement upstream from the fishery was a few fish caught at Yale. These fish were not observed at Hell's Gate and never reached the spawning grounds.

An escapement of approximately 10,000 fish was obtained from the July 8-10 closure. These fish would normally arrive at Yale Rapids between July 12-14 and at Hell's Gate 1 day later. The river level was gauge 74 on July 12 and this level must have been at least partially passable on the right bank since some fish reached Hell's Gate on July 13. The left bank at Yale Rapids would have been blocked. On July 13 the river level dropped to gauge 73 and remained between gauge 73 and 70 until July 19 so that both banks at Yale Rapids would then have been blocked. During this period only a few sockeye appeared at Hell's Gate. The first sockeye seen above Hell's Gate were observed above the left bank high level fishway on July 14 at gauge 71.6. Apparently none of these fish reached the spawning grounds.

Evidence of dead sockeye on the rocks at Yale Rapids indicated the existence of a block at that point which prevented the migration of all but the few fish seen at Hell's Gate. It is now suggested that the fish which passed Yale Rapids to reach Hell's Gate on July 13 did so by passage up the right bank at Yale Rapids as far as Site 3 and then crossing over to the left bank to continue their migration, the same as the fish did in the July 2-4, 1954 escapement (FIGURE 7).

It also appears that during the period July 13 to July 19 both the right and left banks at Yale Rapids were blocked as well as the right banks at Sites 2 and 3.

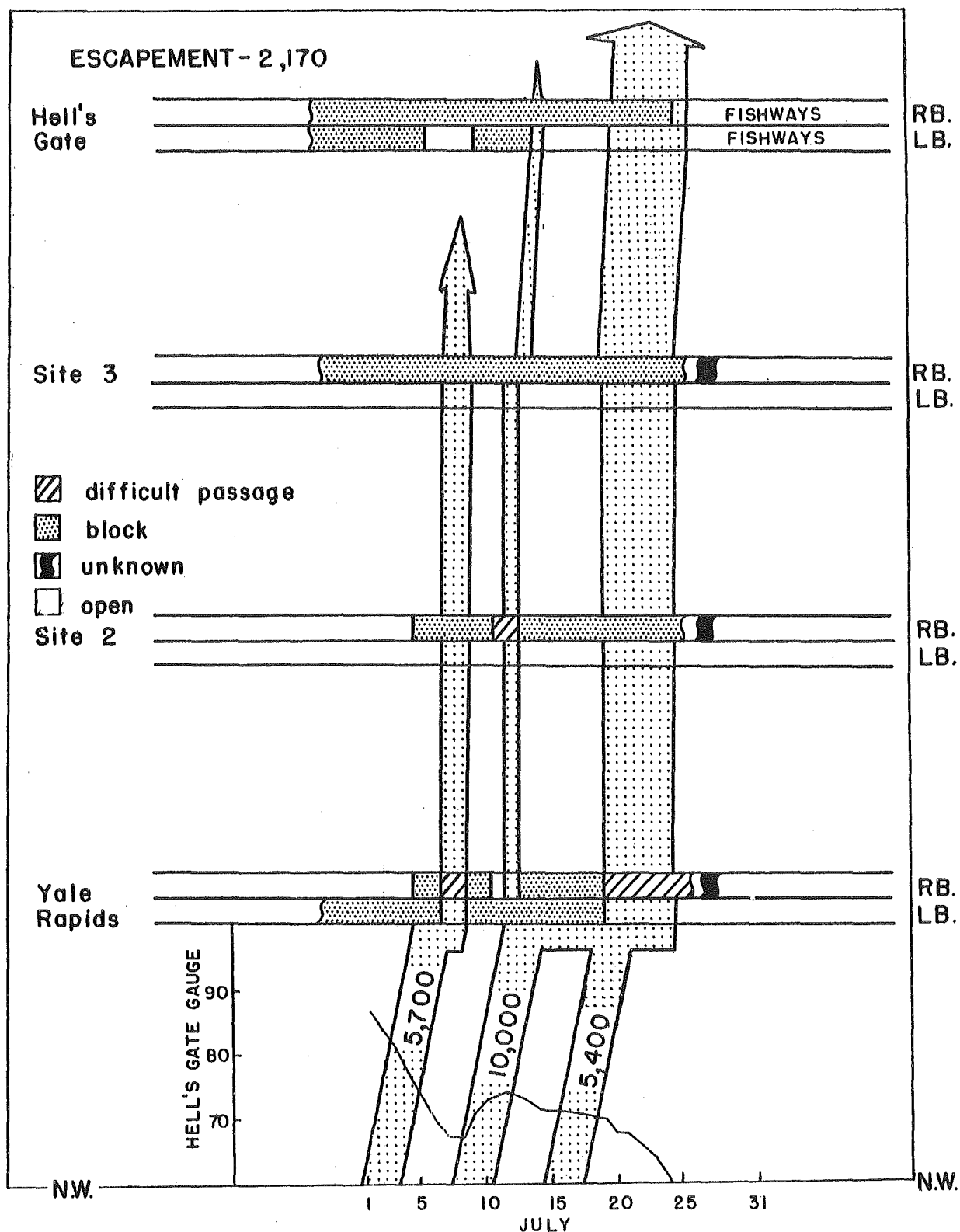


FIGURE 8 - Passage of the 1955 Early Stuart sockeye run in relation to certain Fraser Canyon obstructions.

The first surge of sockeye appeared at Hell's Gate on July 20 when the river level was at gauge 68. This corresponds to the normal arrival date for the escapement from the July 15-17 closure. The first fish arrived at Forfar Creek on August 8 and the fish were reported to be weak and badly bruised. This may be partially explained by the fact that the only Early Stuart fish to reach the spawning grounds in 1955 were from the tail-end of the run and these fish are generally in poorer condition than the one's arriving earlier.

There were indications that some of the previous weekend escapement (July 8-10), which had been blocked at Yale Rapids, were included in the fish getting by Yale Rapids beginning July 20, since many of the salmon in this group were reported ascending Seton, Texas and Williams Lake Creeks, which are small tributaries upstream from Hell's Gate and several hundred miles from the natural spawning grounds (Internat. Pacific Salmon Fish. Comm., 1956). Furthermore, sockeye continued to migrate past Hell's Gate in numbers until July 25, three days longer than normally would be expected.

It is concluded that in 1955 a block existed on both banks at Yale Rapids which was effective in the range of river levels from gauge 73 to 70 and that passage at gauge 74 was very limited. Below gauge 70 passage was available on the left bank at Yale Rapids, but the right bank remained blocked. It is also concluded that the left bank high level fishway at Hell's Gate passed fish at gauge 71.6, although it may not be very efficient at this high water stage. The blocks occurring on the right bank at Site 3 apparently could be surmounted by fish crossing to the other side.

The 1960 Early Stuart Run

As mentioned previously, out of a total estimated Early Stuart escapement of approximately 39,500 fish in 1960, around 4,130 were calculated to have been caught in the Indian fishery and 14,572 arrived on the spawning grounds leaving about 20,800 fish unaccounted for and presumably lost during the migration upriver. Evidence of this is found in the fact that dead unspawned sockeye were found in the

various lakes of the Stuart system which is not a normal condition.

On the basis of the block conditions observed in 1955, two fishways had been constructed on the right bank at Yale Rapids which would operate over a range of water levels corresponding to gauge 78 to 62. FIGURE 9 illustrates the passage of the various segments of the 1960 escapement migration in relation to conditions at the block points.

