LOWER DESCHUTES RIVER, OREGON;

DISCHARGE AND THE FISH ENVIRONMENT

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Oregon State Game Commission
Portland, Oregon

Lower Deschutes Flow Study Final Report

November 1967

Abstract

The lower Deschutes River of northcentral Oregon has a historically uniform discharge record. Significant reductions in discharge below the seasonal norms will degrade the environment for migratory and resident salmonids by increasing siltation and gravel compaction, and by reducing intragravel water dissolved oxygen content. Fish spawning will be limited by reductions in amount of spawning gravel available at preferred water depths and velocities. Minimum discharge recommendations are specified that will meet fish requirements.

Data are presented on stream discharge; water quality; gravel bar distribution, size, and composition; recreational usage; trout and salmon spawning numbers, distribution, and embryo survival; water flow over spawning gravels and fish preferences; and the intragravel environment of spawning beds including the dissolved oxygen content of intragravel water, gravel permeability, and intragravel water temperatures.

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Note: Detailed Tables of Contents appear at the beginning of each part.

Introduction

This report is a summary of data and observations gathered during what came to be commonly known as the Lower Deschutes Flow Study. Based on preliminary work by Montgomery and Lichens, the study started in early 1961 under the instigation of Federal Power Commission licensing of Pelton and Round Butte hydroelectric projects. Licensing provisions established certain minimum discharge standards to be met at these project, subject to review after two year's operation of the Round Butte project. The purpose of the Lower Deschutes Flow Study and this report is to furnish information and recommendations pertinent to this review.

Field work for this study was accomplished by personnel of the Oregon State Game Commission with some direct assistance from conservation personnel of the Confederated Tribes of the Warm Springs Reservation. Other assistance and cooperation was provided by the U. S. Geological Survey, Bureau of Indian Affairs, U. S. Fish and Wildlife Service, Bureau of Land Management, Portland General Electric Company, Fish Commission of Oregon, Oregon State Water Resources Board, and Oregon State University.

Oregon State Game Commission personnel assisting on this project included Donovan N. King, Jr., Julius B. Massey, Ronald S. Rohweder, Kenneth L. Witty, Norman L. Behrens, and Ronald R. Bartels of the Central Region; James M. Hutchison, Robert W. Phillips, William E. Pitney, Gregory J. Hattan, Kenneth E. Thompson, and Gary Hewitt of the Basin Investigations Section; and Andy Smith, superintendent of Oak Springs Hatchery (several of these staff members have subsequently retired, received promotions, or have resigned.)

Except where otherwise credited, all photographic and illustrative work were done by the authors. Harold Smith, Game Commission staff artist, prepared Figs. 2.2.2 and 4.1.1.

Statistical consultation and advice were provided by Dr. Lyle Calvin of Oregon State University and Dr. Quentin D. Clarkson of Portland State College. Computer programming was by Florence Harteloo, formerly of Clark College, Vancouver, Washington, where reports and analyses were made using an IBM 1620 computer.

Special thanks are due Mr. and Mrs. Zane Jackson of Warm Springs, Oregon for welcoming our use of their river frontage; Zeke Madden of Portland General Electric for advice, cooperation and valuable liaison; Don McLucas, formerly of Maupin, Oregon for advice and cooperation; Al Troutman, Maupin, for advice and assistance; Jim Palmer, formerly of Maupin, for assistance and cooperation; Mrs. Jones, Deschutes Motel, Maupin, for hospitality; Art Sharp, The Dalles, Oregon for allowing use of his access road; and to Earl Miller and Cecil Bruno of Warm Springs for much assistance, cooperation and advice.

Background information for Part One was obtained from the Oregon Historical Society; the Spokane, Portland and Seattle Railroad; and the Union Pacific Railroad.

In its basic form, this report is published in five parts: Study Area Description; Trout and Salmon Spawning; Water Flow Over Spawning Gravels; Intragravel Environment of Spawning Gravels; and Conclusions and Recommendations. These cover the major efforts of this study -- evaluations and surveys of current spawning, measurement of conditions where spawning occurs, an evaluation of the intragravel environment, and recommendations based on these evaluations and measurements.

Warren W. Aney
December 26, 1967
Portland, Oregon

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PART ONE
Study Area Description

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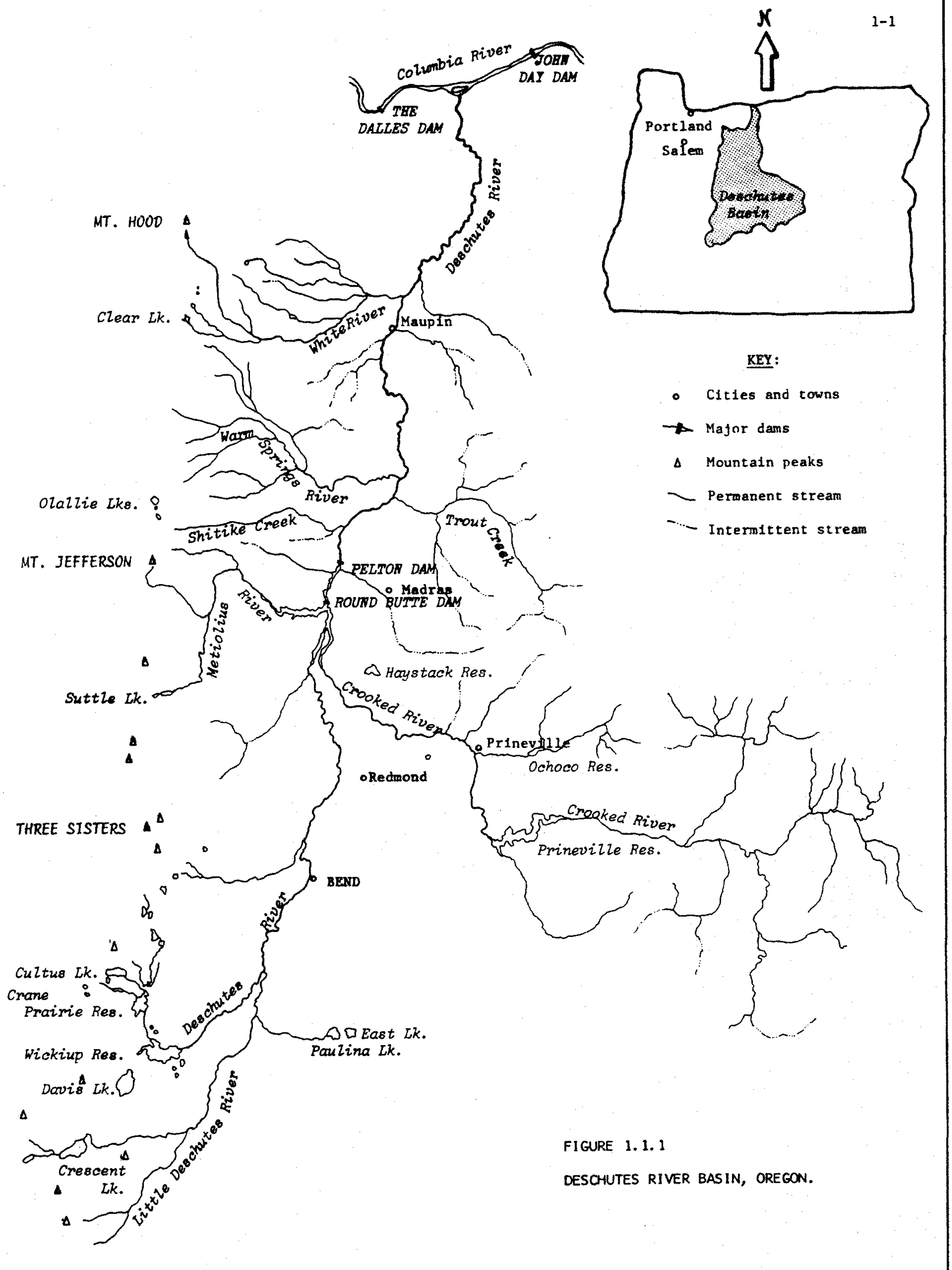

FIGURE 1.1.1

DESCHUTES RIVER BASIN, OREGON.

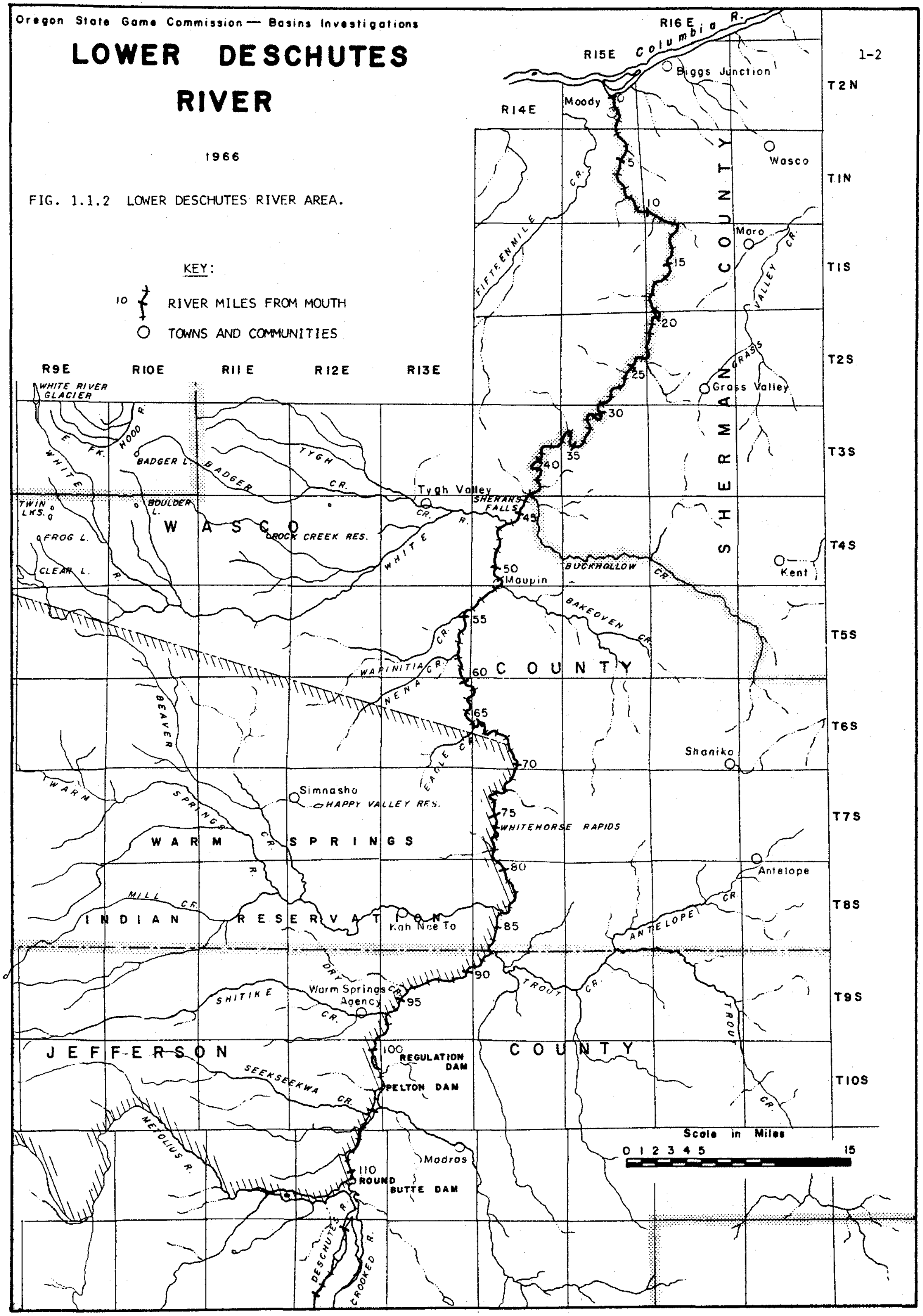

FIG. 1.1.2 LOWER DESCHUTES RIVER AREA.

Part One. Study Area Description

Physical Description

1.1 Geographical Location

The Deschutes River basin occupies most of central Oregon. From its sources in the high Cascade Range the river flows east and north to its mouth on the Columbia River 204 miles from the ocean. The basin covers 10,400 square miles and is 170 air line miles long by 125 air line miles wide, greatest dimensions (Ore. State Water Resources Board, 1961). See Fig. 1.1.1. The Deschutes River watershed ranks with the Willamette watershed as largest in the state of Oregon.

Of the major tributaries only Crooked River has its source in the eastern side of the basin. All other major tributaries, the Metolius, Warm Springs, and White Rivers, flow out of the Cascades on the west side of the basin.

Our study encompassed that part of the Deschutes River below the Pelton-Round Butte Dam complex. This river section, 100.1 miles long, we refer to as the lower Deschutes River (Fig. 1.1.2). The two largest tributaries within the study area are the Warm Springs and White Rivers. Shitike Creek is the only other tributary providing a substantial year-round stream flow. Anadromous fish runs are found in the Warm Springs River and Shitike Creek but not in White River which is blocked 2 miles above its mouth by a 100-ft. falls. Smaller tributaries known to be used by anadromous fish are Trout, Nena, Wapinitia, Bakeoven, and Buckhollow Creeks.

For purposes of this study the lower Deschutes River was divided into four stream sections based on the influence of its major tributaries: Beginning upstream at the Pelton Regulation Dam, Section I includes the portion of the study area between the dam and the mouth of Shitike Creek, a distance of 3.3 river miles. Stream Section II covers from the mouth of Shitike Creek to the mouth of Warm Springs River, a distance of 13.0 river miles. Stream Section III covers from the mouth of Warm Springs River to the mouth of White River, a distance of 37.4 miles. Stream Section IV extends 46.4 river miles from the mouth of White River to the confluence of the Deschutes River with the Columbia River. See Fig. 1.1.3.

1.2 Topography and Geology

The lower Deschutes River gorge is a narrow, winding canyon 700 to 2,200 feet deep (Fig. 1.2.1). Phil F. Brogan, in his newspaper feature articles on Oregon geology, described the gorge as follows:

> "There, Columbia basalts overlie John Day beds, which in turn rest on the ancient Clarno clays. Above massive Columbia basalts are more recent lavas which mount to the horizontal Madras rims.
>
> The lavas, with beds of soil between layers of rock, serve as graphic illustrations for Oregon's Book of the Ages. In some of the lava flows, or in soil that formed between the flows, are casts of ancient trees, or tree petrifactions.
>
> In the deep Deschutes gorge between its confluence with the Columbia and South Junction can be traced some 40 million years of history. It is a record in stone that will last for eons." (1962)

The stream elevation of the lower Deschutes River at the Pelton Regulation Dam is 1,393 feet. In 100.1 miles the river drops over 1,233 feet to meet the Columbia River at an elevation of 160 feet. The average gradient is 0.233% or 12.3 feet per mile. Major water features are Sherars Falls, a practically sheer drop of 15 feet, and White Horse Rapids with a drop of 35 feet in one mile. See Fig. 1.2.2.

The average stream width of the lower Deschutes River is 236 feet, with a range from 30 to 560 feet (excluding islands). Total water surface area is about 121 million square feet at usual discharges. See Table 1.2.1.

The lower Deschutes watershed below 2,500 feet elevation was originally open range dotted with sagebrush and juniper. Most of the deep soil areas are now used for growing grains and where irrigation is available, alfalfa hay, mint, potatoes, and similar crops. The higher elevations support extensive coniferous forests. Lower elevation perennial streams are margined with deciduous trees and brush, primarily alders and willows.

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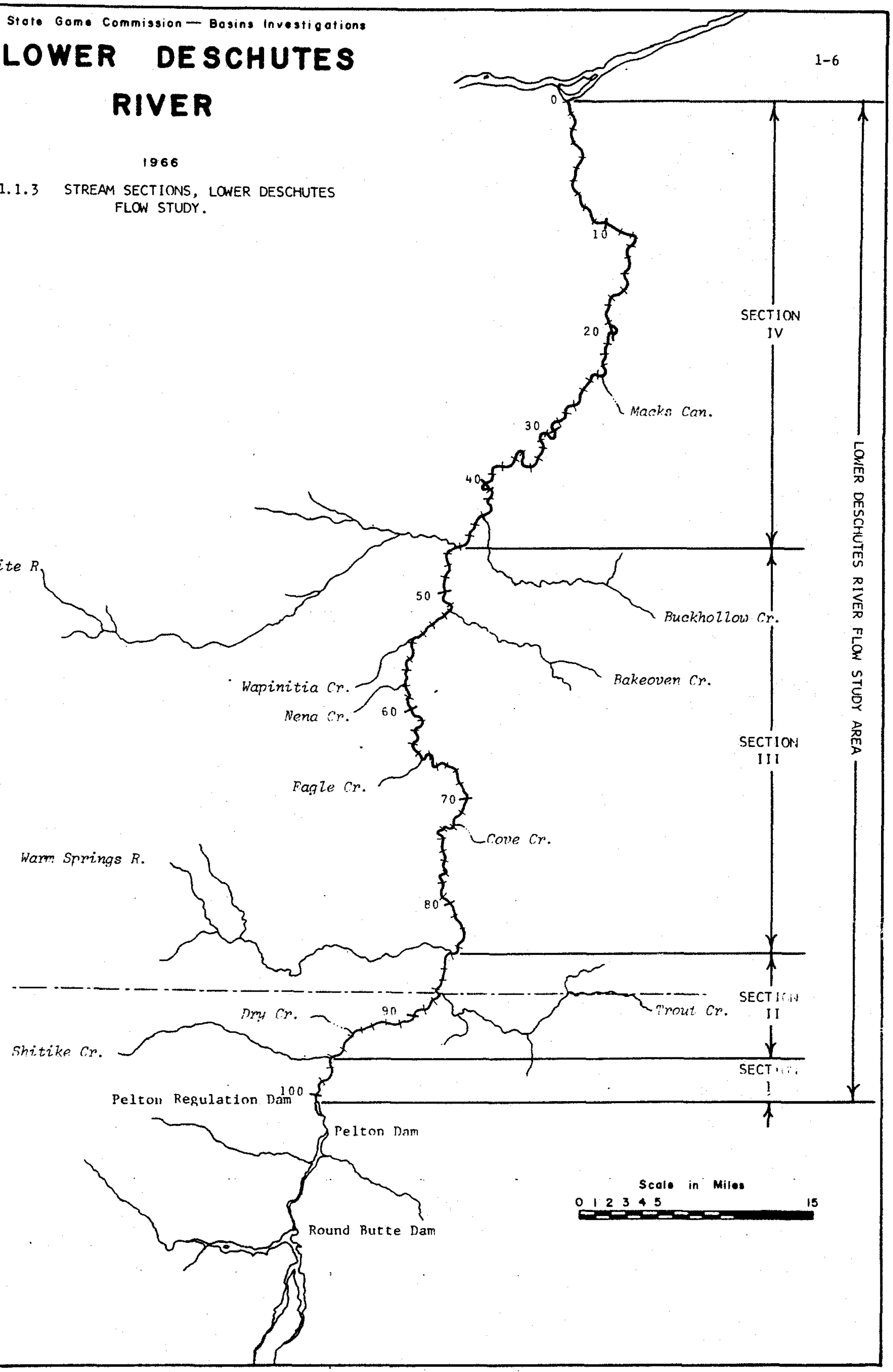
FIG. 1.1.3 STREAM SECTIONS, LOWER DESCHUTES FLOW STUDY.



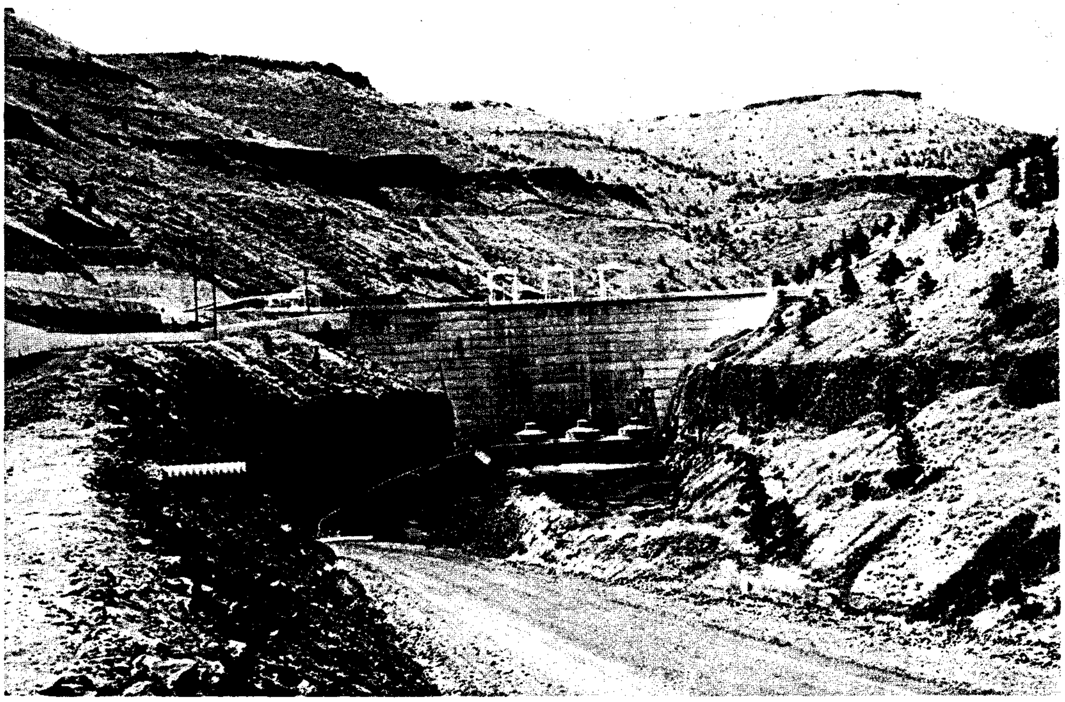


FIG. 1.1.4 PELTON DAM

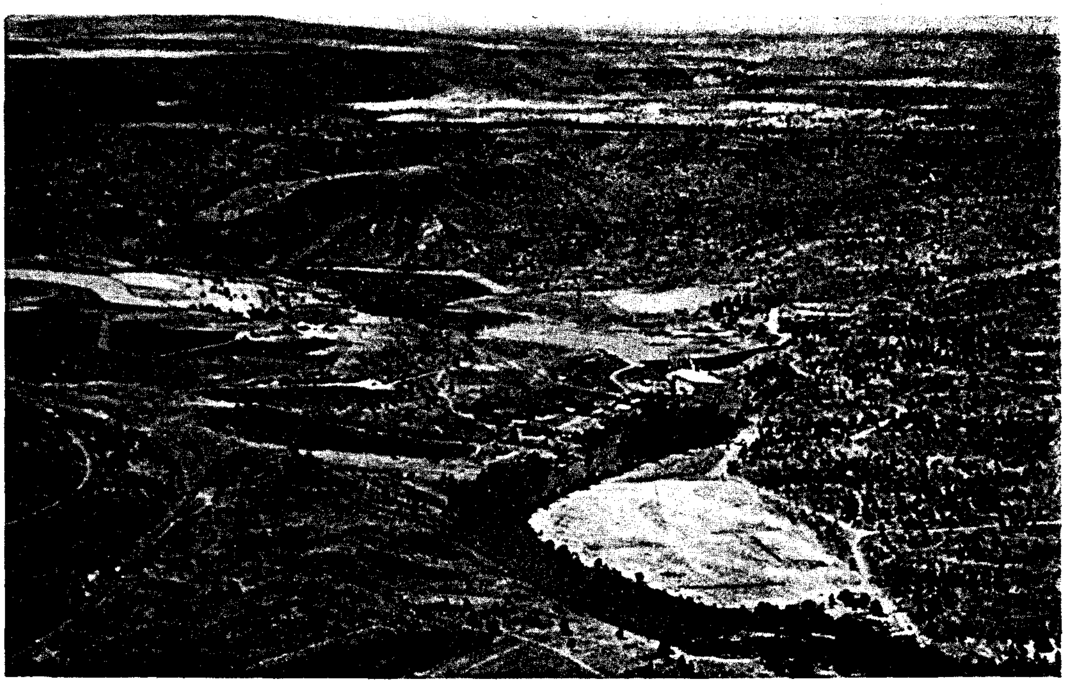


FIG. 1.1.5 PELTON REGULATION DAM, UPSTREAM END OF STUDY AREA

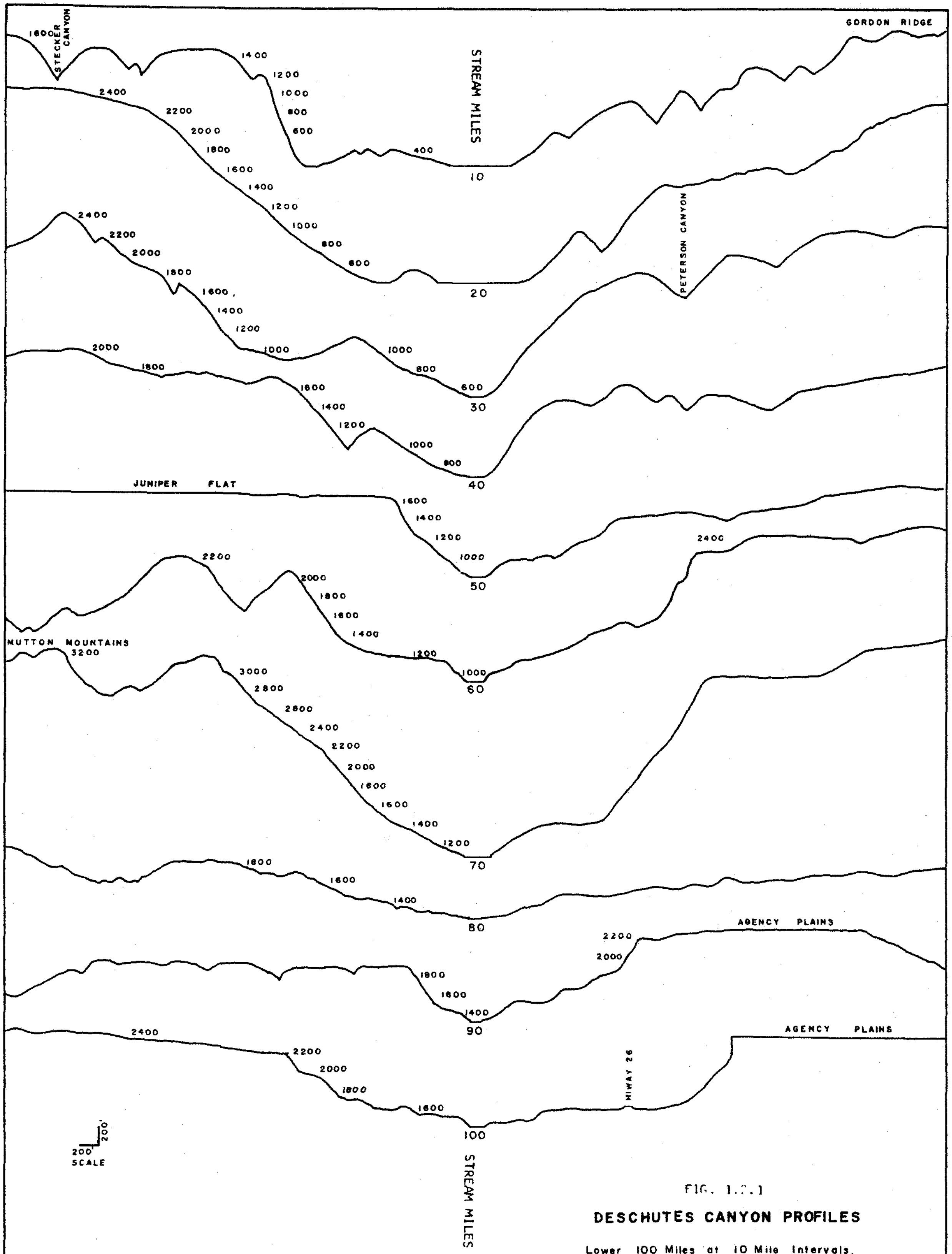


FIG. 1.[illegible].1

DESCHUTES CANYON PROFILES

Lower 100 Miles at 10 Mile Intervals.

LOWER DESCHUTES FLOW STUDY

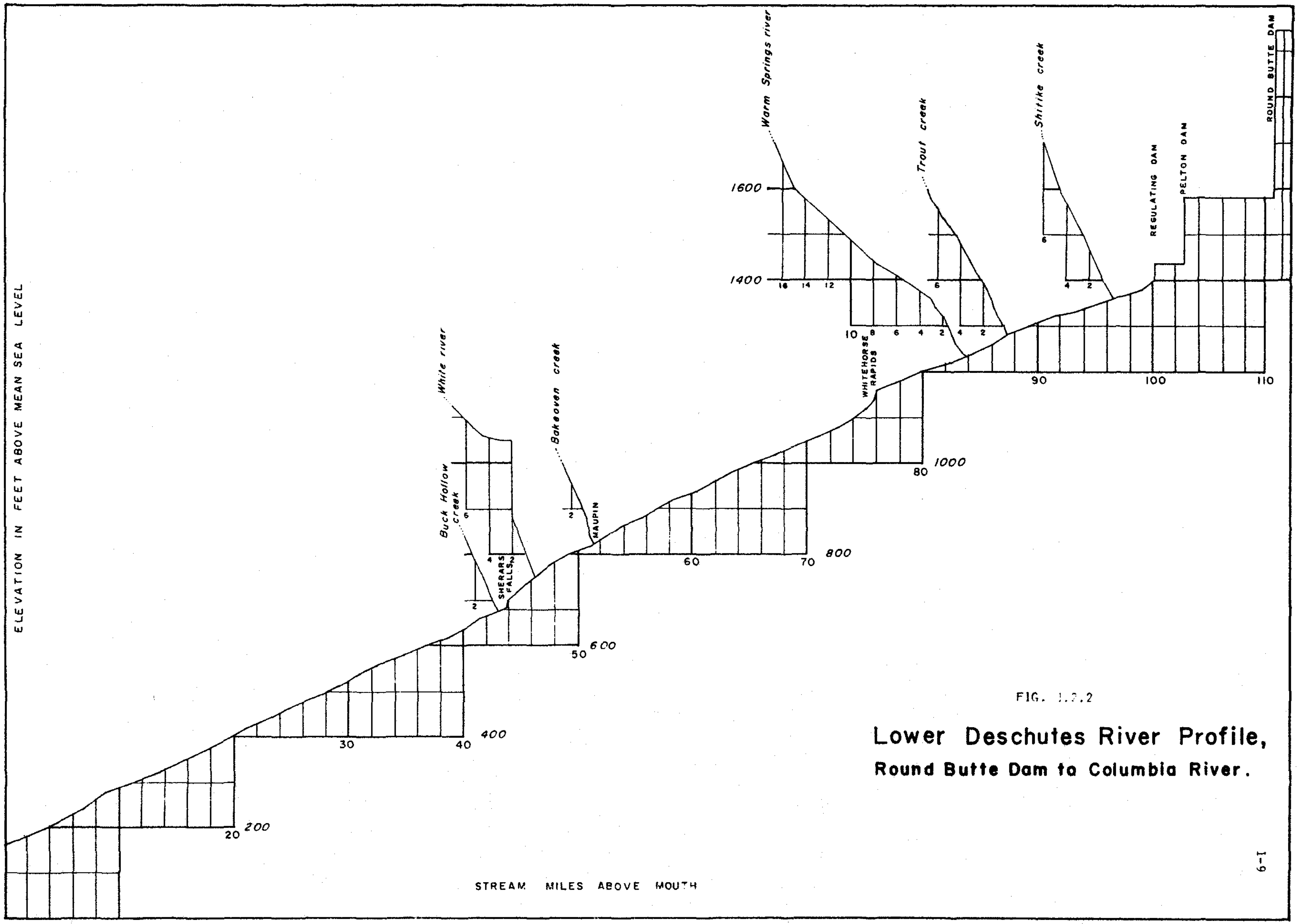


FIG. 1.2.2

Lower Deschutes River Profile,
Round Butte Dam to Columbia River.

TABLE 1.2.2

Physical Characteristics, Lower Deschutes River

	Stream Section I	Stream Section II	Stream Section III	Stream Section IV	Entire Area
Length	3.3 miles	13.0 miles	37.4 miles	46.4 miles	100.1 miles
Mean Width	230 feet	232 feet	204 feet	263 feet	236 feet
Water surface area a/	3,900 th. $ft.^2$	15,000 th. $ft.^2$	39,700 th. $ft.^2$	62,100 th. $ft.^2$	121,000 th. $ft.^2$
Island area a/	128 th. $ft.^2$	960 th. $ft.^2$	580 th. $ft.^2$	2,500 th. $ft.^2$	4,053 th. $ft.^2$
Upstream elevation	1,393 ft.	1,360 ft.	1,232 ft.	749 ft.	1,393 ft.
Downstream elevation	1,360 ft.	1,232 ft.	749 ft.	160 ft.	160 ft.
Difference (drop)	33 ft.	128 ft.	483 ft.	589 ft.	1,233 ft.
Mean gradient, %	0.189	0.186	0.245	0.240	0.233
Mean gradient, ft/mi b/	10.0	9.8	12.9	12.7	12.3

a/ th. $ft.^2$ = thousand square feet

b/ ft/mi = feet per mile

1.3 Stream Discharges

Deschutes River discharges have been exemplified for their uniformity. Miller, in his article "Rivers" in Encyclopedia Americana, states (writing about rivers fed by springs and groundwater): "Such streams have extremely uniform flow; the Deschutes River in Oregon, which drains a large volcanic area, is an example of this kind." (1957)

Maximum recorded Deschutes River discharge, 75,700 cubic feet per second (cfs) occurred on December 23, 1964. Eight within-Oregon rivers exceeded this figure but all except one recorded minimum discharges much lower than the Deschutes' minimum of 3,270 cfs (Table 1.3.1). Deschutes River discharge on over half the days on record has been between 4,000 and 6,500 cfs. Discharge has been below 3,500 cfs less than 10% of the days between 1898 and 1962 (unpublished data, U.S. Geological Survey).

Average annual runoff is over 4.2 million acre-feet of which 1.2 million acre-feet enter the Deschutes within the study area (i.e., below Pelton Dam). As shown in Table 1.3.1, only five within-Oregon rivers have greater average annual runoffs.

Deschutes River discharge measurement records are available back to 1897. Although we have no information of any prior discharge measurements, early residents wrote about an unusually high flood occurring in the winter of 1861-62. This flood carried away the original "Sherars bridge," built by John Y. Todd in 1860 (McArthur, 1929). Because the 1964 flood, largest measured discharge on record, did not touch the present Sherars bridge (Figure 1.3.1) and because it is unlikely that the early bridge would have been built at a more vulnerable site, the 1861 flood discharge could have been much greater, probably at least 100,000 cfs.

The U. S. Geological Survey (USGS) has maintained stream discharge gages near the mouth of the Deschutes River for over 60 years. A recording gage has also been maintained at the upstream end of the study area since 1923, just below the present site of the Pelton Regulation Dam. Gages were also maintained at Mecca for a period of 16 years and at Sherars for 11 years. A recording gage has been maintained on White River near its mouth since 1917. No other gages are presently maintained in the lower Deschutes River study area, although in the past several recording and staff gages were established on the mainstems and tributaries of White River, Warm Springs River, Trout Creek, Shitike Creek, and Wapinitia Creek (Table 1.3.2, Fig. 1.3.2). Table 1.3.3 lists mean monthly discharges for the lower Deschutes mainstem and its three major tributaries, based on available discharge record summaries (see also Fig. 1.3.3). The measured and estimated mean monthly stream section discharges listed in Table 1.3.4 were derived from these data.

Upstream regulation of the Deschutes River and its tributaries occurs at Ochoco and Prineville Reservoirs (Crooked River subbasin) and at Crescent Lake, Crane Prairie and Wickiup Reservoirs (upper Deschutes basin). This storage and irrigation diversion alters the upstream flow patterns of the Deschutes River from what would naturally occur without regulation. Deschutes River discharge is also profoundly affected by regulation at the Pelton-Round Butte complex. Under terms of the Federal Power Commission license and the Oregon State Water Resources Board Lower Deschutes Program, a temporary minimum allowable discharge regimen has been established for these projects. Except when the upstream inflow is less, the discharge from the Pelton Project must be at least 3,500 cfs during the months of March, April, May and June and 3,000 cfs during the remainder of the year. Normal project operation will routinely reduce discharge to these minimums during the spring and early summer to refill the project reservoirs. These minimums may also be realized during the fall and winter after periods of heavy storage releases required for power production during periods of peak power demand. This peaking operation will also result in sporadic short-term maximum discharges of 6 to 10 thousand cfs.

Whenever river discharge is reduced at Pelton Dam to the allowed minimum, downstream discharges will be correspondingly reduced depending on tributary inflow. For example, the mean January discharge for Shitike Creek for the period of record was 103 cfs. Without reduction the mean January discharge for the Deschutes River in Section I, just below Pelton Dam, is 5,307 cfs (Table 1.3.3). Therefore, the resultant mean Section II discharge for January would be 5,307 + 103 or about 5,400 cfs (Table 1.3.4). Whenever discharges at Pelton are reduced to the minimum allowed, Section I discharge becomes 3,000 cfs and Section II discharge, on the average, is most likely to be about 3,100 cfs. This latter figure is the predicted mean January discharge for Section II under minimum allowed releases from the Pelton-Round Butte projects. In a similar manner, predicted mean discharges have been determined, by month and stream section, for the entire river as listed in Table 1.3.5 (see also Fig. 1.3.5).

If higher minimum discharges were specified, this would result in higher predicted downstream discharge means, as listed in Tables 1.3.6, 1.3.7 and 1.3.8 (see also Figs. 1.3.6, 1.3.7 and 1.3.8).

Filling of the Round Butte Reservoir began on January 2, 1964. At that time river discharge was reduced to near 3,000 cfs, the allowed minimum. Except for several short periods of higher releases necessitated by facility readjustments, river discharge was maintained near this point until March 1 when it was increased to 3,500 cfs, the allowed minimum for the spring months. On July 1 it was again reduced to near 3,000 cfs where it substantially remained until a period of cold weather in mid-December stimulated the release of additional water for power production. This was soon followed by the record breaking December 1964 flood. Therefore, during the period January 1 through December 15, 1964, the lower Deschutes River experienced discharges that were essentially those minimums presently specified under state and federal restrictions. Table 1.3.9 compares the 1964 monthly means measured in study sections I and IV with those predicted in Table 1.3.5. According to these data, measured flows under minimum allowed releases averaged 163 cfs more than predicted flows in Section I, and 171 cfs less than predicted flows in Section IV. (See also Fig. 1.3.9).

There is no important discharge regulation on any of the tributaries downstream from the Pelton Project. A potential exists for regulating the flow of such tributaries as Bakeoven, Buckhollow and Trout Creeks with the construction of upstream reservoirs. These reservoirs could reduce the rapid early spring runoff and supplement low summer flows.

TABLE 1.3.1

Comparison of Discharge Records in Oregon's Ten Largest Rivers
(from U.S. Geological Survey, 1967)

River	Tributary to	Average Annual Run-off (Thousands of acre-feet)	Discharge Extremes (cfs) Maximum	Discharge Extremes (cfs) Minimum	Watershed (Thousands of sq. miles)
1. Willamette	Columbia River	25,440 a/	540,000a/	3,500a/	10+ a/
2. Rogue	Pacific Ocean	7,969 b/	450,000a/	1,000a/	5+ a/
3. Umpqua	Pacific Ocean	7,752 b/	265,000	640	3.7
4. Santiam	Willamette River	5,640	197,000	260	1.8
5. McKenzie	Willamette River	4,319	88,200	1,080	1.3
6. Deschutes	Columbia River	4,217	75,500	2,400	10.5
7. Middle Fork	Willamette River	2,944	94,000	366	1.3
8. Clackamas	Willamette River	2,500 a/	120,000	354	0.9
9. Grande Ronde	Snake River	2,323	42,200	418	3.3+ a/
10. Nehalem	Pacific Ocean	1,964	43,200	54	0.7

a/ Published figures vary or are unavailable.
b/ Derived from figures published by Wilson et al, 1967.

FIG. 1.3.1 SHERARS BRIDGE, MARCH 1910.

Ore. Historical Society photograph

TABLE 1.3.2

U.S.G.S. Stream Discharge Gaging Stations, Lower Deschutes River

Gage No.	Location	Period of Record	Average Discharge (cfs)	Average Annual Runoff (Thousands of Acre-ft.)	Maximum Discharge (cfs)	Minimum Discharge (cfs)
765	Deschutes near Culver, river mile 120.6	July 1952 on	919	665.3	6,680	418
874	Crooked R. below Opal Springs, mile 6.7	Oct. 1961 on	-	-	6,660	972
875	Crooked R. near Culver, river mile 1	Oct. 1917-Sept. 1963	1,553	1,124	8,260	920
915	Metolius R. near Grandivew, mile 13.1	Apr. 1910-Feb. 1912, Mar. 1912-Dec. 1913, Oct. 1921 on	1,483	1,074	7,530	1,080
925	Deschutes near Madras, river mile 100.1	Oct. 1923 on	4,427	3,025	15,800	1,200
930	Shitike Cr. at Warm Springs, mile 2	June 1911-Oct. 1917, Apr. 1923-Sept. 1928	107	-	1,100	32
935	Deschutes at Mecca, river mile 95.5	June 1911-Jan. 1927	4,891	-	15,800	3,170
940	Trout Cr. near Antelope	Apr-Aug. 1915, Mar. 1916-June 1917	-	-	790	0.2
945	Trout Cr. near Willowdale	? 1915-? 1916	-	-	-	-
950	Hay Cr., trib. to Trout Cr., mile 11.5	Apr-Sept. 1915, Mar-July 1916	-	-	18.5	0.4
955	Warm Springs R. at HeHe Mill	June-Sept. 1915, Aug. 1949-Sept. 1954	185	133.9	662	97
965	Mill Cr. trib. to Warm Springs R.					
970	Warm Springs R. near Kah-Nee-la, river mile 8	Aug-Dec. 1911, May 1912-Sept. 1918	461	-	2,930	166
975	Clear Cr. near Government Camp, trib. to White R.	Dec. 1940-Sept. 1941, Oct. 1946-Sept. 1953	21.8	15.78	150	1.6
980	Clear Cr. near Clear Lake trib. to White R.	Portions of 1918, 1919, 1920, 1921, 1922, 1934, 1935	-	-	-	4
985	Clear Cr. at Oak Grove road, trib. to White R.	Oct. 1917-Sept. 1918	-	-	226	-
990	White R. near Wapinitia	Oct. 1942-Sept. 1950	279	-	3,620	54
995	Gate Cr. at Purcell ranch, trib. to White R.	Nov. 1920-July 1921, July 1922, Nov. 1922-June 1923	-	-	-	0.5
1000	Gate Cr. near Wamic, trib. to White R.	Oct. 1917-Sept. 1918	-	-	128	0.4
1005	White R. near Tygh Valley	July 1911-Dec. 1918	392	-	3,800	75
1010	Tygh Cr. at Tygh Valley, mile 1.75	Portions of 1911, 1912, 1913, 1914, 1918, 1919	-	-	354	11
1015	White R. below Tygh Valley, mile 2.0	Oct. 1917 on	433	313.5	13,300	7.5
1020	Deschutes at Sherars Bridge, about mile 43	June-Sept. 1923, July-Nov. 1924, July 1925-Sept. 1923	5,020	-	32,000	3,450
1030	Deschutes at Moody, river mile 1.4	Oct. 1897-Dec. 1899 July 1906 on	5,835	4,224	75,500	3,270

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FIG. 1.3.2 STREAM DISCHARGE GAGING STATIONS.

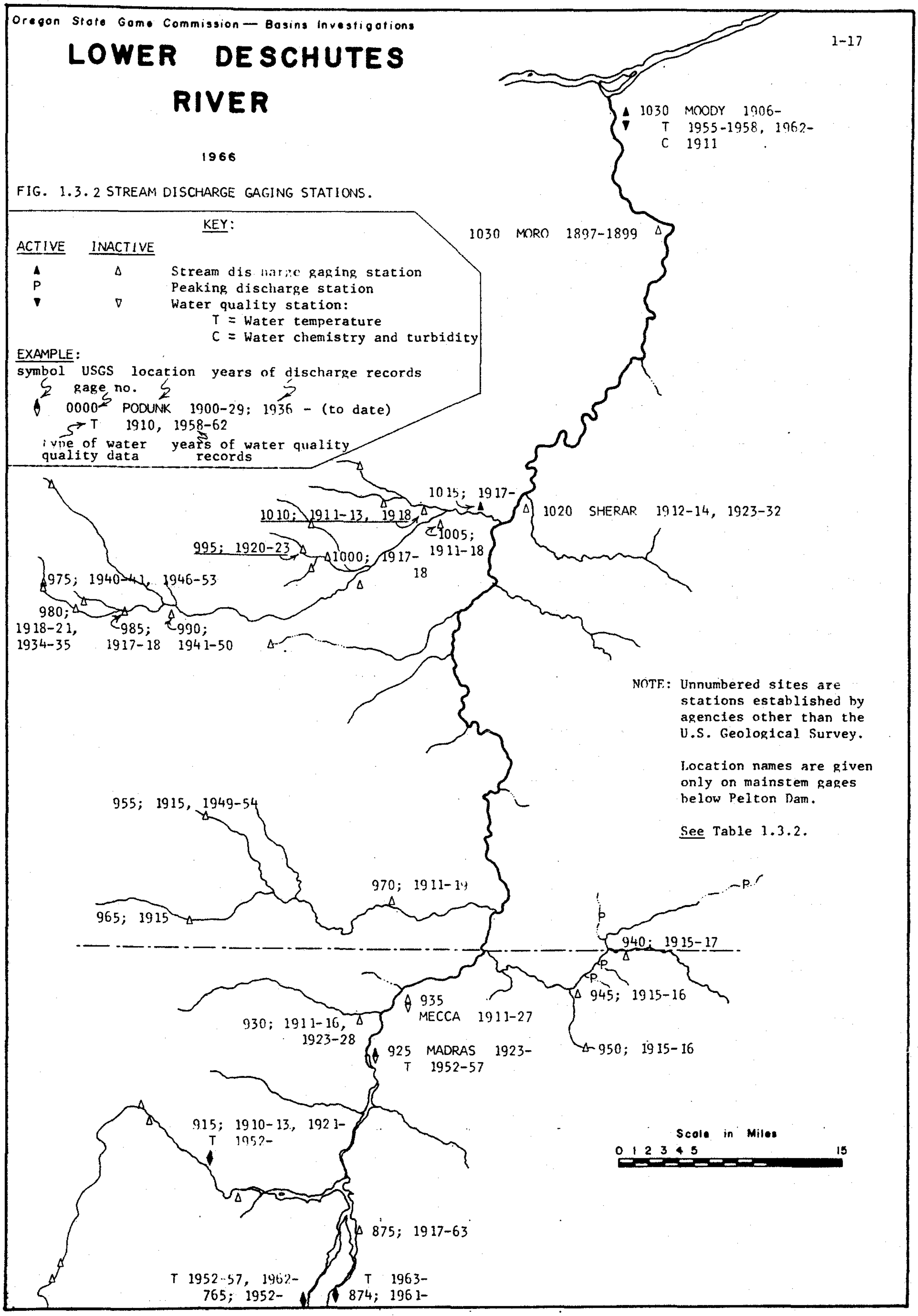


TABLE 1.3.3

Mean Monthly Discharges,
Lower Deschutes Mainstem and Tributaries

Month	Deschutes Below Pelton[a]	Shitike Creek[b]	Warm Springs River[c]	White River[d]	Deschutes at Mouth[e]
January	5307 cfs	103 cfs	467 cfs	620 cfs	6718 cfs
February	6352	141	547	797	8156
March	6422	121	620	631	7748
April	6424	139	685	839	7983
May	5543	157	672	937	7115
June	5163	143	509	607	6269
July	4324	108	357	235	4954
August	4165	67	293	156	4694
September	4148	61	285	142	4654
October	4282	65	291	195	4839
November	4732	98	302	327	5443
December	5078	92	417	517	6210
Mean	5153 cfs	108 cfs	453 cfs	498 cfs	6219 cfs

[a] USGS gage near Madras, water years 1948-62.

[b] USGS gage at the Warm Springs Agency, 1911-16 and 1923-28.

[c] USGS gage near the present location of Kah-Nee-Tah Resort, 1912-13 and 1914-19.

[d] USGS gage below the town of Tygh Valley, water years 1948-62.

[e] USGS gage near Moody, water years 1948-62.

FIG. 1.3.3

MEAN MONTHLY DISCHARGES,
LOWER DESCHUTES RIVER MAINSTEM AND TRIBUTARIES.

(SEE TABLE 1.3.3)

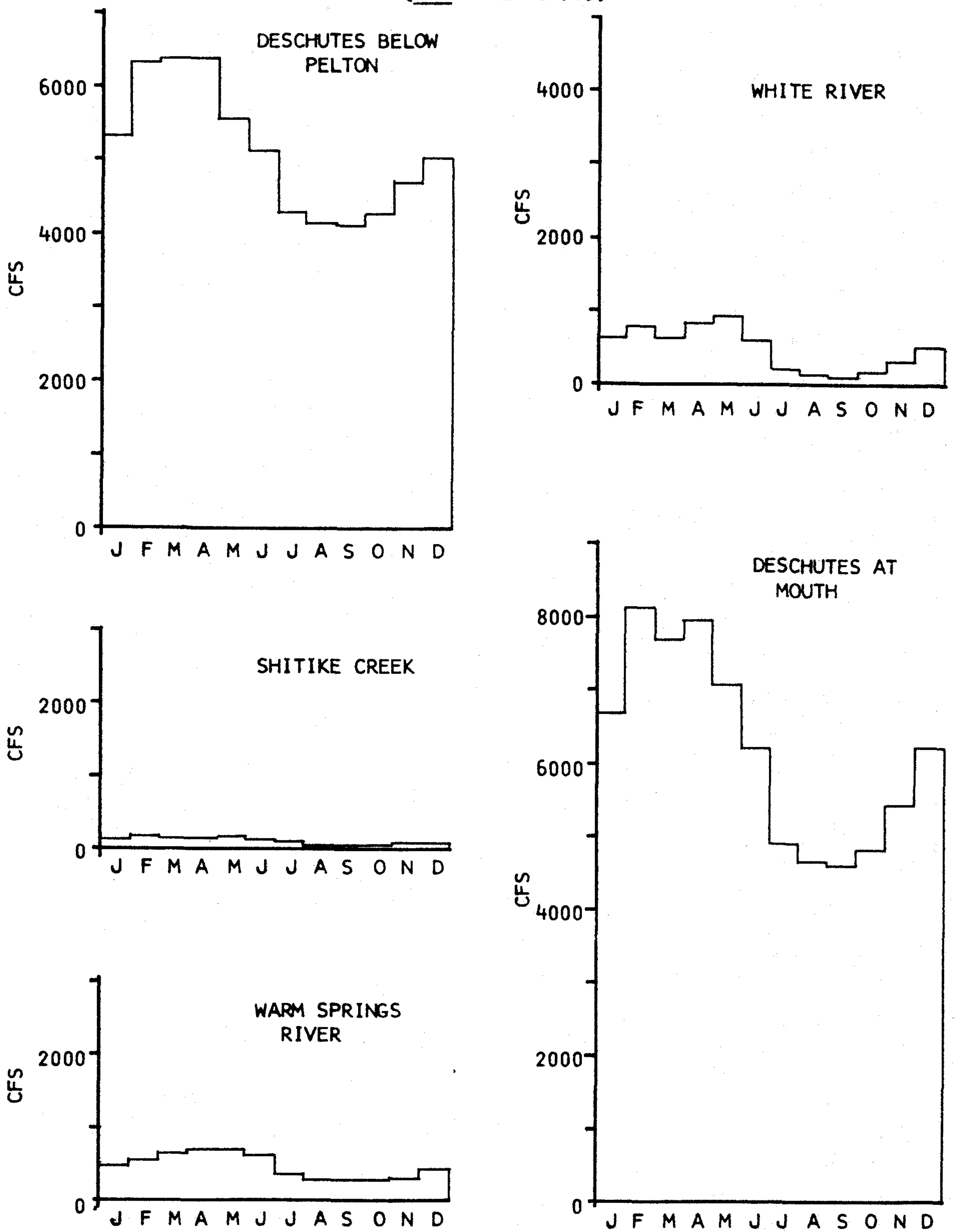


Table 1.3.4

Estimated Mean Monthly Discharges by Stream Section, Lower Deschutes River

Month:	Section I	Section II	Section III	Section IV
January	5300 cfs	5400 cfs	5980 cfs	6720 cfs
February	6360	6500	7200	8160
March	6420	6540	7140	7740
April	6420	6560	7200	7980
May	5540	5700	6280	7120
June	5160	5300	5740	6260
July	4320	4440	4760	4960
August	4160	4240	4540	4700
September	4140	4200	4500	4660
October	4280	4340	4640	4840
November	4740	4820	5120	5440
December	5080	5160	5640	6200
Mean	5151 cfs	5258 cfs	5718 cfs	6219 cfs

Constructed from USGS stream gage records (See Table 1.3.3) as follows:

Section I D_1 = Deschutes River monthly means as measured at stream gage near Madras (river mile 100.1), water years 1948-62;

Section II $d_2 = D_1 + S$, where S = Shitike Creek monthly means as measured at stream gage near Warm Springs Agency, water years 1911-16 and 1923-28;

Section III $d_3 = \frac{(D_1 + S + W_a) + (D_4 - W_h)}{2}$, where W_a = Warm Springs River monthly means as measured at stream gage near the present location of Kah-Nee-Tah Resort, water years 1912-13 and 1914-19; and W_h = White River monthly means as measured below Tygh Valley, water years 1948-62;

Section IV D_4 = Deschutes River monthly means as measured at stream gage near Moody, river mile 1.4, water years 1948-62.

FIG. 1.3.4

ESTIMATED MEAN MONTHLY DISCHARGE BY STREAM SECTION, LOWER DESCHUTES RIVER

(SEE TABLE 1.3.4)

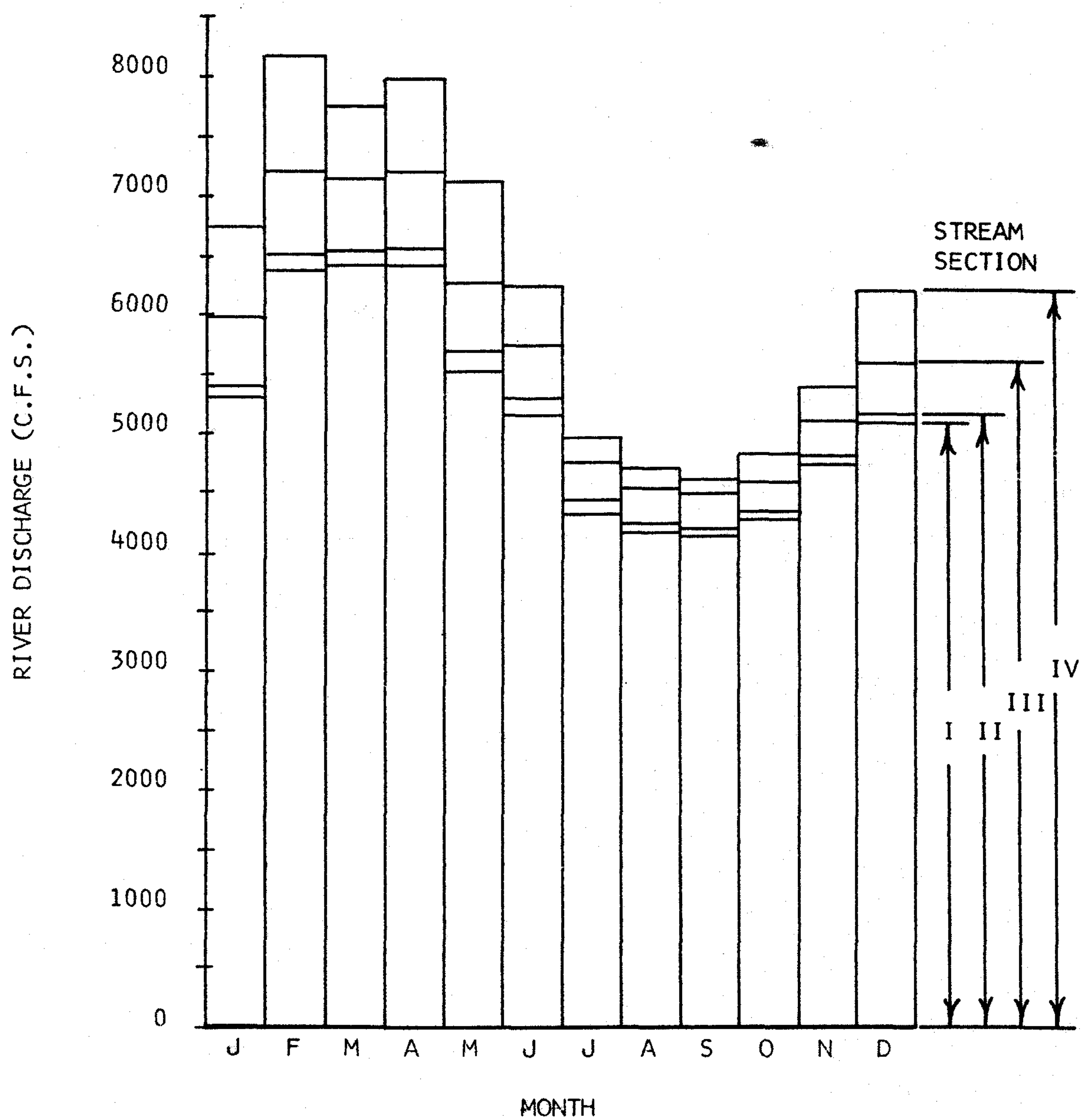


TABLE 1.3.5

Predicted Mean Discharges, by Month, Under Minimum Allowed Releases[a] from Pelton-Round Butte Projects, Lower Deschutes River

Month	Section I	Section II	Section III	Section IV
January	3000	3100	3680	4420
February	3000	3140	3840	4800
March	3500	3620	4220	4820
April	3500	3640	4280	5060
May	3500	3660	4240	5080
June	3500	3640	4080	4600
July	3000	3120	3440	3640
August	3000	3080	3380	3540
September	3000	3060	3360	3520
October	3000	3060	3360	3560
November	3000	3080	3380	3700
December	3000	3080	3560	4120

[a] Based on Federal Power Commission decision of September 12, 1960:

(Article 37) "During construction and the first two years of operation of the Round Butte development the Licensee (Portland General Electric Company) shall maintain minimum stream flows at river mile 100.0 during the months of March, April, May and June in the amount of 3,500 cubic feet per second or the inflow to the...reservoirs, whichever is less..."

and Oregon State Water Resources Board order of November 25, 1959:

(5) "The licensee shall maintain a minimum flow, main stem Deschutes River, at river mile 100.0, of not less than 3,000 cubic feet per second..."

FIG. 1.3.5

PREDICTED MEAN DISCHARGES, BY MONTH AND STREAM SECTION,
UNDER MINIMUM ALLOWED RELEASE REGIMEN
LOWER DESCHUTES RIVER

(SEE TABLE 1.3.5 AND FIG. 1.3.4)

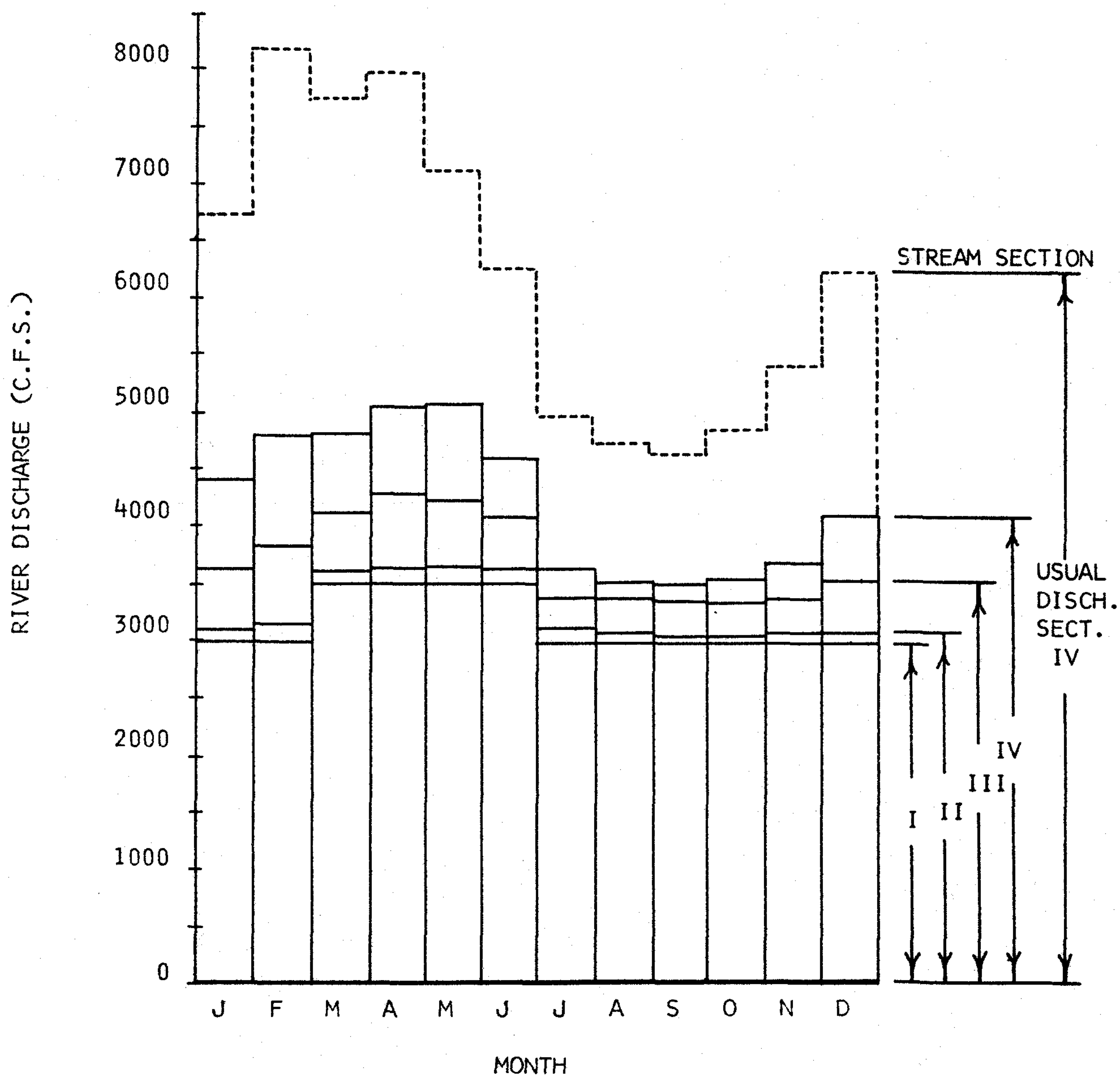


TABLE 1.3.6

Predicted Mean Discharges, by Month, Under Hypothetical Minimum Discharge Regimen A, Lower Deschutes River

Month	Section I	Section II	Section III	Section IV
January	3500 cfs	3600 cfs	4180 cfs	4920 cfs
February	3500	3640	4340	5300
March	4000	4120	4720	5320
April	4000	4140	4780	5560
May	4000	4160	4740	5580
June	4000	4140	4580	5100
July	3500	3620	3940	4140
August	3500	3580	3880	4040
September	3500	3560	3860	4020
October	3500	3560	3860	4060
November	3500	3580	3880	4200
December	3500	3580	4060	4620

Hypothetical Minimum Discharge Regimen A:

March through June ----- 4000 cfs minimum discharge at mile 100.0

July through February -- 3500 cfs minimum discharge at mile 100.0

FIG. 1.3.6

PREDICTED MEAN DISCHARGES, BY MONTH AND STREAM SECTION
UNDER HYPOTHETICAL MINIMUM FLOW REGIMEN A
LOWER DESCHUTES RIVER

(*SEE* TABLE 1.3.6)

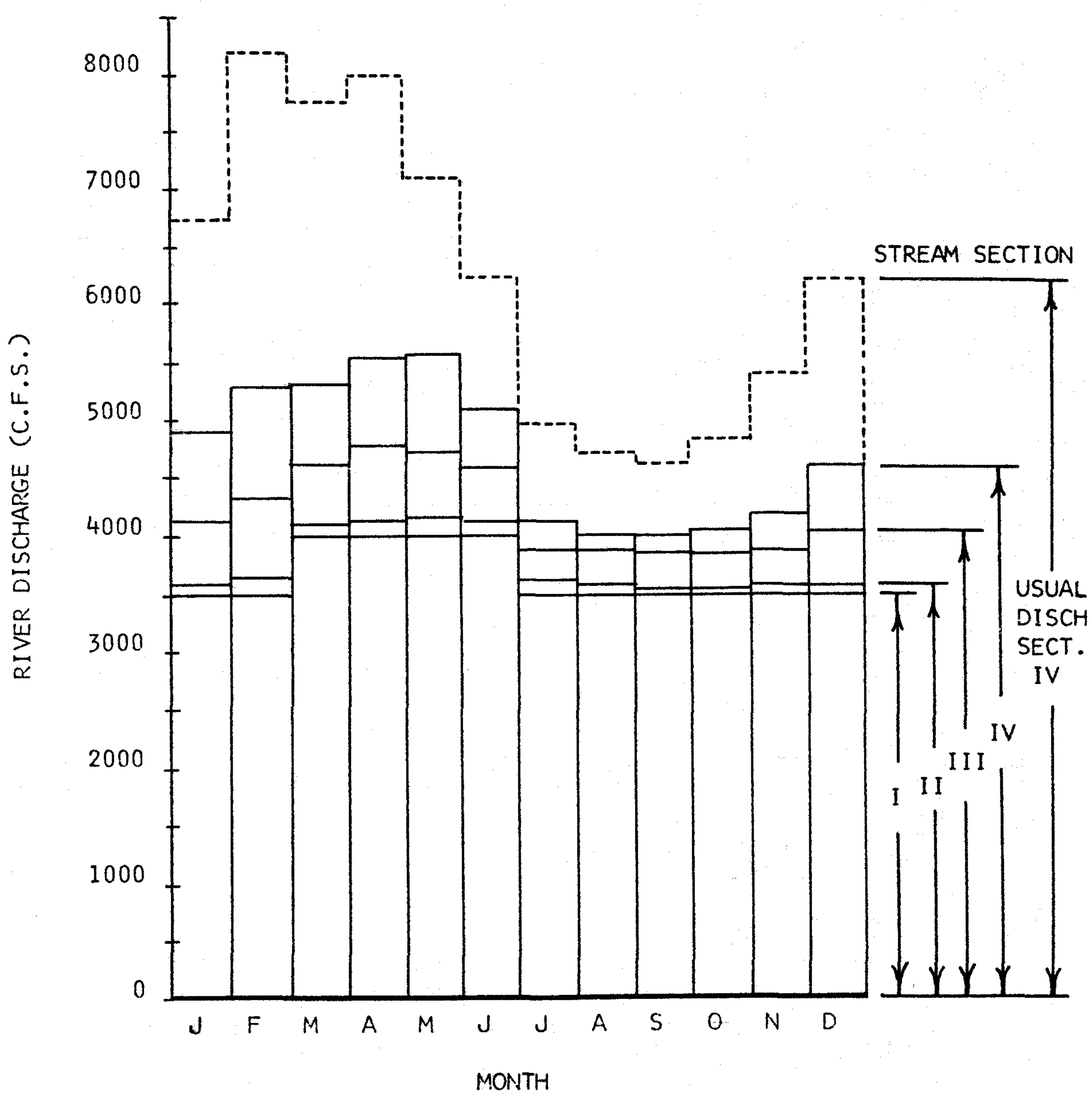


TABLE 1.3.7

Predicted Mean Discharges, by Month, Under Hypothetical Minimum Discharge Regimen B, Lower Deschutes River

Month	Section I	Section II	Section III	Section IV
January	4000 cfs	4100 cfs	4680 cfs	5420 cfs
February	4000	4140	4840	5800
March	4500	4620	5220	5820
April	4500	4640	5280	6060
May	4500	4660	5240	6080
June	4500	4640	5080	5600
July	4000	4120	4440	4640
August	4000	4080	4380	4540
September	4000	4060	4360	4520
October	4000	4060	4360	4560
November	4000	4080	4380	4700
December	4000	4080	4560	5120

Hypothetical Minimum Discharge Regimen B:

March through June -- 4500 cfs minimum discharge at mile 100.0

July through February -- 4000 cfs minimum discharge at mile 100.0

FIG. 1.3.7

PREDICTED MEAN DISCHARGES, BY MONTH AND STREAM SECTION,
UNDER HYPOTHETICAL MINIMUM FLOW REGIMEN B,
LOWER DESCHUTES RIVER

(SEE TABLE 1.3.7)

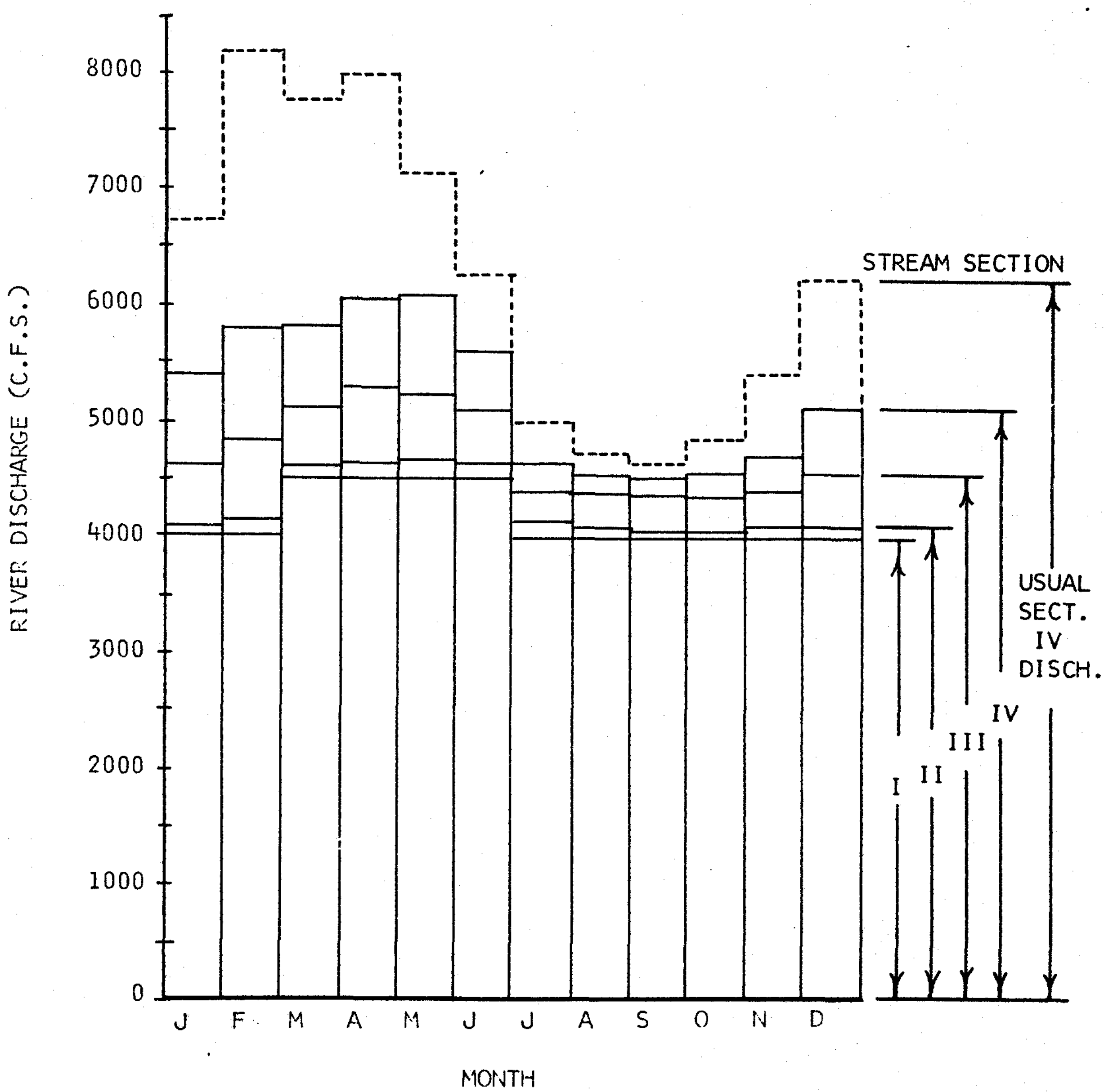


TABLE 1.3.8

Predicted Mean Discharges, by Month, Under Hypothetical Minimum Discharge Regimen C, Lower Deschutes River

Month	Section I	Section II	Section III	Section IV
January	4500 cfs	4600 cfs	5680 cfs	5920 cfs
February	4500	4640	5340	6300
March	5000	5120	5720	6320
April	5000	5140	5780	6560
May	5000	5160	5740	6580
June	5000	5140	5580	6100
July	4500	4620	4940	5140
August	4500	4580	4880	5040
September	4500	4560	4860	5020
October	4500	4560	4860	5060
November	4500	4580	4880	5200
December	4500	4580	5060	5620

Hypothetical Minimum Discharge Regimen C:

March through June -- 5000 cfs minimum discharge at river mile 100.0

July through February -- 4500 cfs minimum discharge at river mile 100.0

FIG. 1.3.8

PREDICTED MEAN DISCHARGES, BY MONTH AND STREAM SECTION,
UNDER HYPOTHETICAL MINIMUM FLOW REGIMEN C,
LOWER DESCHUTES RIVER

(SEE TABLE 1.3.8)

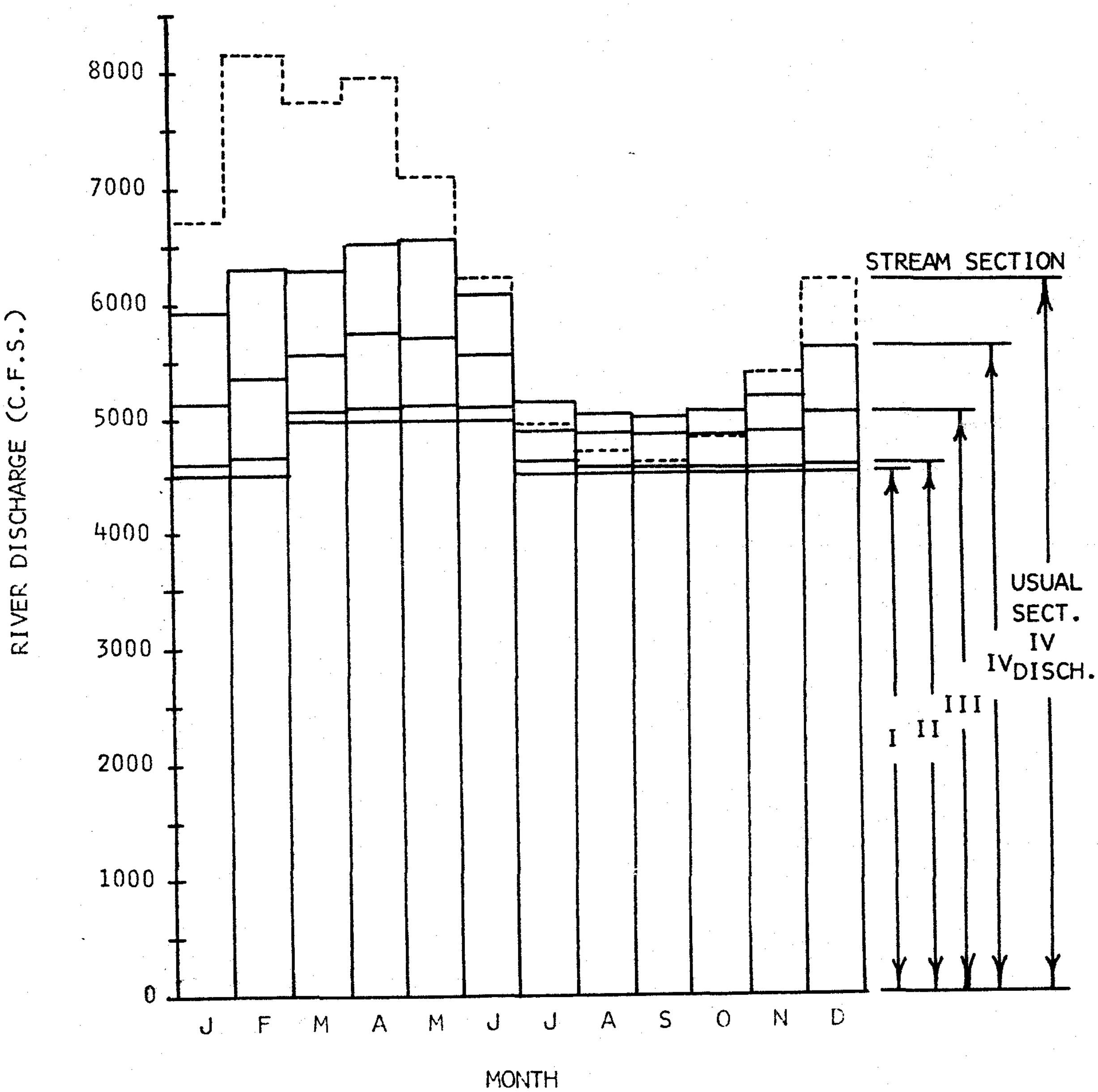


TABLE 1.3.9

Comparison of Predicted Mean Discharges Under Minimum Release Conditions, and Measured Discharges During the Filling of Round Butte Reservoir, January 1 through December 15, 1964
Stream Sections I and IV, by Month
Lower Deschutes River

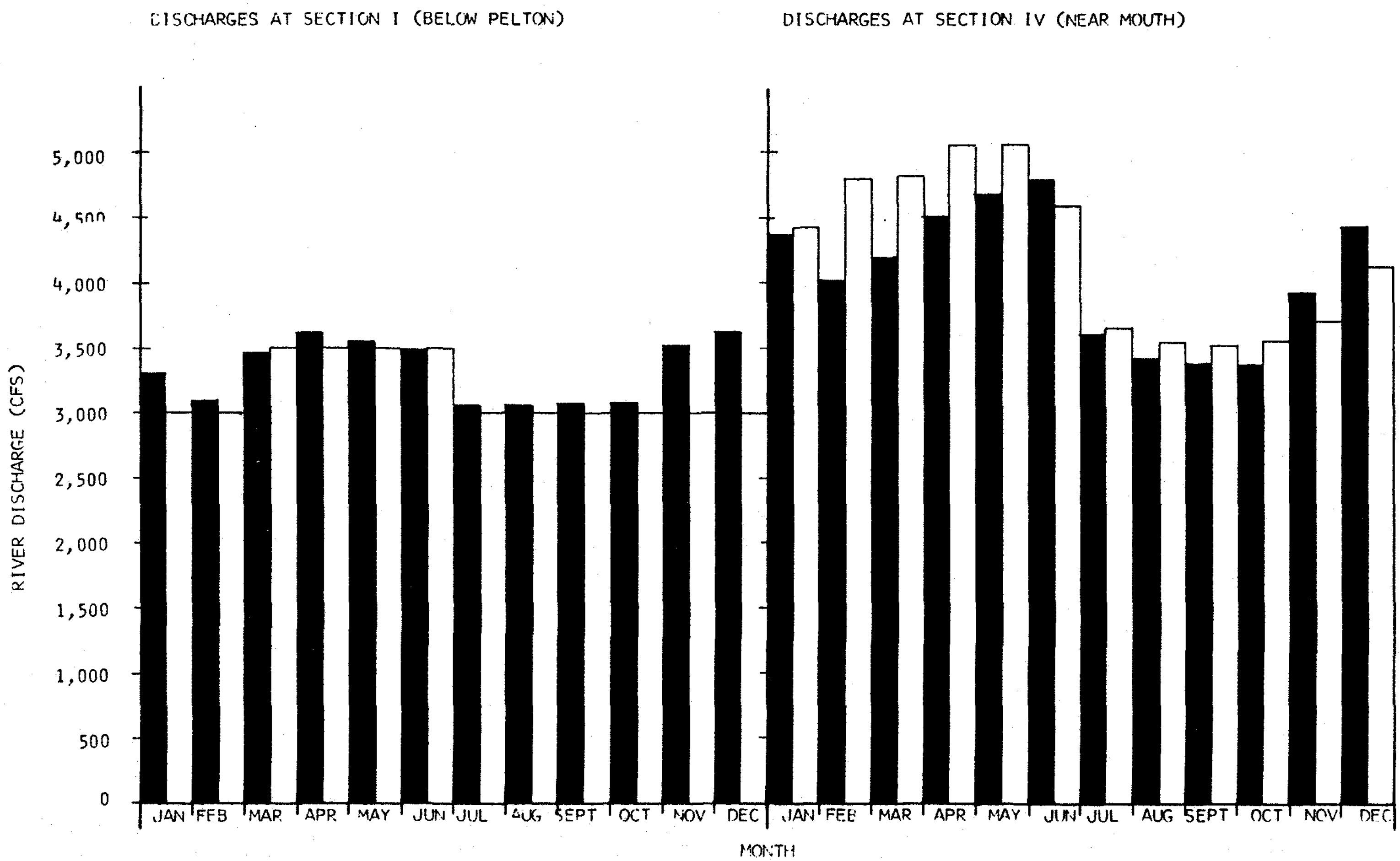
Month	Section I		Section IV	
	Measured	Predicted	Measured	Predicted
January	3305 cfs	3000 cfs	4378 cfs	4420 cfs
February	3094	3000	4021	4800
March	3455	3500	4192	4820
April	3613	3500	4512	5060
May	3554	3500	4682	5080
June	3492	3500	4795	4600
July	3059	3000	3597	3640
August	3064	3000	3411	3540
September	3081	3000	3394	3520
October	3085	3000	3385	3560
November	3521	3000	3910	3700
December (1-15)	3637	3000	4426	4120

	Section I	Section IV
Mean difference	+163 cfs	-171 cfs
Mean absolute diff.	172 cfs	290 cfs

FIG. 1.3.9

PREDICTED AND MEASURED MEAN RIVER DISCHARGES UNDER MINIMUM RELEASE CONDITIONS, LOWER DESCHUTES RIVER

(SEE TABLE 1.3.9)



Mean discharges recorded under minimum allowed releases during filling of Round Butte reservoir (January 2 through December 15, 1964) compared with predicted mean discharges under minimum allowable release regimen (Table 1.3.5 and Fig. 1.3.5). Solid bars indicate measured discharge, open bars indicate predicted discharge.

All lower elevation tributaries of the Deschutes are subject to flash flooding. A common cause is the "chinook", a weather phenomena characterized by rapid snow melt, warm winds and rain. Runoff from a chinook may be relatively insignificant when snow cover is light and the ground thawed and dry, or it may be severe as in the most extreme cases known, the floods of December 1861 and 1964, when frozen ground prevented the soaking-in of rain and a rapidly melting heavy snow cover. From Trout Creek downstream, the east side tributaries are also vulnerable to summer flooding from localized cloudbursts or "waterspouts" as they are called by residents of the area.

Any sudden increase in lower elevation tributary runoff whether caused by precipitation or snowmelt causes severe watershed and stream channel erosion. These flood flows are therefore characterized by extreme water turbidity and heavy sediment loads, adversely effecting all stream areas between the source of the disturbance and the mouth of the Deschutes. For example, highly turbid flows of 25 cfs from Trout Creek have been observed to discolor over 5,000 cfs of Deschutes mainstem discharge, noticeably reducing water clarity all the way to the mouth.

River flows in Section I originate almost entirely from above the Pelton-Round Butte Dam complex. Because of this, project operations have a pronounced affect on river discharge patterns in this stream section. This area is subjected to less turbidity and sedimentation than the remaining downstream sections.

Section II stream quality is affected by flows from Shitike and Trout Creeks. Shitike Creek is normally quite stable and clear, whereas flows from Trout Creek are more erratic, frequently off-color and occasionally heavily loaded with suspended material.

Section III is influenced by these upstream flows as well as Warm Springs River, normally stable and clear, and several small tributaries characterized by intermittent discharge and occasional flash floods.

White River has a major effect on Section IV. Of the same general size as the Warm Springs River, White River has greater discharge variability and at times will carry heavy loads of glacial silt and sands. Except for Buckhollow Creek all of the tributaries downstream from White River are usually dry.

1.4 Stream Qualities

This section covers three aspects of stream quality: water turbidity, water temperature, and streambed composition. The dissolved oxygen content of river water and gravel permeability are both covered in Part Four.

Water turbidity was determined in equivalent parts per million (ppm) with a visual extinction turbidity rod [1/]. Table 1.4.1 summarizes results of observations made between September 1963 and June 1964. Mean turbidities for river Sections II, III and IV were compared statistically but we were unable to show significant differences among these means (analysis of variance, 5% level of significance).

In 1911-12 a series of water turbidity analyses were made from the Deschutes River near its mouth (Table 1.4.2). These analyses showed a mean turbidity of 31.5 ppm, slightly greater than the 23.2 ppm mean for six Section IV measurements made in 1963-64, although we were not able to show that the difference between these two means was statistically significant (two-tailed *t*-test, 10% level of significance).

USGS water temperature data summaries for the lower Deschutes, Warm Springs and White Rivers through 1962 are listed in Table 1.4.3 (from Moore, 1964). As shown in this table, extreme water temperatures recorded at the mouth ranged from a minimum of 33 degrees Fahrenheit (°F) to a maximum of 71°F. However, in a typical year such as 1963 temperatures at the mouth stayed within the range of

---

1/ Of a type adopted by the Oregon State Sanitary Authority from a USGS design, featuring a platinum or stainless steel needle at the end of a brass rod calibrated in ppm equivalent turbidity. Original source of this design unknown.

35 to 68°F and diurnal fluctuation ranged from a maximum of 4°F in the summer to less than 1°F in the winter (USGS, 1963).

River temperature differences between upper and lower ends of the study area are significant but not drastic. Prior to the completion of Pelton Dam, the Deschutes River in its lower 100 miles usually lost about 2° to 4°F in winter and gained about 6° to 8°F in summer (Fig. 1.4.1, data from Moore, 1964).

Downstream water temperature patterns may be modified by the Pelton and Round Butte reservoirs. The most obvious place to look for any such modification would be in the temperature records from the USGS gaging station just below the Pelton Regulation Dam. However, because this thermometer is located near the point of discharge from the Pelton fish collection facilities recorded temperatures have been artificially affected since completion of Pelton Dam in 1957 precluding identification at this point of any river temperature modifications.

Temperature records from the USGS gaging station near the mouth of the Deschutes River show some change in minimum temperatures during the spring months in recent years. Fig. 1.4.2 compares the record minimum monthly temperatures between 1955 and 1962 with the minimum monthly temperatures for the years 1963, 1964, and 1965. These data show new record minimum temperatures in March, April, May and September of 1965 and in May of 1964. Round Butte Reservoir storage started in January of 1964, but with such meager evidence we cannot attribute these lowered temperatures to reservoir effects.

The streambed of the lower Deschutes River is mostly coarse rubble, boulders and bedrock. Throughout the 100-mile study area gravel beds suitable for fish spawning make up less than one percent of the total stream bottom (Table 1.4.4).

Relative spawning gravel concentration in the streambed is highest in Section I (between Pelton Dam and Shitike Creek): about 9% of the total streambed is suitable for spawning (348,000 of 3.9 million square feet streambed area). These gravels are of good quality for spawning primarily because they contain relatively little sand and silt.

Section II contains a lower relative concentration of spawning gravels (1.4% of the total streambed area or 211,000 of 15 million sq. ft.). The quality of these gravel beds is generally good except where it is adversely affected by sediments from tributaries such as Shitike and Dry Creeks.

Section III contains 331,000 sq.ft. of spawning gravel, approximately 0.8% of the streambed area. Most of the higher quality gravel beds within this stream section are found above Nena Creek (See Fig. 1.4.3).