The escapement of an estimated 2,000 fish from the closure of June 24-26 should have arrived at Yale Rapids on June 28-30 when the river level was between gauge 74 and 75. These fish would have been blocked on the left bank (on the basis of the 1954 run) but the fishway provided passage on the right bank. Furthermore, there is a channel alongside the upper fishway, (part of the original channel that sockeye used to bypass this block at water levels above gauge 73) and fish could also migrate up this. A casual observation on June 30 found the fishways operating and no fish were seen. From the events of 1954, it is concluded that only a few of these fish would have been able to reach Hell's Gate through the restricted passage on the right bank at Site 2 and these would then have had to cross the river at Site 3 to the left bank. However, they would have been blocked on both banks at Hell's Gate until July 8-9 when the river dropped to the operating level of the left bank high level fishway. There are no reports of fish being present at Hell's Gate during this period and these fish never reached the spawning grounds. This path of migration again would be similar to the one depicted in FIGURE 7 for the 1954 escapement.

The escapement from the closure of June 30 to July 3 contained an estimated 16,200 fish and, with the possible exception of a few fish from the first two days of the escapement containing about 4,400 fish, these fish also never appeared on the spawning grounds. The escapement should have reached Yale Rapids on July 4-7 when the river levels were from gauge 76.6 to 72. They would have been blocked on the left bank, (again on the basis of 1954), but should have found passage through the

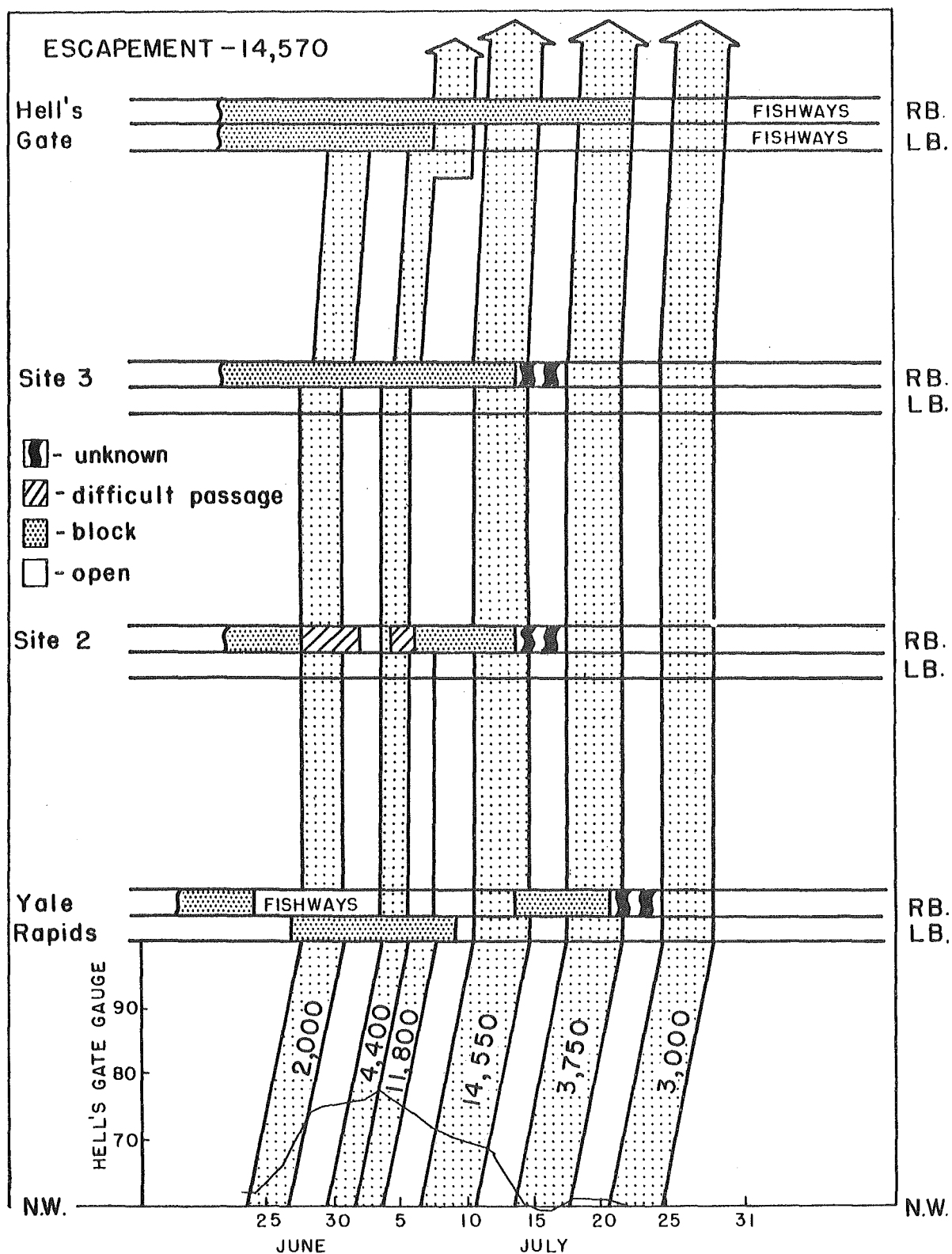


FIGURE 9 - Passage of the 1960 Early Stuart sockeye run in relation to certain Fraser Canyon obstructions.

right bank fishway or the channel alongside the upper fishway. In a half-hour observation on July 8 at Yale Rapids, only 3 fish were seen, 2 ascending the lower fishway and 1 attempting to swim up the channel alongside the upper fishway. At the time this channel was nearly dry and was impassable. Since this particular weekly escapement should have contained an estimated 16,200 fish it is concluded from the absence of delayed fish that there was no obstruction on the right bank of Yale Rapids at that time.

The June 30 to July 3 escapement would normally reach Hell's Gate on July 5-8. At that time in 1960 river levels were from gauge 75 to 71, respectively. Therefore, these fish could have been delayed up to 3 days in passage at Hell's Gate, since Hell's Gate is not passable above gauge 71.6. This amount of delay does not seem sufficient to account for the disappearance of these fish and there is no reason to suspect any obstruction upstream from Hell's Gate. Furthermore, these fish were reported present at Soda Creek, about 132 miles above Hell's Gate on July 12-13.

Examination of the 1954 and 1955 Early Stuart runs suggests that Site 2 may be a block up to gauge 73 with limited passage up to gauge 76. This suggestion is supported by the physical nature of the drop which is created by two bedrock pinnacles protruding from the river bed. At very high river flows the local drop in water surface around these pinnacles would disappear. There is no reason to believe that Site 3 would be drowned out except at very high river levels, and both Site 2 and 3 may be obstructions at river levels considerably below gauge 70. Using this premise, the following explanation of the block of the June 30 to July 3 escapement can be made and the proposed migration route is the same as previously shown diagrammatically in FIGURE 7.

The June 30 and July 1 escapements estimated at 4,400 fish, would arrive at Yale Rapids on July 4 and 5 with the river level at gauge 76.6 to 75.5 and could have passed Yale Rapids on the right bank only. They also would have passed Site 2, although only in limited numbers, but would have been stopped at Site 3. They would

then have crossed the river at Site 3 and would have reached Hell's Gate on July 6-7, allowing 2 days for crossover and travel time to Hell's Gate. They would not have been able to pass Hell's Gate until July 9, making a total delay of 3 to 4 days. Allowing 20 days travel time to Forfar Creek, these fish would have arrived there on July 29 and this corresponds to the recorded date of first arrival at that point. Field observers reported the fish in Rossette, Forfar and Gluske Creeks to be more scarred than usual that year, and that they commenced spawning soon after arrival. Dead unspawned fish were reported in Trembleur Lake, Tachie River and Stuart Lake on August 10. It appears therefore, that some of these 4,400 fish reached the spawning grounds generally in poor condition, but that the majority of them died en route. The total delay of this group of fish of 3 to 4 days, is not significantly different from the delay of 3 days on the first escapement in 1954 and requires explanation, since the 1954 fish spawned successfully. Examination of water temperatures in the Nechako and Stuart Rivers during these two migrations (FIGURE 10) shows that the 1954 run migrated through temperatures 4°F to 6°F colder than in 1960 and that the 1960 migration was in temperatures ranging from 62°F to 67°F. Since temperatures in excess of 63°F are known to cause mortalities to sockeye on the spawning grounds, it is possible that this early portion of the 1960 Early Stuart escapement which had delayed sufficiently to be almost ready for spawning, as a result suffered large mortalities in the Nechako and Stuart Rivers as well as in Stuart and Trembleur Lakes and Tachie River.