The gravel beds found in Section IV are of poor quality and most of the streambed is large boulders, rubble and bedrock. Approximately 221,000 sq. ft. of spawning gravel exists in this stream section, 0.4% of the streambed area. Because White River and other upstream tributaries introduce large quantities of silt and fine sand most of the gravel beds in Section IV contain high proportions of these deleterious materials.

In the seven miles nearest the mouth and in the area between Maupin and Twin Tunnels (11 stream miles) the streambed is nearly all basalt bedrock.

TABLE 1.4.1

Summary of 18 Water Turbidity Observations, Lower Deschutes River; September 10, 1963 - June 5, 1964

	Section I	Section II	Section III	Section IV	All Sections
No. of observations	0	4	8	6	18
Mean turbidity	-	16.6 ppm	22.4 ppm	23.2 ppm	21.4 ppm
Minimum observation	-	11 ppm	6 ppm	8 ppm	6 ppm
Maximum observation	-	24 ppm	40 ppm	35 ppm	40 ppm
Standard deviation	-	6.21	12.4	11.4	10.7

TABLE 1.4.2

Summary of 34 Water Turbidity Analyses From the Deschutes River at Moody (Section IV); August 21, 1911 - July 25, 1912 (Van Winkle, 1914)

No. of observations	34
Mean turbidity	31.5 ppm
Minimum observation	Trace (< 1 ppm)
Maximum observation	280 ppm
Standard deviation	50.7

TABLE 1.4.3

Water Temperatures, Lower Deschutes River Mainstem and Major Tributaries

Station	River Mile	Period of Record		Water Temperature (°F) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Deschutes R. near Madras	101.6	1952-57	Mean	46	46	47	51	54	55	56	56	54	52	49	46
			Max-Min	48 43	49 43	51 44	56 46	59 49	59 51	59 53	59 50	58 50	55 49	52 44	50 43
Warm Springs[a] R. at HeHe		1950-54	Mean	37	38	40	44	46	50	53	51	48	44	40	38
			Max-Min	41 32	45 33	46 33	53 38	54 39	57 44	59 45	58 43	55 41	49 39	46 34	42 32
White R. below Tygh V.[b]	2.0	1946-62	Mean	38	40	43	46	51	59	61	61	57	50	44	39
			Max-Min	43 32	46 36	50 36	53 36	64 42	69 45	72 48	70 51	67 47	61 41	51 37	45 35
Deschutes R. at Moody	1.4	1955-62	Mean	42	44	47	53	58	62	64	64	60	53	46	44
			Max-Min	46 34	49 35	53 42	63 47	66 51	71 53	71 55	69 56	67 54	59 47	53 36	50 33

[a] Measurements made upstream from the influence of the major thermal springs. Warm Springs River temperatures are usually considerably higher where it flows into the Deschutes River.

[b] 119 spot observations, adjustments to Mean, Minimum and Maximum values based on correlation with thermograph record for Desolation Creek near Dale.

All data and correlations by Moore (1964).

FIG. 1.4.1

MINIMUM, MAXIMUM AND MEAN RIVER TEMPERATURES FOR PERIOD OF RECORD, USGS GAGES AT RIVER MILES 101.6 AND 1.4, LOWER DESCHUTES RIVER

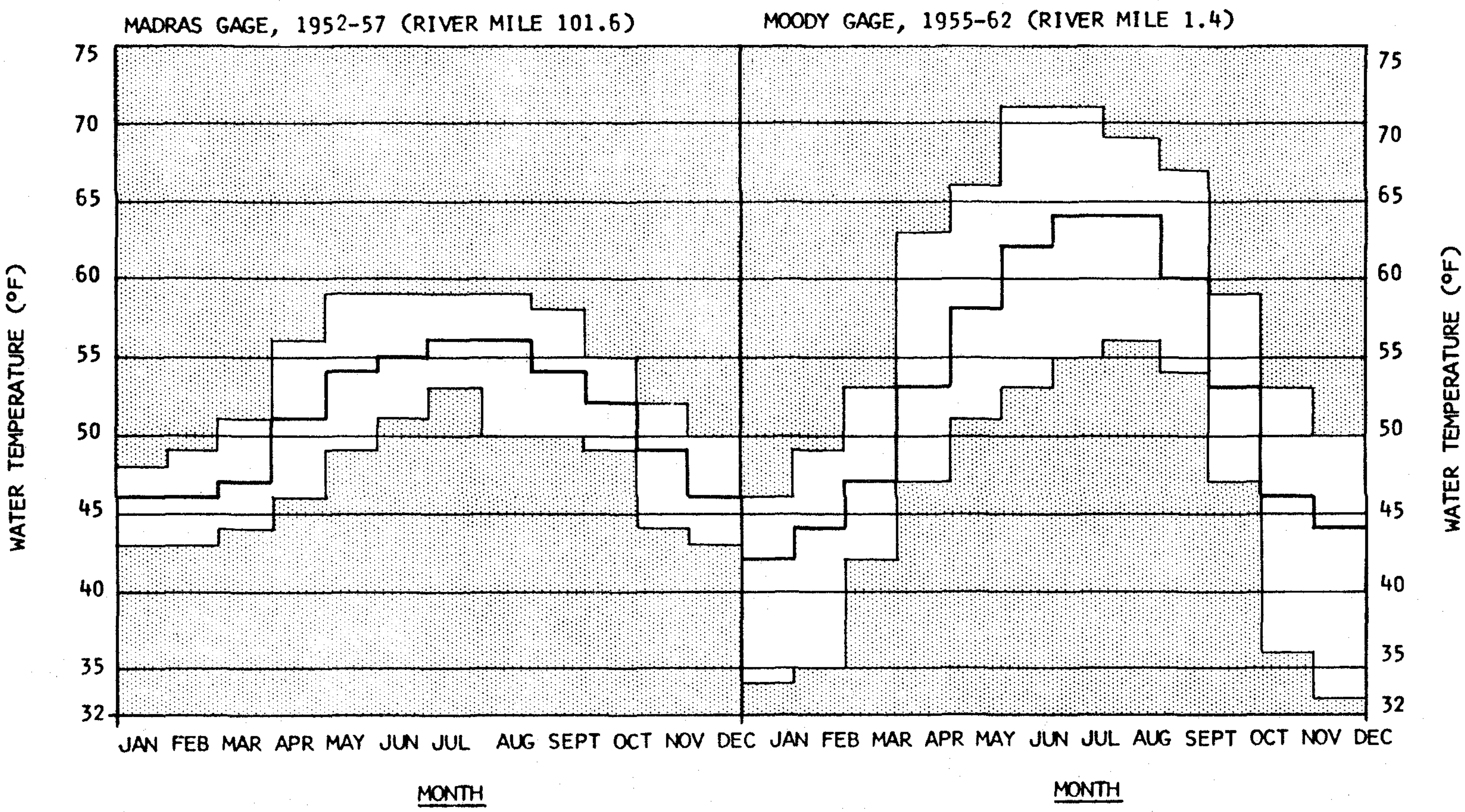


FIG. 1.4.2

MINIMUM TEMPERATURES AT RIVER MILE 1.4, BY MONTH.
PERIOD OF RECORD (1955-1962) COMPARED WITH THE YEARS 1963, 1964 AND 1965,
LOWER DESCHUTES RIVER.

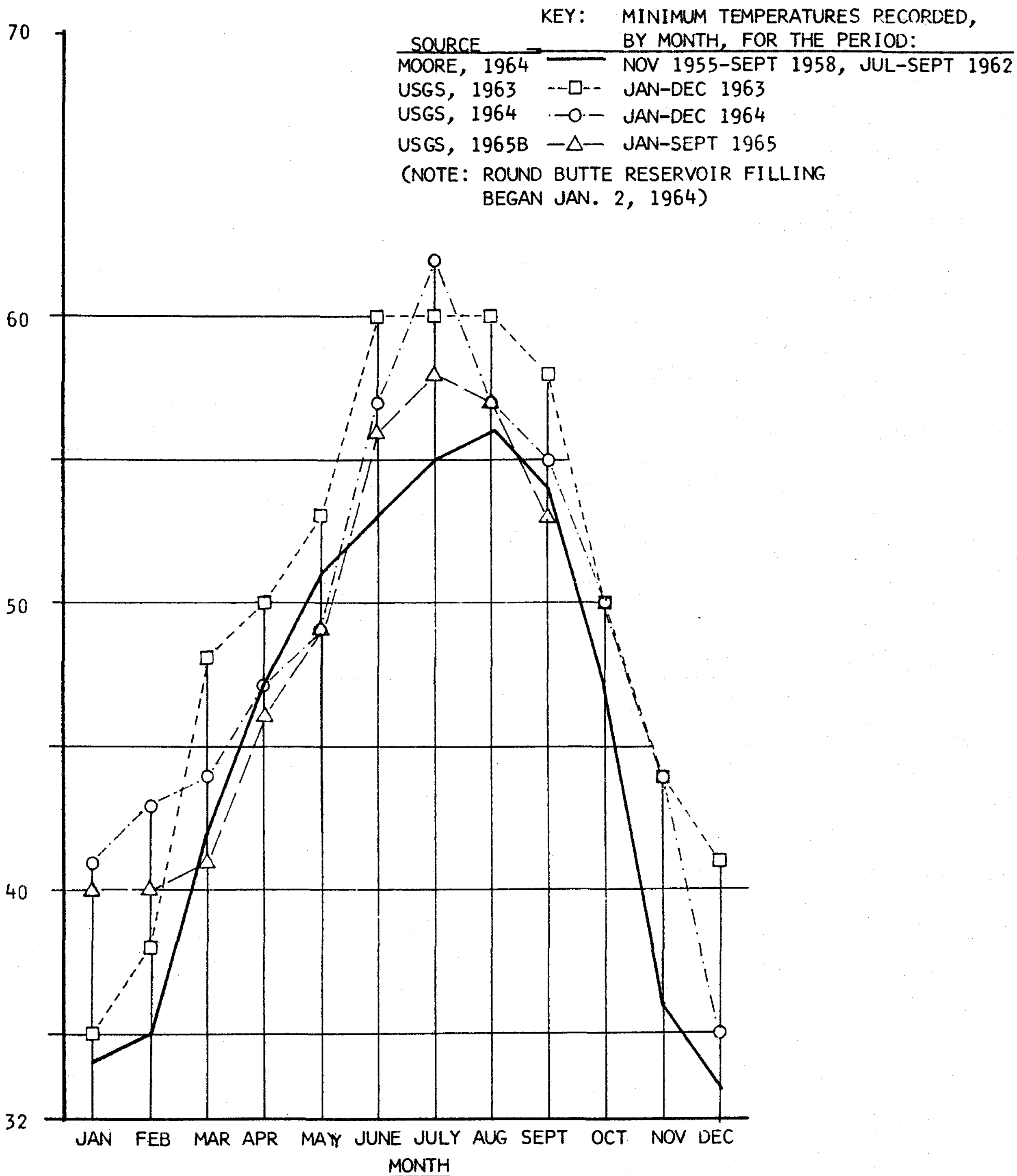


TABLE 1.4.4

Estimated Useable Spawning Gravel Area, by Stream Section, Lower Deschutes River

	Section I	Section II	Section III	Section IV	Total Area
Wetted area (water surface area)	3,900,000 sq. ft.	15,000,000 sq. ft.	39,700,000 sq. ft.	62,100,000 sq. ft.	121,000,000 sq. ft.
Spawning gravel area a/	348,000 sq. ft.	211,000 sq. ft.	331,000 sq. ft.	221,000 sq. ft.	1,111,000 sq. ft.
Spawning gravel per stream mile	105,000 sq. ft.	16,000 sq. ft.	8,800 sq. ft.	4,800 sq. ft.	11,100 sq. ft.
Percent of total spawning gravel in section	31%	19%	30%	20%	100%
Percent of wetted area that is spawning gravel	8.9%	1.4%	0.8%	0.4%	0.9%

a/ Based on aerial photo measurements and measurements made during a partial field survey of spawning gravels. Estimates for Section I were derived from aerial photo measurements. Estimates for Sections 2, 3 and 4 expanded from field measurements of gravel bars in 5 one-mile segments, according to the formula:

$$\hat{N}_i' = N \frac{n'}{n} \frac{\Sigma xhg}{n'}$$

Where, $\hat{N}_i'$ = estimated area of gravel suitable for spawning in stream section i

N = 302 = number of gravel bars located during entire study

n = 38 = number of gravel bars located during entire study in areas sampled

n' = 25 = actual number of gravel bars counted in areas sampled at time of sampling

x = total area of sampled bar

h = proportion of bar area over 0.5 feet deep

g = proportion of bar area containing gravels predominantly between 0.25 and 6 inches in diameter.

Oregon State Game Commission — Basins Investigations

LOWER DESCHUTES RIVER

1966

FIG. 1.4.3

DISTRIBUTION OF GRAVEL BARS LOCATED DURING LOWER DESCHUTES FLOW STUDY, 1961-1966.

NOTE: Numbers indicate approximate sequence of bars located in original survey. Bars located in later work were given numbers with alphabetic suffixes, such as 58A, 58B, 58C, etc.

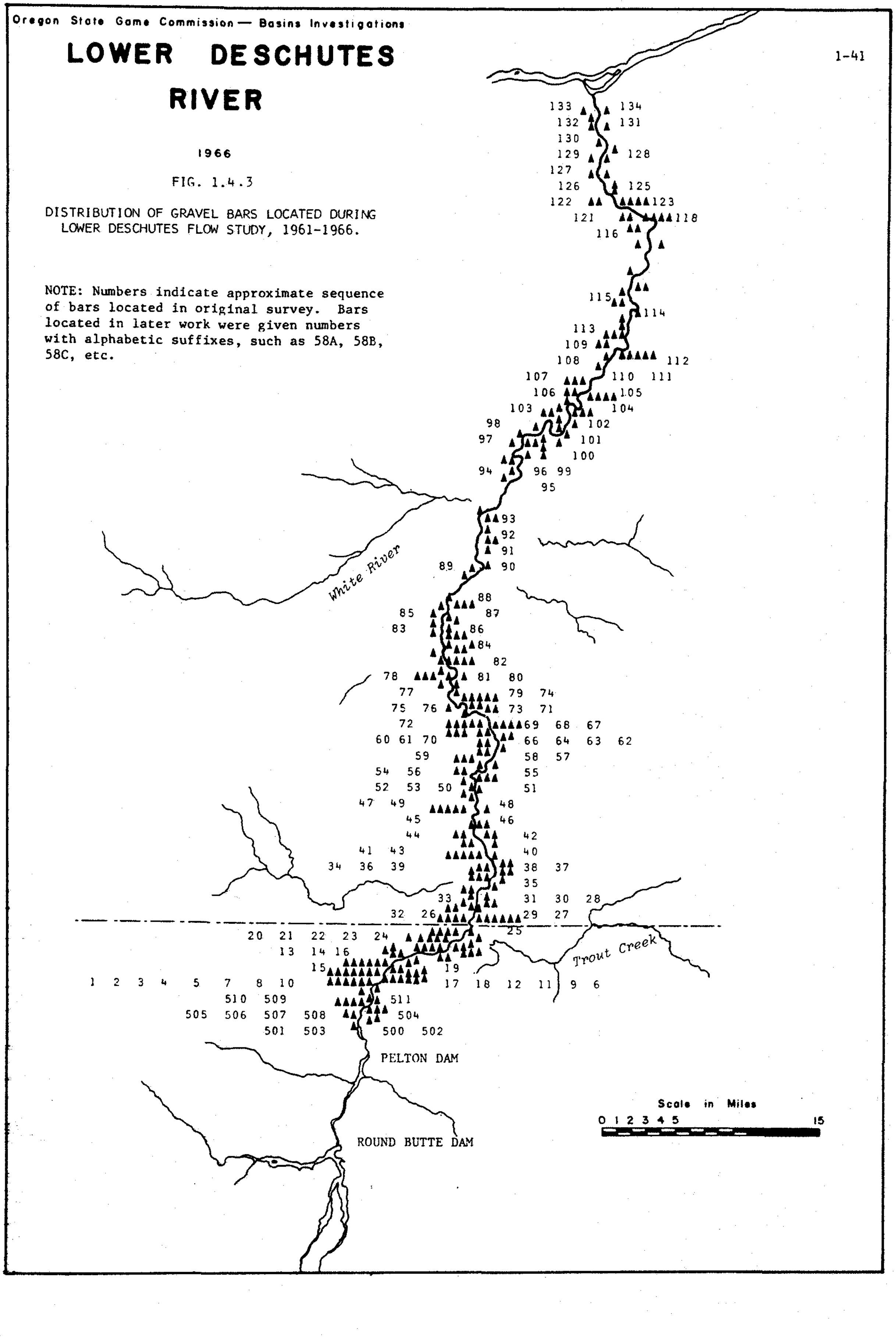


TABLE 1.4.5

Distribution of Gravel Bars Located During Lower Deschutes Flow Study, 1961 - 1966*

River mile:

Tens \ Units	0	1	2	3	4	5	6	7	8	9	Total
00	2	2	1	1	2	1	1	2	2	3	17
10	4	5	1	2	0	0	1	2	0	2	17
20	0	4	3	4	3	0	2	0	5	4	25
30	0	3	2	2	2	3	0	4	3	1	20
40	1	2	0	1	0	0	3	2	1	0	10
50	1	1	2	0	1	5	4	4	7	2	27
60	3	3	3	1	4	8	3	3	2	9	39
70	2	3	5	4	3	1	3	6	0	3	30
80	6	6	8	3	4	4	9	7	7	3	57
90	3	5	5	3	14	8	8	2	6	5	59
100	1	-	-	-	-	-	-	-	-	-	1
										Total:	302

* All gravel bars located during the course of this study are included, regardless of the use for spawning. A few bars are included which existed prior to the 1964-65 floods but not after; and a few are also included which did not exist prior to these floods.

TABLE 1.4.6

Characteristics of an Average Spawning Bar, Lower Deschutes River

Length	154 feet
Width	41 feet
Gravelled area	5,200 square feet

Area of bar under less than 0.5 feet of water a/	280 square feet	...5% of bar
Area of bar under 0.5 to 3 feet of water	4,190 square feet	...81% of bar
Area of bar under water over 3 feet deep	725 square feet	...14% of bar
Area of bar where gravel is predominantly less than 1/4 inch in diameter a/	139 square feet	...3% of bar
Area of bar where gravel is predominantly between 1/4 and 1 inch in diameter	481 square feet	...9% of bar
Area of bar where gravel is predominantly between 1 and 3 inches in diameter	2,010 square feet	...39% of bar
Area of bar where gravel is predominantly between 3 and 6 inches in diameter	1,830 square feet	...35% of bar
Area of bar where gravel is predominantly between 6 and 10 inches in diameter a/	621 square feet	...12% of bar
Area of bar where gravel is predominantly over 10 inches in diameter a/	120 square feet	...2% of bar
Area useable for trout spawning (adequate water depth and gravel size) b/	4,050 square feet	...78% of bar

a/ Generally unsuitable for spawning.

b/ $\bar{y} = \frac{\Sigma xhg}{n}$

TABLE 1.4.6 (continued)

where:

$\overline{y}$ = area useable for spawning

x = total area of gravel measured over sampled bar

h = proportion of bar over 0.5 foot deep under water

g = proportion of bar containing gravel predominantly between 0.25 and 6 inches in diameter

n´= number of gravel bars measured

Biological Description

1.5 Salmonid Fishes

The steelhead trout (Salmo gairdneri gairdneri, the anadromous subspecies of the rainbow trout, Salmo gairdneri) is the highest valued fish species of the lower Deschutes River. The major portion of the steelhead run enters the river from late July through September, spawning during April and May of the following year. However, adult fish enter the stream each month of the year and spawning occurs as early as March and as late as June.

Young steelhead fry emerge from the gravel between late May and July and usually remain in the Deschutes between one and two years before migrating to the ocean. These fish mature in the ocean and most return to spawn during the fourth spring following hatching. See Table 1.5.1. Few adult fish survive spawning to return to the ocean and migrate upstream again. Deschutes River steelhead are not large, ranging between 4 and 6.5 pounds with an average weight of 6.0 pounds (King, 1965).

Resident rainbow trout inhabit the entire lower Deschutes River but are most abundant in Sections I, II and III. These fish grow quite large for resident trout, are characteristically deep-bodied, and range up to 20 inches in length. The majority spawn in the lower Deschutes River mainstem between mid-April and late June and in tributaries during March and early April. Little is known about inter-relationships between the life history of these mainstem resident fish and migrant steelhead, Columbia River resident, and tributary resident races.

The "spring" run of chinook salmon (Oncorhynchus tschawytscha) enters the Deschutes River mainly in the months of April and May. Smaller "summer" and "fall" runs enter the river between July and November. Most chinook salmon spawn between the last of September and mid-November. Salmon fry start emerging from the gravel around the first of January and continue through late March. Most young fish migrate to the ocean in their first and second years, mature at sea and return to spawn four or five years after the parent run.

Other salmonid species inhabiting the lower Deschutes River include brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta), both introduced species; and the native Dolly Varden (Salvelinus malma) and mountain whitefish (Prosopium williamsoni). Coho salmon (Oncorhynchus kisutch) have been recently stocked; unverified reports state this species once was a fairly common spawner below Sherars Falls.

1.6 Other Fish Species

Several native non-salmonids are also present in considerable numbers in the lower Deschutes River, such as northern squaw fish (Ptychocheilus oregonensis), chiselmouth (Acrocheilus alutaceus) and suckers (Catostomus spp.).

TABLE 1.5.1

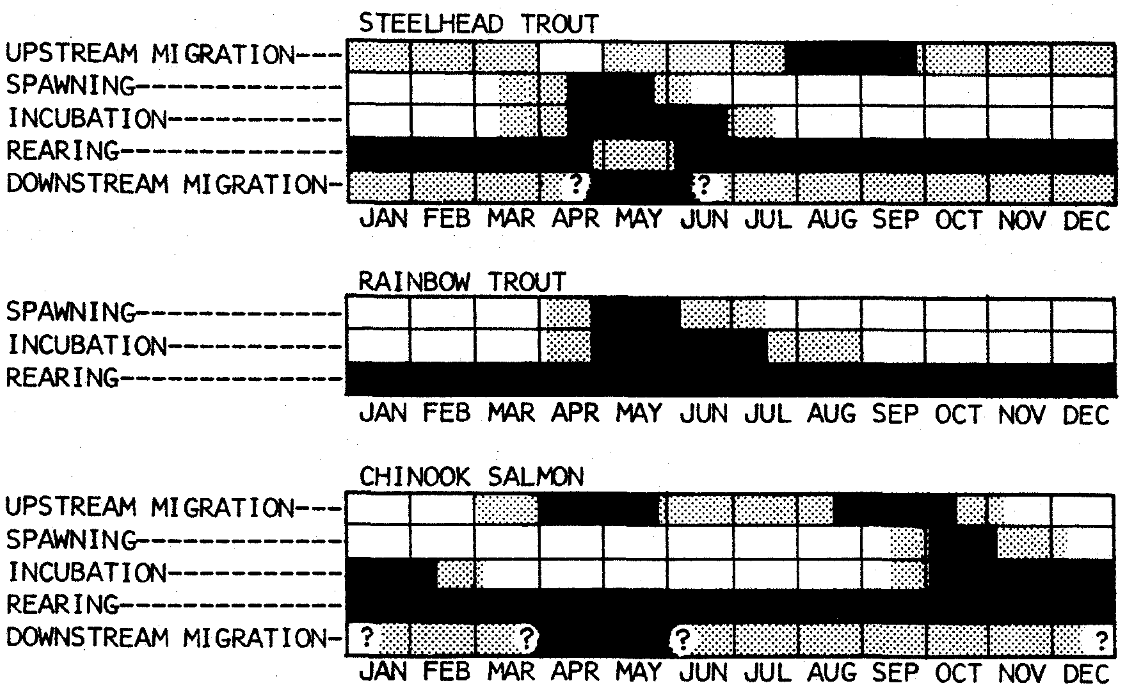
Summer Steelhead Life Cycles,[a] Deschutes River

Brood Age	Approximate Cycle Freshwater	Ocean	Freshwater	No. of Females	No. of Males	No. of Fish	Percent of Total
3 years	1 yr.	1 yr.	1 yr.	13	17	30	11.6
4 years	1 yr.	2 yrs.	1 yr.	6	3	9	
	2 yrs.	1 yr.	1 yr.	93	66	159	
				99	69	168	64.9
5 years	2 yrs.	2 yrs.	1 yr.	17	6	23	
	3 yrs.	1 yr.	1 yr.	14	19	33	
				31	25	56	21.6
6 years	2 yrs.	3 yrs.	1 yr.	2	0	2	
	3 yrs.	2 yrs.	1 yr.	2	0	2	
	4 yrs.	1 yr.	1 yr.	1	0	1	
				5	0	5	1.9
		Totals:		148	111	259	100.0
		Percent:		57.1	42.9	100.0	

[a] From a series of scales collected from adult steelhead in 1952 and 1954. Scales read by Francis H. Sumner, Oregon State Game Commission, 1966.

FIGURE 1.5.1

PERIODICITY CHART, STEELHEAD TROUT, RAINBOW TROUT AND CHINOOK SALMON, LOWER DESCHUTES RIVER.



STREAM USE KEY:

SOLID AREAS----PERIODS OF HEAVIEST USE
SHADED AREAS---PERIODS OF MODERATE USE
BLANK AREAS----PERIODS OF LITTLE OR NO USE

1.7 Invertebrates

Aquatic invertebrates such as insects and crustaceans are a major part of the diet of juvenile salmon and trout. Because of relatively high water fertility and discharge stability the lower Deschutes River is a rich breeding ground for invertebrate life.

Two one-square foot bottom samples collected in 1964 and analyzed by the Oregon State University's Department of Entomology illustrate the rich and varied bottom fauna of Deschutes River gravel bars (Table 1.7.1). In the sample collected at gravel bar station 123 (river mile 10.3, stream section IV) 189 arthropods (insects and mites) were collected representing 18 different genera. The other sample, collected a day later at station 58B (river mile 69.3, stream section III), contained 508 arthropods representing 23 different species of genera.

Both bottom samples were collected in areas exhibiting similar conditions of water depth, water velocity, and gross gravel particle size. The first gravel bar (123) was nearest the mouth and below the confluence of all major tributaries. During most of the year preceding this sampling there was little discharge fluctuation but there was a great deal of sediment accumulation from White River downstream.

TABLE 1.7.1

Aquatic Arthropods* Collected in 2 One-Square Foot Bottom Samples, Lower Deschutes River, 1964

	Station 58B 4-18-64	Station 123 4-17-64
Ephemeroptera (mayflies)		
Baetis sp.	47	10
Cinygmula sp.	1	
Ephemerella Walkeri group	2	
Ephemerella inermis	97	16
Epeorus sp.	1	
Rithrogena decora	71	3
Totals	219	29
Plecoptera (stoneflies)		
Isogenus ?	4	
Isoperlinae	1	
Chloroperlinae	1	
Totals	6	
Diptera		
Chironomidae (midges)	102	4
Tipulidae (crane flies)	18	4
Simulidae (black flies)		1
Empididae	9	1
?	1	
Totals	130	10
Trichoptera (caddis flies)		
Leucotrichia sp.	3	8
Hydroptila sp.		11
Amiocentrus sp.	8	1
Agapetus sp.	6	4
Glossosoma sp.	101	27
Psychomyia sp.	1	3
Hydropsyche sp.	15	50
Cheumatopsyche sp.	1	17
Hydropsychidae ?		1
Totals	135	122
Lepidoptera		
Paragyractus sp.	2	
Coleoptera		
Elmidae	15	5
(Acarina)		
mites	1	23
TOTAL ORGANISMS COUNTED (Including mites):	508	189

* Identifications by Donna Buck, Department of Entomology, Oregon State University, 1967.

1.8 Aquatic plant life

Aquatic plants play several important roles in river ecology. They provide food for the various aquatic organisms eaten by trout and salmon; they provide shelter and escape cover for young fish; in their growth they collect and bind together gravel particles, sand and silt, changing the physical characteristics of gravel bars used for fish spawning; when alive they respirate oxygen and carbon dioxide; and when dead decomposition of plant material removes oxygen from the river water.

In the Deschutes River we commonly found two aquatic plants on spawning gravel beds; Tabellaria, a filamentous diatom, and Ranunculus, a flowering plant. Ranunculus with its extensive fine root system and frond-like stem and leaf structures will entrap and hold fine sediments. These accumulations spread and eventually change the composition and useability of a gravel spawning area if left undisturbed. Tabellaria, whose growth seemed to be associated with long exposure to sunlight in mid-summer, traps silt and other debris in its moss-like growth and may start the chain that eventually leads to complete deterioration of a gravel bar area.

Other than these observations, no attempt was made to survey and evaluate aquatic plant forms as a part of this study.

Social, Economic, and Recreational Development

1.9 Recent History and Development

Indians have lived in the Deschutes country for at least 10,000 years. For these prehistoric residents the Deschutes River was an important source of food such as mussels, fish and edible plants. For example, a prehistoric steelhead and salmon fishery probably existed at Sherars Falls using fishing platforms and dip nets in a manner similar to that of today.

The first recorded visit of a white man to the Deschutes River occurred on Tuesday, October 22, 1805 when the Lewis and Clark Expedition reached the mouth of the river during their journey down the Columbia. According to the journals and diaries from this expedition the river was called at that time by several names -- Towornehiooks, Shoshone, Kimooeenem, Snake and Clarks River. Captain Clark described the Deschutes River in the following terms:

> "... we discovered the entrence of a large river on the Lard Side which appeared to come from the S.E. We landed at some distance above the mouth of this river and Capt. Lewis and my Self set out to view this river above its mouth...we Separated (and) I proceeded on to the river and Struck it at the foot of a verry Considerable rapid, here I beheld an emence body of water compressed in a narrow chanel of about 200 yds in width, fomeing over rocks maney of which presented their tops above the water, when at this place Capt. Lewis joined me haveing delayed on the way to examine a root of which the Nativs had been digging great quantities in the bottoms of this river. at about two miles above this river appears to be confined between two high hills below which it (is) divided by numbers of large rocks and Small Islands covered with a low groth of timber (alders), and has a rapid as far as the narrows...it appears to discharge 1/4 as much water as runs down the Columbia." (Thwaites, 1905).

Peter Skene Ogden, a Hudson's Bay trapper, visited the Deschutes River several times during the years 1824 through 1826. Nathaniel J. Wyeth, leader of an American fur trapping party, travelled up the Deschutes River as far as the present site of Bend during the winter of 1834-35. Other noteworthy explorations were made by John Charles Fremont in 1844 and the Pacific Railroad Survey expedition in 1855. The latter expedition made some of the first specimen collections of fish from the Deschutes River.

The first permanent settlers arrived in 1863 (Oregon State Water Resources Board, 1961) and by the turn of the century this area had become fairly well civilized.

Irrigation projects have a prominent place in the development of the lower Deschutes area. The Wapinitia Project, started many years ago but basically complete only since 1960, stores water at Clear Lake (Wasco Reservoir) and Rock Creek Reservoir in the White River drainage. Diversion canals supply this and other diverted water to several thousand acres on Juniper Flat, in the Wamic area, and in Tygh Valley.

Irrigation diversion and storage began in other parts of the Deschutes River basin as early as 1871. The development having the most profound effect on Deschutes River flows is the U. S. Bureau of Reclamation's Deschutes Project, begun in 1921. These upper Deschutes projects utilize three large storage reservoirs on the headwaters plus numerous smaller reservoirs and diversions to supply irrigated acreage in the vicinity of Bend, Redmond and Madras. Another irrigation project has also been constructed to serve the Prineville area (Crooked River Project).

The first hydroelectric power plant in the lower Deschutes River area was completed on White River near its mouth about 1917. Presently an inactive part of the Pacific Power & Light Company system, it consists of a small diversion dam at the top of a natural falls and a 2,250 kilowatt (kw) power plant. Since the early 1900's several large dams were considered for the lower Deschutes River mainstem at such sites as Moody, Sinamox, Sherars Falls, Maupin, and White Horse Rapids. <u>See</u> Fig. 1.9.2 and Table 1.9.1. Portland General Electric's Pelton Dam, completed in 1958 with a power capability of 124,000 kw, was the first large hydroelectric power storage dam in the Deschutes River basin. Round Butte Dam with a production capability of 300,000 kw was completed just upstream from Pelton and began power production in late 1964.

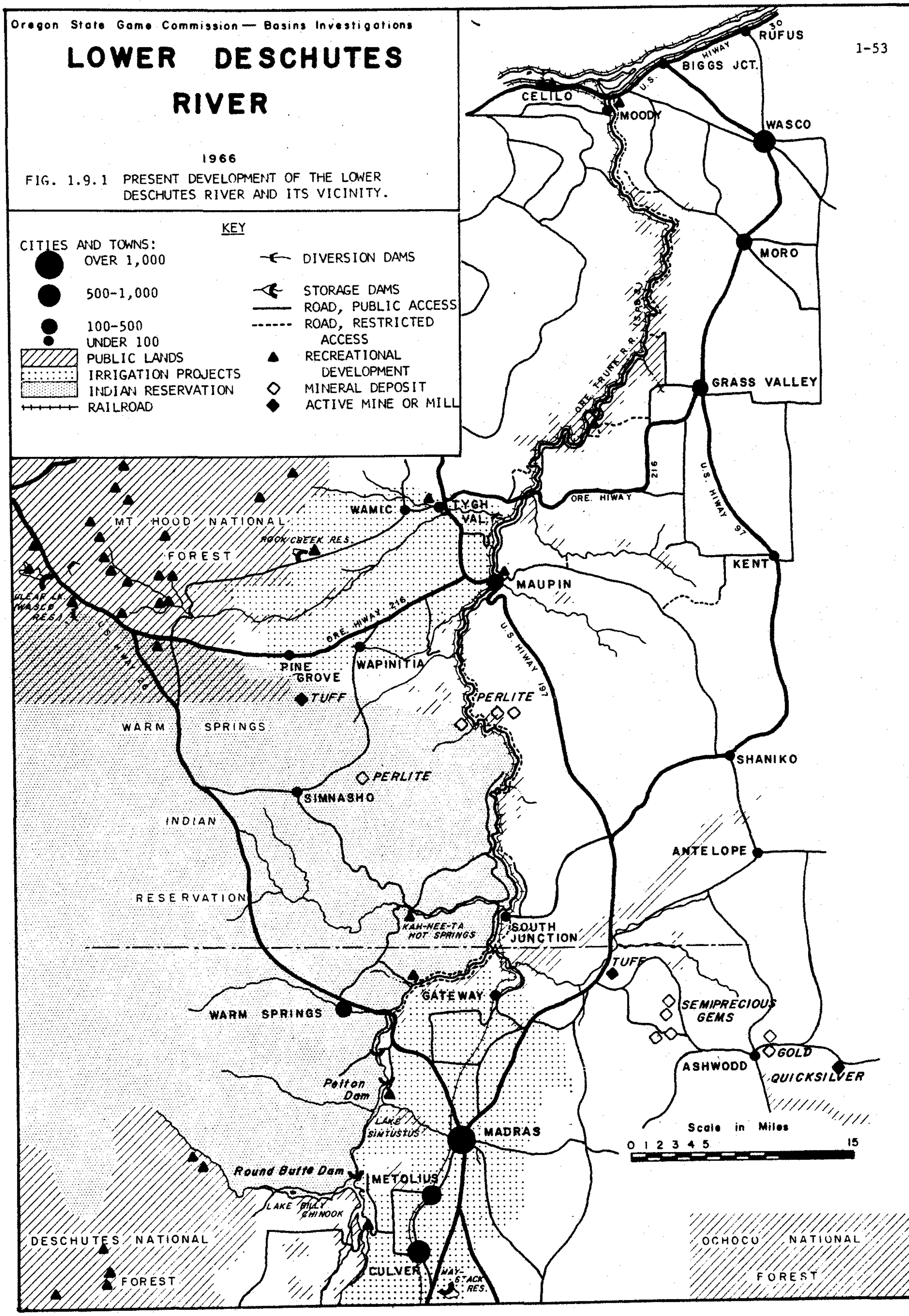


FIG. 1.9.1 PRESENT DEVELOPMENT OF THE LOWER DESCHUTES RIVER AND ITS VICINITY.

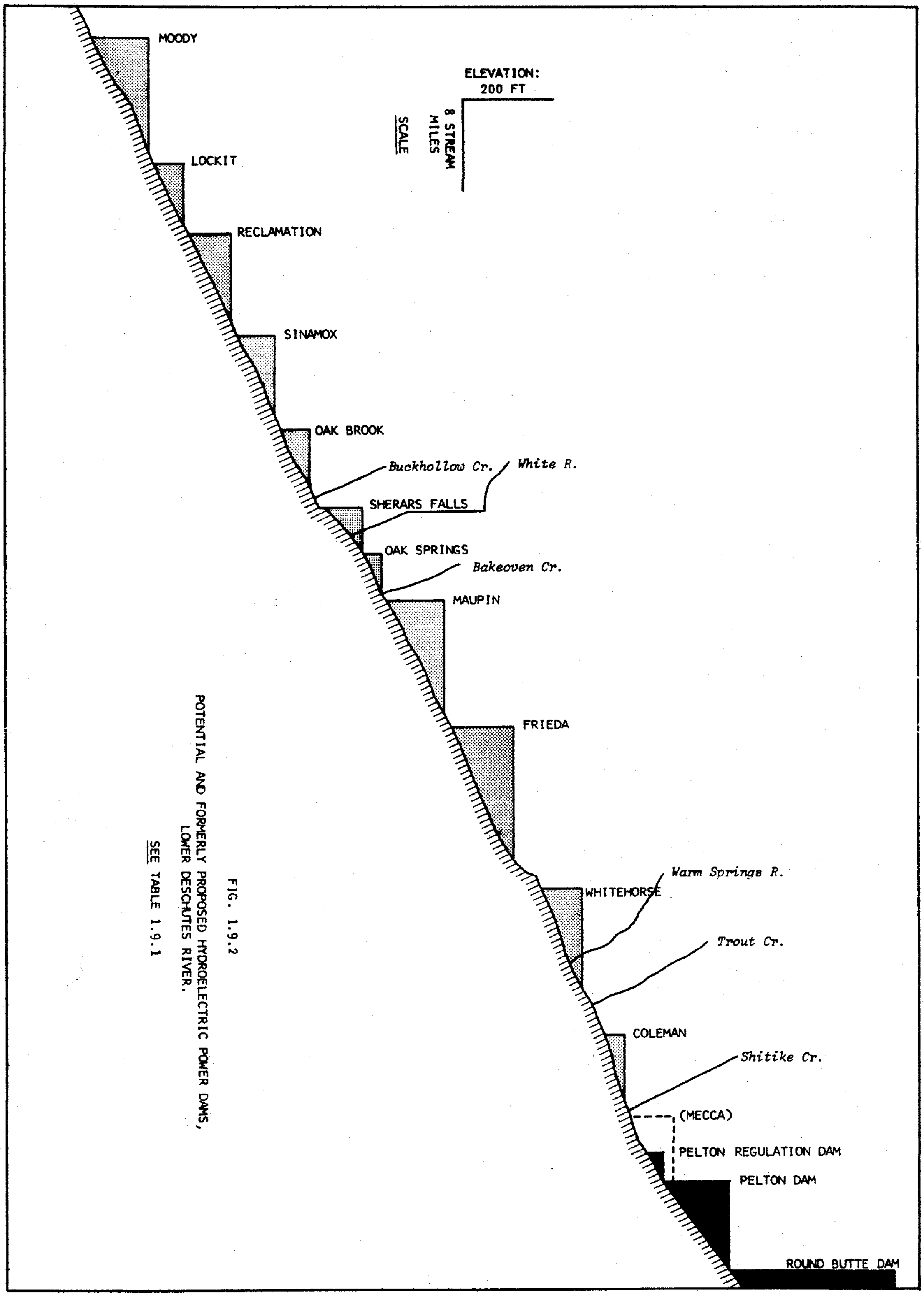


FIG. 1.9.2

POTENTIAL AND FORMERLY PROPOSED HYDROELECTRIC POWER DAMS, LOWER DESCHUTES RIVER.

<u>SEE</u> TABLE 1.9.1

TABLE 1.9.1

Potential and Formerly Proposed Hydroelectric Power Dams,
Lower Deschutes River
(Oregon State Water Resources Board, 1961)

Site	Dam Height	Max. Pool Elev.	Stream Mile	Source a/
Rimrock	-	-	0	4
Moody	180	312	3	2,4,5,6
Lockit	94	390	14	2,4,5,
Reclamation	118	490	20	2,4,5,6
Sinamox	104	590	29	2,4,5
Oak Brook	98	665	37	2,4,5
Sherars Falls	88	780	44	2,4,5,6
Oak Springs	50	820	48	2,4,5
Maupin	148	960	52	2,5
Frieda	178	1,110	63	2,4,5
Two Springs	-	-	65	-
North Junction	-	-	72	-
Whitehorse Rapids	122	1,260	77	4,5
Trout Creek	-	-	85	-
Coleman	78	1,355	90	5
Mecca b/	110	1,457	97	5,6
Lower	-	-	-	6

a/ Original data compilation from:

2 Dept. of the Army, Corps of Engineers
4 " " " Interior, Federal Power Commission
5 " " " " , Geological Survey
6 Oregon Cooperative Work, Dept. of the Interior with State of Oregon

b/ Conflicts with project in existence.

1.10 Sports Fishery

The Deschutes River of Oregon is one of the most famous trout fishing streams in the world. The lower Deschutes, particularly that area upstream from the mouth of White River, supports a highly productive and popular sports fishery both for native or "wild" trout and for hatchery reared fish. The season runs from late April through October and provides recreation equivalent to about 72,000 angler trips annually. Several thousand 10 to 12 inch hatchery reared rainbows are planted monthly in the area between Oak Springs and Nena Creek and in the area immediately upstream from the mouth of Shitike Creek (see Table 1.10.1). "Redside" or native rainbow trout fishing is excellent and well-exploited in such lower Deschutes River areas as below the mouth of Dry Creek, and in the South Junction-North Junction area. See Fig. 1.10.2.

Next to the resident rainbow trout, the seagoing steelhead trout is the most fished-for species in the lower Deschutes River system, providing about 12,000 angler trips each year. Most steelhead anglers fish the lower ten miles of the Deschutes River during July, August and September. Some anglers also fish upstream at such places as Sherars Falls, near Oak Springs, and in the Trout Creek area. See Fig. 1.10.3 and 1.10.4. In past years some steelhead angling took place at Steelhead Falls on the Deschutes mainstem above the study area. Very few steelhead are now caught above Pelton Dam.

Chinook salmon angling takes place primarily during April and May in the Sherars Falls area. Little angling is done specifically for salmon in other areas although in late summer several hundred chinook are caught incidental to steelhead angling near the mouth. Of the three sport fisheries this is third in importance, representing about 9,000 angler trips annually.

Analyses of salmon and steelhead sport fishery estimates indicate a statistically significant upward trend in the annual salmon catch and a significant downward trend in steelhead angler success in recent years (Fig. 1.10.5 and 1.10.6). Steelhead catch and angling pressure show no significant trends, but since angler success shows a significant trend down this must be explained by either an increase in angling pressure, a decreased catch, or a combination of both. On the basis of our field observations, we feel that an increase in angling pressure (more anglers spending more time) is the best explanation for decreased angler success, and that the total steelhead catch has actually remained relatively static.