The third and fourth days of the June 30 to July 3 escapement, containing about 11,800 fish and arriving at Yale Rapids on July 6 and 7, would have been blocked on the left bank and after passing through the fishways in the right bank, would have been blocked at Site 2. These fish could not have passed upstream until July 9 or 10 and even then only by dropping back downstream and moving up the left bank at Yale Rapids. Thus they would have been delayed at least 4 to 5 days, allowing only 1 day for crossover at Yale Rapids. On the basis of the 1955 run and also data on

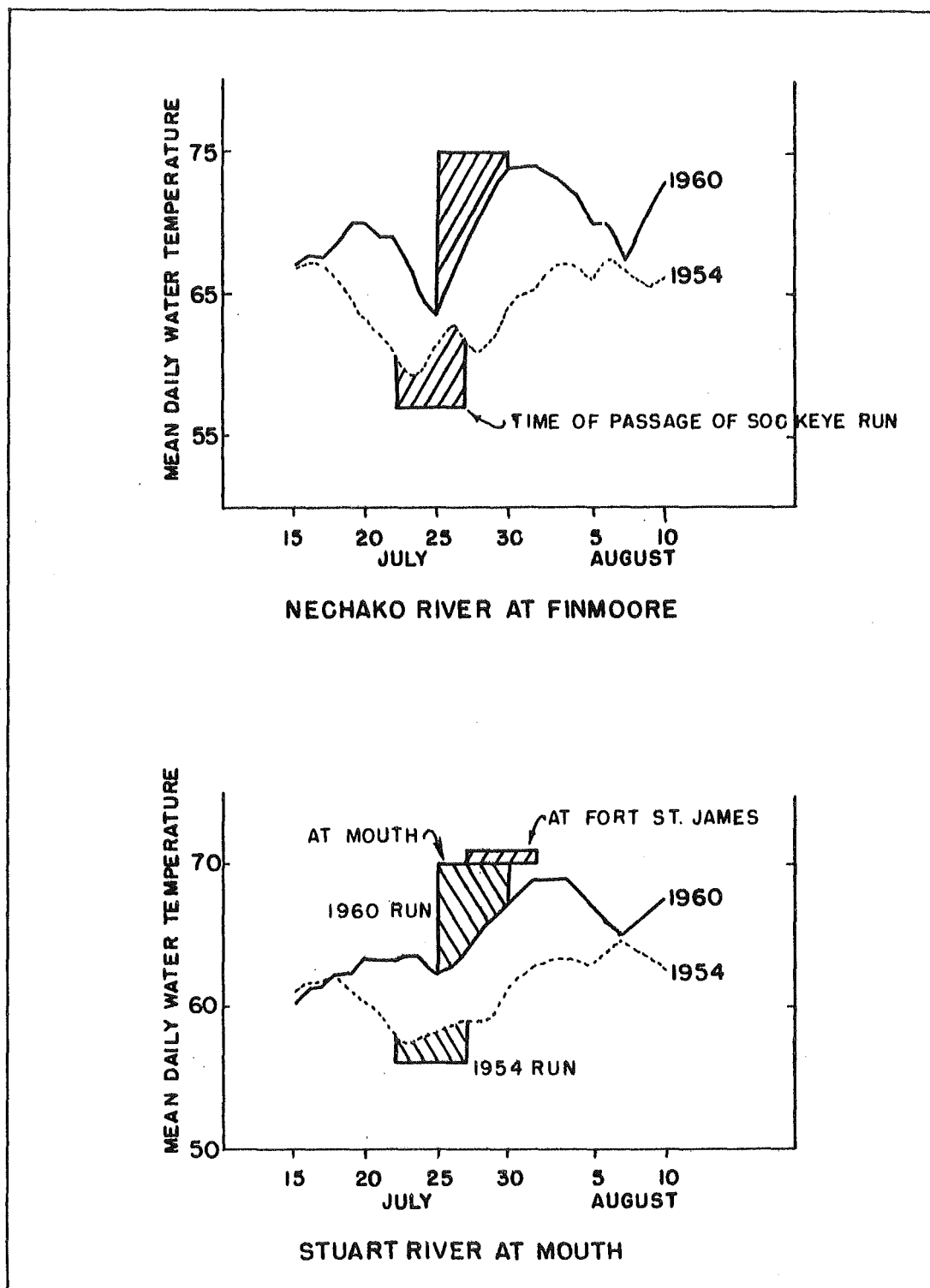


FIGURE 10 - Water temperatures in the Nechako and Stuart Rivers during the period of migration of sockeye in 1954 and 1960.

energy reserves (Idler and Clemens, 1959), this delay probably would be sufficient to prevent these fish from reaching the spawning grounds. The possible migration route for this group of fish is shown in FIGURE 11.

As previously noted, an observation at the Yale Fishways on July 8 did not reveal any large numbers of fish to be present. No observation was made at Site 2 at that time, but an observation on July 16 (gauge 59) found fish resting in eddies between the Yale Rapids fishways and Site 2, with no fish above this point. Pink and red sockeye were seen below Yale Rapids at that time and as late as July 20. Pink and red sockeye also were seen at Hell's Gate on July 12, and reports were received of pink sockeye being caught at Soda Creek, 132 miles above Hell's Gate. No dead sockeye were seen at Yale Rapids and it is concluded that these fish passed upstream commencing July 9-10, when the left bank at Yale became passable, but they never reached the spawning grounds.

The third escapement group of about 14,550 sockeye should have arrived at Yale Rapids between July 11-14, at gauge 69 to 60. The first three days arrival, July 11-13, should have been able to pass on either bank, although those going up the right bank would have been blocked at Site 2, since it is known from observations that Site 2 was still obstructing sockeye when the river was at gauge 59. An observation at Hell's Gate on July 14 showed sockeye to be passing in good numbers, and they apparently had been doing so since July 12, indicating that there had not been any measurable delay on at least a portion of this group of fish at Yale Rapids or Sites 2 and 3. It is concluded that the fish that reached Hell's Gate on July 12 passed upstream on the left bank at Yale Rapids, therefore avoiding Sites 2 and 3. These fish took 22 days from Hell's Gate to reach the tributaries of Middle River. A substantial percentage of the fish arriving in Forfar, Gluske and Kynoch Creeks prior to August 6 died unspawned. It is possible that these fish were largely from the previous weekend's escapement, but they may also have contained the weaker individuals from the July 7-10 escapement which were unable to withstand the added

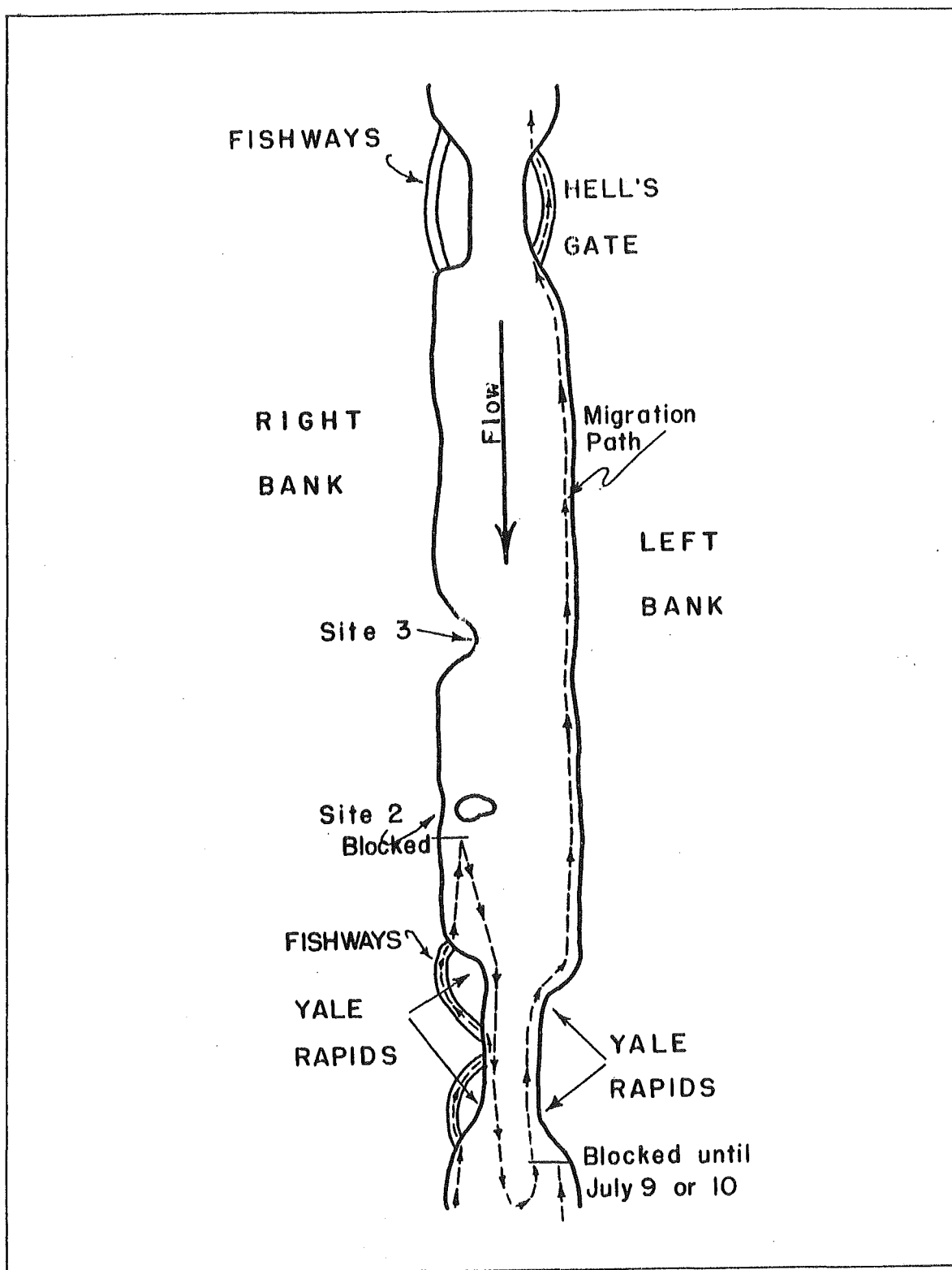


FIGURE 11 - Possible migration route from Yale Rapids to Hell's Gate of the July 2-3, 1960 Early Stuart sockeye escapement.

stress of temperatures of 64°F to 68°F in the Stuart River. It is noted that the first fish arriving in Narrows Creek on August 3 had a greater success of spawning.

The escapement of approximately 3,750 fish from the July 14-17 closure should have reached Yale Rapids on July 18-21 when the river level was between gauge 60 and 61. This level is just below the lower operating limit of the Yale fishways (FIGURE 12) and fish were reported having difficulty on the right bank at the drop adjacent to the fishway entrance with apparently very few fish successful in passing the drop. Fish were having no difficulty on the left bank, however, and apparently most of this escapement passed upstream on the left bank. These fish would have arrived at Hell's Gate the next day, and would have been able to pass through the left bank high level fishway. The right bank would have been blocked since fish apparently are not able to reach the right bank high level fishway until gauge 58. Fish approaching Yale Rapids on the right bank, or crossing over to the right bank above Site 3 could have been delayed at least 2-3 days due to the necessity of crossing over to the left bank to avoid the block at Yale Rapids and Hell's Gate. When this group of the escapement reached the Nechako and Stuart Rivers between July 30 and August 4 they would have encountered water temperatures of 73°F to 74°F in the Nechako River and 67°F to 69°F in the Stuart River. It is possible that those fish which had been delayed were not able to withstand these high water temperatures so close to the spawning ground and would have died without spawning.

The escapement of approximately 3,000 fish from the July 21-24 closure should have arrived at Yale Rapids on July 25-28 when the river was between gauge 53 and 48. They should not have had any difficulty at Yale Rapids, and no evidence of any block at this site was observed on July 27. These fish should have been able to pass Hell's Gate on both banks, but no conclusion can be made regarding Sites 2 and 3. These fish also would have encountered high temperatures in the Nechako and Stuart Rivers and may have suffered some mortality of the weaker individuals.