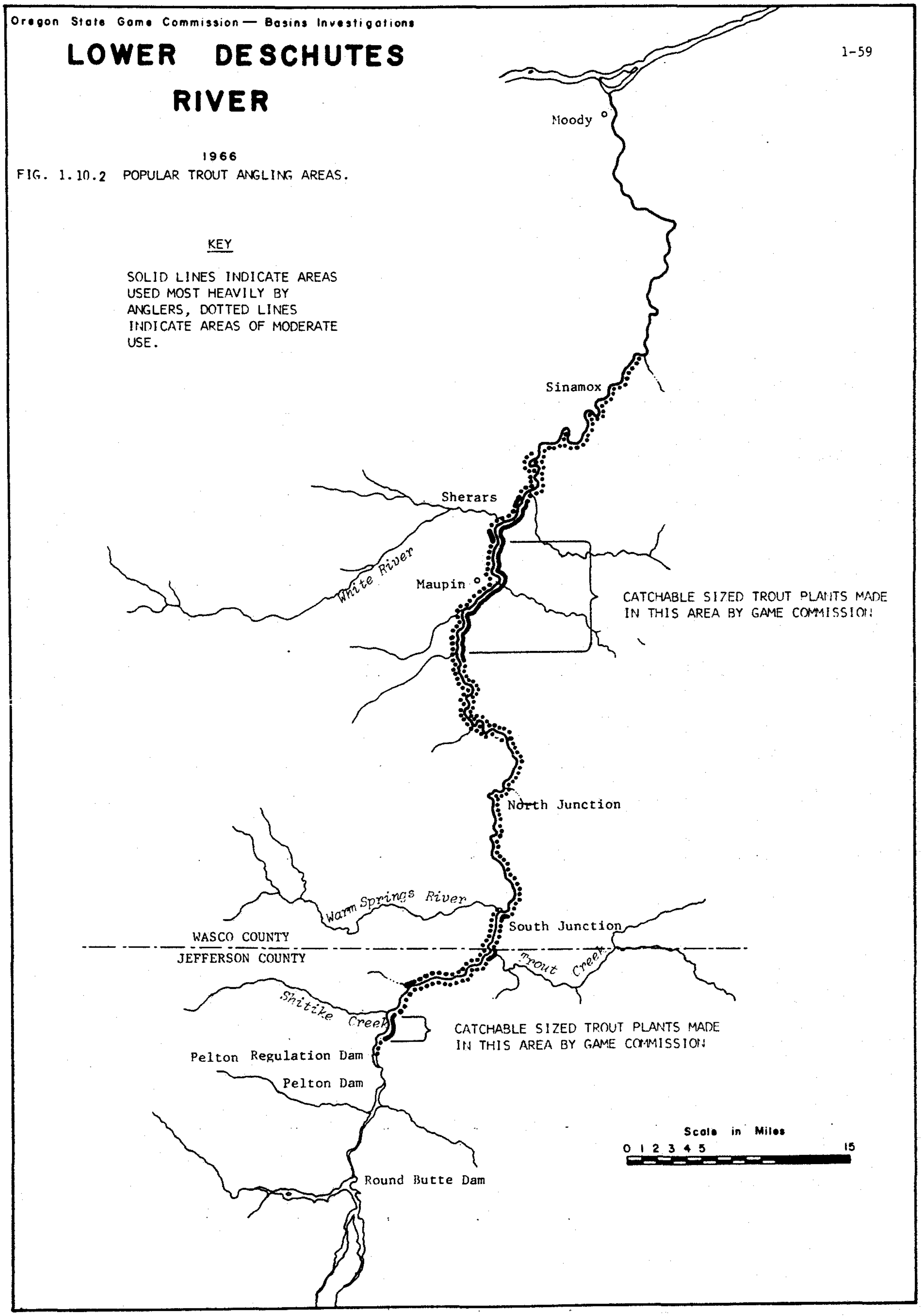
TABLE 1.10.1

Summary of Fish Stocking by the Oregon State Game Commission in Recent Years, Lower Deschutes River

	Rainbow Trout		Steelhead Trout	
Year	Number	Pounds	Number	Pounds
1966	61,931	22,915	113,551	11,635
1965	56,573	25,552	43,120	319
1964	62,773	18,195	0	0
1963	60,544	26,790	0	0
1962	57,825	25,276	0	0
--	--	--	--	--
1952	122,659	21,146	0	0

FIG. 1.10.1 STEELHEAD ANGLERS NEAR KLOAN

Photograph by Robert W. Phillips


Oregon State Game Commission — Basins Investigations
LOWER DESCHUTES RIVER
1966
FIG. 1.10.2 POPULAR TROUT ANGLING AREAS.
KEY
SOLID LINES INDICATE AREAS USED MOST HEAVILY BY ANGLERS, DOTTED LINES INDICATE AREAS OF MODERATE USE.
Moody
Sinamox
Sherars
White River
Maupin
CATCHABLE SIZED TROUT PLANTS MADE IN THIS AREA BY GAME COMMISSION
North Junction
Warm Springs River
South Junction
WASCO COUNTY
JEFFERSON COUNTY
Trout Creek
Shitike Creek
CATCHABLE SIZED TROUT PLANTS MADE IN THIS AREA BY GAME COMMISSION
Pelton Regulation Dam
Pelton Dam
Round Butte Dam
Scale in Miles
0 1 2 3 4 5 15

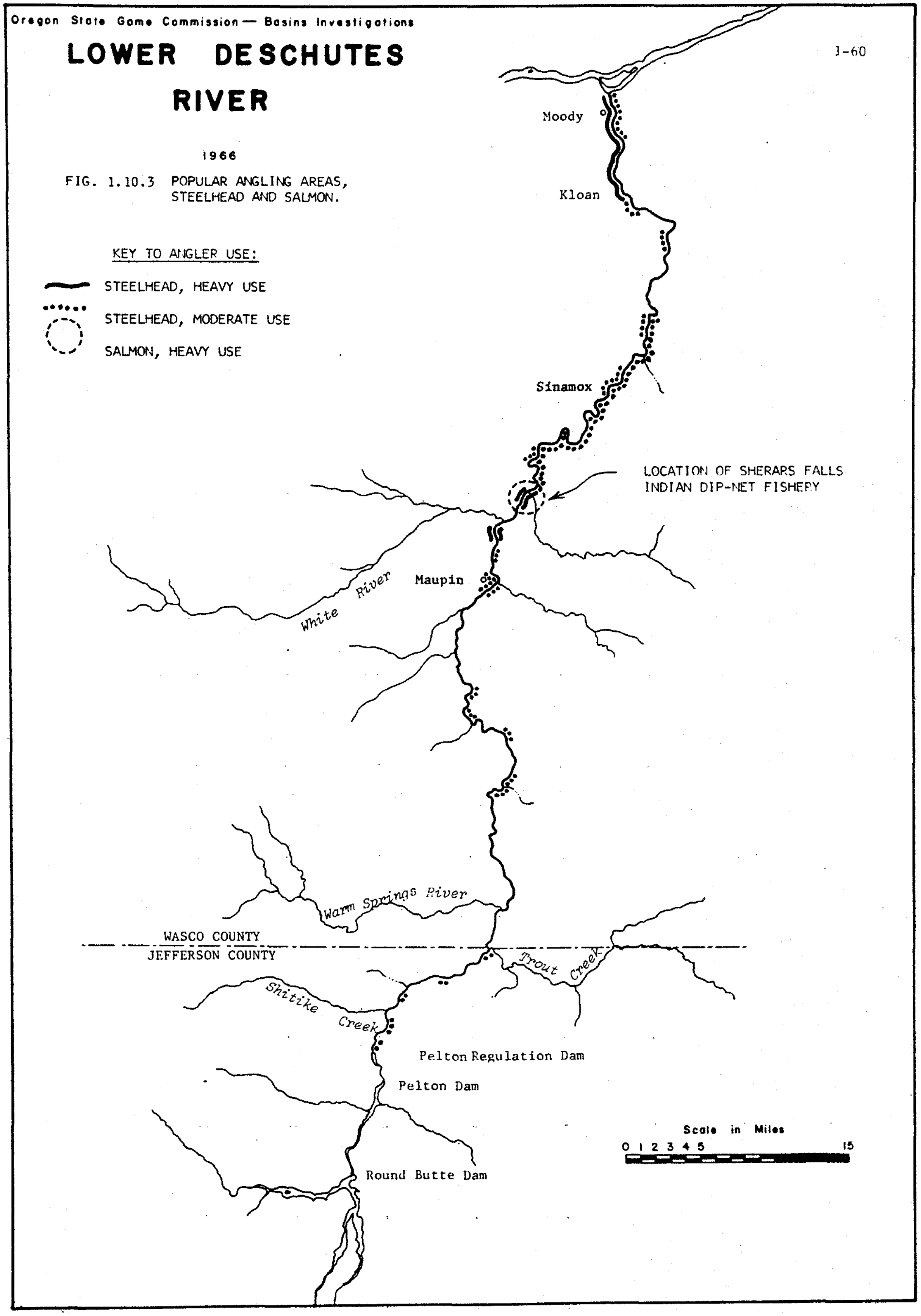
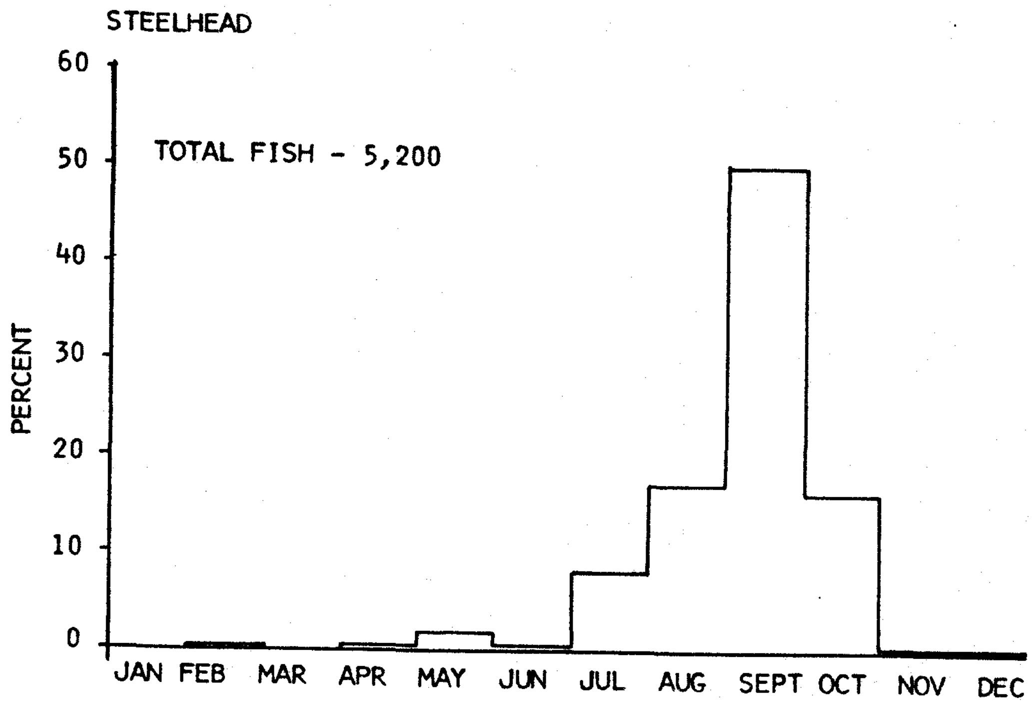

Oregon State Game Commission — Basins Investigations
LOWER DESCHUTES RIVER
1966
FIG. 1.10.3 POPULAR ANGLING AREAS, STEELHEAD AND SALMON.
KEY TO ANGLER USE:
STEELHEAD, HEAVY USE
STEELHEAD, MODERATE USE
SALMON, HEAVY USE
J-60
Moody
Kloan
Sinamox
LOCATION OF SHERARS FALLS INDIAN DIP-NET FISHERY
Maupin
White River
Warm Springs River
WASCO COUNTY
JEFFERSON COUNTY
Trout Creek
Shitike Creek
Pelton Regulation Dam
Pelton Dam
Round Butte Dam
Scale in Miles
0 1 2 3 4 5
15

FIGURE 1.10.4
PERCENTAGE DISTRIBUTION BY MONTH, ESTIMATED SPORT CATCH OF STEELHEAD AND SALMON, LOWER DESCHUTES RIVER, 1965



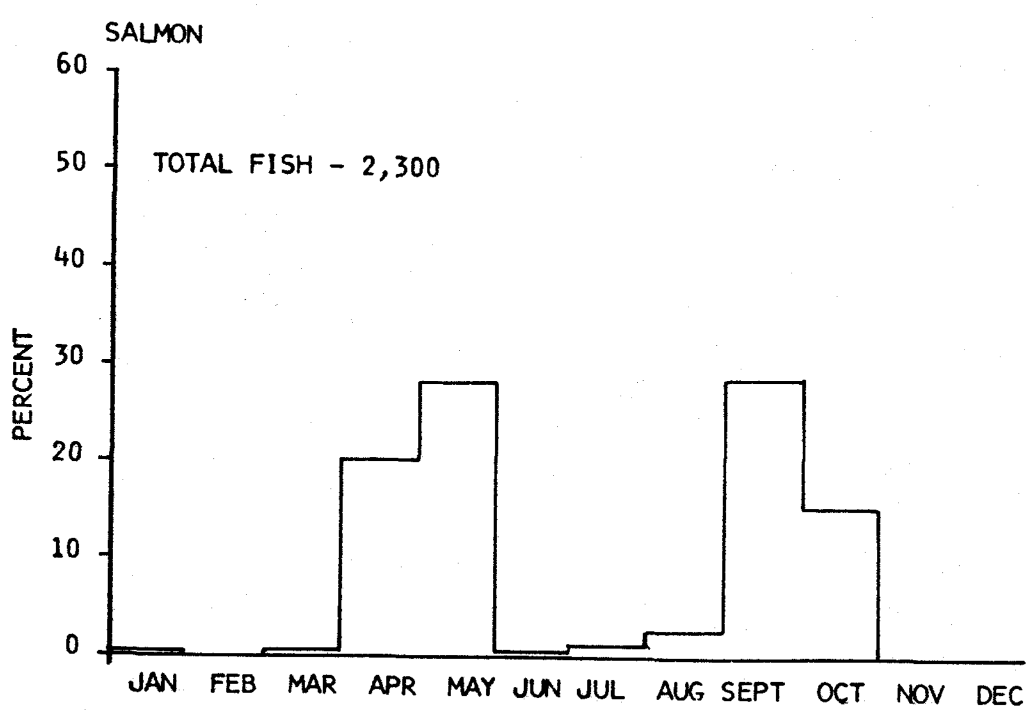
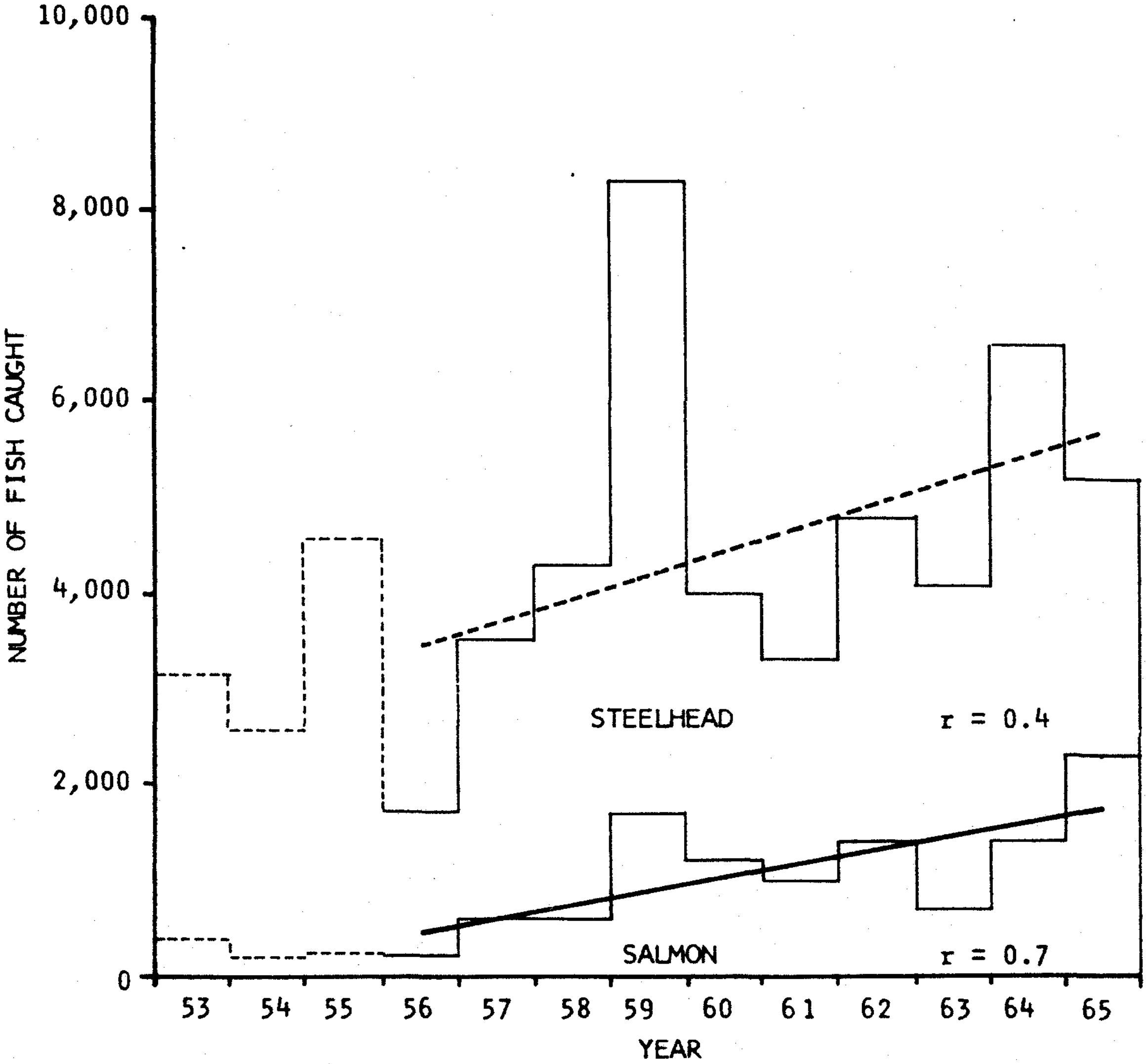


FIG. 1.10.5

SALMON AND STEELHEAD SPORT CATCH TRENDS,
DESCHUTES RIVER, 1953-1965.

(SEE TABLE 1.10.2)



Steelhead and salmon sports catch trends based on punch card returns for entire Deschutes River mainstem. 1953, 1954 and 1955 data is considered to be of marginal reliability. 1956 through 1965 data has been corrected for non-response bias and is considered highly reliable in the upper ranges and of fair to good reliability in the lower ranges. The sloping broken line indicating the trend of steelhead catch is not significant, the slope of the solid line indicating salmon catch trends is significant (F-test of regression coefficients, 5% level of significance).

TABLE 1.10.2

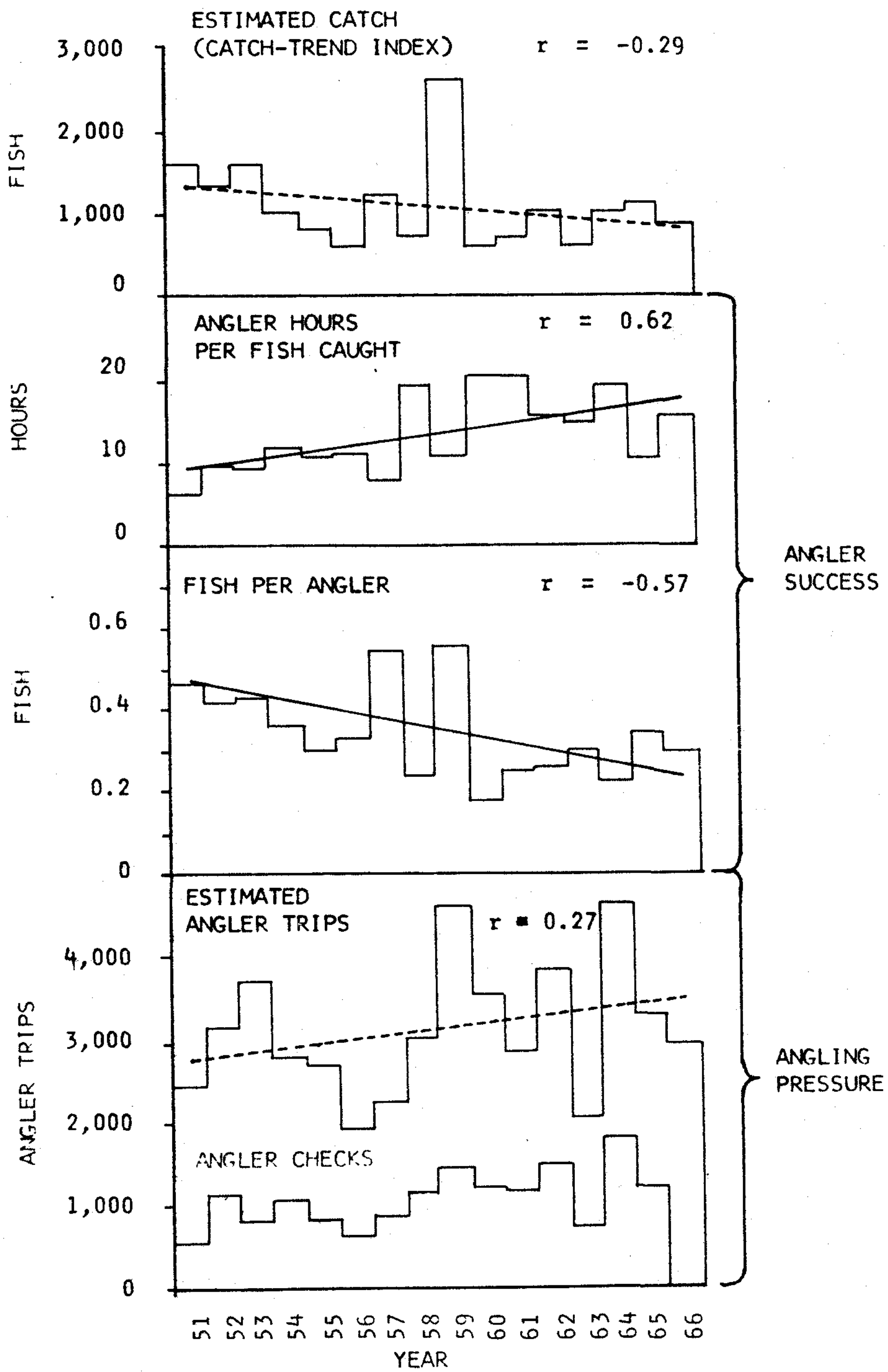
Steelhead and Salmon Sport Catch Estimates Based on Punch Card Return Data, Deschutes River, 1953-1965

	Steelhead	Salmon
1965	5,200	2,300
1964	6,600	1,400
1963	4,100	700
1962	4,800	1,400
1961	3,300	1,000
1960	4,000	1,200
1959	8,300	1,700
1958	4,300	600
1957	3,500	600
1956	1,700	200
1955*	(4,500)	(200)
1954*	(2,600)	(160)
1953*	(3,100)	(360)

* Data for these years of marginal reliability and uncorrected for non-response bias.

From unpublished data compilations by Reino O. Koski, Oregon State Game Commission.

FIGURE 1.10.6
ANGLING PRESSURE AND SUCCESS ESTIMATES AND TRENDS, SUMMER STEELHEAD SPORTS FISHERY, KLOAN TO MOUTH ON LOWER DESCHUTES RIVER, 1951-1966
(SEE TABLE 1.10.6)



Data on summer steelhead sports fishery between Kloan area and the mouth, gathered by intensive creel survey July-September, 1951-1965. Trend estimates are portrayed by solid lines if significant and by dotted lines if not significant (at the 5% level). Correlation coefficient, r, also given.

TABLE 1.10.3

Summary of Data From an Intensive Creel Check of the Summer Steelhead Sports Fishery in the Mouth and Kloan Areas, Lower Deschutes River, 1951-1965

Year	Anglers Checked	Fish per Angler Checked	Hours per Fish	Estimated Angler-Trips	Catch-Trend a/ Index
1966	b/	0.29 b/	15.7 b/	2,952 b/	870 b/
1965	1,201	0.34	11.4	3,320	1,100
1964	1,844	0.22	19.1	4,650	1,000
1963	757	0.30	15.0	2,060	600
1962	1,498	0.26	15.7	3,880	1,000
1961	1,186	0.25	20.4	2,890	700
1960	1,218	0.18	20.4	3,590	600
1959	1,464	0.55	10.8	4,660	2,600
1958	1,168	0.24	19.2	3,030	700
1957	888	0.54	7.9	2,270	1,200
1956	633	0.33	11.1	1,960	600
1955	843	0.30	11.0	2,700	800
1954	1,070	0.36	11.8	2,800	1,000
1953	882	0.43	9.5	3,740	1,600
1952	1,054	0.42	9.7	3,190	1,300
1951	562	0.64	6.6	2,450	1,600

a/ Catch-Trend Index is a figure relatable to the true annual catch but, since based on creel checks of incompleted anglers, may be lower than the true catch:

Catch-Trend Index = (F) X (A)

Where F = Fish per angler checked, and
A = Estimated angler trips

b/ An enlarged area is included in 1966 surveys, reducing the comparability of these data with previous years' data.

Based on data published in Oregon State Game Commission Annual Fisheries Reports, except 1965 and 1966 data from unpublished annual reports by Allan B. Lichens, district fisheries biologist.

TABLE 1.10.4

Summary of 1965 Angling Statistics From Three Sources, Lower Deschutes River

	Catch	Angler Trips	Fish per Angler Trip
Salmon and Steelhead			
1965 Statewide Angler Survey	8,540	19,600	0.436
Angler Creel Census	--	--	0.356
Salmon-Steelhead Punchcard Returns	7,480	--	--
Steelhead Only			
1965 Statewide Angler Survey	3,750	12,100	0.310
Angler Creel Census	--	--	0.342
Salmon-Steelhead Punchcard Returns	5,200	--	--
Salmon Only			
1965 Statewide Angler Survey	2,260 a/	9,970	0.227
Angler Creel Census	--	--	0.6
Salmon-Steelhead Punchcard Returns	2,280	--	--
Resident Trout			
1965 Statewide Angler Survey	223,000	72,400	3.08
Angler Creel Census	--	--	1.6

a/ Excluding 4,721 jacks caught

Data Sources:

1965 Statewide Angler Survey

Angler Creel Census - Unpublished 1965 annual report by Allan B. Lichens, district fisheries biologist, Oregon State Game Commission.

Salmon-Steelhead Punchcard Returns - Unpublished salmon and steelhead catch data compiled by Reino O. Koski, Oregon State Game Commission.

1.11 General Recreational Use

The lower Deschutes River is used as a focal point for several other recreation activities less directly related to water. These include, in approximate order of importance: Game hunting (chukar partridge, mule deer, ringnecked pheasant, mourning dove, valley and mountain quail, and waterfowl); camping and picnicking; rock and mineral collecting; hiking and pleasure driving; and hunting for Indian artifacts. Many facilities have been developed for these recreationists and for the fishermen such as the U.S. Bureau of Land Management's (BLM) access roads and campgrounds between Maupin and Macks Canyon, campground developments by the Confederated Tribes on the Warm Springs Indian Reservation, the Maupin City Park and Campground, and state park with campground facilities at the mouth of the Deschutes River. Maupin and several other communities profit directly and substantially from this intensive recreational utilization of the lower Deschutes River area.

Restriction on public access remains one of the major factors affecting recreational use of this area. Approximately one-half of the 200-plus miles of lower Deschutes River frontage is in public ownership (administered by the BLM). Private holdings account for about 35%, and about 15% of the frontage is within the Warm Springs Indian Reservation.

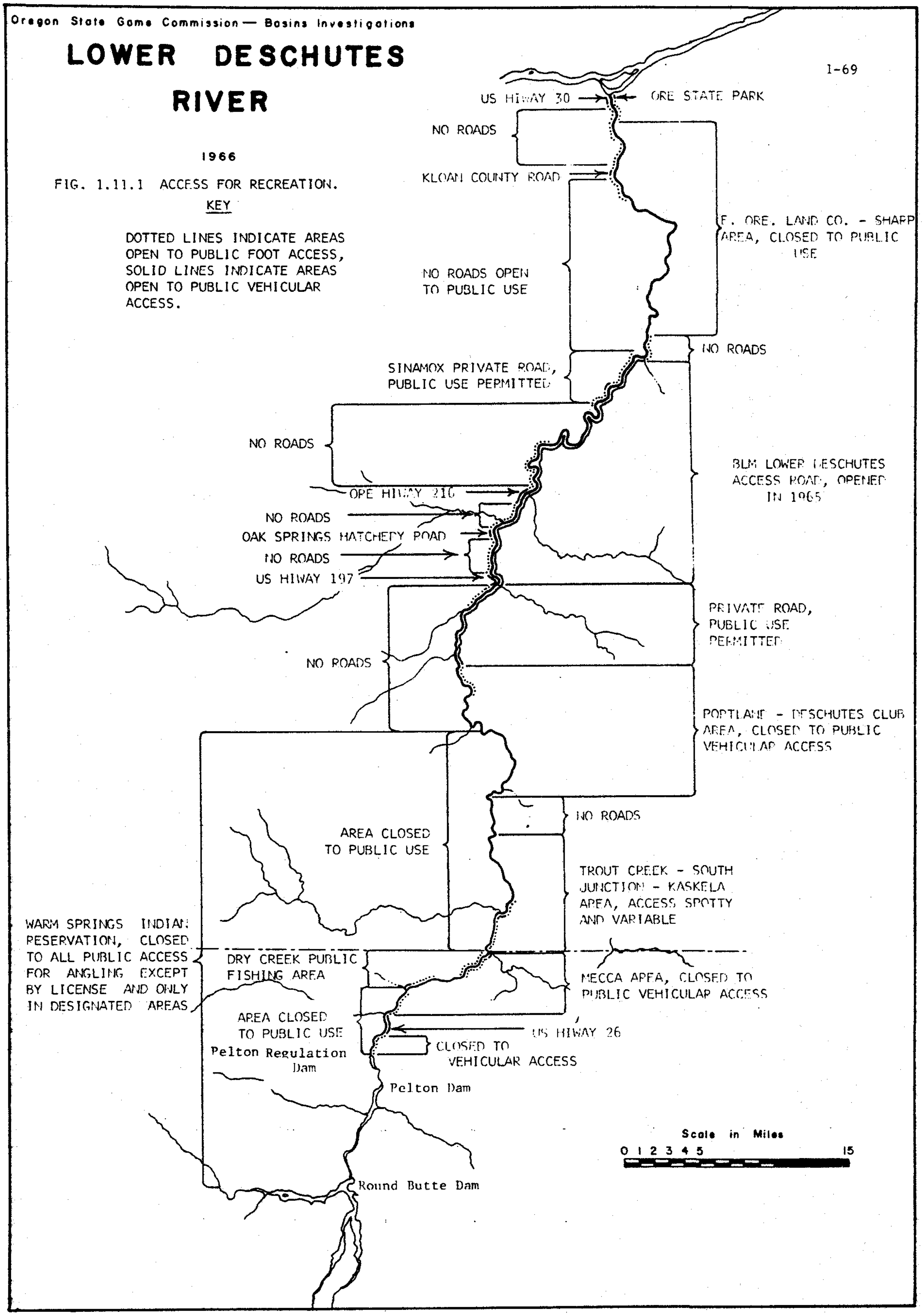
Deschutes River frontage access falls into four general classifications based on degree of public access permitted:

1. Permanently unrestricted access - In these areas routes and means of access are permanently unrestricted and the public has free access by any means including motor vehicles. About 13%, or 25 1/2 out of 200 miles of lower Deschutes River frontage is in this classification (note that 100 miles of stream has 200 miles of frontage).

2. <u>Presently unrestricted access</u> - In these areas routes and means of access are subject to private control but are presently unrestricted and the public has free access by any means including motor vehicles. An additional 11%, or 22 1/2 miles of frontage is in this classification.

3. <u>Partially restricted access</u> - The method or degree of access if presently restricted in these areas. For example, the area may be open to foot travel but motor vehicles are barred by lack of roads or presence of locked gates. The largest portion of river frontage, 48% or 95 miles, falls into this classification.

4. <u>Closed to public access</u> - Public access to these areas is effectively excluded by landowner trespass restrictions or lack of nearly all motor vehicle access. Generally, any area more than two miles from a publicly used road or where the landowner actively discourages any form of access is defined as closed to public access. Over 28% (57 miles) of the river frontage is presently closed to public access.


Oregon State Game Commission — Basins Investigations
LOWER DESCHUTES RIVER
1966
FIG. 1.11.1 ACCESS FOR RECREATION.
KEY
DOTTED LINES INDICATE AREAS OPEN TO PUBLIC FOOT ACCESS, SOLID LINES INDICATE AREAS OPEN TO PUBLIC VEHICULAR ACCESS.
1-69
US HIWAY 30
ORE STATE PARK
NO ROADS
KLOAN COUNTY ROAD
E. ORE. LAND CO. - SHARP AREA, CLOSED TO PUBLIC USE
NO ROADS OPEN TO PUBLIC USE
NO ROADS
SINAMOX PRIVATE ROAD, PUBLIC USE PERMITTED
NO ROADS
BLM LOWER DESCHUTES ACCESS ROAD, OPENED IN 1965
ORE HIWAY 216
NO ROADS
OAK SPRINGS HATCHERY ROAD
NO ROADS
US HIWAY 197
PRIVATE ROAD, PUBLIC USE PERMITTED
NO ROADS
PORTLAND - DESCHUTES CLUB AREA, CLOSED TO PUBLIC VEHICULAR ACCESS
NO ROADS
AREA CLOSED TO PUBLIC USE
TROUT CREEK - SOUTH JUNCTION - KASKELA AREA, ACCESS SPOTTY AND VARIABLE
WARM SPRINGS INDIAN RESERVATION, CLOSED TO ALL PUBLIC ACCESS FOR ANGLING EXCEPT BY LICENSE AND ONLY IN DESIGNATED AREAS
DRY CREEK PUBLIC FISHING AREA
MECCA AREA, CLOSED TO PUBLIC VEHICULAR ACCESS
AREA CLOSED TO PUBLIC USE
US HIWAY 26
CLOSED TO VEHICULAR ACCESS
Pelton Regulation Dam
Pelton Dam
Scale in Miles
0 1 2 3 4 5 15
Round Butte Dam

LOWER DESCHUTES RIVER, OREGON;

DISCHARGE AND THE FISH ENVIRONMENT

Warren W. Aney
Monty L. Montgomery and
Allan B. Lichens

Oregon State Game Commission
Portland, Oregon

PART TWO
Trout and Salmon Spawning

Lower Deschutes Flow Study Final Report (Draft)

November 1967

Table of Contents

Part Two. Trout and Salmon Spawning

Methods

2.1 Redd Counts

Systematic, random and incidental counts of trout and salmon redds were made by airplane, drift boat and wading.

During aerial counts an attempt was made to tally all visible redds in randomly or systematically selected sample areas. This method was generally used for counting chinook salmon redds since they are characteristically found in deeper water away from the shoreline. When visibility was good it was possible to see most of the redds in open water areas. From the air, redds could be seen at a greater depth than from a drift boat.

Use of the Rogue River style drift boat with outboard motor enabled us to cover shallow water areas either directly from the boat or by wading. This was the primary method used to survey trout and steelhead spawning since these fish tended to use shallows near the shoreline which would be obscured from aerial observation by overhanging brush and trees. Fig. 2.1.1.

2.2 Embryo Survival

Two methods were used to obtain data on intragravel survival of trout and salmon embryos.

In one method selected redds of various ages were excavated to sample condition and survival of embryos. Redds were dug up with an ordinary shovel and embryos collected in a screen or net placed about three feet downstream. See Fig. 2.2.1. Several factors appeared to limit the accuracy and efficiency of this method: (1) We observed evidence of predation or scavenging on embryos by intragravel organisms such as insect larvae; (2) redds were superimposed one on another; (3) false redds were constructed; (4) dead embryos decomposed rapidly; and (5) we experienced difficulty in determining redd age and the beginning of fry emergence from the gravel.

During redd sampling we gathered data on redd location, approximate redd age, total number of embryos excavated, a descriptive breakdown on embryo condition (live or dead eggs, live or dead fry, and egg cases recovered), and apparent development stage of the embryos. Embryo development was graduated into (1) green or uneyed eggs, (2) eyed eggs, (3) sac fry, (4) intermediate fry, (5) advanced fry, and (6) emergent fry. See Fig. 2.2.2. In cases of overlapping redds or varying growth rates within the same redd the sample was classified according to the predominating development stage reached by the embryos recovered. An attempt was made to sample redds during the fifth, or advanced fry stage.

Since many eggs and pre-emergent fry were injured by the shovelling, the following method was used to separate live and dead embryos: Very small embryo particles were discarded and not enumerated; larger particles, if they were a major portion of an egg or fry, were counted; these particles were classified as dead if decomposition had obviously taken place or as live at the time of excavation if showing no evidence of decomposition. Decomposition of dead organisms was quickly evident in the Deschutes River. Fry remains showed pronounced tissue deterioration and fungus growth while dead eggs turned opaque white from protein precipitates.

In the second method used to test intragravel survival we placed green steelhead eggs in artificially established redds and subsequently trapped any fry successfully emerging from these redds. On March 17, 1965 winter steelhead eggs were obtained from Alsea Trout Hatchery and divided in 22 lots of one hundred eggs each. Eighteen of these one hundred egg lots were placed in randomly located artificial redds within the lower Deschutes River study area. See Table 2.2.1. Plastic intragravel standpipes were also placed in these artificial redds. On April 28th, 29th and 30th emergent fry traps were placed over 11 of these artificial redds. The emergent fry traps, 6 by 8 feet in size, were constructed of 1/8 inch mesh nylon netting after a design developed and reported by Phillips (1966).

An additional 22 artificial redds were established in a like manner on May 22, 1965 using fertilized eggs obtained from three steelhead trapped at Pelton Dam (two females and one male). In each case, March and May, eggs were also placed in hatchery troughs at Oak Springs Trout Hatchery to measure egg lot survival under controlled conditions.

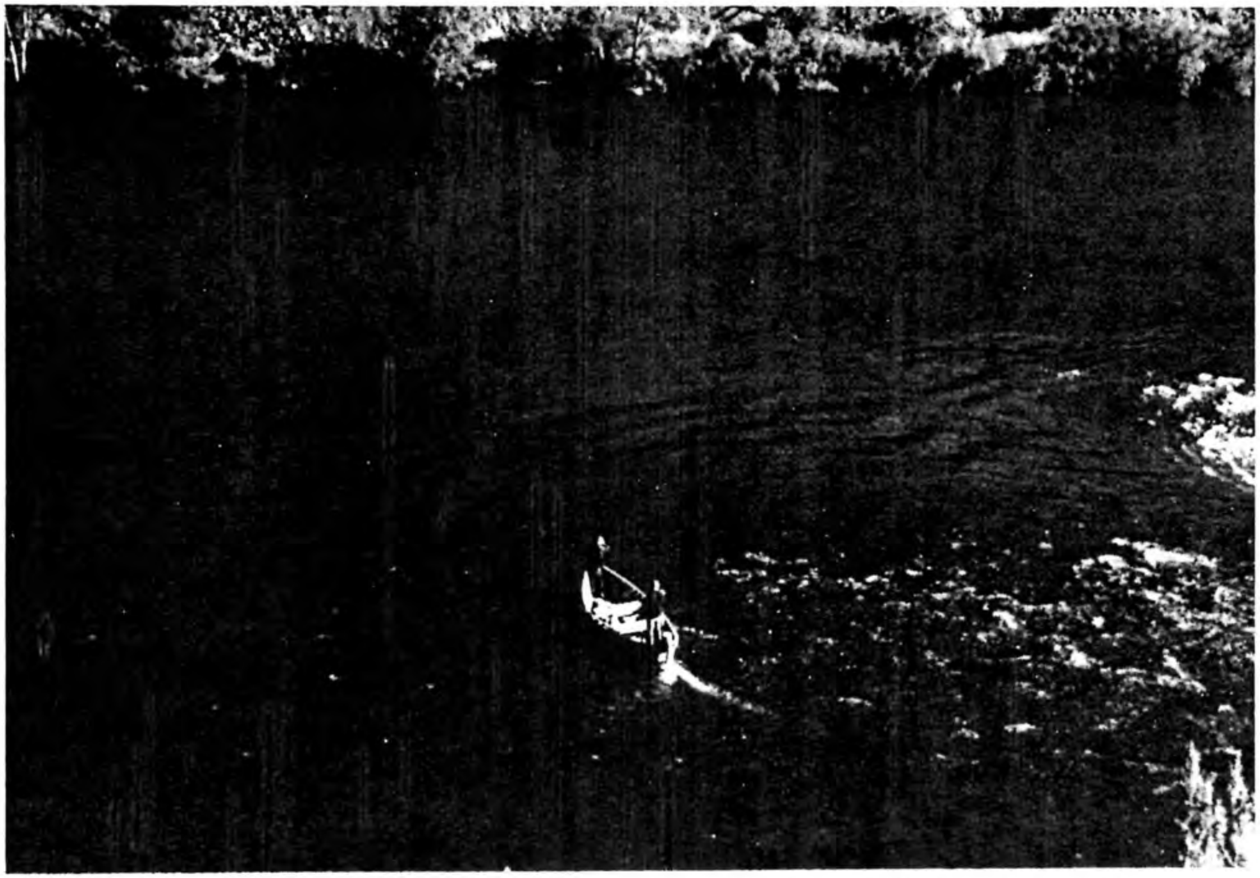


FIGURE 2.1.1 SPAWNING GROUND SURVEY BY DRIFT BOAT, NEAR CEDAR ISLAND

FIGURE 2.2.1 EXCAVATION OF NATURAL REDD TO SAMPLE EMBRYO SURVIVAL; DON KING AND RON SLOAN; STATION 47A; JULY 10, 1964

FIG. 2.2.2

EMBRYO DEVELOPMENT STAGES USED, LOWER DESCHUTES STUDY

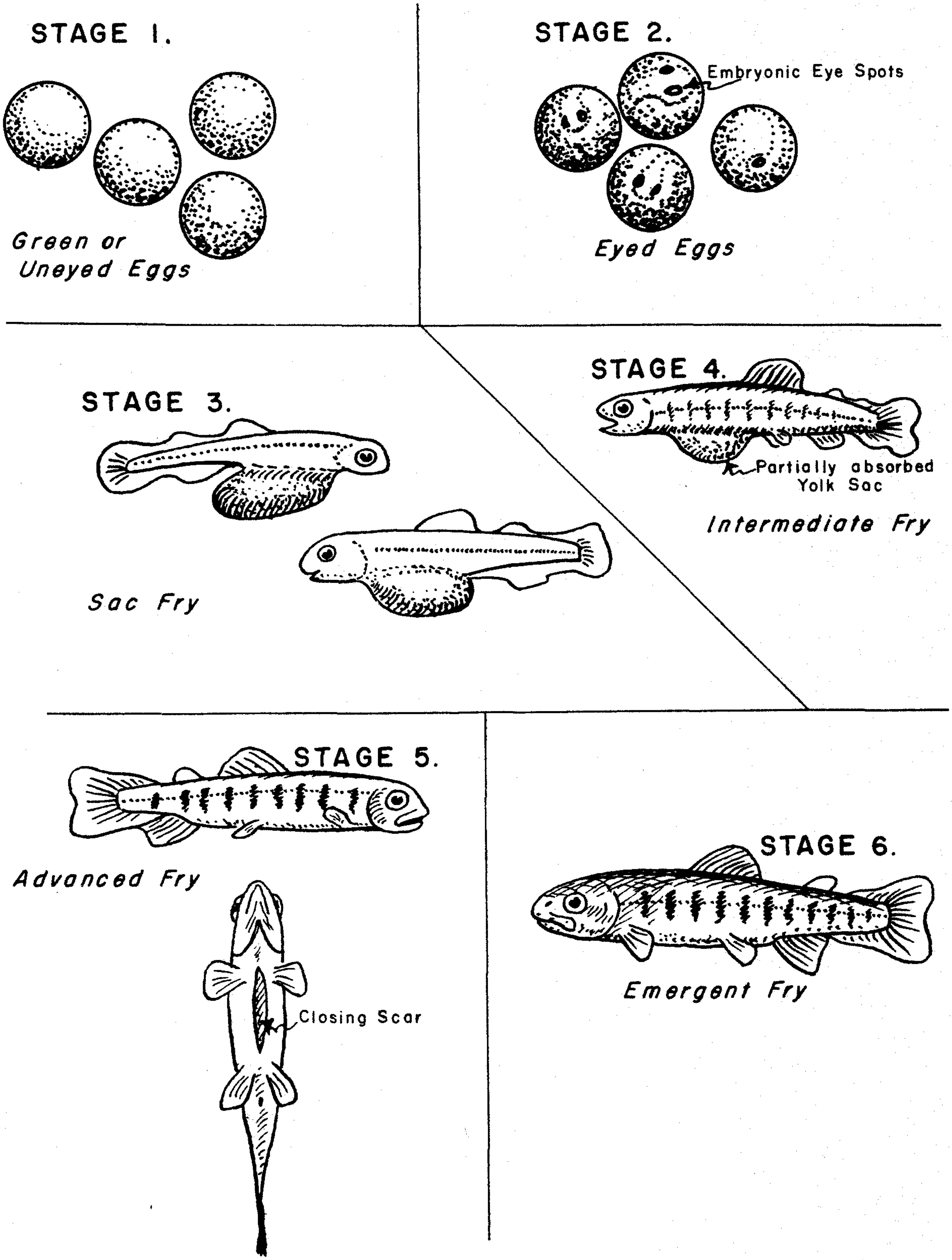


TABLE 2.2.1

Artificial Redds Constructed on March 17 and May 20, 1965. Lower Deschutes Flow Study.

Date	Redd No.	Station No.	River Mile	Water Depth Over Gravel	Gravel Depth Over Eggs
Mar 17	1	501	99.8	0.9 ft.	0.90 ft.
Mar 17	2	501	99.8	0.6	0.90
Mar 17	3	501	99.8	0.5	0.85
Mar 17	4	501	99.8	1.0	0.85
Mar 17	5	501	99.8	0.8	0.80
Mar 17	6	501	99.8	0.7	0.80
Mar 17	7	9	94.3	0.8	0.90
Mar 17	8	15A	90.8	0.9	1.00
Mar 17	9	9	94.3	1.2	1.00
Mar 17	10	9	94.3	1.2	0.90
Mar 17	11	9	94.3	0.5	1.10
Mar 17	12	47B	77.1	0.5	1.00
Mar 17	13	56	70.4	0.8	0.90
Mar 17	14	56	70.4	0.7	1.00
Mar 17	15	56	70.4	0.5	1.00
Mar 17	16	56	70.4	0.9	0.90
Mar 17	17	123	10.3	0.7	1.00
Mar 17	18	123	10.3	0.6	1.00
May 20	19	504	99.0	0.7	0.80
May 20	20	501	99.8	0.4	0.85
May 20	21	504	99.0	0.8	0.90
May 20	22	501	99.8	0.3	0.90
May 20	23	504	99.0	0.8	0.90
May 20	24	501	99.8	0.9	0.90
May 20	25	9	94.3	0.9	0.80
May 20	26	9	94.3	0.9	0.80
May 20	27	9	94.3	0.9	0.80
May 20	28	9	94.3	0.6	0.90
May 20	29	9	94.3	0.8	0.90
May 20	30	9	94.3	0.6	0.90
May 20	31	11A	92.7	1.3	0.90
May 20	32	47B	77.1	1.0	0.90
May 20	33	47B	77.1	0.8	0.90
May 20	34	47B	77.1	1.2	0.80
May 20	35	73	61.6	0.5	0.75
May 20	36	73	61.6	0.8	0.90
May 20	37	73	61.6	1.0	0.90
May 20	38	73	61.6	0.8	0.90

March 17: All eggs buried between 7:15 a.m. and 12:45 p.m., eggs spawned March 16 at 3:30 p.m.

May 20: All eggs buried between 11:30 a.m. and 5:10 p.m., eggs spawned at 9:00 a.m. same day.

Results

2.3 Spawning Distribution and Density

Throughout the course of the study steelhead and rainbow trout spawning was concentrated in stream Sections I, II and the upstream half of III. Early in this study steelhead and rainbow trout spawning was observed in scattered downstream locations in Sections III and IV but since 1964 no evidence of trout spawning has been found. The heaviest density (redds per stream mile) of trout spawning occurs in stream Section I.

Based on redd count data gathered throughout the course of the study rainbow and steelhead trout redds were distributed as follows:

Stream Section I	40%
Stream Section II	35%
Stream Section III	22%
Stream Section IV	3%

Chinook salmon distribution was about as follows:

Stream Section I	12%
Stream Section II	14%
Stream Section III	57%
Stream Section IV	17%

See Table 2.3.1, Figs. 2.3.3 and 2.3.4.

During the first years of this study steelhead trout spawning was usually first observed around mid-March. During the years 1963, 1964 and 1965 no completed redds were found earlier than April 15. Of all the fresh steelhead and rainbow trout redds counted during the course of this study (1961-1966), most were found during May and June (Table 2.3.1). Although we were able to classify only one-third of the trout redds by subspecies, the bulk of the classified rainbow trout redds were observed somwhat later than most steelhead redds. See Fig. 2.3.1. Steelhead are probably the first to start spawning in any year, although rainbow redds have been found as early as April 9 (1961). Fresh rainbow redds have been observed as late as July 16 and steelhead redds as late as June 13 (both cases in 1963).

Chinook salmon spawning occurs primarily during October. <u>See</u> Fig. 2.3.2. Fresh chinook redds were found as early as September 28 and as late as December 10 (1965 in each case).

Based on relative numbers of redds identified as to subspecies, it is probable that the amount of rainbow trout spawning taking place exceeds that of steelhead trout by nearly two times. Since no attempt was made to equalize counting effort between spring and fall surveys it is not possible to directly compare chinook spawning effort with trout spawning effort by use of redd count data.

We found it easy to distinguish between fresh redds, "middle-aged" redds two to four weeks old, and old redds. At river discharges within normal spawning season ranges, redds started to lose their distinctive gravel coloring and contours within two weeks: Disturbed gravels are of a lighter cast than the undisturbed bottom material covered with fine sediment and stream bottom flora. This coloring material usually recovered disturbed gravel within two to four weeks and redds then became indistinguishable by color.

Redd contours remained distinguishable six to eight months if river discharges were low. Under higher discharges in the range of five to seven thousand cfs many redds became indistinguishable by contour within 10 to 14 days.

Although it is difficult to make conclusive comparisons of yearly redd counts, we did find evidence that 1963 counts were significantly higher than counts for the ensuing three years. <u>See</u> Tables 2.3.2, 2.3.3, 2.3.4, and 2.3.5.

TABLE 2.3.1

Distribution of Redds Counted, by Month and Stream Section, Lower Deschutes River, 1961-1966

RAINBOW AND STEELHEAD TROUT REDDS

Month	Stream Section I	II	III	IV	Total	Percent
March	0	0	1	0	1	1%
April	16	36	173	18	243	10
May	706	529	220	0	1455	57
June	635	77	67	7	786	31
July	32	29	0	0	61	2
Total a/	1389	1219	745	104	3457	100
Percent	40%	35%	22%	3%	100%	

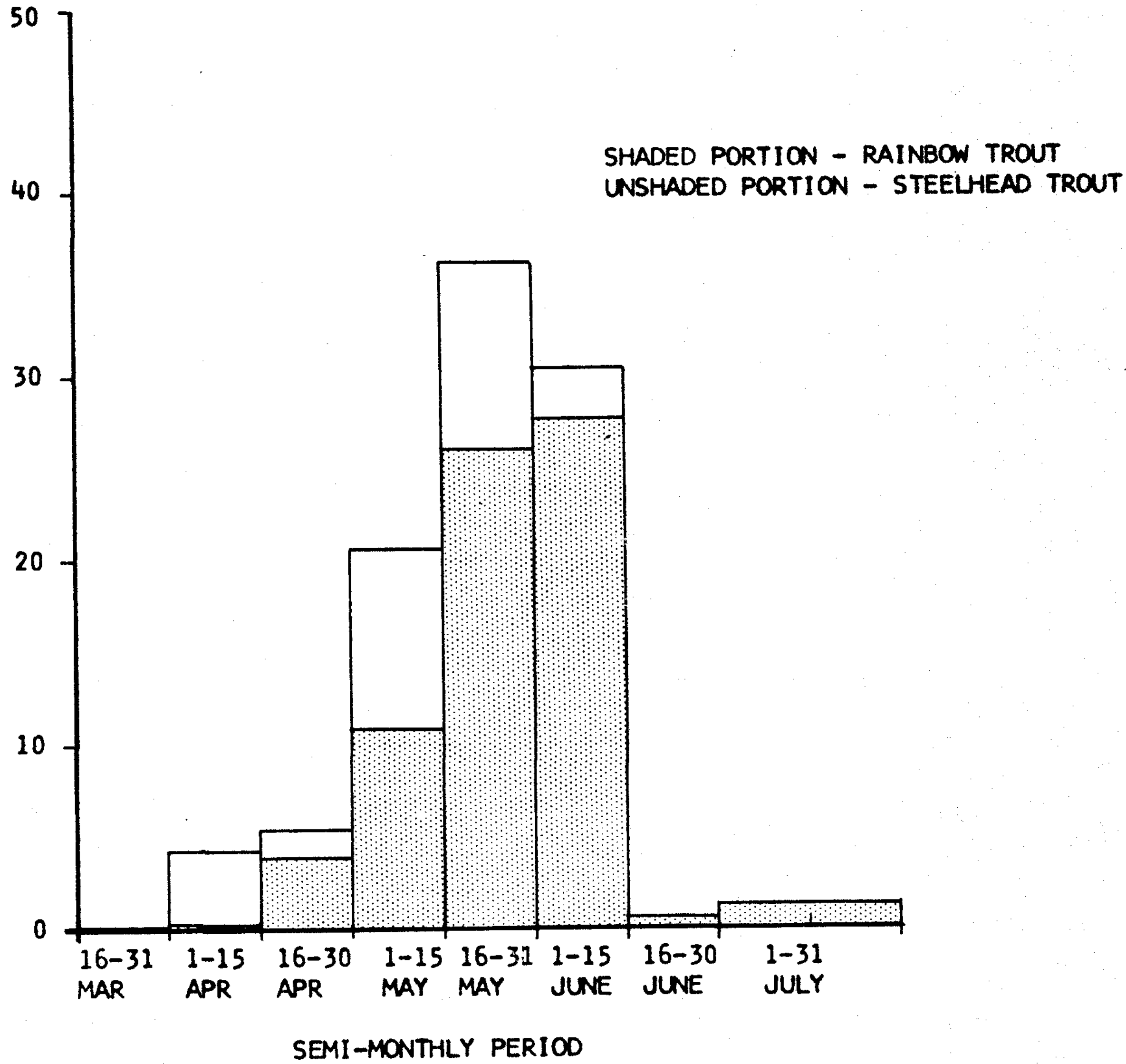
CHINOOK SALMON REDDS

Month	Stream Section I	II	III	IV	Total	Percent
September	8	6	19	18	51	4%
October	165	195	522	176	1058	73
November	0	0	192	45	237	16
December	3	0	92	0	95	7
Total	176	201	825	239	1441	100
Percent	12%	14%	57%	17%	100%	

a/ Totals include 911 trout redds counted in 1963 when no record was made of the date of the counting.

FIG. 2.3.1

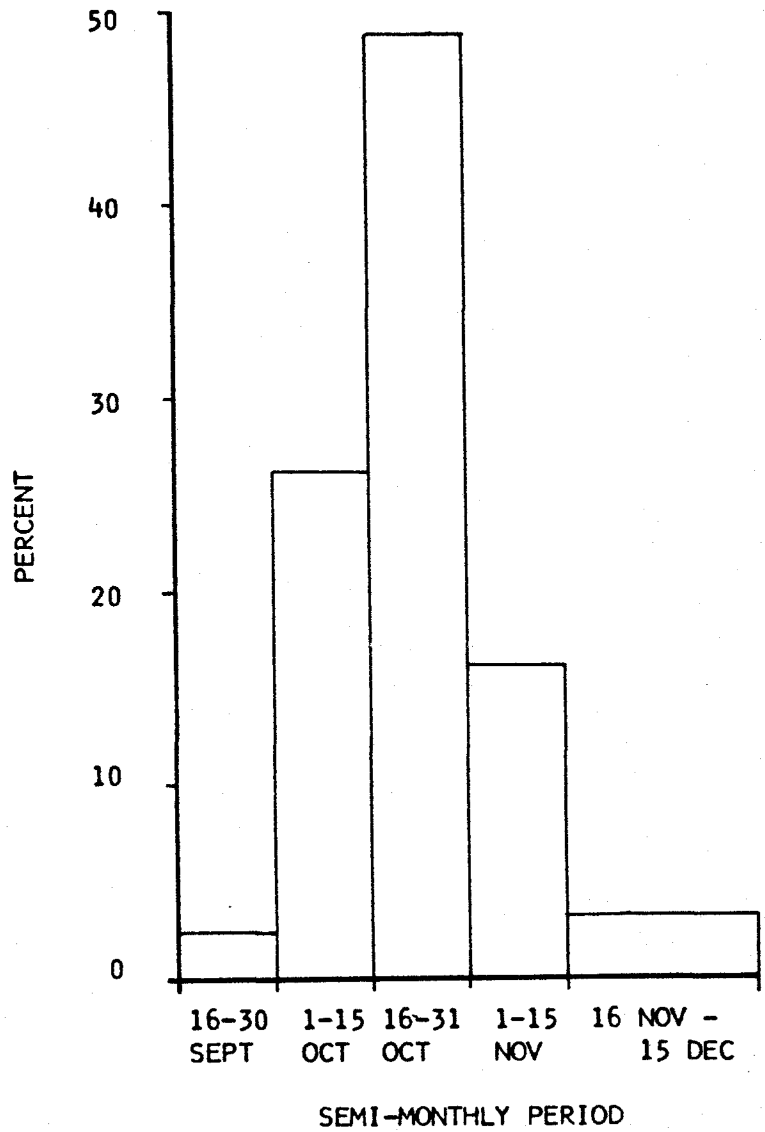
RELATIVE DISTRIBUTION OF STEELHEAD AND RAINBOW TROUT SPAWNING BY SEMI-MONTHLY PERIODS, LOWER DESCHUTES RIVER, 1963-1966



Total trout spawning recorded during 1963, 1964, 1965, and 1966, expressed as semi-monthly percentages. Relative proportions of rainbow and steelhead redds in each period based on distribution of redds clearly identified as to subspecies.

FIG. 2.3.2

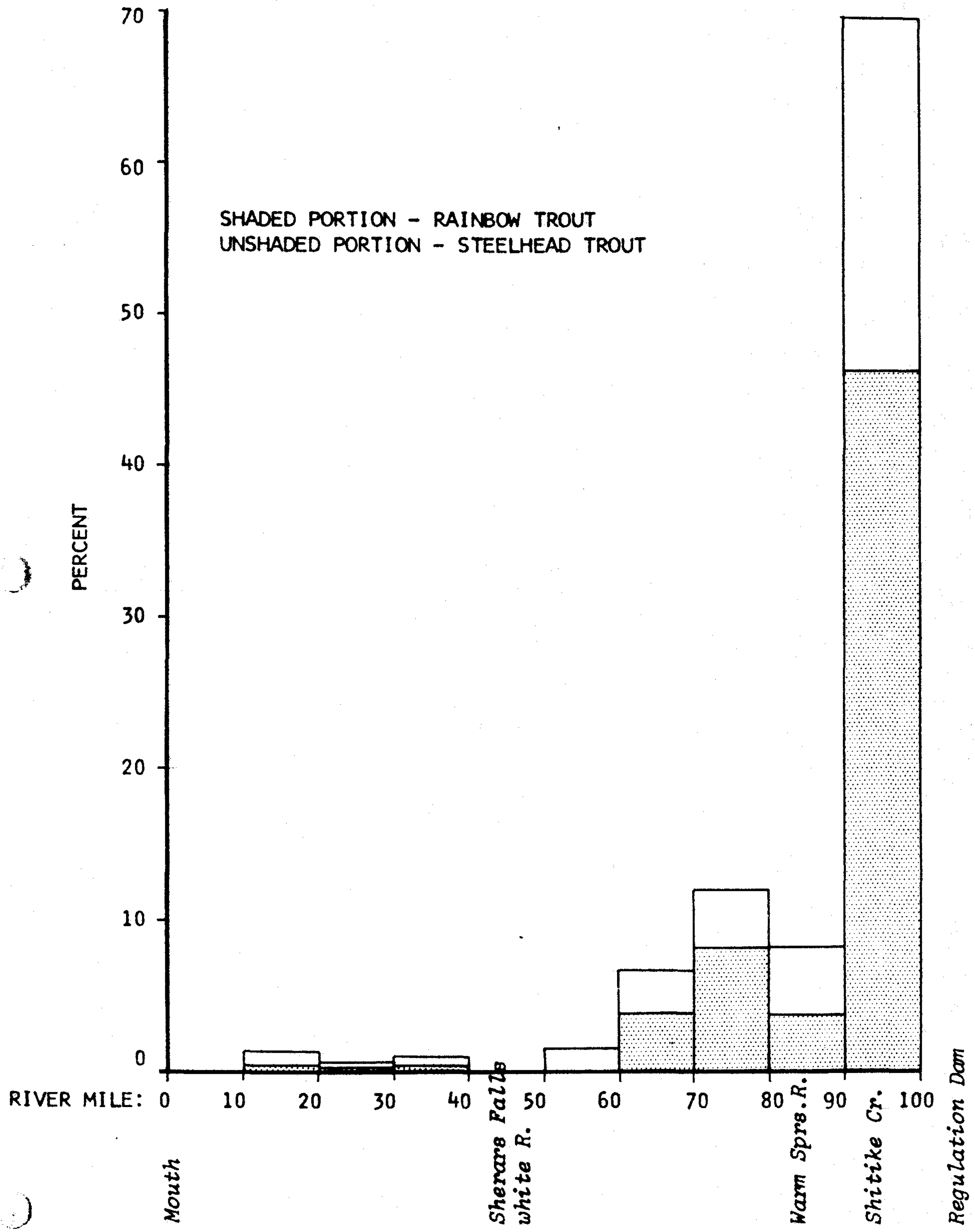
RELATIVE DISTRIBUTION OF CHINOOK SALMON SPAWNING BY SEMI-MONTHLY PERIODS, LOWER DESCHUTES RIVER, 1961-1965



Total salmon spawning recorded during 1961, 1962, 1963, 1964 and 1965 expressed as semi-monthly percentages. Earliest recorded spawning observed September 28, latest observed December 10 (both records in 1965).

FIG. 2.3.3.

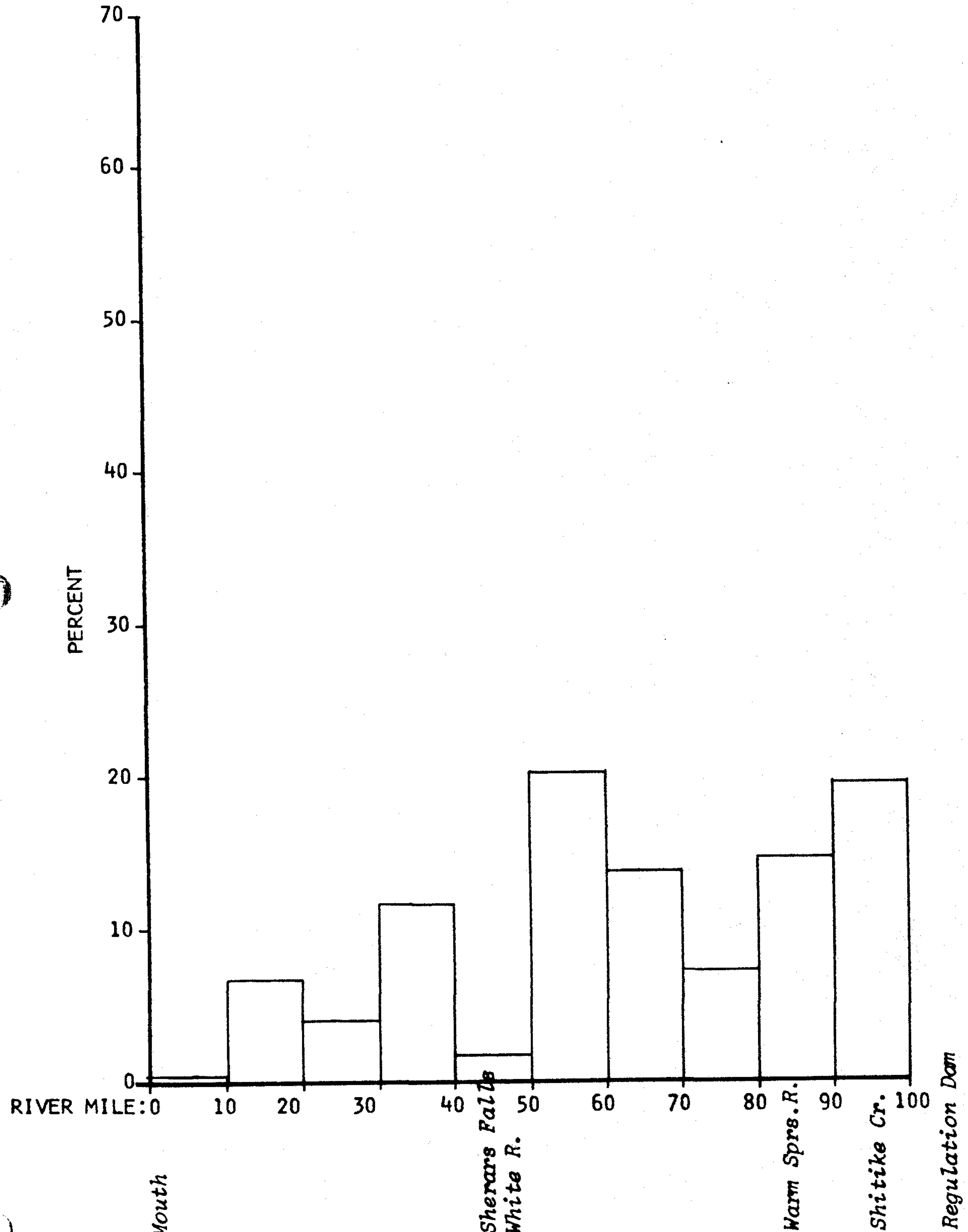
RELATIVE DISTRIBUTION OF STEELHEAD AND RAINBOW TROUT SPAWNING BY 10-MILE SEGMENTS, LOWER DESCHUTES RIVER, 1961-1966



Total trout spawning recorded during 1961, 1963, 1964, 1965 and 1966 expressed as percentages occurring in each 10-mile segment. Relative proportions of rainbow and steelhead redds in each segment based on distribution of redds clearly identified as to subspecies.

FIG. 2.3.4.

RELATIVE DISTRIBUTION OF CHINOOK SALMON SPAWNING BY 10-MILE SEGMENTS, LOWER DESCHUTES RIVER, 1961-1965



Total salmon spawning recorded during 1961 through 1965, expressed as percentages occurring in each 10-mile segment.

TABLE 2.3.2.

Counts of Rainbow and Steelhead Trout Redds on 5 Gravel Bars, Lower Deschutes River, 1963 through 1966

Gravel Bar Station No. (r)	Year (t) 1963	1964	1965	1966	Station Total (T_r)	Station Mean ($\bar{Y}_r$)
501	178	17	81	144	420	105
504	106	60	32	52	250	62.5
10	87	3	21	20	131	32.75
47B	75	4	16	8	103	25.75
58B	6	2	3	0	11	2.75
Yearly total (T_t)	452	86	153	224	915	
Yearly Mean ($\bar{Y}_t$)	90.4	17.2	30.6	44.8		45.75

TABLE 2.3.3

Analysis of Variance, Randomized Blocks; Counts of Rainbow and Steelhead Trout Redds on 5 Gravel Bars, Lower Deschutes River, 1963 through 1966

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Replication	24,836.50	n - 1 = 4	6,209.125	
Years	15,195.75	k - 1 = 3	5,065.250	5.862
Error	10,369.50	(k-1)(n-1)=12	864.125	
Total	50,401.75	kn-1=19		

Tabular F at 5% with 3 and 12 d.f. is 3.4903
Conclusion: There are significant differences between the means of the yearly counts.

TABLE 2.3.4

New Multiple Range Test (Li, p. 270); Counts of Rainbow and Steelhead Trout Redds on 5 Gravel Bars, Lower Deschutes River, 1963 through 1966

Year	$\bar{y}$	$\bar{y}$ - 17.2	$\bar{y}$ - 30.6	$\bar{y}$ - 44.8
1963	90.4	73.2 (40.5)	59.8 (42.5)	45.6 (43.8)
1966	44.8	27.6 (40.5)	14.2 (42.5)	
1965	30.6	13.4 (40.5)		
1964	17.2			

Significant studentized ranges at 5% significance level (in parentheses).
Conclusions: Redd counts for the year 1963 are significantly greater than counts for the other years. There are no significant differences between the counts for 1964, 1965 and 1966.

TABLE 2.3.5

Rainbow and Steelhead Trout Redd Counts, by Year and Stream Section, Lower Deschutes River, 1961-1966

	1961	1962a/	1963	1964	1965	1966	Total
Total redds, Stream Section I	a/	-	577	138	267	407	1389
Total redds, Stream Section II	11	-	619	76	121	392	1219
Total redds, Stream Section III	88	-	374	101	89	93	745
Total redds, Stream Section IV	18	-	79	1	6	0	104
Total no. of steelhead b/redds, all Stream Sections	75	-	53	86	120	7	341
Percent of classified redds that are steelhead	64.1	-	20.8	44.8	35.3	14.9	35.9
Total no. of rainbow b/redds, all Stream Sections	42	-	202	106	220	40	610
Percent of classified redds that are rainbow	35.9	-	79.2	55.2	64.7	85.1	64.1
Total no. of unclassified b/ redds, all Stream Sections	0	-	1394	124	143	845	2506
Percent of all redds that are unclassified	0	-	84.5	39.2	29.6	94.7	72.5
Total redds counted	117 c/	a/	1649 c/	316 c/	483 c/	892 c/	3457

a/ No redd counts made

b/ Classification of redds as to subspecies (rainbow or steelhead) dependent upon the skill of the observers, presence or absence of spawning fish on the redds, time and location of spawning, and size of redd when completed. Redds which could not be identified as to subspecies were listed as "Rb/St" or "Unclassified".

c/ Counting effort was roughly the same during the 1963, 1964 and 1965 spawning season. In 1961 counting effort was considerably less and in 1966 it was considerably greater.

2.4 Spawning Success

Over 7,000 embryos were recovered from 72 natural redds sampled by excavation in the 1963, 1964, 1965, and 1966 spring spawning seasons. Although we tried to keep track of redd age to enable sampling when embryos were well advanced in development but not yet emerging from the gravel, redds were actually sampled at all development stages. See Table 2.4.1. Where age was accurately known, average redd age at time of sampling was 49.4 days. Most of the redds sampled contained predominantly sac fry (29% of the redds), intermediate fry (19%) or advanced fry (24%).

On over one-half the sampled redds we were not able to determine which subspecies, rainbow or steelhead, made the redds. These we listed as "undetermined" or "rainbow/steelhead" (Rb/St) redds. See Table 2.4.2. Where subspecies could be determined, three out of four of the redds sampled were rainbow.

During 1966 redd sampling we recorded the number of "false" redds encountered. A false redd was defined as an incompleted redd in which spawning did not occur and which usually cannot be distinguished from a true or completed redd containing embryos. About one-third of the redds sampled did not contain embryos and were classified as false but our marking and sampling methods may have inflated the number of false redds. See footnotes to Tables 2.4.1 and 2.4.2.

Of the embryos recovered one-third of the eggs were alive, over 80% of the sac fry were alive, and 95 to 100% of the intermediate, advanced and emergent fry were alive. This high rate for live fry was partially attributed to very rapid decomposition of dead fry as contrasted to greater persistence of dead eggs which are protected by tough egg capsules.

Raw data given in Table 2.4.3 was refined prior to statistical analysis by the following methods: Anomalous green and eyed eggs recovered from redds containing pre-emergent fry were excluded whenever we recorded presence of overlapping or superimposed redds of much lesser age. Likewise, anomalous sac fry were not included in refined data for redds containing advanced fry. Redds containing fry of sufficient development that emergence from the gravel had possibly already started were also excluded.

Most of the statistical analyses were on data from stage 3, 4 and 5 redds (predominantly sac fry, intermediate fry and advanced fry). Survival in these redds was estimated by dividing number of live fry by total number of embryos recovered (live + dead). Comparison of embryo survival estimates at these three pre-emergent stages produced the following observations:

1. In 1966, mean survival in stream Section I was 58%, in stream Section II 28% and in stream Section III, 46%. The differences between these means is statistically significant at the 5% level.

2. Mean embryo survival for all years was 60% in stream Section I, 47% in Section II, 30% in Section III, and 1% in Section IV. Due to wide variation in sample sizes these differences were not tested statistically.

3. Mean survival in 1964 was 40%, which is significantly less (at the 5% level) than mean survival in 1966, 47%. (Figures for 1966 and 1964 were compared since sample size and distribution were most nearly equal these two years.)

Plastic standpipes were placed in a number of redds and were used to obtain samples of intragravel water for dissolved oxygen analysis. This technique is described in detail in Part Four of this report. Twenty-two standpiped redds were dug up and sampled for embryo survival -- 14 of these redds contained pre-emergent fry (Table 2.4.6). Linear regression showed a significant correlation (at the 5% level) between the proportion of live embryos recovered from these redds and minimum amounts of dissolved oxygen observed in intragravel water samples (Fig. 2.4.1, Table 2.4.7).

TABLE 2.4.1

Summary of Natural Trout Redd Sampling, Lower Deschutes River, 1963-1966

Year	Number of Redds Containing Embryos, by Development Stage a/ 1	2	3	4	5	6	Total Redds
1963	1	2	4	1	0	0	8
1964	3	2	9	5	9	0	28
1965	0	2	1	0	0	1	4
1966 b/	2	2	9	8	8	3	32
Totals:	5	8	23	14	17	4	72

a/ Development stage of redd based on stage reached by a significant portion of live embryos recovered: 1. Green or uneyed eggs; 2. Eyed eggs; 3. Sac fry; 4. Intermediate fry; 5. Advanced or pre-emergent fry; 6. Emergent fry.

b/ In 1966 a tabulation was made of false redds encountered (no embryos recovered when redd dug up). 17 false redds were recorded, or 34.7% of the 49 redds excavated that year.

TABLE 2.4.2
Species Distribution of Trout Redds Sampled,
Lower Deschutes River, 1963-1966

Year	Rainbow	Steelhead	Undetermined	Total
1963	2	3	3	8
1964	3	3	22	28
1965	3	1	0	4
1966 a/	19	3	27	49
Total	27	10	52	89

a/ Includes 7 false rainbow redds, 1 false steelhead redd, and 9 false undetermined redds.

TABLE 2.4.3

Summary of Data on Embryo Survival in Natural Rainbow and Steelhead Trout Redds, by Redd Stage and Embryo Development Stage, 1963 - 1966

REDD STAGE[b]	RECOVERED EGGS				DEVELOPMENT STAGE OF RECOVERED FRY[a]												OVERALL			
	Dead eggs	Live Eggs		Total Eggs	Sac Fry			Intermediate Fry			Advanced Fry			Emergent Fry						
		Green	Eyed		Dead	Live	Total	Dead	Live	Total	Dead	Live	Total	Dead	Live	Total	Dead	Live	Total	Survival
1.	225	469	0	694													225	469	694	0.676
2.	228	39	547	814	2	0	0										230	586	816	0.718
3.	1458	1[c]	201	1660	142	597	739										1600	799	2399	0.333
4.	364	290[c]	25[c]	679	0	57	57	40	788	828							404	1160	1564	0.742
5.	804	3[c]	2[c]	809	20[c]	43[c]	63[c]	0	2	2	22	485	507				846	535	1381	0.387
6.[d]	96	0	0	96	0	0	0	0	0	0	0	0	0	0	187	187	96	187	283	0.661
Total	3175	802	775	4752	164	697	861	40	790	830	22	485	507	0	187	187	3401	3736	7137	
Survival				0.332			0.810			0.952			0.957			1.000				0.523

[a] Development stage of recovered fry (Embryo Development Stage): 1. Green (uneyed) eggs 2. Eyed eggs 3. Sac fry 4. Intermediate fry (yolk sac partially absorbed) 5. Advanced fry (pre-emergent, no yolk sac) 6. Emergent fry (probably emerging or near emergence)

[b] Redd stage based on development stage reached by a significant portion of live embryos recovered.

[c] Anomalies attributable to superimposition or overlapping of more recent redds over older redds.

[d] Redds at the stage not included in data analyses because of bias of already emerged fry.

TABLE 2.4.4

Size Distribution of 131 Measured Fry From Six Excavated Natural Steelhead and Rainbow Trout Redds, Lower Deschutes River, 1964

Length (mm)	3. Sac Fry		4. Intermediate		5. Advanced		6. Emergent	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
13	1	2						
14	0	0						
15	1	2						
16	2	4						
17	3	6						
18	13	27						
19	15	31						
20	7	15	2	7				
21	6	13	10	34				
22			13	45	2	4		
23			2	7	7	13		
24			2	7	25	46		
25					20	37		
Total	48	100	29	100	54	100	0	

TABLE 2.4.5

Summary of Embryo Survival in Natural Redds to the Pre-Emergent Development Stages, a/ by Year and Stream Section, Lower Deschutes River, 1963-1966

	STREAM SECTION I			STREAM SECTION II			STREAM SECTION III			STREAM SECTION IV			ENTIRE STUDY AREA		
Year	Redds Sampled	Recovery: Live Embryos / Total Embryos	Embryo Survival	Redds Sampled	Recovery: Live Embryos / Total Embryos	Embryo Survival	Redds Sampled	Recovery: Live Embryos / Total Embryos	Embryo Survival	Redds Sampled	Recovery: Live Embryos / Total Embryos	Embryo Survival	Redds Sampled	Recovery: Live Embryos / Total Embryos	Embryo Survival
1963 b/	0			0			5	24/253	0.095	1	0/48	0.000	6	24/301	0.080
1964	3	81/100	0.810	3	466/735	0.634	15	327/1295	0.252	3	1/60	0.017	24	875/2190	0.400
1965	0			0			1	1/23	0.043	0			1	1/23	0.043
1966	9	627/1081	0.580	7	176/625	0.282	9	331/725	0.457	0			25	1134/2431	0.466
Total	12	708/1181	0.599	10	642/1360	0.472	30	683/2296	0.297	4	1/108	0.009	56	2034/4945	0.411

a/ Survival of embryos in redds containing sac fry, intermediate fry, and advanced fry development stages (see Fig. 2.2.2).

b/ Only redds exhibiting obviously detrimental environment qualities were sampled in 1963. In 1964 and 1966 an effort was made to sample redds with a wide range of environmental characteristics (i.e., siltation, intragravel water dissolved oxygen, gravel composition, gravel permeability, and surface water velocity).

TABLE 2.4.6

Summary of Data Used in Correlating Embryo Survival to Intragravel Water Quality, Lower Deschutes River, 1963-66

		Intragravel Water Sampling			Redd Sampling			
			Minimum Values		Develop-ment	Embryos Recovered		
	Redd Number a/	No. of Samples	mg02/l.	Saturation	Stage b/	Total	Live	Survival (Live/Total)
1.	63-47B-5	4	8.5	81.6%	Sac fry	5	5	1.000
2.	63-58B-2	3	7.4	71.0	" "	7	7	1.000
3.	64-501-1	4	6.9	70.3	" "	46	46	1.000
4.	66-73-14	4	2.9	27.0	" "	121	22	0.182
5.	66-10-53	1	3.8	35.4	" "	198	4	0.020
6.	66-29B-3	2	6.0	58.2	" "	28	24	0.857
7.	63-58B-16	4	7.4	73.3	Interm. fry	34	15	0.441
8.	64-501-3	3	7.4	71.9	" "	14	12	0.857
9.	64-501-19	4	6.9	63.8	" "	54	51	0.944
10.	64-504-29	3	5.8	55.4	" "	424	400	0.943
11.	66-58A-21	5	4.1	37.6	" "	138	73	0.529
12.	66-47A-26	2	0.4	3.7	" "	77	9	0.117
13.	66-25B-3	5	3.6	33.9	Adv. fry	84	19	0.226
14.	66-10-51	4	0.8	7.4	" "	104	15	0.144
	Totals	48	--	--	--	1,334	702	0.526

a/ First two digits = year, second two or three digits (or letter) = station number, third digit (s) = intragravel standpipe number.

b/ See Figure 2.2.2

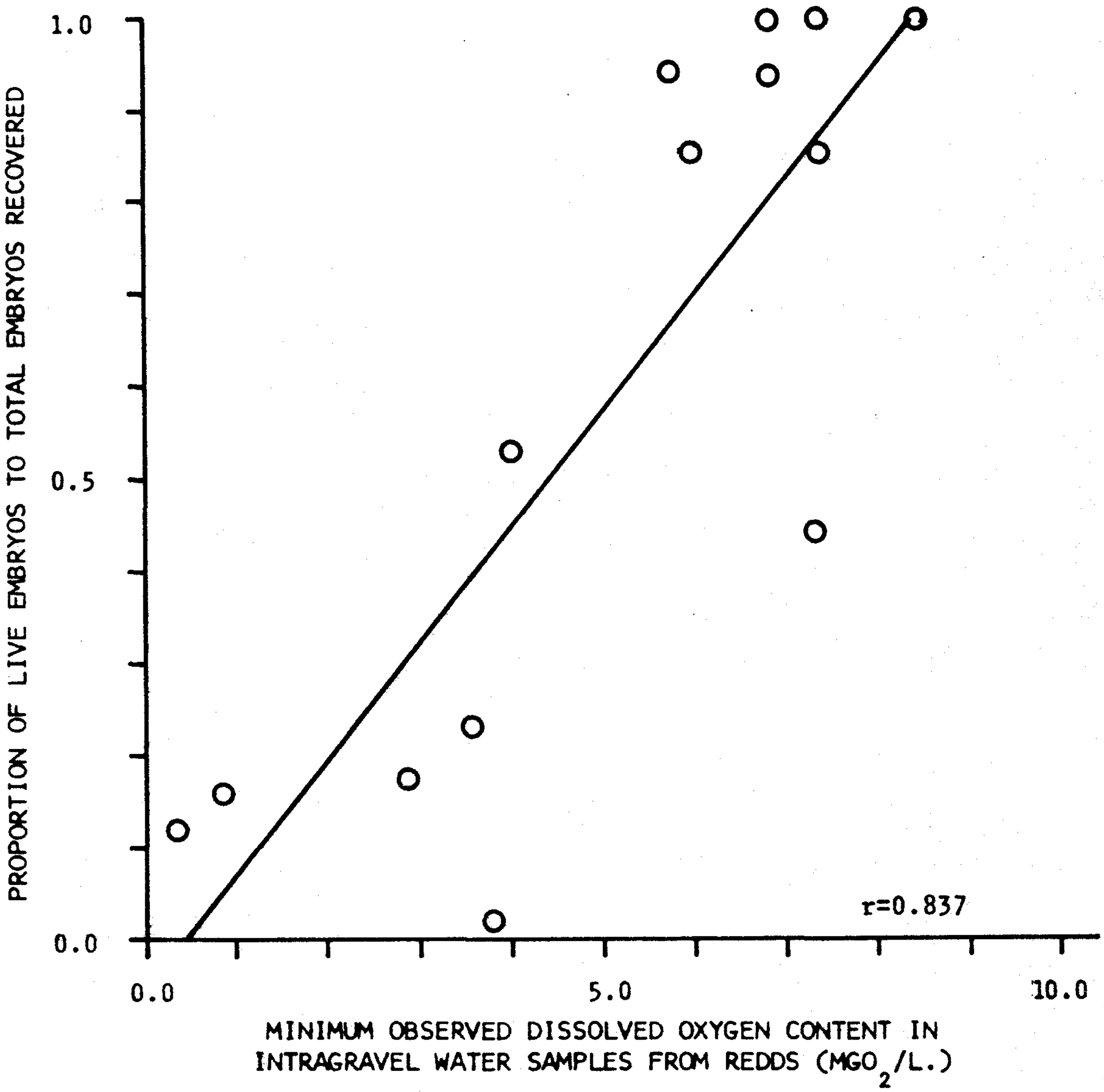
Table 2.4.7

Summary of Correlations, Proportion of Live Embryos to Total Embryos Recovered With Intragravel Water Dissolved Oxygen, Lower Deschutes River, 1963-66

Correlation	No. of Redds Sampled (n)	Regression Coefficient (b)	Correlation Coefficient (r)	Standard Deviation (s)	Calculated F	Tabular F (at 5%)	Conclusion: Correlation is...
Proportion of live:total eggs recovered with intragravel water dissolved oxygen...							
...milligrams per liter	4	0.17	0.968	0.142	30.196	18.513	Significant
...percent saturation	4	1.54	0.894	0.255	7.943	18.513	Not Significant
Proportion of live:total sac fry recovered with intragravel water dissolved oxygen...							
...milligrams per liter	6	0.19	0.926	0.191	23.98	7.709	Significant
...percent saturation	6	0.02	0.940	0.173	30.32	7.709	Significant
Proportion of live:total intermediate and advanced fry recovered with intragravel water dissolved oxygen...							
...milligrams per liter	8	0.10	0.808	0.224	11.25	5.987	Significant
...percent saturation	8	0.01	0.788	0.234	9.80	5.987	Significant
Proportion of live:total sac fry, intermediate fry and advanced fry recovered with intragravel water dissolved oxygen...							
...milligrams per liter	14	0.13	0.837	0.222	27.97	4.747	Significant
... percent saturation	14	0.01	0.834	0.223	27.50	4.747	Significant

FIG. 2.4.1

RELATION BETWEEN EMBRYO SURVIVAL AND THE DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER IN 14 RAINBOW AND STEELHEAD TROUT REDDS, LOWER DESCHUTES RIVER, 1963-66.



Embryo survival to the pre-emergent fry stages is correlated with minimum absolute dissolved oxygen content of intragravel water sampled from natural rainbow and steelhead trout redds. Fourteen redds were sampled for fry survival and intragravel water quality; 1,334 live and dead embryos were recovered and 48 intragravel water samples were analyzed for dissolved oxygen content. The correlation is significant at the 5% level.

The other major attempt to gather data on embryo survival in lower Deschutes River gravels -- placing green steelhead eggs in artificial redds -- did not provide conclusive results. Control egg lots in hatchery troughs showed highly variable survival rates. These controls were handled the same as the test lots -- this high variability may therefore indicate faulty methodology. See Table 2.4.8.

Pre-emergence survival in the artificial redds was low as indicated by 10 excavated redds: Out of an original 1,000 eggs placed in these 10 redds only 180 embryos were recovered, indicating high egg and fry decomposition prior to redd excavation. Only 22.5% of the 180 embryos recovered were alive. Live embryos recovered were predominantly sac fry and advanced fry. See Table 2.4.9.

As might be predicted from low and variable pre-emergent survival experienced in hatchery troughs and in sampled artificial redds, very few emergent fry were recovered from the 11 installed traps. Traps were in place April 15 through July 18, or during the 30th through 114th day of embryo development. Only 9 emergent fry were trapped and recovered. See Table 2.4.10. The redd exhibiting consistently highest intragravel water dissolved oxygen content produced 7 of these 9 emergent fry. One fry was recovered from a redd showing near average intragravel environment quality, and the 9th fry was recovered from a redd showing a very low quality environment. This latter fry emerged very late, 114 days as opposed to 78 to 92 days for the other emerging fry, and was noticeably smaller (length 24.5 mm, weight 150 mg., compared to 27 to 29 mm and 185 to 249 mg for 8 fry emerging earlier).

Fry recovered from hatchery controls, excavated artificial redds and emergent fry traps were noticeably larger than fry recovered from natural Deschutes River spawning (compare Table 2.4.11 with Table 2.4.4).