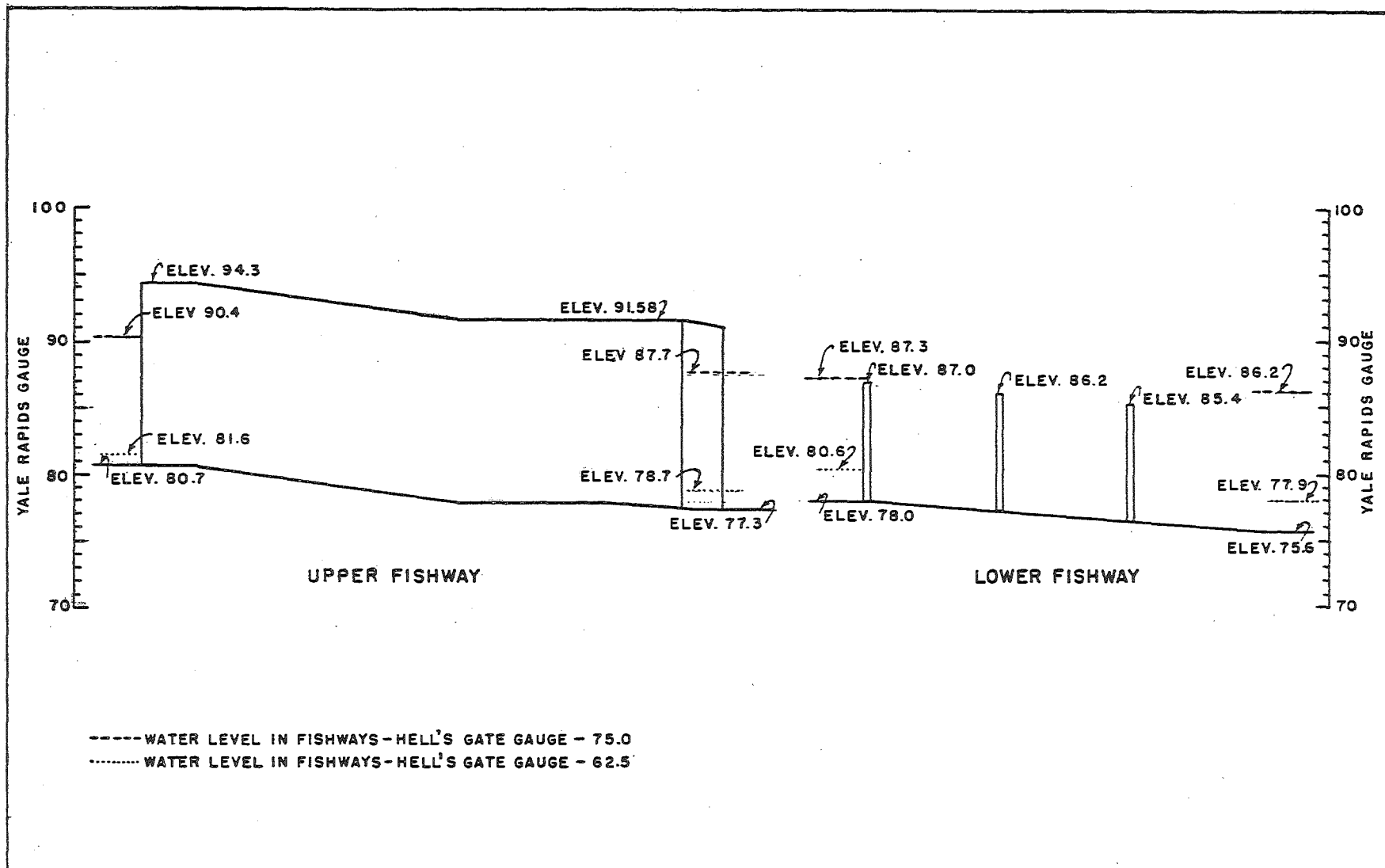


FIGURE 12 - Profile of the Yale Rapids Fishways.

CONCLUSIONS

The total size of the Early Stuart sockeye run can be grouped into three distinct groups for the period from 1900 to 1961 - poor abundance (1900-1914); mediocre abundance (1915-1948); good abundance (1949-1961). This run has periodically encountered blocks to its upriver migration to the spawning grounds which have severely limited the number of fish actually reaching the spawning grounds and spawning effectively. The partial correction of these blocks has permitted this run to increase its production significantly since 1949 so that it is now producing more sockeye than it ever has in its history. This increased production has amounted to an increased catch valued at almost \$9 million for the 13 year period from 1949 to 1961. It is not possible to determine exactly how large this run could become with the complete elimination of all blocks, but it might become one of the major producers of sockeye salmon in the Fraser River watershed.

The present status of the four blocks discussed in this report, as of the end of 1961, are shown graphically in FIGURE 13, in comparison with the status of these blocks prior to any improvements. From the available information, the following conclusions are drawn with respect to obstructions at high river levels to the migration of Early Stuart sockeye runs in the Fraser Canyon. These conclusions were tested against known events during the runs of 1933, 1954, 1955 and 1960, as illustrated previously in FIGURES 5, 7, 10 and 12 respectively.

1. There are as many as four points of obstruction in the Lower Canyon which caused or contributed to the loss and delay of spawners from the 1933, 1954, 1955 and 1960 Early Stuart sockeye runs.

(i) Hell's Gate

Thompson (1945) showed that after the slide and prior to the construction of the fishways at Hell's Gate, sockeye runs were blocked between gauges 26-40 and above except for brief openings at 40 and 50. On the basis of model studies the left bank was always blocked above gauge 50 while the right bank had only limited passage

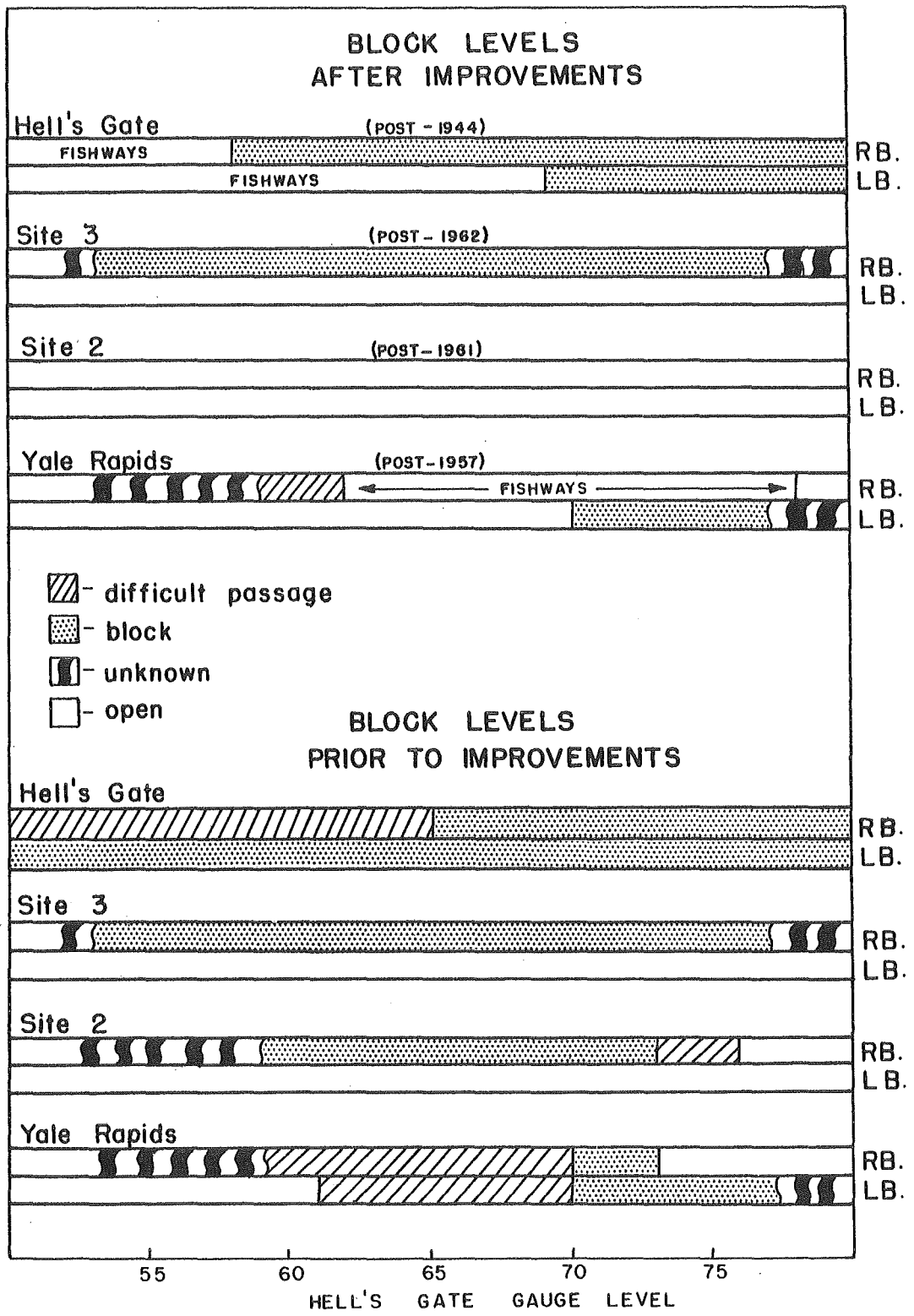


FIGURE 13 - Block levels of certain Fraser Canyon obstructions after and prior to improvements.

between gauges 50-65 and was blocked above gauge 65. Historical records on the time of passage of Early Stuart sockeye confirm that some degree of passage was available at Hell's Gate between gauges 50-65. The high level fishways on both banks at Hell's Gate were designed to operate up to gauge 70. However, observations in 1954 and 1955 showed that the left bank high level fishway functioned to a limited extent up to gauge 71.6, indicating that some fish actually sounded to enter the fishway. Also, observations in 1950 showed that the turbulence along the right bank prevents sockeye from reaching the right bank high level fishway at river levels above gauge 58. Therefore, there is a complete obstruction at Hell's Gate at river levels above gauge 71.6 and passage on the left bank only at river levels between gauge 58 and 71.6.

(ii) Site 3 - 3.5 miles above Yale, Right Bank only

The available data is not sufficient to distinguish the effect of the drop at this point from the effect of drops downstream. Physical measurements indicate very strongly that this drop would block the movement of sockeye along the right bank over a wide range of river levels from at least gauge 77 possibly down as low as gauge 53. Records of past runs indicate that if there is a block at this point, sockeye are able to get past by moving to the other side of the river. Evidence of the existence of a block is speculative, involving at worst a delay of 1 or 2 days for fish to cross to the other bank of the river.

(iii) Site 2 - 3.3 miles above Yale, Right Bank only

This drop blocked the movement of fish along the right bank upstream from the Yale Rapids fishways over a range of river levels extending from gauge 74 down to at least gauge 59. From gauge 74 to 76 the drop was not a complete block, but a point of very difficult passage which limited the number of fish passing. The effect of this drop on sockeye migration could not have been observed in 1955 since fish were stopped at Yale Rapids immediately downstream. The effect became obvious in 1960 since it stopped the migration of fish which had passed through the fishway

at Yale Rapids. Detailed examination of this drop in 1960 indicated that it could easily be remedied at minor cost by removal of two bedrock pinnacles protruding from the river bed. It was recommended that this work be done early in 1961 prior to the 1961 sockeye runs. The work was completed in April, 1961 and measurements made during the 1961 high water on the Fraser River, together with observations of the movements of the early sockeye run, indicate that there is no longer any obstruction at this point. Comparative water surface profiles before and after this work are shown on FIGURE 14.

(iv) Yale Rapids, Right and Left Banks

(a) Right Bank

The two drops on the right bank at Yale Rapids are known to have been an obstruction between gauges 70 and 73. Apparently above gauge 73 there was no obstruction because of the side channels formed at the upper drop. FIGURE 15 shows water surface profiles for the right bank at Yale Rapids. The appearance of the side channels is noted by the dotted portions of profiles 1 and 2. Observations in 1960 indicated restricted passage at the upper end of these rapids between gauges 59 and 61 and it is assumed from physical measurements that this difficult passage originally prevailed between gauge 70 and gauge 61. It is known from observations that there is no obstruction at this site at gauge 50 and judging from water surface profiles (FIGURE 15), this difficult passage probably disappears at a river level between gauge 53 and 58. The Yale fishways provide passage between gauge 78 and 62. Consequently, the remaining difficult passage occurs from gauge 62 down to some level between gauge 58 and 53.

(b) Left Bank

The two drops on the left bank at Yale Rapids are known to be an obstruction from gauge 70 up to at least gauge 77. Measurements taken up to gauge 77 show no significant change in the water surface profile over this range. There has been no evidence of any obstruction on this bank below gauge 70, at least for the size

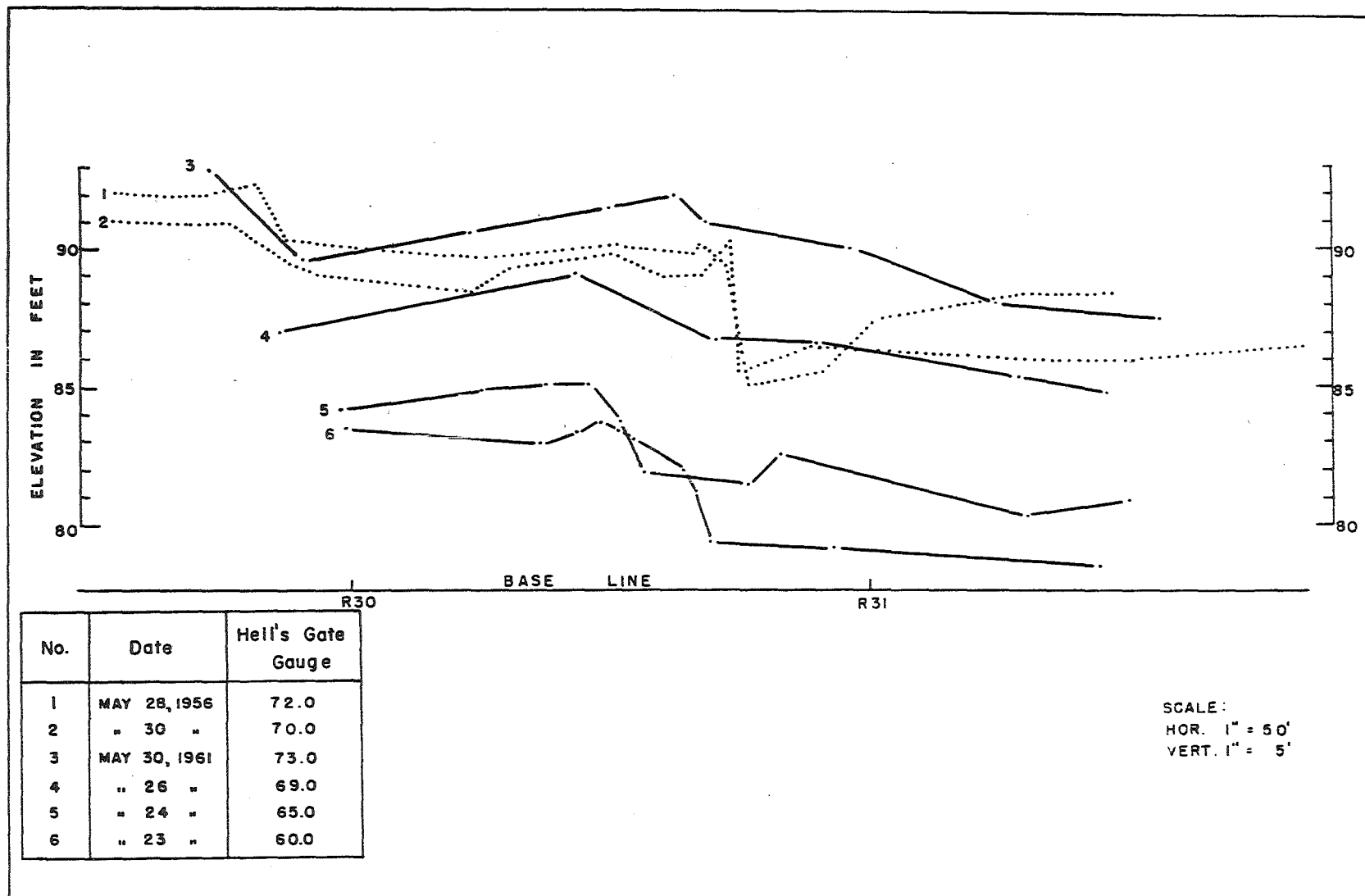


FIGURE 14 - Water surface profiles of the Right Bank of the Fraser River, 33 miles above Yale (Site 2).