Siltation under emergent fry traps built up rapidly and in some cases the gravel was completely covered with as much as one inch of fine silt and sand. Where water velocities were high, numerous holes were abraded in the trap material. These holes were repaired as discovered. Algae growths had to be cleaned off periodically on traps exposed to sunlight. Late in the trapping period the zipper tapes disintegrated.

TABLE 2.4.8
Steelhead Embryo Survival to "Swim-Up" Stage in Hatchery Troughs, Six Lots From Artificial Redd Trials, Lower Deschutes River Flow Study, Mar. 17-Apr. 28, 1965. See Figure 2.4.6

		Number of Embryos Surviving						
Date	Days	Lot #1	Lot #2	Lot #3	Lot #4	Lot #5	Lot #6	Total
Mar. 17	0	200	300	100	100	100	100	900
Mar. 25	8	198	298	99			79	874
Mar. 29	12	192	294	97	98	96	72	849
Apr. 3	17	191	293	96	98	91	67	836
Apr. 5	19	187	287	94	97	89	62	816
Apr. 7	21	185	279	90	97	86	52	789
Apr. 8	22	181		89	95	84	48	776
Apr. 9	23	179	273	88		82	43	760
Apr. 11	25	174	257	87	94	79	27	718
Apr. 12	26	168	249				22	699
Apr. 14	28	159	245	86	92		20	681
Apr. 19	33	156				79		678
Apr. 22	36			85				677
Apr. 28	40	156	231	85	88	76	15	651
Time, spawning to troughs a/		24:45	24:40	16:30	22:25	22:00	24:50	--
Overall survival		78%	77%	85%	88%	76%	15%	72.3%
Mean length, mm		26.0	26.4	26.5	26.5	26.4	24.8	26.1
Mean weight, mg		218	221	226	232	230	186	218.7

a/ Elapsed time from spawning to placement in hatchery troughs, hours: minutes.

Mean length and weight determined from a representative sample (n = 10) of preserved "swim-up" (intermediate) fry.
Hatchery water temperature at Oak Springs is a constant 54° F., therefore embryo development is faster than in the Deschutes River which is considerably cooler at this time of the year.

Statistical comparison of overall survival data with elapsed time from spawning to placement in hatchery troughs did not show a correlation significant at the 5% level. Likewise, comparison of length and weight measurements with elapsed time showed no correlations significant at the same 5% level.

Elapsed time and overall survival - $b = -0.037$, $r = -0.433$, $F = 0.924$;
Elapsed time and mean length - $b = -0.101$, $r = -0.488$, $F = 1.250$;
Elapsed time and mean weight - $b = -2.399$, $r = -0.455$, $F = 1.042$;
where 5% point of F-distribution with 1 and 5 degrees of freedom = 6.608.

TABLE 2.4.9

Summary of Data From Excavated Artificial Redds -- Embryo Survival and Intragravel Water Quality, March-July 1965

		Intragravel Water Sampling			Redd Excavation Data			
Redd No.	Station No.	No. of Samples	Minimum $mgO_2/l.$	Minimum Saturation	Redd Age	Embryos Recovered Total	Embryos Recovered Live	Survival (Live/Total)
6 a/	501	7	10.2	93%	64 days	34	28	0.824
9	9	2	9.8	87	78	2	2	1.000
14	56	3	10.5	91	57	19	1	0.053
17	123	4	3.8	34	57	10	0	0.000
24 b/	501	6	6.6	64	49	28	1	0.036
31	11A	7	0.2	2	77	3	1	0.333
32	47B	1	2.6	24	42	35	0	0.000
33	47B	3	0.3	3	49	16	0	0.000
37	73	3	3.8	38	43	3	0	0.000
38	73	3	1.5	15	43	30	0	0.000
Totals		39	-	-	-	180	33	-
Means		3.9	4.9	45%	56 days	18	3.3	0.225

a/ Redds numbered 6 through 17 established March 17, 1965 using freshly spawned winter steelhead eggs from Alsea Hatchery.

b/ Redds numbered 24 through 38 established May 20, 1965 using freshly spawned eggs from Deschutes River summer steelhead obtained from Pelton upstream migrant trap.

Tests of the relationships between embryo survival and intragravel water quality were unable to show statistically significant correlations

(5% point of the F-distribution with 1 and 9 degrees of freedom = 5.117):
Minimum mgO_2/l - b = 0.054, r = 0.577, F = 3.99;
Minimum saturation - b = 0.006, r = 0.572, F = 3.88.

TABLE 2.4.10

Emergent Fry Trapping Data, Artificial Redd Trials, Lower Deschutes Flow Study, 1965

Redd No.	Station No.	Critical Environmental Factors			No. of Fry Emerging	Redd Age at d/ Emergence
		Min.DO2 a/	Min.Perm.b/	Max.Temp.c/		
1	501	8.3 Mg/1	23.5	50.8°F.	7	78, 85, 92 d. e/
2	501	2.9	7.0	50.2	0	
3	501	5.5	24.5	50.2	0	
4	501	7.3	34.5	50.4	0	
5	501	1.3	9.5	50.2	0	
8	15A	2.3	11.5	53.0	0	
11	9	4.0	3.0	53.2	0	
12	47B	0.3	1.5	55.0	1	114 d.
13	56	6.8	2.0	53.8	1	79 d.
15	56	6.9	1.5	55.1	0	
18	123	4.4	3.0	58.9	0	
				Total	9	

a/ Minimum observed dissolved oxygen content of intragravel water samples

b/ Minimum observed plastic intragravel standpipe permeability index value, see Part Four.

c/ Maximum observed intragravel water temperature.

d/ Number of days elapsed between spawning and recovery of emergent fry from trap.

e/ One fry recovered at 78 days, 4 fry recovered at 85 days, and 2 fry recovered at 92 days.

Tests of relationships between number of fry emerging and intragravel environment factors were not able to show any significant correlations (5% point of the F-distribution with 1 and 10 degrees of freedom = 4.96):

Minimum dissolved oxygen - b = 0.348, r = 0.440, F = 2.16;
Minimum permeability value - b = 0.053, r = 0.288, F = 0.82;
Maximum temperature - b = -0.137, r = -0.184, F = 0.32.

TABLE 2.4.11

Size Distribution of 94 Measured Steelhead Fry From Artificial Redd Trials, Lower Deschutes Study, 1965

Length	3. Sac Fry		4. Intermediate		5. Advanced		6. Emergent	
(mm)	No.	Percent	No.	Percent	No.	Percent	No.	Percent
13								
14								
15								
16								
17								
18								
19								
20								
21	4	16						
22	9	36						
23	8	32	1	2				
24	4	16	3	5			1	11
25			13	22				
26			20	33				
27			18	30			2	22
28			5	8			2	22
29							4	44
30								
Totals	25 a/	100	60 b/	100	0	0	9 c/	99

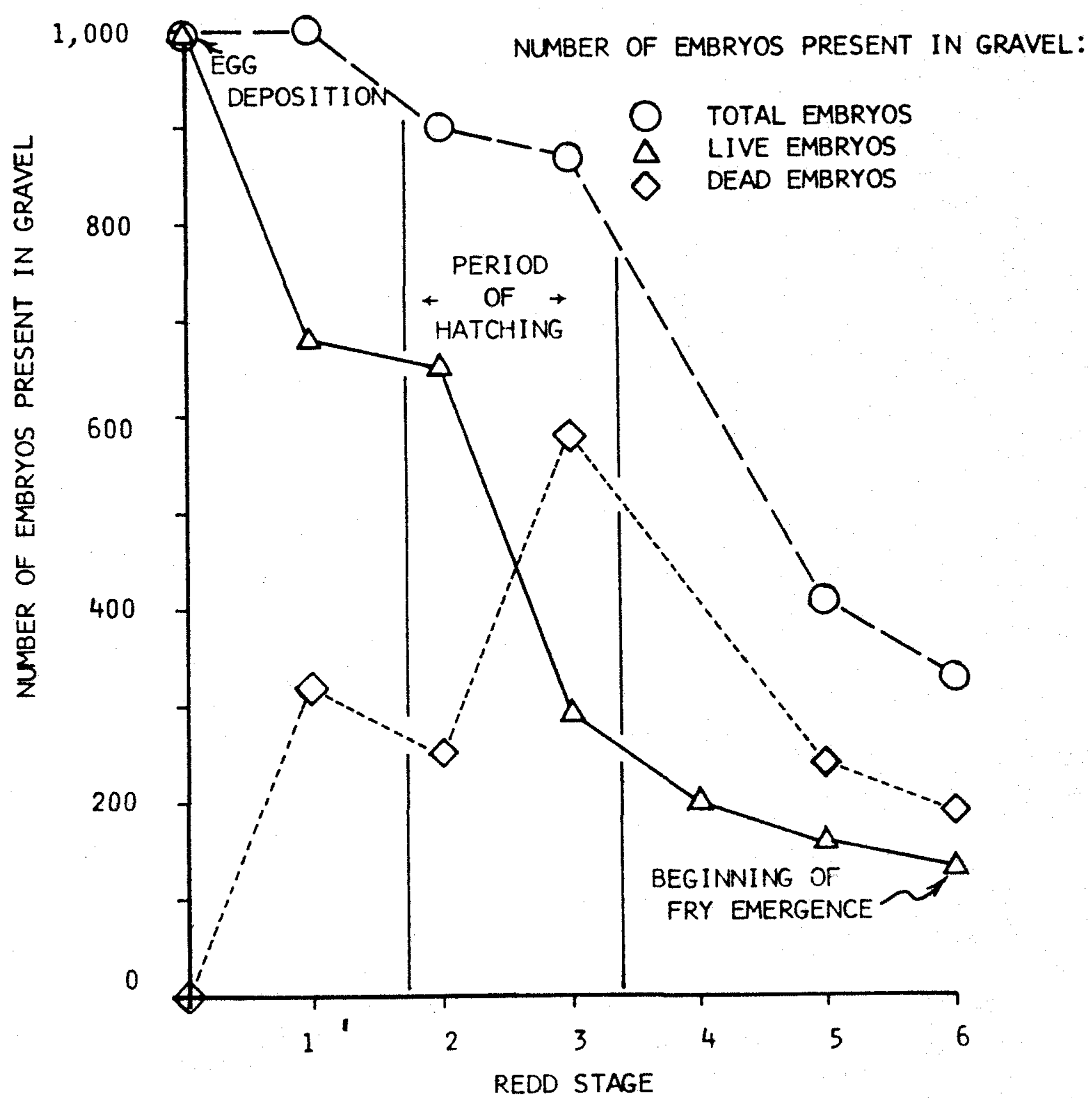
a/ All recovered from excavated artificial redd number 6.

b/ All from hatchery control lots.

c/ All emergent fry recovered from traps over artificial redds.

FIG. 2.4.2

SIMULATION OF EMBRYO SURVIVAL TO EMERGENCE IN A TYPICAL TROUT REDD, LOWER DESCHUTES RIVER

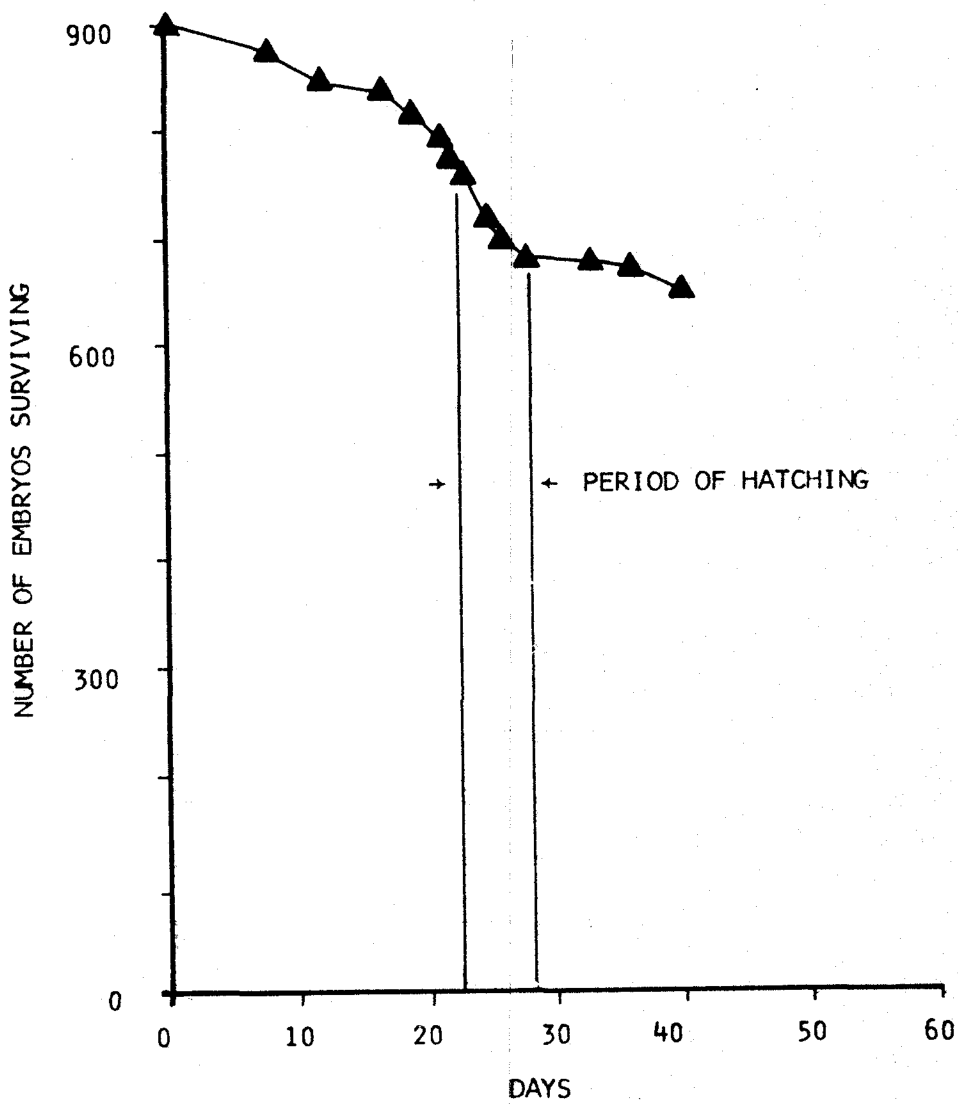


Based on ratios of embryos recovered from 72 steelhead and rainbow trout redds excavated between 1963 and 1966, assuming 1,000 eggs originally deposited and also assuming gradual decomposition of dead eggs over all six development stages and rapid decomposition of dead fry within two development stages. Redd stages are explained in the text (page 2-2). Each stage is equivalent to about 10 to 12 days, depending primarily on prevailing water temperatures.

FIG. 2.4.3

STEELHEAD EMBRYO SURVIVAL TO "SWIM-UP" (INTERMEDIATE FRY) STAGE IN HATCHERY TROUGHS, ARTIFICIAL REDD TRIALS, LOWER DESCHUTES STUDY, MARCH 17 TO APRIL 28, 1965

(COMPARE WITH FIG. 2.4.2)



Survival of 900 steelhead embryos from artificial redd trials conducted in early 1965. Green eggs were obtained from winter steelhead brood stock at Alsea Hatchery on March 16, transported to Oak Springs Hatchery where they were divided into 100 egg lots. One lot of 100 eggs was placed in hatchery troughs prior to the start of artificial redd construction in the lower Deschutes River. The remaining lots were carried to the field for placement in artificial redds---eight left-over egg lots were returned to the hatchery and placed in troughs to determine their survival under controlled conditions. <u>See</u> Table 2.4.8.

Discussion

2.5 Relationship Between Spawning and Discharge

Abnormally low or fluctuating discharges may adversely affect salmon and trout reproduction. When Round Butte Reservoir was filled in 1964 subnormal discharge levels were maintained practically all year. During that year's spring spawning period we observed several deviations in spawning behavior of steelhead and rainbow trout: Steelhead spawning appeared to start later than normal; fewer steelhead and rainbow trout redds were observed despite our increased efforts and proportionately more spawning than usual occurred in low quality gravels.

It is possible that delays in spawning by nominally mature trout could have been caused by changes in water quality, water temperature and total discharge. Factors that might have caused a reduction in spawning numbers were not clearly evident. However, we can speculate on the following questions:

1. Did fish spawn in other locations of the Deschutes River that were less preferable or possibly even completely unsuited for redd construction?

Many previously unused areas of the river were checked during the 1964 spawning surveys in an effort to determine where fish were spawning when so few redds were observed on the usual spawning bars. No redds or spawning activities were observed in gravels judged to be completely unsuitable and very few redds were observed in locations previously unused and classified as poor quality sites for redd construction. Most gravels in this latter category that were used for spawning were adjacent to higher quality gravel beds used in previous years but now unavailable because of low water.

2. How many trout and steelhead spawned in other streams as a result of the reduction of available spawning areas in the Deschutes River mainstem?

No evidence has been found to show whether or not resident and anadromous trout will leave a river system or ascend its tributaries in search of spawning gravel in place of that which may have been rendered unavailable in the usual places in the mainstem.

3. <u>With the amount of spawning area severely limited did the trout fail to spawn or die before spawning?</u>

Again, no evidence has been found to support or refute this possibility.

Conversely to the problem of low flow spawning, some redds were constructed during periods of relatively high flow in areas that were exposed or otherwise subjected to conditions disadvantageous to embryo survival during later periods of reduced flow. This was particularly observable after the 1964-65 winter floods when early redds were constructed in gravel deposits adequately covered by water at 5 to 7 thousand cfs but were completely exposed at later season discharges of 4 to 4.5 thousand cfs. There is also a possibility that redds constructed during periods of low discharge may be washed out by increases of several thousand cfs over that occurring during spawning.

2.6 Relation Between Embryo Survival and Discharge

Redd sampling by excavation showed mean survival of pre-emergent trout fry was significantly lower in 1964, a year of sub-normal discharge, than in 1966, a year of near normal discharge (See Appendix II for discharge comparison data). If this loss is an effect of sub-normal discharge, which this study indicates, then it represents an actual difference in survival of nearly 7%.

The method of sampling redds by excavation cannot provide data on fry survival through emergence. Attempts to measure this by using emergent fry traps failed. Authorities disagree on whether or not there is a significant mortality during emergence (McNeil, 1963b), however, most of these conclusions were based on pink and chum salmon studies in Canadian and Alaskan coastal streams. We are convinced that sub-normal Deschutes River discharge has adversely effected fry emergence through increased deposition of silt and other fines over spawning beds and a lower rate of intragravel water flow and interchange. In effect, emerging embryos are faced with the task of burrowing upwards through silt-compacted gravels under liability of a stagnated intragravel environment low in dissolved oxygen and high in metabolic wastes.

Comparisons of 1966 pre-emergent trout fry survival by stream sections also showed significantly different means. Stream Section I showed highest survival. This section, between Pelton regulation dam and the mouth of Shitike Creek, has the most stable discharge pattern and is most free of silt and turbidity due to settling effects of upstream reservoirs and absence of significant tributaries.

Section II showed lowest 1966 survival. During the 1964-65 floods this section received a large quantity of silt, sand and fine gravel from tributaries such as Shitike, Dry, and Trout Creeks. Most of the gravel beds used for spawning are now heavily loaded with this fine material and as a result gravel permeability is excessively low. (See Part Four). Prior to these floods gravel quality and embryo survival were both higher. In 1964 embryo survival in Section II was well above average.

Section III showed near average survival in 1966. This section, between Warm Springs and White Rivers, is influenced by flows from inconstant minor tributaries and usually consistent Warm Springs River discharges. Silt and turbidity loads can be quite heavy but since these conditions are frequently associated with high mainstem discharges most of this deleterious material is carried downstream and relatively little is deposited over the streambed.

No redds were located in Section IV in 1966. In four Section IV redds sampled in other years survival was extremely low. Gravel quality in this section is to a great extent determined by White River's propensity for discharging loads of silt and fine sand. Mainstem flows in this section are more uneven and turbid than flows in any of the other sections.

Another point of interest is the observation that fry recovered from natural redds were definitely shorter than fry obtained from artificial redd trials (compare Tables 2.4.4 and 2.4.11). This may be explained by any or all of the following facts: Artificial redd trial fry measured were all of Alsea Hatchery winter run stock, whereas all steelhead fry recovered from natural Deschutes spawning were of native summer run lineage; natural Deschutes River redds were both of the rainbow and steelhead subspecies whereas the artificial redd fry were all steelhead (nevertheless, even the largest fry measured from natural redds were only as long as the shortest fry measured from the artificial redd trials); and there is evidence in the literature that embryo length can be influenced by intragravel environmental qualities such as low dissolved oxygen supply during development (Silvers, 1960).

2.7 Estimating Size of Spawning Population From Redd Count Data

Presently no methods exist for relating redd count data to numbers of spawning fish in the river without aid of other population estimaters such as fishway counts. Chinook and coho salmon redd counts on the Rogue River system above Gold Ray Dam, where fishway counts were made, showed ratios of 7.1 upstream migrants to each redd for chinook and 7.8 upstream migrants to each redd for coho (U.S. Fish & Wildlife Service, 1956). Redd count methods used to survey chinook spawning on the Deschutes were similar to those methods used in the Rogue system -- a combination of aerial, streamside, and drift boat counts. Coho salmon spawn in a manner and in locations roughly more similar to steelhead trout. Redd counting conditions and methods for coho in the Rogue were comparable to those used for trout in the Deschutes. It might therefore be possible to apply these Rogue River chinook and coho ratios to Deschutes chinook and trout redd counts in an effort to surmise spawning population sizes.

As listed in Table 2.7.1, the best and most complete count of lower Deschutes River chinook redds (1965) tallied 1,034 redds. Applying the Rogue River factor of 7.1 redds per upstream migrant, and adding to this result the estimated Deschutes River sports catch (2,300), upstream migrant counts at Pelton Dam (398), and an estimate of migration up Warm Springs River (800) results in a conjectural run of 10,800 chinook (plus the unestimated Sherars Falls dipnet catch) entering the Deschutes River in 1965. This may be a fairly reliable estimate, depending on validity of the following assumptions:

(1) That the ratio of 1 redd to 7.1 fish represents an accurate estimate of the relationship between chinook redd numbers and fishway counts in the Rogue River.

(2) That redd counting methods and efficiency were nearly the same in the lower Deschutes River and the Rogue River system.

(3) That actual lower Deschutes River sports catch of chinook is the same as the reported salmon sports catch (1965 Statewide angler Survey catch estimate = 2,261 salmon; 1965 punchcard return catch estimate = 2,276 salmon).

(4) That the 1965 Warm Springs River run was not greatly different from the estimated 800 based on the incomplete 1963 count and the 1964 total count at the Warm Springs River weir near Kah-Nee-Ta.

(5) That significant numbers of salmon do not spawn in the Warm Springs River below the Kah-Nee-Ta weir or in other lower Deschutes River tributaries.

Steelhead estimates are derived in Table 2.7.1 based on 1963 and 1966 trout redd counts (1962 and 1965 upstream migrations). Although these represent the two most complete spring redd counts available, the derived spawning run estimates are unacceptable because of the many assumptions of questionable validity. These assumptions are:

(1) That 35.9 of the unclassified trout redds are steelhead redds. This is the average ratio of classified steelhead redds to classified steelhead and rainbow redds (Table 2.3.5).

(2) That the ratio of 1 redd to 7.8 fish represents an accurate estimate of the relationship between coho redd numbers and fishway counts in the Rogue River.

(3) That the coho redd to fish ratios in the Rogue are applicable to steelhead in the lower Deschutes River.

(4) That redd counting methods and efficiency for steelhead in the lower Deschutes River were nearly the same as for coho in the Rogue River system.

(5) That actual lower Deschutes River sports catches were about the same as reported catches. (1965 Statewide Angler Survey catch estimate -- 3,746 steelhead; 1965 punchcard return catch estimate -- 5,201 steelhead; 1962 punchcard return catch estimate -- 4,800 steelhead).

(6) That the 1962 and 1965 Warm Springs River runs were not greatly different from an estimated 100 fish. Based on a nearly complete 1964 count of 119 steelhead at Kah-Nee-Ta weir.

(7) That an estimated average total of 1,000 steelhead spawn annually in the Warm Springs River below Kah-Nee-Ta weir, in Trout Creek, Bakeoven Creek, Buckhollow Creek and in other lower Deschutes River tributaries. This assumption is based on these further assumptions:

(a) That the following stream areas are available for steelhead spawning and contain sufficient spawning gravels: Buckhollow Creek -- 15 stream miles; Bakeoven Creek -- 10 stream miles; Trout Creek -- 40 stream miles; Warm Springs River below Kah-Nee-Ta weir -- 8 stream miles; Shitike Creek -- 20 stream miles; miscellaneous tributaries -- 10 stream miles. (Based on spawning area surveys conducted on Buckhollow, Bakeoven, Trout and Wapinitia Creeks).

(b) That average spawning densities for these streams are: Buckhollow Creek, Bakeoven Creek, and lower Warm Springs River -- 6.7 redds per stream mile; Trout Creek and Shitike Creek -- 2.5 redds per stream mile; miscellaneous tributaries -- 0.5 redds per stream mile. (Based on several years' redd counts on Bakeoven and Buckhollow Creeks and one year's counts on Wapinitia and Trout Creeks).

(c) That because of the small size of most of the streams involved, nearly all redds constructed are observed and counted and nearly all steelhead entering these streams spawn. Therefore, the ratio of redds to mature fish is assumed to be around 1 redd to 2.5 steelhead.

Results of computations based on these assumptions produce conjectural runs of 10,200 steelhead in 1963 and 9,100 steelhead in 1966 (plus the undetermined Sherars Fall dipnet catch for each year). The estimated sports catch was 40% and 57% of the surmised runs -- since it is highly unlikely that the sports catch harvests these high proportions of the run, it is very probable that these conjectural steelhead spawning run figures are too low.

TABLE 2.7.1

Conjectural Sizes of Salmon[a] and Steelhead Spawning Runs, Deschutes River System

	Chinook[a]	Steelhead	
	1965	1963	1966
Redds counted	1,034	590[b]	296[b]
Rogue River factor[c]	x 7.1	x 7.8	x 7.8
Spawning population	7,300	4,600	2,300
Sports catch	2,300	4,100[d]	5,200[e]
Pelton count	398	351[d]	512[e]
Warm Springs River weir	800[f]	100[g]	100[g]
Miscellaneous tributaries	0	1,000	1,000
Sherars dipnet fishery	unknown[i]	unknown[i]	unknown[i]
Conjectural totals:	10,800[h]	10,200[h]	9,100[h]

a Jacks excluded

b 35.9% of total redds counted (35.9% being the ratio of steelhead redds to all classified trout redds counted).

c Number of fish counted over Gold Ray Dam per redd seen upstream, 1949 through 1954 studies (U.S. Fish and Wildlife Service, 1956).

d 1962 data (1963 spawning stock)

e 1965 data (1966 spawning stock)

f 1965 estimate based on an incomplete 1963 count of 431 chinook and a complete 1964 count of 1,096 chinook

g Estimates based on an incomplete 1964 count of 119 steelhead

h Plus Sherars Falls dipnet fishery catch

i No estimates of catch available -- may be as small as several hundred of each species or as large as several thousand.

LOWER DESCHUTES RIVER, OREGON;

DISCHARGE AND THE FISH ENVIRONMENT

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PART THREE
Water Flow Over Spawning Gravels

Lower Deschutes Flow Study Final Report (Draft)

November 1967

Table of Contents

Part Three. Water Flow Over Spawning Gravels

Methods

3.1 Measurement of Water Flows at Natural Redd Sites

A Price or Gurley type water velocity meter was used to measure water velocities at natural trout and salmon redds. Each year representative redds were measured to obtain data on water conditions selected by spawning fish.

During the fall spawning season from September through December all redds observed were assumed to be of chinook salmon. In the spring spawning season redds were identified as either rainbow or steelhead trout according to redd size, location and characteristics of fish observed. Where we could not tell whether a redd was made by a steelhead or a large rainbow trout it was classified as "Rainbow/Steelhead" signifying an indefinite identification between these two subspecies.

Since we wanted to measure conditions at the redd corresponding as nearly as possible to conditions at time of spawning, only fresh redds were selected for measurement, preferably with fish still on them. If no fish were seen on the redd, age was estimated by differences in coloration between disturbed gravel and adjacent undisturbed gravels, by distinctness of redd contours, and by the amount of accumulated silt in the redd area. No redds were selected for measurement where it was determined that the redd was more than one week old or where there had been possible changes in river discharge since time of spawning.

Early in the study water depth and velocity measurements were made at one foot upstream from the lead edge of the redd and one foot to each side of the redd over undisturbed gravel. Late in 1964 it was determined that the mean of the three measurements did not differ enough from the one upstream measurement to warrant the extra effort, so all 1965 and 1966 water velocity and depth measurements were made at that one location only. See Table 3.1.1.

Two methods were used in measuring water velocities; the six-tenths depth method and the 0.4 foot method. The six-tenths depth method is used to determine mean velocity in the vertical plane at the point of measurement. The measurement is made at six-tenths of water depth from the surface. With this method, for example, if water depth is 1.2 feet water velocity is measured at 0.5 foot (1.2 x 0.6 = 0.72; 1.5 - 0.72 = 0.48 which roundsout to 0.5).

The 0.4 foot method is based on the premise that velocities having the most effect on fish spawning are found near the bottom and the mean overall velocity as obtained by the six-tenths method may not be representative of actual velocities affecting fish. In this latter method water velocity is always measured at the same point 0.4 foot above the streambed.

Supplemental observations were recorded of gravel size at redd site, redd dimensions, estimated age of redd, water temperature and water turbidity. These data and measurements were recorded on the standard form illustrated in Fig. 3.1.1.

3.2 Gravel Bar Cross Section Measurements

The relationship between river discharge and the amount of water flow over spawning gravel bars was determined by establishing a series of gravel bar cross sections throughout the study area. In early 1961 we installed 22 such cross sections on selected representative spawning bars. In subsequent years we added cross sections until a total of 38 permanent cross sections were established. These spawning gravel cross sections ranged in width from 24 to 200 feet, were established at varying angles to river flow, and were marked with steel fence posts or other semi-permanent bench marks.

Cross sections were of three general types designated BB, BS, and SS in Tables 3.2.1, 3.2.2, 3.2.3 and 3.2.4: Type BB (Bank-to-Bank) usually extended across a side channel between the river bank and a river island. Both ends of this cross section were on shore. Type BS (Bank-to-Stream) extended from the river bank to a point in the stream channel itself. It usually covered a gravel bar that was adjacent to the shore line. Type SS (Stream-to-Stream) extended from one point in the stream to another point in the stream. See Fig. 3.2.1.

The Gurley velocity meter was used to measure water velocities and depths on gravel bar cross sections. Measuring points along the cross section were determined with a tag line or steel tape. See Fig. 3.2.2.

We measured gravel bar cross sections by first extending a steel tape or tag line from one end of the cross section to the other. If all the cross section area was not under water, a measurement was made of cross section "wetted" length (area under water). Water depths and velocities were then metered at measured points along the cross section line. Due to limitations of the Gurley velocity meter and the fact that fish seldom spawn in water less than one-half foot deep, no velocity measurements were made in water this shallow. In many cases, water velocities were measured using both the six-tenths depth method (to determine mean vertical velocities) and the 0.4 foot method (to determine velocities at or near the location of fish during spawning).

We recorded supplemental observations on gravel composition, presence of aquatic and semi-aquatic vegetation, water temperatures and water turbidity.

TABLE 3.1.1

Comparisons of One-Point Redd Measurements Made One-Foot Upstream From the Lead Edge of the Redd with Three-Point Redd Measurements Made One-Foot Upstream Redd and One-Foot to Each Side of Redd, Lower Deschutes Flow Study, 1963-1964

	PARAMETER[a]						
	Water Velocity, by Species[b]				Water Depth, by Species[b]		
	St	Rb	Ch	Total	St	Ch	Total
Sample size (n)	24	9	15	48	13	15	28
Measured mean, 3-point	2.279	2.469	2.758	2.464	0.9246	1.681	1.330
Measured mean, 1-point	2.252	2.326	2.423	2.319	0.9269	1.893	1.445
Mean difference ($\bar{y}$)	-0.0275	-0.1433	-0.3347	-0.1452	+0.0023	+0.2127	+0.115
Variance of difference (s^2)	0.0531	0.0429	0.2424	0.1240	0.0154	0.0873	0.0636
$t = \frac{\bar{y} - 0}{\sqrt{s^2/n}}$	-0.5846	-2.0756	-2.633	-2.8568	+0.0668	+2.7881	+2.4130
Significance of difference (95%)	none	none	yes	yes	none	yes	yes

[a] Water velocity reported in feet-per-second (fps) and water depth reported in feet.

[b] Steelhead trout (St), rainbow trout (Rb) and chinook salmon (Ch).

FIGURE 3.1.1

Redd Measurement Data Form, Lower Deschutes Flow Study, 1961-1966

WATER VELOCITY OVER REDDS

Species Rainbow Temperature 47.2° Average Width N/A Date Apr. 14, 1966

Stream Deschutes R. Location and Description of Bar Below Trout Creek Chute — #25B

Water condition Clear

C. f. s.

Redd No.	Velocity at .4 ft. L.	R.	Above	Av.	Water Depth L.	R.	Above	Av.	Redd size L.	W.	Gravel size	Estimated age	
8			2.71				1.0		2	4	II	3-4 days	
9			2.71				1.2		4	2	II	" "	
10			2.28				1.2		4	2	II	" "	
11			1.95				1.5		5	2	II	4-5 days	

Remarks

Checker Behrens and King

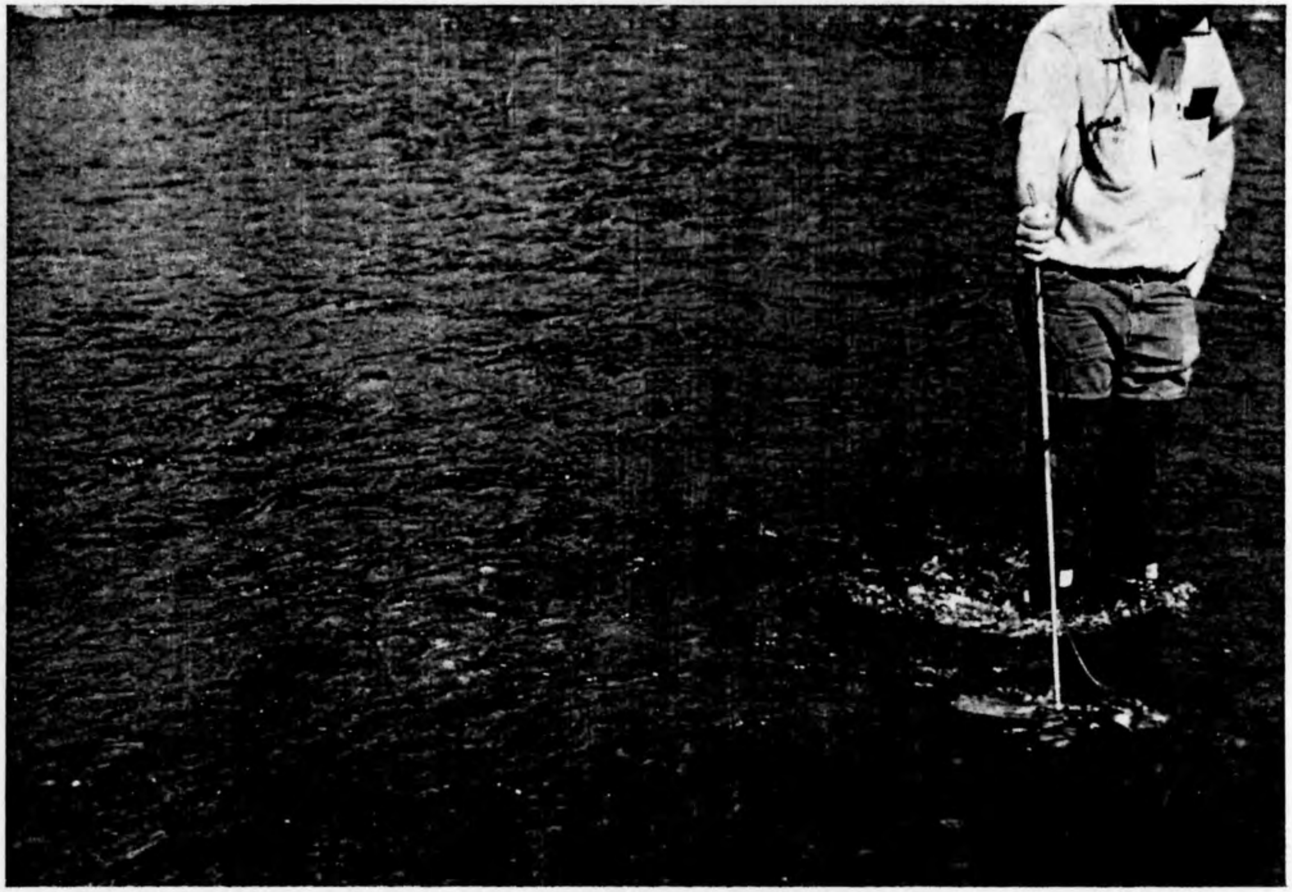


FIGURE 3.1.2 MEASURING WATER VELOCITY ABOVE A TROUT REDD, STATION 73, 1966.

TABLE 3.2.1

Description of Spawning Gravel Cross Sections
Lower Deschutes River, Section I

Station No.	River Mile	Date Estab.	Cross Section Type*	Cross Section Length	Use of Bar for Spawning Trout	Use of Bar for Spawning Salmon	Remarks
501	99.8	2/64	A/SS	100 ft.	Heavy	Moderate	Contours considerably altered by 1964-65 floods. In side channel.
504	99.0	2/64	R/SS	57	Heavy	Light	Contours changed little by 1964-65 flood. At head of side channel.

* Type of Cross Section (see Figure 3.2.1):

R - Cross section line at right angles or perpendicular to stream flow direction.
A - Cross section line not perpendicular to direction of stream flow.
BB - Cross section line runs from bank to bank, usually in side channels where one end of the cross section is on the riverbank and the other end is on the island.
BS - Cross section line runs from bank to midstream, usually on gravel bars adjacent to the shoreline where one end of the cross section is on the riverbank and the other end is in the water towards the midstream side of the gravel bar.
SS - Cross section line runs from midstream to midstream, usually on a gravel bar that is not close to the shore and so both ends of the cross section are in the stream.

TABLE 3.2.2

Description of Spawning Gravel Cross Sections
Lower Deschutes River, Section II

Station No.	River Mile	Date Estab.	Cross Section Type*	Cross Section Length	Use of Bar for Spawning: Trout	Use of Bar for Spawning: Salmon	Remarks
2	96.7	2/64	A/SS	55 ft.	Moderate	None	In side channel
3	96.7	2/64	A/BS	145	Moderate	None	In side channel just downstream from #2 above.
6A	95.1	3/61	R/BB	60	Light	None	No spawning observed since 1964.
6B	95.1	3/61	R/BS	70	Light	None	No spawning observed since 1963.
9	94.3	3/61	R/BS	100	Heavy	Light	
9A	94.5	2/64	R/BB	51	Light	Light	Contours greatly altered by 1964-65 floods. No spawning observed since.
9B	94.5	2/64	R/BS	90	Light	None	Contours greatly altered by 1964-65 floods. No spawning observed since. Just downstream from #9A.
9C	94.4	2/64	A/BS	91	Light	None	Contours greatly altered by 1964-65 floods. No spawning observed since. Just downstream from #9B.
9D	94.3	2/64	A/SS	88	Moderate	None	Contours and gravel composition greatly altered by 1964-65 floods. No spawning observed in 1965, several redds in 1966. Below #9C.
10	94.2	2/64	R/BB	83	Mod-Heavy	None	Contours and gravel composition greatly altered by 1964-65 floods. Heavy spawning use prior to floods, moderate after. Just below #9D.
19	88.5	4/61	A/BS	195	Moderate	None	
19A	88.4	4/61	R/BS	97	Light	None	At lower end of side channel.
19B	88.3	4/61	R/BS	46	None	None	Coarse gravel.
19C	88.2	4/61	R/BS	48	None	None	Coarse gravel.

* Type of Cross Section (see Figure 3.2.1):
R - Cross section line at right angles or perpendicular to stream flow direction.
A - Cross section line not perpendicular to direction of stream flow.
BB - Cross section line runs from bank to bank, usually in side channels where one end of the cross section is on the riverbank and the other end is on the island.
BS - Cross section line runs from bank to midstream, usually on gravel bars adjacent to the shoreline where one end of the cross section is on the riverbank and the other end is in the water towards the midstream side of the gravel bar.
SS - Cross section line runs from midstream to midstream, usually on a gravel bar that is not close to the shore and so both ends of the cross section are in the stream.

TABLE 3.2.3

Description of Spawning Gravel Cross Sections
Lower Deschutes River, Section III

Station No.	River Mile	Date Estab.	Cross Section Type*	Cross Section Length	Use of Bar for Spawning: Trout	Use of Bar for Spawning: Salmon	Remarks
46	77.9	4/61	R/BS	99 ft.	Slight	None	No spawning since 1963. Heavy encroachment of vegetation over gravel bar, cleaned off by 1964-65 flood, some re-growth since.
47	77.3	4/61	R/BS	54	Heavy	None	At head of side channel. Washed out by 1964-65 flood.
47B	77.1	4/61	R/SS	30	Heavy	Moderate	
48	76.8	4/61	R/BS	24	Slight	None	No spawning since 1961. Encroachment of vegetation over gravel by late 1964.
54A	71.6	3/61	R/BS	70	Slight	None	No spawning since 1964. Channel filled by 1964-65 floods.
54AX	71.6	4/61	A/SS	80	None	None	Extension of 54A. No spawning gravel.
58A	69.4	2/64	R/BS	30	Heavy	Slight	Major part of bar washed out by 1964-65 floods. Only a few trout spawning in 1965 and 1966.
58B	69.3	7/63	R/BS	70	Moderate	None	Filled in by 1964-65 floods. Few trout redds in 1965-66.
58D	69.2	2/64	A/SS	70	Heavy	None	Washed out by 1964-65 flood. One trout redd since.
62	65.7	3/61	A/BS	150	None	None	
64	65.4	4/61	A/SS	200	Slight	None	
73	61.6	6/65	A/SS	155	Heavy	Heavy	Only measured once.

* Type of Cross Section (see Figure 3.2.1):

R - Cross section line at right angles or perpendicular to stream flow direction.

A - Cross section line not perpendicular to direction of stream flow.

BB - Cross section line runs from bank to bank, usually in side channels where one end of the cross section is on the riverbank and the other end is on the island.

BS - Cross section line runs from bank to midstream, usually on gravel bars adjacent to the shoreline where one end of the cross section is on the riverbank and the other end is in the water towards the midstream side of the gravel bar.

SS - Cross section line runs from midstream to midstream, usually on a gravel bar that is not close to the shore and so both ends of the cross section are in the stream.

TABLE 3.2.4

Description of Spawning Gravel Cross Sections
Lower Deschutes River, Section IV

Station No.	River Mile	Date Estab.	Cross Section Type*	Cross Section Length	Use of Bar for Spawning: Trout	Salmon	Remarks
99	37.9	4/61	R/BS	39 ft.	Moderate	None	
100	37.8	4/61	R/BS	29	None	Moderate	
105	29.7	4/61	R/BS	98	None	None	Coarse gravel and rubble.
110	23.8	4/61	R/BS	54	Slight	None	Considerable disturbance by 1964-65 floods.
114	21.2	3/64	A/SS	130	Moderate	Moder-ate	No trout spawning after 1964. Altered by 1964-65 floods.
122	10.4	2/64	A/BS	45	Moderate	"	No trout spawning after 1964.
123 1/2	10.3	2/64	A/SS	55	Slight	Slight	No spawning after 1964.
123	10.3	4/61	R/BS	96	Slight	Slight	" " " "
123A	10.2	4/61	A/BS	85	Slight	Moderate	
125A	9.1	4/61	A/BB	80	None	None	Measured once. No spawning gravel.

* Type of Cross Section (see Figure 3.2.1):

R - Cross section line at right angles or perpendicular to stream flow direction.

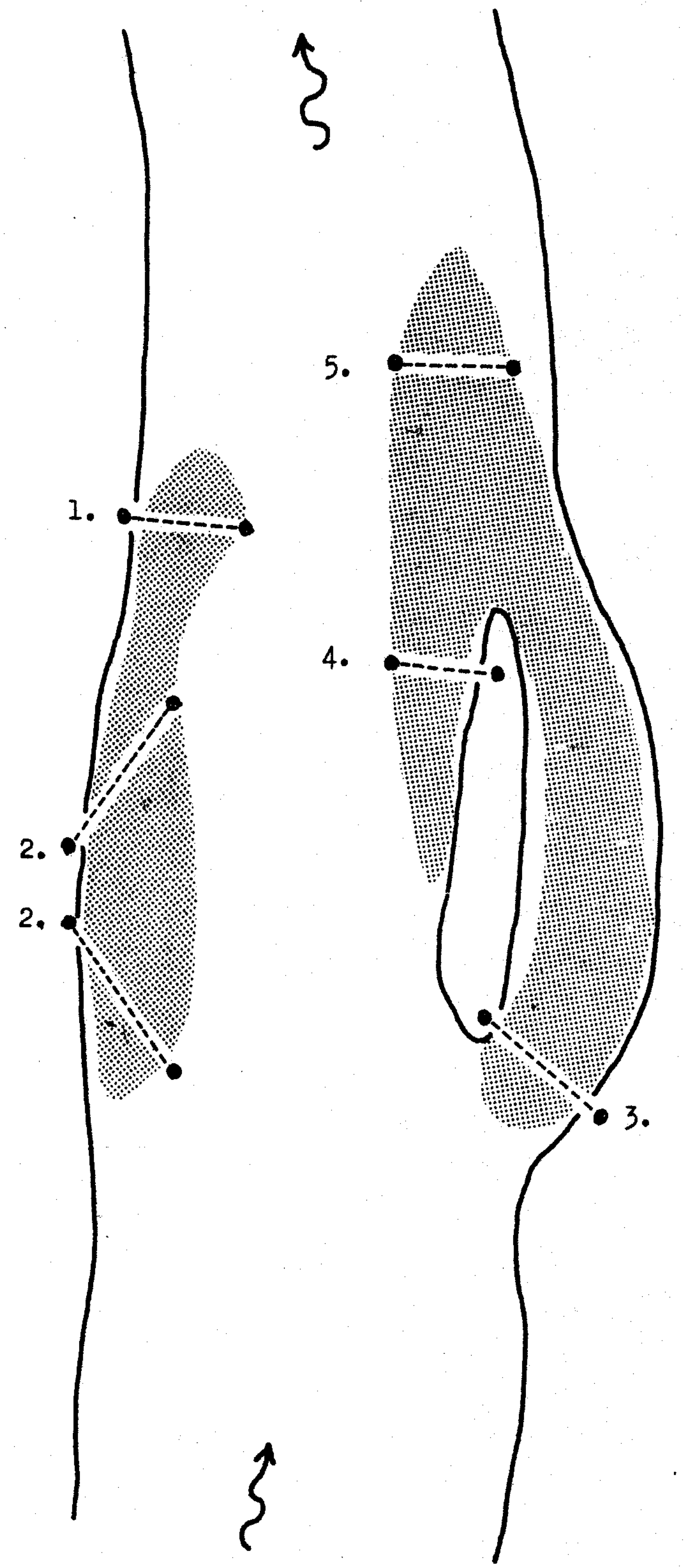
A - Cross section line not perpendicular to direction of stream flow.

BB - Cross section line runs from bank to bank, usually in side channels where one end of the cross section is on the riverbank and the other end is on the island.

BS - Cross section line runs from bank to midstream, usually on gravel bars adjacent to the shoreline where one end of the cross section is on the riverbank and the other end is in the water towards the midstream side of the gravel bar.

SS - Cross section line runs from midstream to midstream, usually on a gravel bar that is not close to the shore and so both ends of the cross section are in the stream.

Figure 3.2.1
Types of Spawning Gravel Cross Sections, Schematic
(See Tables 3.2.1-4)



Type of Cross Section

R/(1.) Cross section line at right angles or perpendicular to direction of stream flow.

A/(2.) Cross section lines not perpendicular to direction of stream flow.

BB (3.) Cross section line runs from bank to bank (both ends out of water).

BS (4.) Cross section line runs from bank to midstream (one end in water).

SS (5.) Cross section line runs from midstream (both ends in water).

FIGURE 3.2.2 CROSS SECTION MEASURING EQUIPMENT: GURLEY WATER VELOCITY METER WITH GRADUATED STAFF, STOPWATCH (IN OPERATOR'S LEFT HAND) AND BEADED TAG-LINE.

Oregon State Game Commission — Basins Investigations

LOWER DESCHUTES RIVER

1966

FIGURE 3.2.3

LOCATION OF SPAWNING GRAVEL CROSS SECTIONS

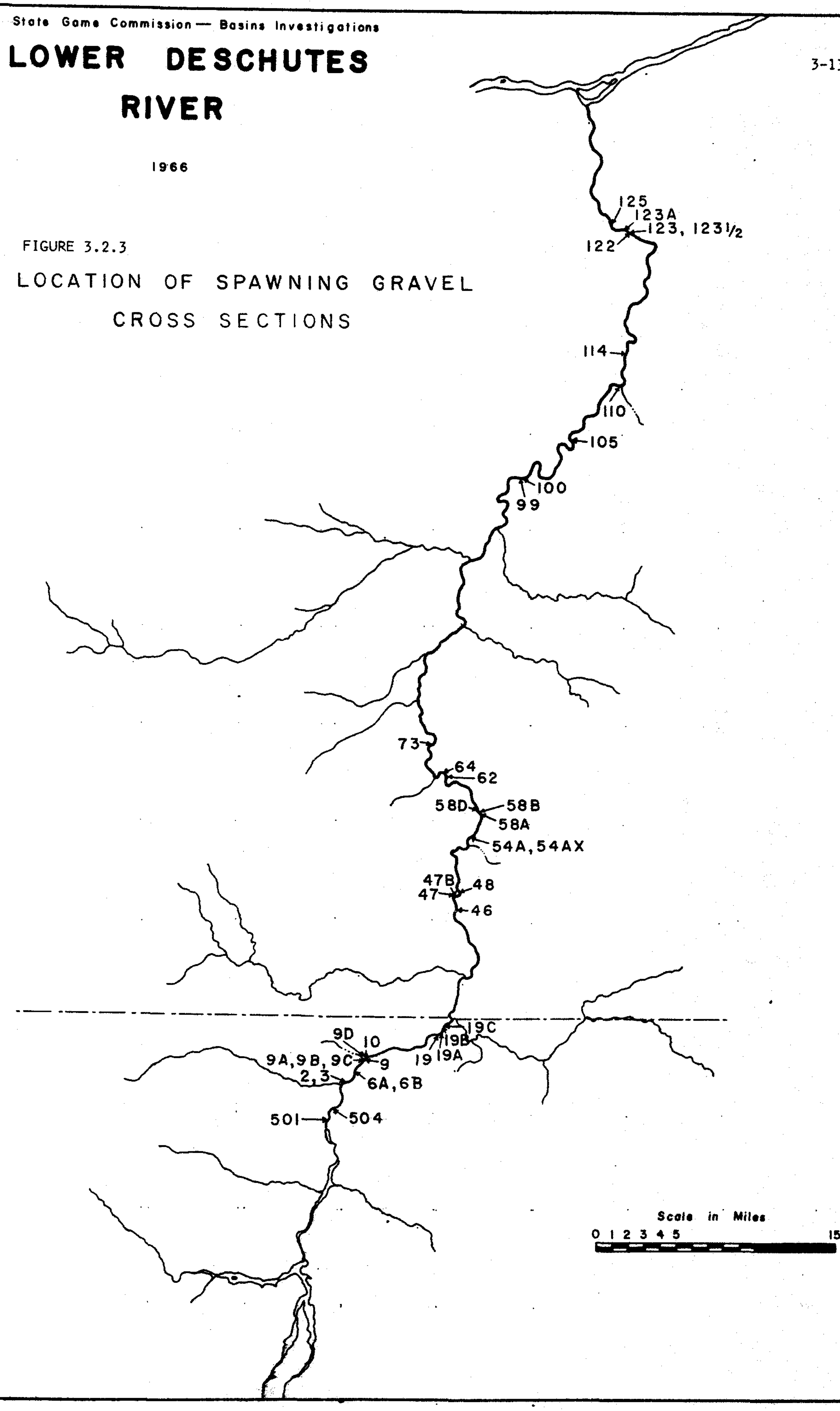


FIGURE 3.2.4 MEASURING SPAWNING GRAVEL CROSS SECTION, STATION 10, JAN. 27, 1965.

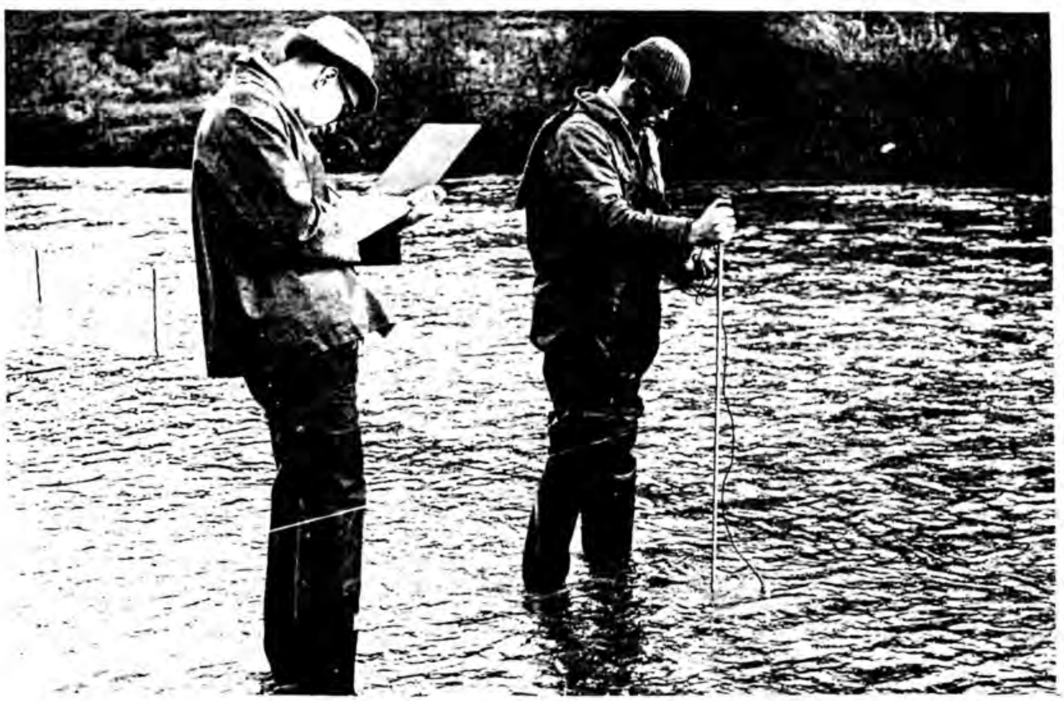


FIGURE 3.2.5 MEASURING SPAWNING GRAVEL CROSS SECTION, STATION 504, FEB. 12, 1964.

FIGURE 3.2.6

Spawning Gravel Cross Section Measurement Data Recording Form
Lower Deschutes Flow Study

OREGON STATE GAME COMMISSION
Flow Measurements

Stream and Location Deschutes R., Station No. 19A Above Trout Creek. At lower end of island.

Date Jan. 21, 1964 Temperature: Air 42° Water 43°

Dist. from Initial Pt.	Width	Depth	Obs. Depth	Revo-lutions	Time in Sec.	Velocity	Area	Flow
10'	–	0.35	0.4	–	–	–		
20'	–	0.5	0.4	20	67	0.69		
31'	–	1.1	0.4	30	50	1.35		
40'	–	1.0	0.4	50	50	2.23		
50'	–	0.75	0.4	40	43	2.08		
60'	–	0.5	0.4	30	46	1.47		
71'	–	0.6	0.4	40	52	1.72		
80'	–	0.5	0.4	10	62	0.39		
90'	–	0.15	0.4	–	–	–		
100'	–	0.6	0.4	10	50	0.47		
110'	–	1.4	0.4	30	44	1.53		
112' To	Left	stake	(fence	post)				

Remarks: Initial point – stake in R. bank
Water edge 5' from IP

Results

3.3 Water Flow at Natural Redd Sites

The purpose of gathering data at representative redd sites was to determine water and river bed characteristics preferred by spawning trout and salmon in the lower Deschutes River. Distribution of water velocities and depths measured at salmon and trout redds is summarized in Tables 3.3.1 and 3.3.2.

Water velocities measured at redds ranged from a minimum of 0.83 feet per second (fps) to a maximum of 4.14 fps. These extremes probably do not represent naturally preferred minimum and maximum velocities for spawning fish. Examination of the cumulative percentage distribution of water velocities measured at representative trout redds showed a near normal distribution. See Fig. 3.3.1. It is possible using normal distribution relative cumulative frequency tables to derive an estimate of spawning water velocities preferred by a predetermined percentage of spawning fish. Using water velocity statistics shown in Table 3.3.3 estimates were derived of water velocity limits preferred by 90% of the salmon and trout spawning in the lower Deschutes River (Table 3.3.4). Examination of these estimates shows that 1.5 fps would be a reasonable, overall estimate of the apparent preferred minimum velocity for spawning chinook salmon, rainbow trout and steelhead trout in the lower Deschutes River.

Since all redd measurements were made by wading, the data gathered is somewhat biased in that redds made in deeper water and at higher velocities were not measured. However, in examining the data and observing natural spawning we found that relatively few redds were constructed in water beyond measurable limits. Most trout spawning occurred where water velocities were under 3.25 fps and most salmon spawning took place where velocities were under 3.59 fps (Table 3.3.4). From these estimates, 3.5 fps was selected as the best general estimate of the maximum water velocity apparently preferred by fish spawning in the lower Deschutes River.

Mean water velocity for all chinook salmon redds measured during 1963, 1964 and 1965 was 2.615 ± 0.167 fps (90% confidence interval). Mean water velocity for all trout redds measured in 1961, 1963, 1964 and 1966 was 2.335 ± 0.071 fps. See Table 3.3.3. Analysis of variance of these water velocity measurement data showed significant differences between mean velocities measured over salmon redds and mean velocities measured over trout redds. There also were significant differences between velocities measured in different years. We were not able to show a significant difference between mean velocities over steelhead redds and mean velocities over rainbow redds. See Table 3.3.5. Further analysis of the water velocity data showed that the mean of 1964 redd measurements was significantly lower than the mean of redd measurements for 1963 and that the variance of 1964 measurements was significantly greater than the variance of the 1963 measurements (Table 3.3.6).

A statistical comparison was also made of the difference between the 6/10 depth method and the 0.4 foot method of measuring water velocities. This testing showed no significant differences (Table 3.3.6 and Fig. 3.3.3).

Water depths measured at redds ranged from 0.4 to 2.7 feet. In determining minimum water depths usable by spawning fish we did not use the measured extreme (0.4 feet). Instead we attempted to estimate the preferred minimum water depth by the same method previously described for estimating preferred minimum water velocities. Results of this method, based on estimates of limits chosen by 90% of the spawning fish, are summarized in Table 3.3.9. From these limits, listed by species or subspecies, a single generalized minimum of 0.5 foot was chosen. This single minimum was chosen to be most representative of all spawning observed, particularly that which occurs during the more critical spring trout spawning season.

Statistical analyses of water depth data showed no significant differences between mean water depths measured at rainbow trout, steelhead trout and chinook salmon redds. However, there were significant differences between the means of water depths by year. <u>See</u> Table 3.3.10. Further analyses, summarized in Table 3.3.11, showed that the mean of the water depth observations made in 1963 was significantly greater than the mean of the observations made in 1964, but there was no significant difference between the variances of the observations made these two years.

TABLE 3.3.1

Frequency Distribution of Water Depth and Velocity Measurements at 163 Rainbow and Steelhead Trout Redds in the Lower Deschutes River, 1961-1966

Water Depth			Water Velocity		
Feet	n	Cumulative Percent	Feet per Second	n	Cumulative Percent
0.4	2	1.3	1.2	1	0.6
0.5	2	2.6	1.3	4	3.1
0.6	11	9.7	1.4	3	4.9
0.7	7	14.2	1.5	4	7.4
0.8	11	21.3	1.6	4	9.8
0.9	10	27.7	1.7	3	11.7
1.0	14	36.8	1.8	6	15.3
1.1	10	43.2	1.9	12	22.7
1.2	13	51.6	2.0	12	30.0
1.3	10	58.1	2.1	10	36.2
1.4	16	68.4	2.2	13	44.2
1.5	14	77.4	2.3	10	50.3
1.6	9	83.2	2.4	20	62.6
1.7	3	85.2	2.5	9	68.1
1.8	6	89.0	2.6	10	74.2
1.9	7	93.5	2.7	9	79.8
2.0	3	95.5	2.8	5	82.8
2.1	1	96.1	2.9	7	87.1
2.2	1	96.7	3.0	2	88.3
2.3	1	97.4	3.1	5	91.4
2.4	2	98.7	3.2	1	92.0
2.5	1	99.4	3.3	8	96.9
2.7	1	100.0	3.4	2	98.1
			3.7	2	99.4
			4.2	1	100.0
Σn	155		Σn	163	
$\bar{y}$	1.251		$\bar{y}$	2.335	
s	0.440		s	0.554	

Note: Mean ($\bar{y}$) and variance (s) calculated from velocity and depth readings to two decimal places, not from frequency table.

Fig. 3.3.1

Cumulative Percentage Distribution of Water Velocities Measured at 163 Rainbow and Steelhead Trout Redds Compared With the Relative Cumulative Frequency of the Normal Curve. Lower Deschutes River, 1961-1966.

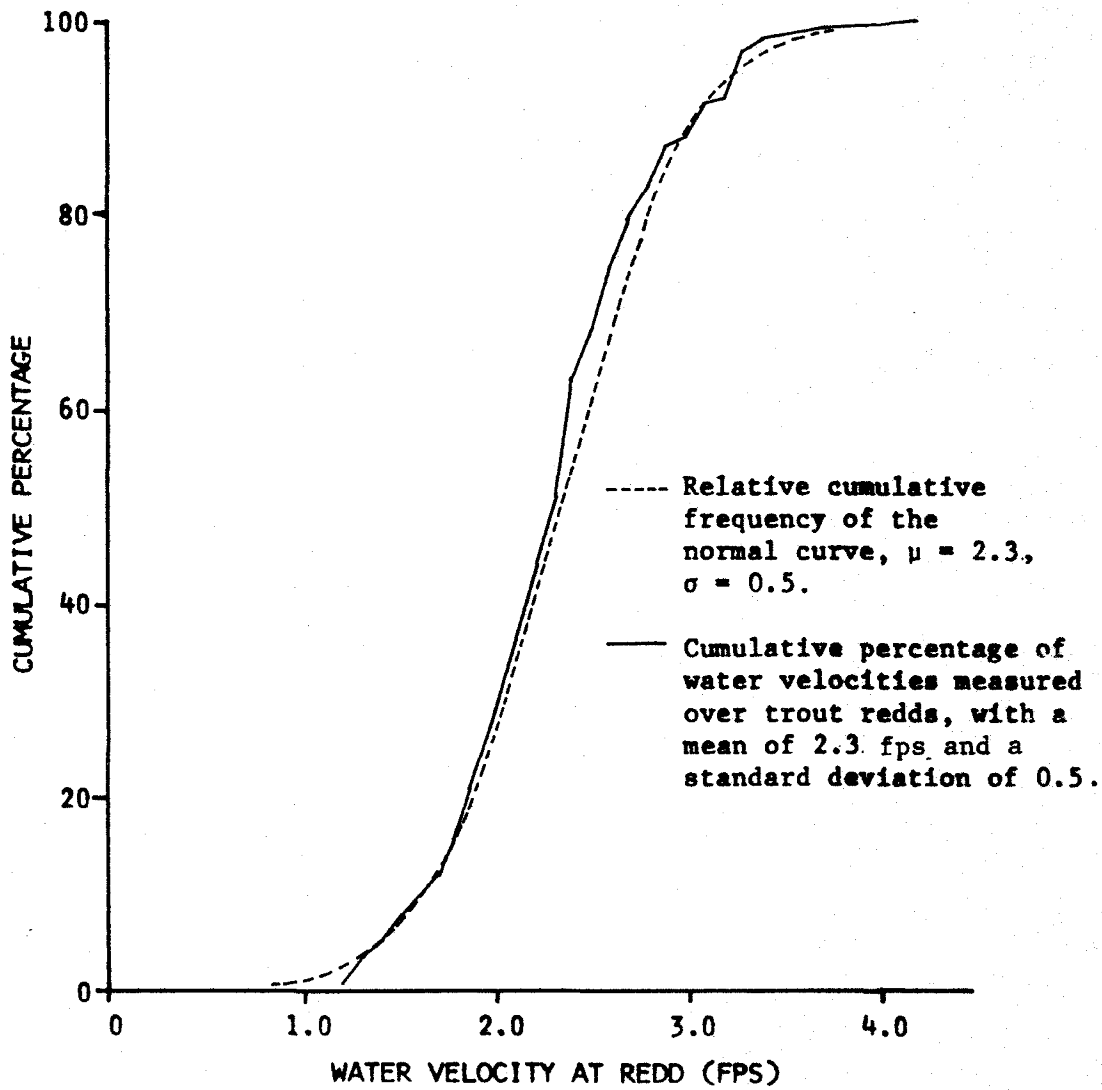


Fig. 3.3.2

Cumulative Percentage Distribution of Water Depths Measured at 155 Rainbow and Steelhead Trout Redds Compared With the Relative Cumulative Frequency of the Normal Curve. Lower Deschutes River, 1961-1966.

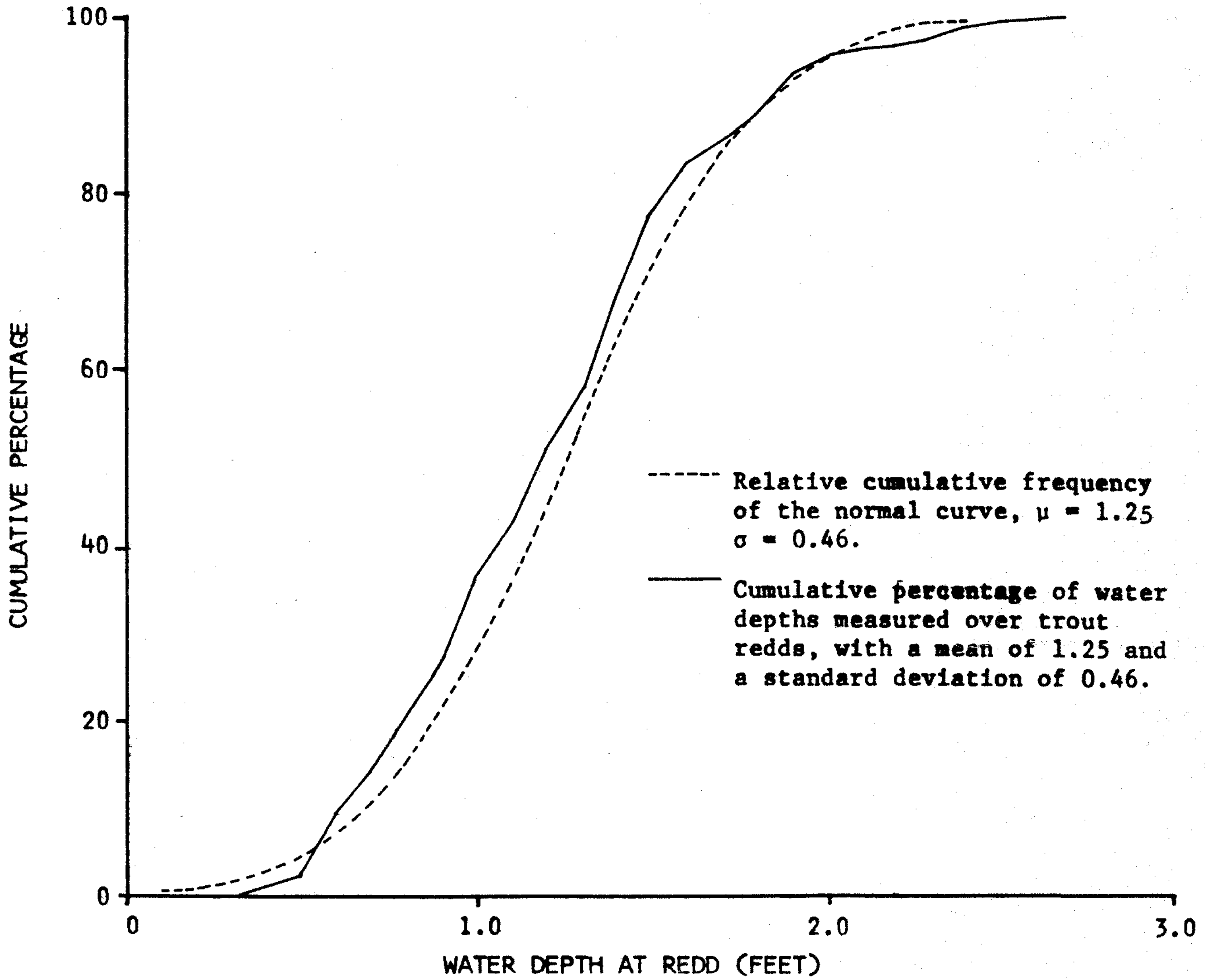


TABLE 3.3.2

Frequency Distribution of Water Depth and Velocity Measurements at 36 Chinook Salmon Redds in the Lower Deschutes River, 1963-1965

Water Depth			Water Velocity		
Feet	n	Cumulative Percent	Feet per Second	n	Cumulative Percent
0.8	1	2.8	0.8	1	2.8
0.9	1	5.6	1.8	1	5.6
1.0	3	13.9	1.9	1	8.3
1.1	1	16.7	2.0	3	16.7
1.2	2	22.2	2.1	3	25.0
1.3	6	38.9	2.2	1	27.8
1.4	3	47.2	2.3	2	33.3
1.6	4	58.3	2.4	1	36.1
1.7	2	63.9	2.5	4	47.2
1.8	5	77.8	2.6	2	52.8
1.9	3	86.1	2.7	1	55.6
2.1	1	88.9	2.8	4	66.7
2.2	2	94.4	2.9	1	69.4
2.4	1	97.2	3.0	3	77.8
2.6	1	100.0	3.1	1	80.6
			3.2	1	83.3
			3.3	3	91.7
			3.4	1	94.5
			3.6	1	97.2
			3.7	1	100.0
Σn	36		Σn	36	
$\bar{y}$	1.556		$\bar{y}$	2.615	
s	0.435		s	0.591	

Note: Mean ($\bar{y}$) and variance (s) calculated from velocity and depth readings to two decimal places, not from frequency table.

TABLE 3.3.3

Water Velocity Statistics, Salmon and Trout Redd Measurements, Lower Deschutes Flow Study

	Year	Sample Size	Sample Mean	10% Conf. Interval	Sample Variance	Sample Standard Deviation
Chinook salmon	1965	13	2.576	± 0.372	0.5653	
	1964	8	2.409	± 0.341	0.2588	
	1963	15	2.758	± 0.210	0.2127	
	All years	36	2.608	± 0.167	0.3497	0.5914
Rainbow Trout	1966	8	2.430	± 0.250	0.1392	
	1964	26	2.244	± 0.167	0.2496	
	1963	13	2.392	± 0.182	0.1352	
	1961	4	1.940	± 0.232	0.0387	
	All years	51	2.287	± 0.106	0.2019	0.4493
Steelhead Trout	1966	8	2.221	± 0.632	0.8886	
	1964	42	2.091	± 0.135	0.2686	
	1963	17	2.418	± 0.146	0.1188	
	1961	23	2.626	± 0.214	0.3582	
	All years	90	2.301	± 0.104	0.3548	0.5956
All Trout	1966	43*	2.459	± 0.161	0.3923	
	1964	68	2.150	± 0.104	0.2630	
	1963	30	2.406	± 0.108	0.1216	
	1961	27	2.524	± 0.200	0.3693	
	All years	168	2.335	± 0.071	0.3075	0.5545

* Includes 27 redds that were classified as indefinite between rainbow and steelhead.

TABLE 3.3.4

Water Velocity Limits for 90% Optimum Salmon and Trout Spawning in the Lower Deschutes River

Species or Subspecies	Water Velocity (fps)
Chinook salmon	1.64 - 3.59
Rainbow trout	1.55 - 3.026
Steelhead trout	1.32 - 3.28
All trout	1.42 - 3.25
Actual limits used:	1.5 - 3.5

TABLE 3.3.5

Water Velocities Measured Over Selected Natural Trout and Salmon Redds in the Lower Deschutes River, 1961-1966; by Year, Species, Subspecies and Genus; Data Summary and Analysis of Variance (Hierarchical Classification)

DATA SUMMARY

Genus	Species or Subspecies	Year	By Year		By Species or Subspecies		By Genus		Grand	
			n	Mean	n	Mean	n	Mean	n	Mean
Salmon	Chinook	1965	13	2.576						
		1964	8	2.409						
		1963	15	2.758	36	2.615	36	2.615		
Trout	Rainbow	1966	8	2.430						
		1964	26	2.244						
		1963	13	2.392						
		1961	4	1.940	51	2.287				
	Steelhead	1966	8	2.221						
		1964	42	2.091						
		1963	17	2.418						
		1961	23	2.626	90	2.301				
	Rb/St	1966	27	2.539	27	2.539	168	2.335	204	2.335

ANALYSIS OF VARIANCE

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Calculated F	Tabular F at 5%
By Genus	49.52	1	49.520	73.910	18.513
By Species or Subspecies Within Genus	1.34	2	0.67000	0.8830	4.459
By Year Within Subspecies or Species	6.07	8	0.75875	2.5931	about 2.0
Error	56.18	192	0.29260		
Total	113.11	203			

Conclusions:

At the 5% level of significance, there is---

(1) a significant difference between the mean of the velocities measured over salmon redds and the mean of the velocities measured over trout redds;

(2) no significant difference between the mean of the velocities measured over steelhead redds and the mean of the velocities measured over rainbow redds; and

(3) a significant difference between the mean of the velocities measured in different years.

TABLE 3.3.6

Statistical Comparison of Water Velocity Measurements (fps) Made Over Steelhead and Rainbow Trout Redds in the Years 1963 and 1964, Lower Deschutes River.

Year	1963	1964
No. of observations (n)	30	68
Mean of observations ($\bar{y}$)	2.406	2.150
Variance of observations (s^2)	0.1216	0.2630

Pooled variance (s_p^2) = 0.2203

$$t = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{s_p^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}} = 2.4886$$

10% points of the *t* distribution with 96 d.f. are ±1.66.
Conclusion: Mean of the observations made in 1963 is significantly greater than the mean of the observations made in 1964.

$$F = \frac{s_1^2}{s_2^2} = 0.4624$$

10% points of the *F* distribution with 29 and 67 d.f. are 1.6 and 0.5714.
Conclusion: The variance of the 1963 observations is significantly less than the variance of the 1964 observations.

TABLE 3.3.7

Paired-*t* Test of the Difference Between the 6/10 Depth Method and the 0.4 Foot Method of Measuring Water Velocity Over Redds.

See Fig. 3.3.3

Difference (6/10 Method)-(0.4 Foot Method)	Frequency of the Differences
0.00 to 0.05 fps	11
0.06 to 0.14 fps	10
0.15 to 0.25 fps	8
0.26 to 0.34 fps	6
0.35 to 0.45 fps	1
0.46 to 0.54 fps	1

Number of observations (n)	37
Mean of the differences ($\bar{y}$)	+0.0605
Variance of the differences (s^2)	0.0407

$$t = \frac{\bar{y} - 0}{\sqrt{s^2/n}} = +1.8242$$

Tabular t at 10% is ±2.03 with 36 d.f.

Conclusion: The 6/10 method of measuring water velocities over redds is not significantly different from the 0.4 foot method.

Fig. 3.3.3

Relationship Between the 6/10-Depth Method and the 0.4-Foot Method of Measuring Water Velocity at Redds, Lower Deschutes River.

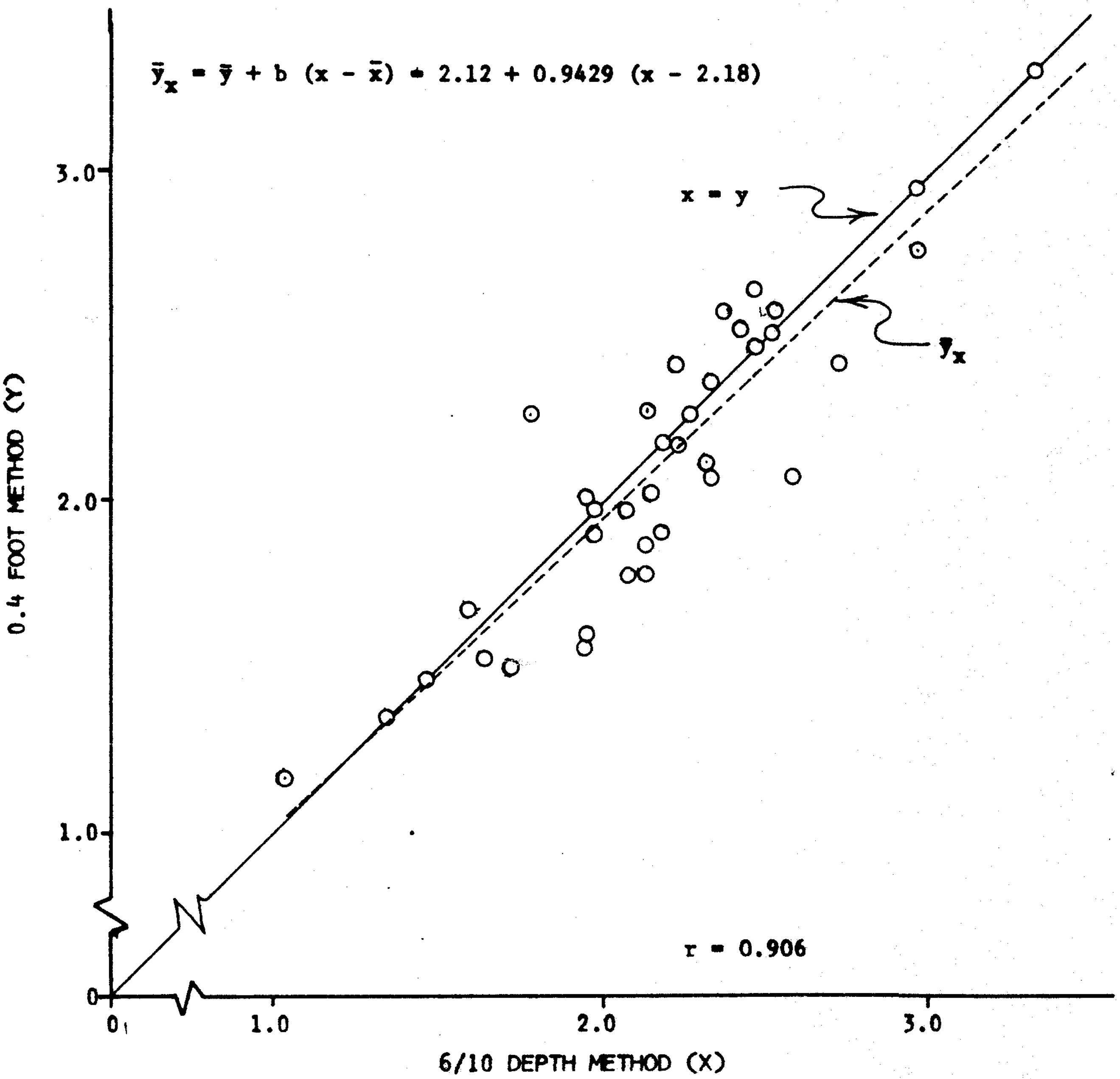


TABLE 3.3.8

Water Depth Statistics, Salmon and Trout Redd Measurements, Lower Deschutes Flow Study

	Year	Sample Size	Sample Mean	90% Conf. Interval	Sample Variance	Standard Deviation
Chinook salmon	1965	13	1.469	± 0.170	0.1186	
	1964	8	1.462	± 0.256	0.1456	
	1963	15	1.681	± 0.236	0.2702	
	All Years	36	1.561	± 0.123	0.1893	0.4351
Rainbow trout	1966	8	1.000	± 0.218	0.1057	
	1964	26	0.981	± 0.126	0.1424	
	1963	13	1.385	± 0.235	0.2264	
	1961	4	1.425	± 0.356	0.0917	
	All Years	51	1.122	± 0.099	0.1789	0.4230
Steelhead trout	1966	8	1.500	± 0.358	0.2857	
	1964	41	1.166	± 0.116	0.1947	
	1963	11	1.512	± 0.295	0.2907	
	1961	23	1.478	± 0.146	0.1663	
	All Years	83	1.331	± 0.087	0.2262	0.4756
All trout	1966	43*	1.249	± 0.095	0.1384	
	1964	67	1.094	± 0.087	0.1802	
	1963	24	1.443	± 0.175	0.2491	
	1961	27	1.470	± 0.124	0.1423	
	All Years	161	1.251	± 0.057	0.1935	0.4399

* Includes 27 redds that were classified "Rb/St" (indefinite between rainbow and steelhead).

TABLE 3.3.9

Water Depth Limits for 90% Optimum Salmon and Trout Spawning in the Lower Deschutes River

Species or Subspecies	Water Depth (ft.)
Chinook salmon	0.84 - 2.27
Rainbow trout	0.43 - 1.82
Steelhead trout	0.55 - 2.11
All trout	0.53 - 1.97
Actual limits used:	0.5 (minimum only)

TABLE 3.3.10

Water Depths Measured Over Selected Natural Trout and Salmon Redds in the Lower Deschutes River, 1961-1966; Data Summary and Analysis of Variance (Hierarchical Classification).

DATA SUMMARY

Genus	Species or Subspecies	Year	By Year		By Species or Subspecies		By Genus		Grand	
			n	Mean	n	Mean	n	Mean	n	Mean
Salmon	Chinook	1965	13	1.469						
		1964	8	1.462						
		1963	15	1.681	36	1.556	36	1.556		
Trout	Rainbow	1966	8	1.000						
		1964	26	0.981						
		1963	13	1.385						
		1961	4	1.425	51	1.122				
	Steelhead	1966	8	1.500						
		1964	41	1.166						
		1963	11	1.512						
		1961	23	1.478	83	1.331				
	Rb/St	1966	27	1.248	27	1.248	161	1.251	197	1.306

ANALYSIS OF VARIANCE

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	Calculated F	Tabular F at 5%
By Genus	2.74	1	2.740	3.942	18.513
By Species or Subspecies Within Genus	1.39	2	0.6950	1.236	4.459
By Year Within Subspecies or Species	4.50	8	0.56250	3.284	about 2.0
Error	31.69	185	0.17130		
Total	40.32	196			

Conclusions:

At the 5% level of significance there is---

(1) no significant difference between the mean of water depths measured over salmon redds and the mean of water depths measured over trout redds;

(2) no significant difference between the mean of the depths measured over steelhead redds and the mean of depths measured over rainbow redds; and

(3) a significant difference between the mean of depths measured in different years.

TABLE 3.3.11

Statistical Comparison of Water Depth Measurements (feet) Made Over Steelhead and Rainbow Trout Redds in the Years 1963 and 1964. Lower Deschutes River.

Year	1963	1964
No. of observations (n)	24	67
Mean of observations ($\bar{y}$)	1.443	1.094
Variance of observations (s^2)	0.2487	0.1802

Pooled variance (s_p^2) = 0.1979

$$t = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{s_p^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}} = 3.2979$$

10% points of the t distribution with 89 d.f. are ± 1.66.
Conclusion: Mean of the observations made in 1963 is significantly greater than the mean of the observations made in 1964.

$$F = \frac{s_1^2}{s_2^2} = 1.3801$$

10% points of the F distribution with 23 and 66 d.f. are 1.6+ and 0.538.
Conclusion: There is no significant difference between the variance of the 1963 observations and the variance of the 1964 observations.

3.4 Gravel Bar Cross Section Measurements

From water depth and velocity data obtained during measurement of a gravel bar cross section we determined the amount of cross section length usable for spawning based on the preferred minimum of 1.5 fps water velocity and 0.5 foot water depth. Usable length data for two or more river discharges were plotted on work graphs such as those in Figs. 3.4.1 and 3.4.2. From these plots interpolated or extrapolated estimates were made of cross section lengths usable at other river discharges.

In stream Section I, two spawning gravel cross sections were established in 1964. These were each measured at three different river discharges in 1964 and 1965. There was an estimated 42% loss in usable cross section length between the measured high discharge of 4,230 cfs and the low discharge of 3,140 cfs. Table 3.4.1.

In Section II, from the mouth of Shitike Creek to the mouth of Warm Springs River, thirteen cross sections were measured at seven general discharges ranging from 3,200 cfs to 6,500 cfs. Data summarized in Table 3.4.2 indicates an average loss in usable cross section length of about 49% between highest and lowest measured discharges.

Ten cross sections were used in river Section III (from the mouth of Warm Springs River to the mouth of White River.) Measurements were made at river discharges between 3,250 cfs and 6,500 cfs. Between these two extremes there was a loss of usable cross section length of about 36%. Table 3.4.3.

In river Section IV, from the mouth of White River to the junction of the Deschutes River with the Columbia River, nine cross sections were measured. Five general discharge levels were measured ranging from 3,380 cfs to 6,490 cfs. Estimated loss of cross section usable length between these two extremes was about 55%. Table 3.4.4.

FIG. 3.4.1

EXAMPLE OF A USABLE LENGTH WORK GRAPH USED TO PLOT CROSS SECTION LENGTH MEETING OR EXCEEDING THE PREFERRED MINIMUM CRITERIA OF 1.5 FPS WATER VELOCITY AND 0.5 FEET WATER DEPTH, LOWER DESCHUTES RIVER. SEE TABLE 3.4.2.