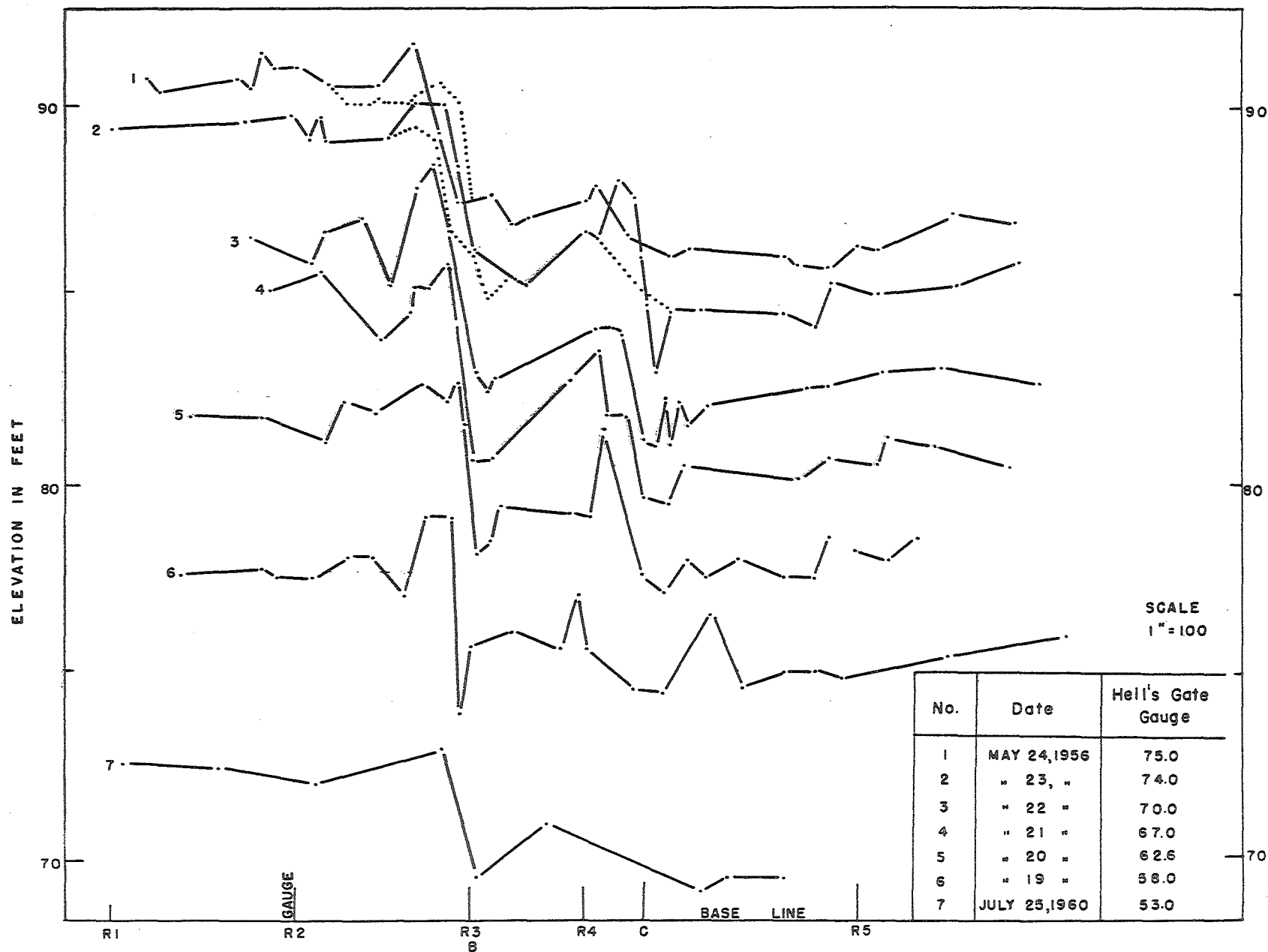


FIGURE 15 - Water surface profiles of the Right Bank of the Fraser River at Yale Rapids.

of the escapements observed, but on the basis of the water surface profiles and observations of the conditions for passage, it is believed that passage along this bank would be limited below gauge 70 down to about gauge 61.

It has not been possible to determine whether only one or both drops are responsible for the obstruction. Water surface profiles indicate that both drops are of sufficient magnitude to be at least points of difficult passage (FIGURE 16). However, the lower (downstream) drop remains almost constant throughout a wide range of river levels, whereas there is a marked change in the upper drop between gauge 74 and 70. This suggests that the upper drop is the point of obstruction, whereas the lower drop is a point of difficult passage which has not restricted passage of sockeye runs with a total escapement of 20,000 fish. The adequacy of passage at this lower drop for escapements of 200,000 or more is doubtful.

2. A combination of the blocks in 1955 permitted only 2,170 Early Stuart sockeye to reach the spawning grounds out of a total escapement of 21,000 fish. This significantly reduced escapement resulted in a relative failure of the 1959 Early Stuart run, and it is estimated that the loss to the fishing industry will be approximately \$400,000 before this cycle can be rehabilitated.

3. The loss of about 20,650 spawners from the 1960 Early Stuart run resulted from a combination of delay in the vicinity of Yale Rapids and Hell's Gate and high water temperatures in the Nechako and Stuart Rivers. The obstructions at Yale Rapids and Hell's Gate delayed at least 13,000 fish sufficiently so that they never reached the spawning grounds. An additional 4,400 fish which managed to pass these points were still delayed sufficiently so that the high water temperatures in the Nechako and Stuart systems caused a large mortality before they reached the spawning grounds. The remaining 3,400 fish in the escapement can not be accounted for and possibly comprise additional loss due to the effects of the high water temperature on slightly delayed weaker individuals. The delays near Yale Rapids were not the result of inadequacy of the existing Yale Rapids fishways, which functioned properly throughout

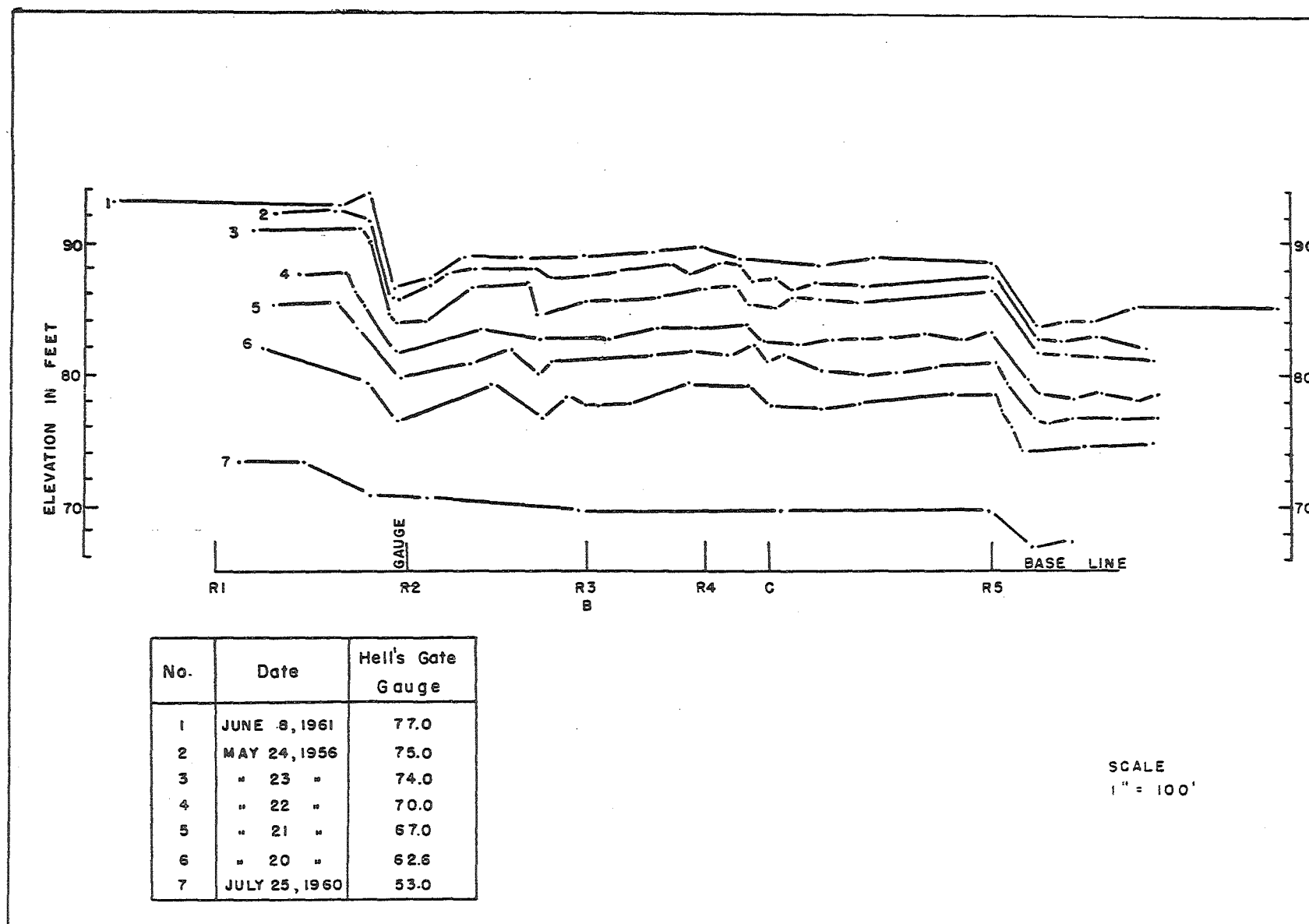


FIGURE 16 - Water surface profiles of the Left Bank of the Fraser River at Yale Rapids.

their operating range. The delays were caused by other obstructions upstream from Yale Rapids which were not known at the time of the fishway construction since the runs had not been able to reach these obstructions prior to that time. It is estimated that the 1960 block will cost the industry about \$450,000 before this cycle can be rehabilitated.

RECOMMENDATIONS

Before making any specific recommendations for the correction of these blocks, there are certain problems that should be recognized. First of all, there is the question of how large an escapement these facilities should be designed to handle. Since some of these blocks have existed periodically from historical times, estimates based on historical run size obviously are not accurate for the eventual run size that will exist after the blocks are all removed. As stated previously, as these blocks are totally or partially eliminated, the production of the Early Stuart run should continue to increase and it is impossible to state at this time just how large the run could become. Practical considerations make it necessary to put a reasonable limit on the size of the structures recommended at this time. However, it is entirely possible that, once freed from the damaging effects of these blocks and with continuing proper management, the Early Stuart sockeye run will increase its production far beyond anything realized to date and could become so large that any current proposed facility could not properly handle the magnitude of the escapement. It must be recognized that if at some future date this situation does occur, these facilities would have to be expanded to accommodate the increased numbers of fish.

Furthermore, it should be recognized that the corrections recommended in this report may not eliminate all the blocks that are present. Certain areas could be blocks at certain water levels, but their effect could be masked by a block further down the river. This was the case with the block at Site 2 inasmuch as the fish were already blocked at Yale Rapids and could not reach this site. With the construction of the Yale Rapids fishways, the block at Site 2 then became apparent. Site 3 might

be similarly affected since an obstruction at this point is, at this time, only speculative.

1. Hell's Gate

The maximum recorded river level during the period of migration of Early Stuart sockeye is gauge 93. This river level has occurred once in 49 years of record and lasted only one day, but the river level remained at gauge 90 or above for a period of five days. Allowing an estimated one foot reduction in level because of diversion of the Nechako River by the Aluminum Company of Canada, the maximum level would be gauge 92. It is known that Hell's Gate would be an obstruction to sockeye migration on the left bank at all levels above gauge 71.6 and on the right bank at all levels above gauge 58. In order to remove this obstruction, it is recommended that the operating limit of at least the left bank fishway be extended to gauge 92. Extension of the operating limit of the right bank high level fishway and the provision of adequate approach to the fishway along the right bank would be a much more difficult and expensive undertaking. It is not recommended that this be done until, and unless, the added facilities are considered necessary due to increased size of runs. Provision of passage at high levels on one bank only at this time will necessarily cause a delay of 1 or 2 days for the portion of each migration that approaches Hell's Gate on the right bank. However if no other delays are encountered, such a delay is not considered to be too serious.

2. Site 3-3.5 Miles Above Yale

The existence of an obstruction at this point is speculative. All the available evidence indicates that sockeye have been able to proceed upstream past this drop by some means, which may include crossing the river to the left bank. Because of the lack of evidence of a block at this point, it is therefore recommended that no action be taken at this time, but that the drop be closely watched until some definite evidence can be obtained on the success of fish passage.

It was hoped this could be done after the 1960 run, but low river levels during the Early Stuart migration prevented this in both 1961 and 1962.

3. Site 2 - 3.3 Miles Above Yale

The obstruction at this point has been removed by remedial measures undertaken in the spring of 1961 and no further action is considered to be necessary. (Internat. Pacific Salmon Fish. Comm., 1962).

4. Yale Rapids - Right Bank

The available evidence indicates that passage for sockeye along the right bank at Yale Rapids may be restricted for a range of river levels from gauge 62 to some level between gauge 58 and gauge 53. If a large migration reaches this point at these river levels, conditions approaching a block could result on the right bank but passage would be available on the left bank. Accumulative delay in passage to a portion of each escapement as a result of making several crossings from one bank of the river to the other in the section between Yale and Hell's Gate should be avoided, since it is known that as little as four days delay could be critical for this early run. Examination of the frequency of river levels at which river levels of gauge 53 to 62 would occur during early Stuart sockeye migrations shows that such levels have occurred for varying periods up to 25 consecutive days on 43 out of 49 years. Therefore, it is recommended that passage for sockeye be improved at the right bank of Yale Rapids to extend down to gauge 53 with a minimum of three feet of operating level at that gauge. It is recommended that this improvement be effected by means of a rock cut, parallel to the existing fishway, excavated in such a manner that it would provide a channel for increasing the capacity of existing fish passage facilities above gauge 62 at some future date.

5. Yale Rapids - Left Bank

The available evidence indicates that this bank is obstructed at river levels from gauge 70 up to an unknown level and that for large escapements passage probably is

limited from gauge 70 down to about gauge 61.

On the basis of the above evidence, it is recommended that a fishway be provided at the upper drop to operate over the range from gauge 61 to gauge 92, with a minimum of three feet of operating level at gauge 61, and that passage be improved over the same range at the lower drop by excavating a channel through the rock ledge creating the restriction at this point.

LITERATURE CITED

- Henry, K.A. 1961. Racial identification of Fraser River sockeye salmon by means of scales and its application to salmon management. Internat. Pacific Salmon Fish. Comm., Bull. 12, 97 pp.
- Idler, D.R. and W.A. Clemens. 1959. The energy expenditures of Fraser River sockeye salmon during the spawning migration to Chilko and Stuart Lakes. Internat. Pacific Salmon Fish. Comm., Prog. Rept. 6, 80 pp.
- International Pacific Salmon Fisheries Commission. 1944. General engineering report covering Fraser River fisheries projects. Manuscript.
1956. Ann. Rept. for 1955. 41 pp.
1962. Ann. Rept. for 1961. 43 pp.
- Jackson, R.I. 1950. Variations in flow patterns at Hell's Gate and their relationship to the migration of sockeye salmon. Internat. Pacific Salmon Fish. Comm., Bull. 3, Pt. 2: 85-129.
- McHugh, J. 1915. Report on the work of removal of obstructions to the ascent of salmon on the Fraser River at Hell's Gate, Skuzzy Rapids, China Bar and White's Creek during the year 1914, and the early portion of the year 1915. Forty Eighth Annual Report, Fisheries Branch, Dept. of the Naval Service 1914-15. Sessional Paper 39: 263-275.
- Pretious, E.S. and W.F. Hiltner. 1942. Hydraulic model of Hell's Gate Canyon Fraser River, British Columbia. Part one. Construction, and correlation to River. A report to the International Pacific Salmon Fisheries Commission. Manuscript.
- Thompson, W.F. 1945. Effect of the obstruction at Hell's Gate on the sockeye salmon of the Fraser River. Internat. Pacific Salmon Fish. Comm., Bull. 1, 175 pp.