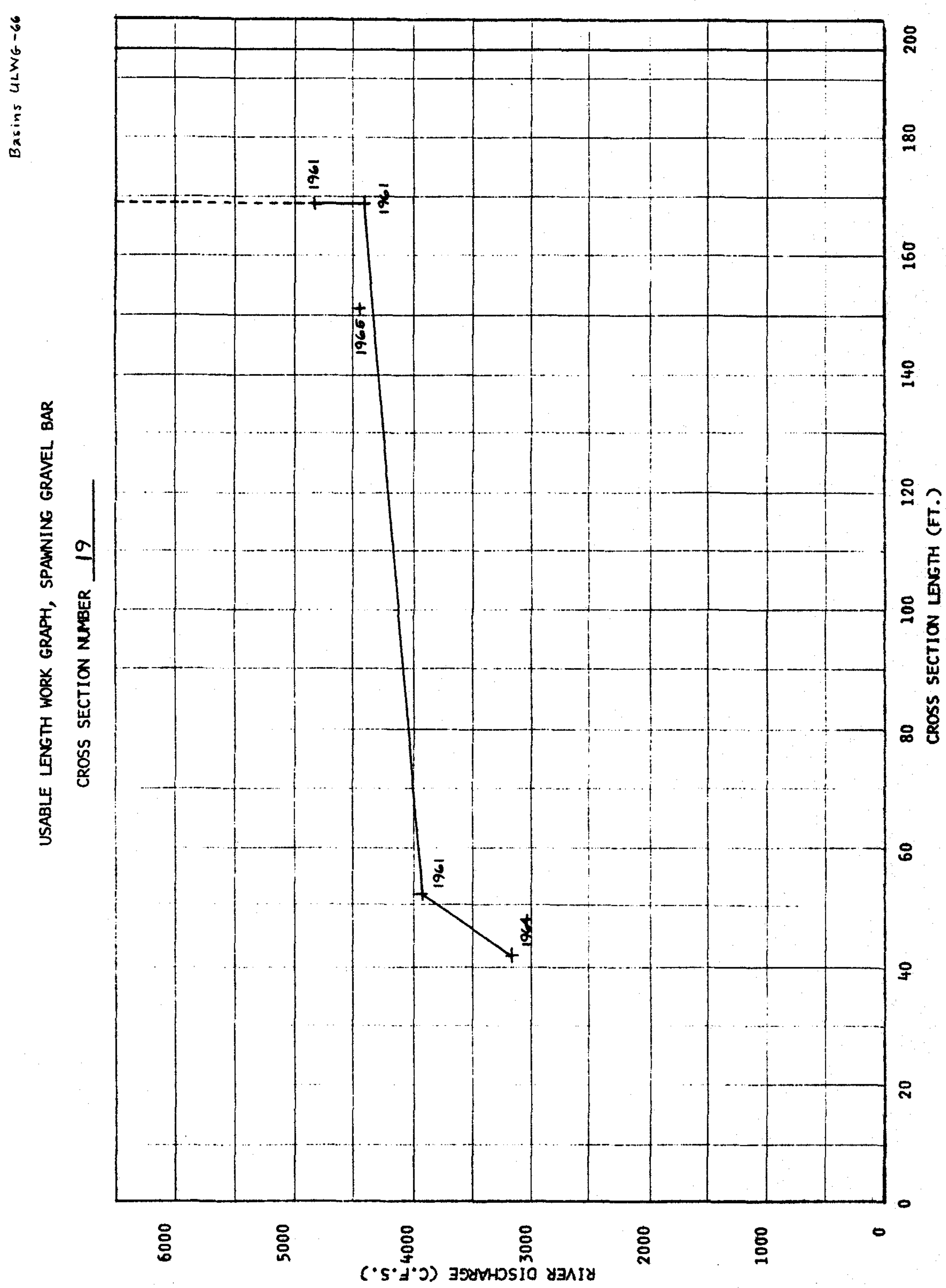


FIG. 3.4.2

EXAMPLE OF A USABLE LENGTH WORK GRAPH USED TO PLOT CROSS SECTION LENGTH MEETING OR EXCEEDING THE PREFERRED MINIMUM CRITERIA OF 1.5 FPS WATER VELOCITY AND 0.5 FEET WATER DEPTH, LOWER DESCHUTES RIVER. SEE TABLE 3.4.3.

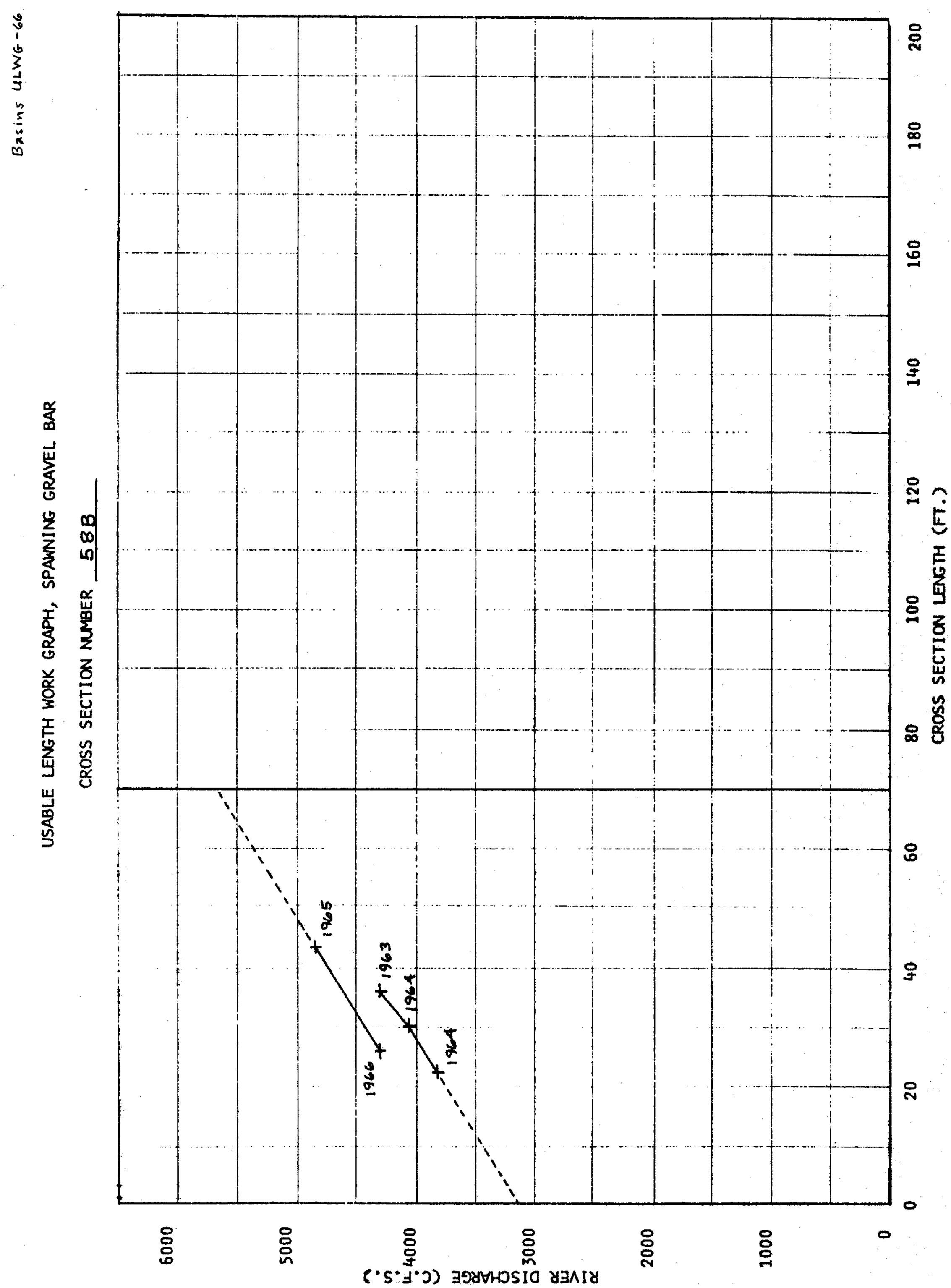


TABLE 3.4.1

Amount of Gravel Bar Cross Section Length Usable for Salmonid Spawning at Various River Discharges, Lower Deschutes River, Section I, 1964-65

Station Number	Cross Section Length	Usable Length 4230 cfs	3550 cfs	3140 cfs
501	100 ft.	(100) ft.[a]	90 ft.	66 ft.
504	57	45	31	13
Total	157 ft.	145 ft.	121 ft.	79 ft.
Percent	100	92.4	77.1	50.3

[a] The figure in parenthesis was extrapolated from 1964 data, since the 1964-65 flood changed the bar's configuration to such an extent that the 1965 measurement taken at this flow was not directly comparable to 1964 measurements.

Determination of amount of cross section usable for spawning based on a minimum water depth of 0.5 feet and a minimum water velocity of 1.5 feet per second.

FIGURE 3.4.3

RELATION BETWEEN STREAM DISCHARGE AND
PERCENT OF GRAVELS USABLE FOR SPAWNING,
LOWER DESCHUTES RIVER,
SECTION I

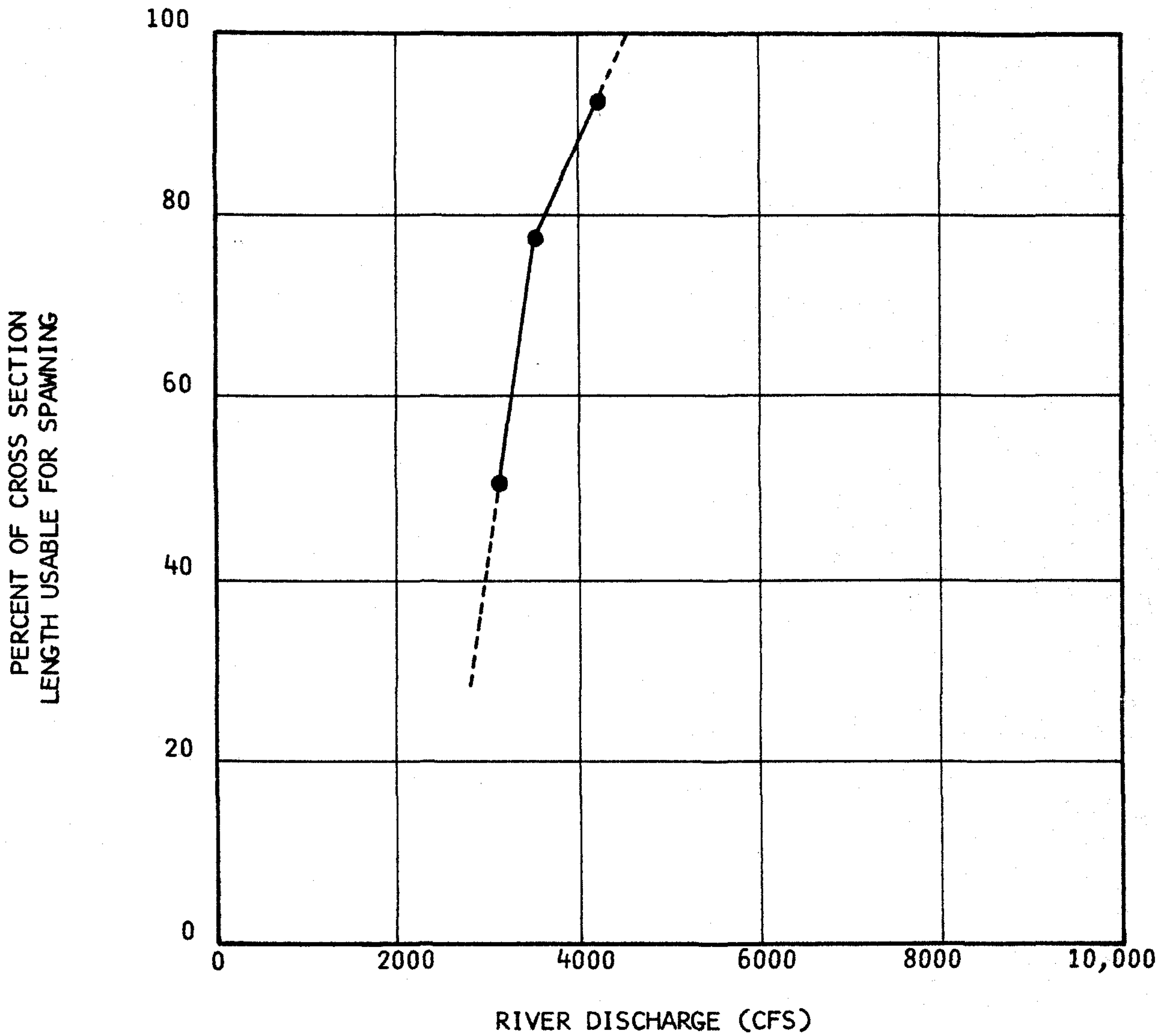


TABLE 3.4.2

Amount of Gravel Bar Cross Section Length Usable for Trout and Salmon Spawning at Various River Discharges, Lower Deschutes River, Section II, 1961-65

Station No.	Cross Section Length	Usable Length						
		6500 cfs	5200 cfs	4800 cfs	4400 cfs	3900 cfs	3700 cfs	3200 cfs
3	145 ft.	(145)ft	(145)ft	(145)ft	119 ft[a]	(83)ft	70 ft	43 ft
6A	60	(42)	39	(38)	37	12	(9)	0[b]
6B	70	(70)	60	(52)	44	27	(25)	20[b]
9	100	(60)	38	(31)	24	75	(77)	81[b]
9A	51	(51)	(51)	(51)	(45)	(27)	21	3
9B	90	53	(51)	(50)	49[a]	(46)	45	23
9C	91	(91)	(89)	(84)	(79)	(72)	70	64
9D	88	88	(87)	(87)	(86)	(86)	86	53
10[c]	83	(69)	(58)	(55)	(52)	(48)	46	42
10[d]	83	49	(29)	(23)	18[a]	(10)	(7)	(0)
19	195	(169)	(169)	169	169	52	(49)	22[b]
19A	97	(78)	(82)	83	84	62	(54)	37[b]
19B	46	(46)	(37)	23	26	11	(11)	10[b]
19C	48	(17)	(17)	17	17	21	(19)	15[b]
Total	1,247	1,028	957	908	849	632	589	413
Percent	100	82.4	76.3	72.8	68.1	50.7	47.2	33.1

[a] Measured at a flow of 4,450 cfs.
[b] " " " " " 3,150 cfs.
[c] 1964 conditions (prior to 1964-65 floods)
[d] 1965 conditions (after 1964-65 floods)

Figures in parenthesis are estimates of usable length based on extrapolation and interpolation of measured data.

Determination of amount of cross section usable for spawning based on a minimum water depth of 0.5 feet and minimum water velocity of 1.5 feet per second.

FIGURE 3.4.4.

RELATION BETWEEN STREAM DISCHARGE AND PERCENT OF GRAVELS USABLE FOR SPAWNING, LOWER DESCHUTES RIVER, SECTION II

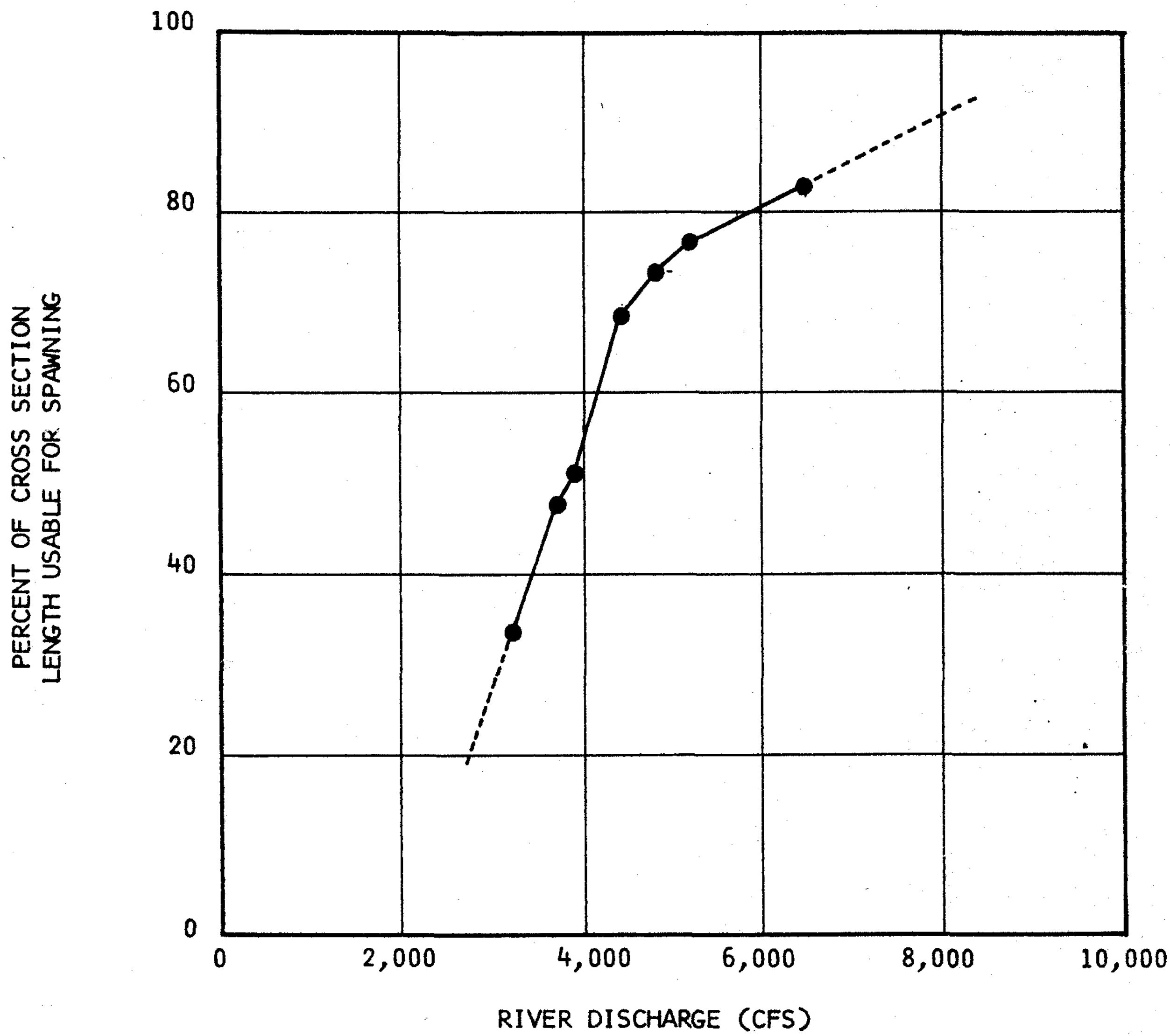


TABLE 3.4.3

Amount of Cross Section Length Usable for Trout and Salmon Spawning at Various River Discharges, Lower Deschutes River, Section III, 1961-65

Station No.	Cross Section Length	Usable Length						
		6,500 cfs	5,600 cfs	4,900 cfs	4,300 cfs	4,050 cfs	3,700 cfs	3,250 cfs
46	99 ft.	(66)ft.	50 ft.	38 ft.	(8) ft.	0 ft.[a]	(0)ft.	0 ft.
47	54	(46)	42	39[b]	(30)	27[c]	(25)	24[d]
47B	30	(30)	30	30[b]	(21)	17[c]	(13)	8[d]
48	24	(18)	17	16	(3)	0[a]	(0)	0
54A	70	56	(25)	1	(1)	(0)	(0)	(0)
58A	30	(30)	(30)	(30)	(30)	27	22[e]	27[d]
58B	70	(70)	(68)	43[f]	36	30	22[g]	(5)
58D	70	(70)	(70)	(70)	(68)	66	66[e]	67[d]
62	149	28	(88)	132	137	125	93[e]	66[d]
64	200	(66)	(53)	44	(36)	32	0[g]	(0)
Total	796	480	473	443	370	324	241	197
Percent	100	60.3	59.4	55.7	46.5	40.7	30.3	24.7

a Measured at a flow of 4,150 cfs.
b " " " " " 5,000 cfs.
c " " " " " 4,000 cfs.
d " " " " " 3,350 cfs.
e " " " " " 3,650 cfs.
f " " " " " 4,800 cfs in 1965.
g " " " " " 3,800 cfs.

Figures in parenthesis are estimates of usable length based on extrapolation and interpolation of measured data.

Determination of amount of cross section usable for spawning based on a minimum water depth of 0.5 feet and a minimum water velocity of 1.5 feet per second.

FIGURE 3.4.5

RELATION BETWEEN STREAM DISCHARGE AND PERCENT OF GRAVELS USABLE FOR SPAWNING, LOWER DESCHUTES RIVER, SECTION III

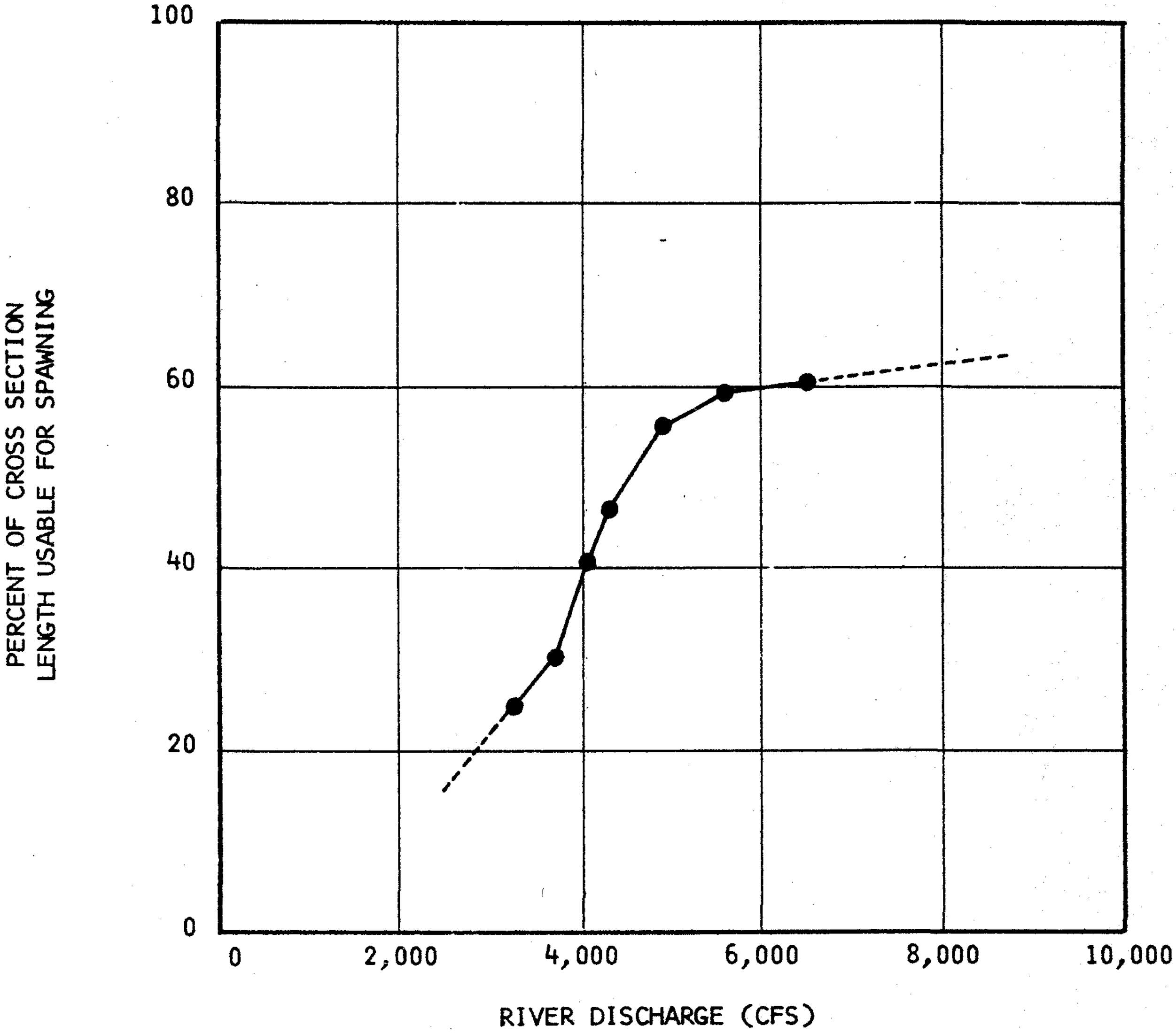


TABLE 3.4.4

Amount of Cross Section Length Usable for Trout and Salmon Spawning
at Various River Discharges
Lower Deschutes River, Section IV,
1961-64

Station No.	Cross Section Length	Usable Length				
		6490 cfs	5370 cfs	4400 cfs	4020 cfs	3380 cfs
99	39 ft.	18 ft.	9 ft.	3 ft.[a]	(1) ft.	(0) ft.
100	29	15	19	0[a]	(0)	(0)
105	98	63	11	5[a]	(3)	(0)
110	54	23	32	26[a]	(24)	(20)
114	130	(130)	(130)	113[b]	49	19
122	45	(45)	(45)	36[b]	17	8
123 1/2	55	(55)	(55)	55[b]	38	18
123	96	60[c]	55	43[b]	39	30
123A	85	44[c]	46	45[b]	31	12
Total	631	453	402	326	202	107
Percent	100	71.8	63.7	51.7	32.0	17.0

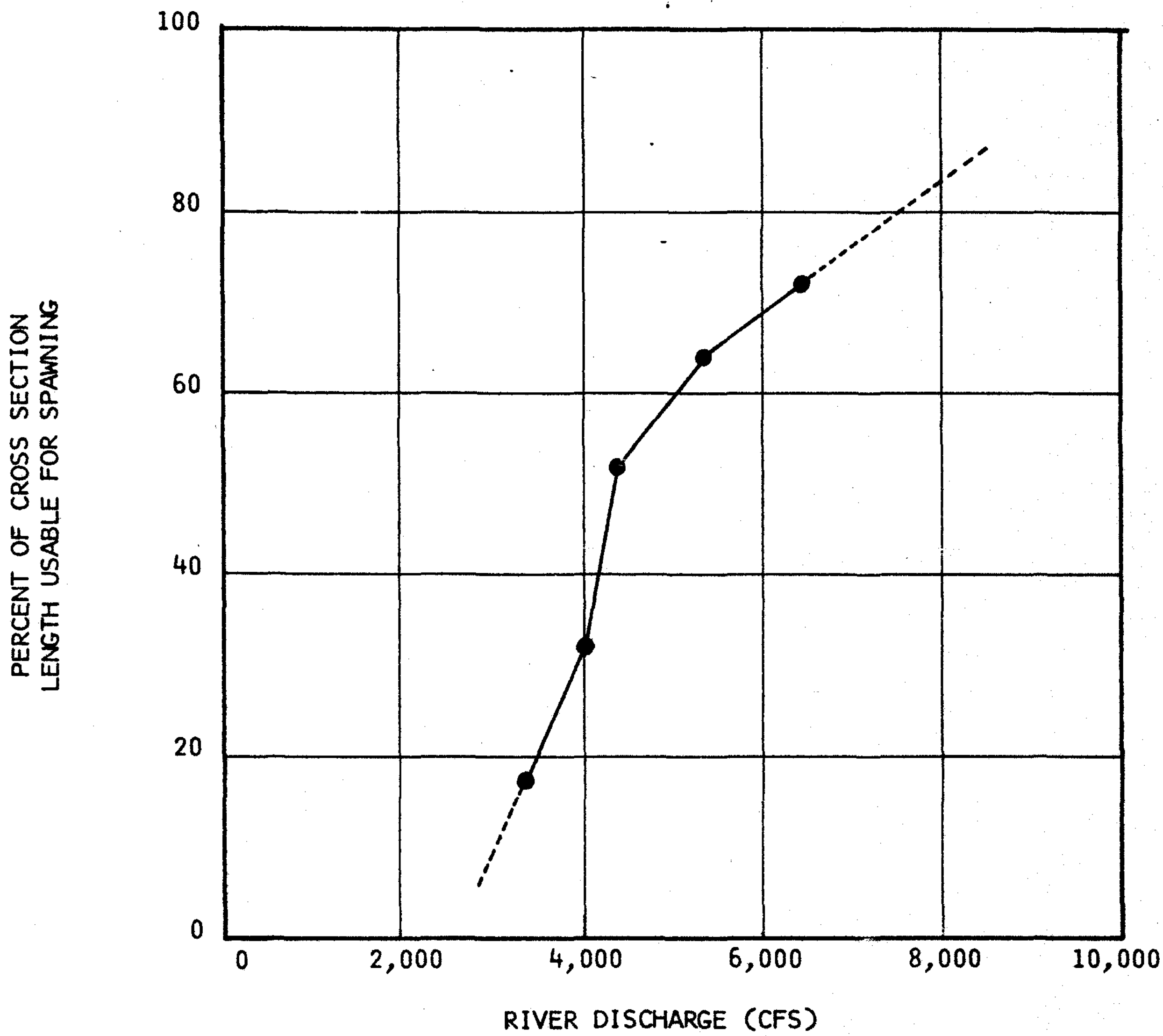
[a] Measured at 4330 cfs.
[b] Measured at 4440 cfs.
[c] Measured at 6420 cfs.

Figures in parenthesis are estimates of usable length based on extrapolation and interpolation of measured data.

Determination of amount of cross section usable for spawning based on a minimum water depth of 0.5 feet and a minimum water velocity of 1.5 feet per second.

FIGURE 3.4.6

RELATION BETWEEN STREAM DISCHARGE AND
PERCENT OF GRAVELS USABLE FOR SPAWNING,
LOWER DESCHUTES RIVER,
SECTION IV



Discussion

3.5 Predicted Minimum Discharges and Usable Spawning Gravel

Lower Deschutes River mean monthly discharges for recent years were summarized by stream section in Part One, Table 1.3.4. Discharges predicted under minimum allowed releases from the Pelton - Round Butte project were presented in Part One, Table 1.3.5. Graphs of the relationship between discharge and cross section length usable for spawning (Figs. 3.4.3, 3.4.4, 3.4.5 and 3.4.6) were used to estimate changes in percent of spawning gravel usable under minimum allowed releases. An example of how this was done is shown in Fig. 3.5.1.

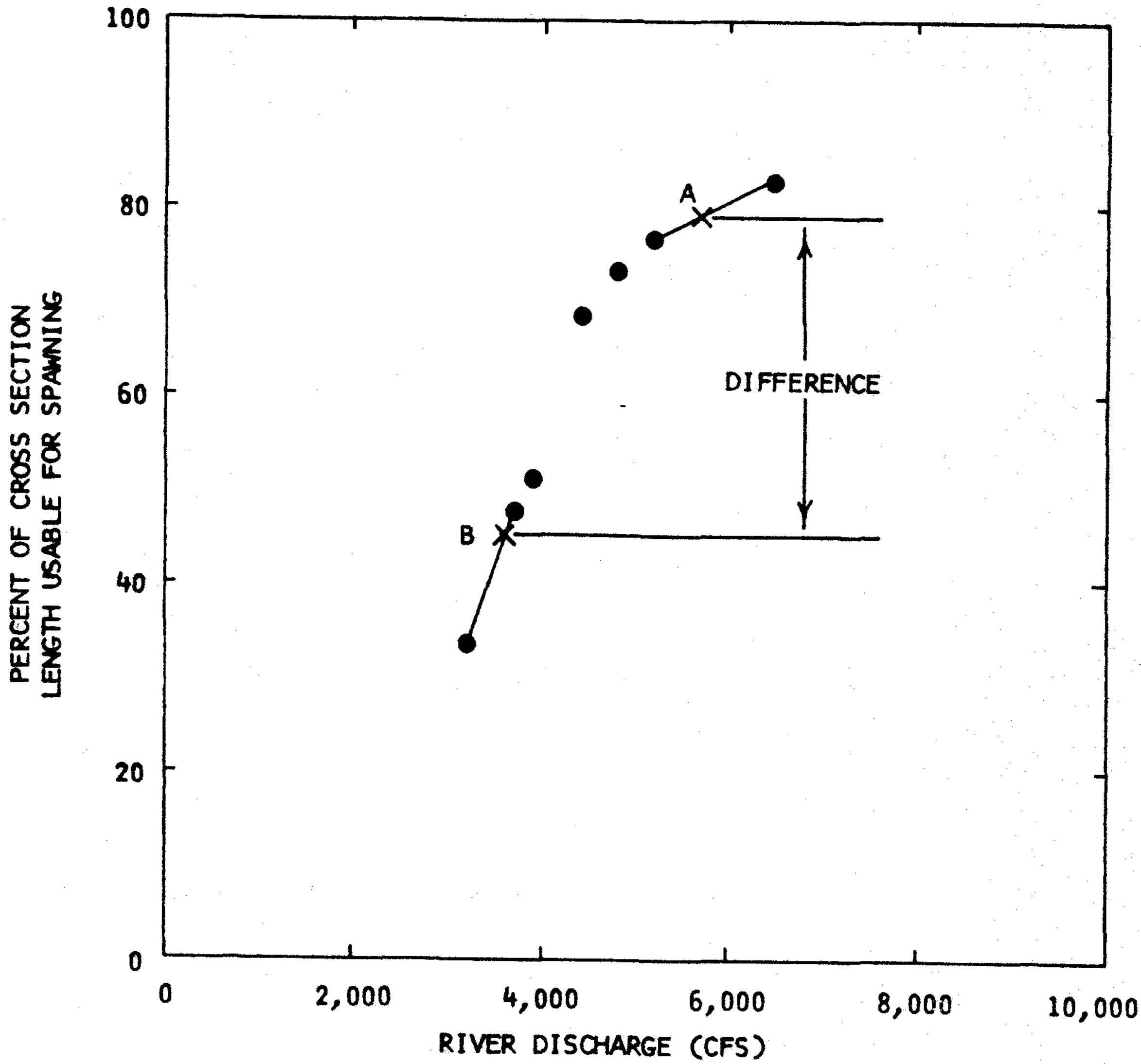
Expected changes in percent of spawning gravel usable between mean and minimum discharges were determined for each of four stream sections for the nine months during which trout or salmon spawn. As listed in Table 3.5.1, these estimated changes ranged from -58% to -15% with an overall raw average of -32.4%. This can be interpreted to mean that, on the average, over 32% of the potential spawning area usable at discharges experienced in the past becomes unusable and is lost for spawning whenever discharges are reduced to the minimum allowed under current Pelton - Round Butte project licensing (see footnote to Table 1.3.5, Part One).

Three hypothetical minimum discharge regimens were summarized in Part One, Tables 1.3.6, 1.3.7 and 1.3.8. These hypothetical regimens are characterized by progressively higher minimum discharges than that allowed under current licensing. Determinations were made of expected changes in percent of spawning gravel usable between these hypothetical minimums and the pre-Round Butte mean discharge in the same manner as outlined above for the currently licensed minimum. Estimated changes in usable area for these three hypothetical regimens are listed in Tables 3.5.2, 3.5.3 and 3.5.4. Under regimen A these changes ranged from -32% to -7%

with an overall raw average of -18.3%. Under regimen B these changes ranged from -19% to -1% with an overall raw average of -7.0%. Under regimen C these changes ranged from a -11% to a +9% with an overall raw average of -0.5%. Figure 3.5.2 illustrates the relationship between the overall means of these changes and the various minimum discharge regimens.

FIG. 3.5.1

AN EXAMPLE OF GRAPHICALLY ESTIMATING CHANGES IN PERCENT OF SPAWNING GRAVEL USABLE BETWEEN MEAN AND MINIMUM DISCHARGES.



This graph, constructed from data in Table 3.4.2 and identical to Fig. 3.4.4, illustrates the relationship between river discharge and percent of measured gravel cross section length usable for trout and salmon spawning.

In this example, "A" is the point of intersection between the mean May monthly discharge in recent years in Section II (5,700 cfs, from Table 1.3.4) and a line connecting percents of cross section length found usable at 5,200 and 6,500 cfs. "B" is the point of intersection between prediced May discharge in Section II under minimum allowed releases (3,660 cfs,from Table 1.3.5) and a line connecting percents of cross section length found usable at 3,200 and 3,700 cfs.

The difference between these two intersections (-33%) is the estimated percent change in spawning area usable under minimum allowed discharge and is so listed in Table 3.5.1.

TABLE 3.5.1

Estimated Changes in Trout and Salmon Spawning Area Usable Under Minimum Allowed Discharges, by Month and Stream Section, Lower Deschutes River

Species	Month	Stream Section I	II	III	IV	Mean Change by Month
Trout	March	-26%	-38%	-16%	-24%	-26.0%
	April	-26	-38	-15	-23	-25.5
	May	-26	-33	-15	-16	-22.5
	June	-26	-32	-18	-16	-23.0
	July	-53	-38	-26	-36	-38.2
	Mean	-31.4	-35.8	-18.0	-23.0	-27.05
Salmon	Sept.	-49	-32	-23	-34	-34.5
	Oct.	-52	-37	-26	-36	-37.8
	Nov.	-58	-43	-31	-40	-43.0
	Dec.	-58	-46	-20	-34	-39.5
	Mean	-54.2	-39.5	-25.0	-36.0	-38.69
Overall Raw Mean		-41.56	-37.44	-21.11	-28.78	-32.417

Based on pre-Round Butte discharges (Table 1.3.4) compared with discharges under minimum allowed releases from Pelton-Round Butte project (Table 1.3.5).

TABLE 3.5.2

Estimated Changes in Trout and Salmon Spawning Area Usable Under Hypothetical Minimum Discharge Regimen A, by Month and Stream Section, Lower Deschutes River

Species	Month	Stream Section I	II	III	IV	Mean Change by Month
Trout	March	-12%	-25%	-8%	-18%	-15.8%
	April	-12	-24	-7	-18	-15.2
	May	-12	-19	-7	-11	-12.2
	June	-12	-18	-8	-10	-12.0
	July	-21	-24	-15	-22	-20.5
	Mean	-13.8	-22.0	-9.0	-15.8	-15.2
Salmon	Sept.	-17	-18	-14	-23	-18.0
	Oct.	-20	-23	-17	-24	-21.0
	Nov.	-26	-29	-21	-24	-25.0
	Dec.	-26	-32	-18	-15	-25.0
	Mean	-22.2	-25.5	-17.5	-21.5	-22.2
Overall Raw Mean		-17.5	-23.6	-12.8	-18.3	-18.3

Based on pre-Round Butte discharges (Table 1.3.4) compared with discharges under minimum discharge regimen A (Table 1.3.6).

TABLE 3.5.3

Estimated Changes in Trout and Salmon Spawning Area Usable Under Hypothetical Minimum Discharge Regimen B, by Month and Stream Section, Lower Deschutes River

Species	Month	Stream Section I	II	III	IV	Mean Change by Month
Trout	March	-1%	-12%	-4%	-14%	-7.8%
	April	-1	-12	-3	-14	-7.5
	May	-1	-8	-3	-7	-4.8
	June	-1	-6	-3	-5	-3.8
	July	-7	-11	-4	-4	-6.5
	Mean	-2.2	-9.8	-3.4	-8.8	-6.1
Salmon	Sept.	-3	-5	-2	-2	-3.0
	Oct.	-6	-10	-5	-3	-6.0
	Nov.	-12	-16	-9	-9	-11.5
	Dec.	-12	-19	-9	-9	-12.2
	Mean	-8.2	-12.5	-6.2	-5.8	-8.2
Overall Raw Mean		-4.9	-9.8	-4.6	-7.5	-7.0

Based on pre-Round Butte discharges (Table 1.3.4) compared with discharges under minimum discharge regimen B (Table 1.3.7).

TABLE 3.5.4

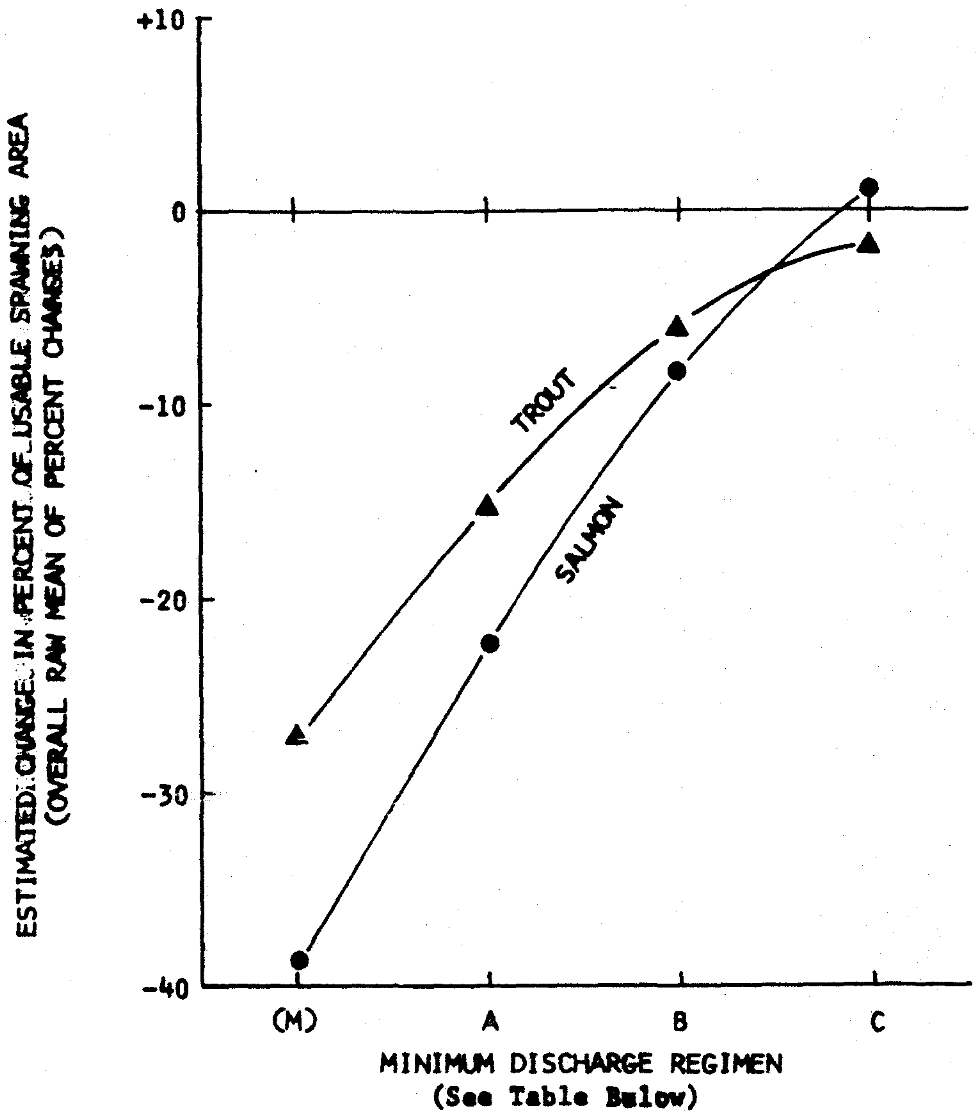
Estimated Changes in Trout and Salmon Spawning Area Usable Under Hypothetical Minimum Discharge Regimen C, by Month and Stream Section, Lower Deschutes River

Species	Month	Stream Section I	II	III	IV	Mean Change by Month
Trout	March	0%	-7%	-2%	-10%	-4.7%
	April	0	-7	-2	-11	-5.0
	May	0	-3	-1	-4	-2.0
	June	0	-1	0	-1	-0.5
	July	+4	+2	+3	+3	+3.0
	Mean	+0.8	-3.2	-0.4	-4.6	-1.8
Salmon	Sept.	+8	+9	+6	+4	+6.8
	Oct.	+5	+4	+3	+3	+3.8
	Nov.	-1	-3	-1	-2	-1.8
	Dec.	-1	-6	-3	-5	-3.8
	Mean	+2.8	+1.0	+1.2	0.0	+1.2
Overall Raw Mean		+1.7	-1.3	+0.3	-2.6	-0.5

Based on pre-Round Butte discharges (Table 1.3.4) compared with discharges under minimum discharge regimen C (Table 1.3.8).

FIG. 3.5.2

ESTIMATED CHANGES IN TROUT AND SALMON SPAWNING AREA USABLE UNDER 4 DIFFERENT MINIMUM DISCHARGE REGIMENS, LOWER DESCHUTES RIVER.



Discharge Regimen		Minimum Releases, Pelton Project March-June	July-September	From Table
Minimum Allowed	(M)	3500 cfs	3000 cfs	1.3.5
Hypothetical Regimen	A	4000	3500	1.3.6
" "	B	4500	4000	1.3.7
" "	C	5000	4500	1.3.8

Area usable under mean discharge in recent years is compared with area usable under the minimum discharge presently allowed and three hypothetical minimum discharge regimens.

3.6 Relating Minimum Discharges to Changes in Spawning

In section 3.5 minimum monthly discharges by stream section were related to changes in percent of gravel cross section area usable for spawning. However, spawning activity is not evenly dispersed over all months and all river sections listed. In fact, months and sections showing greatest predicted changes are the months and sections having the smallest portions of total spawning. Raw data on changes in percent of gravel usable were therefore weighted by the relative amount of spawning observed during each month and in each river section (Part Two, Table 2.3.1). These weighted data, treated in the same way as the raw data in section 3.5, are portrayed in Fig. 3.6.1 as estimates of changes in trout and salmon spawning relatable to changes induced by the four different minimum discharge regimens. There is actually little practical difference between the raw means estimating usable area changes and the weighted means estimating spawning changes.

Changes in spawning area usable and changes in actual spawning may take several forms in the lower Deschutes River, such as: (1) changes in density of spawning effort over higher quality spawning areas; (2) more or less frequent superimposition of spawning; (3) changes in the relative proportion of redds constructed in marginal spawning areas; and (4) actual changes in total numbers of fish spawning in the lower Deschutes River.

Changes estimated in this section and in section 3.5 were based on these three assumptions:

(1) Downstream tributary inflow, on the average, will remain similar to that occurring during past years of record on which mean discharge tables are based (Part One, Tables 1.3.2 and 1.3.3). This assumption is valid since no drastic changes in tributary inflow patterns have occurred in recent years and there is no reason to predict such changes in the near future.

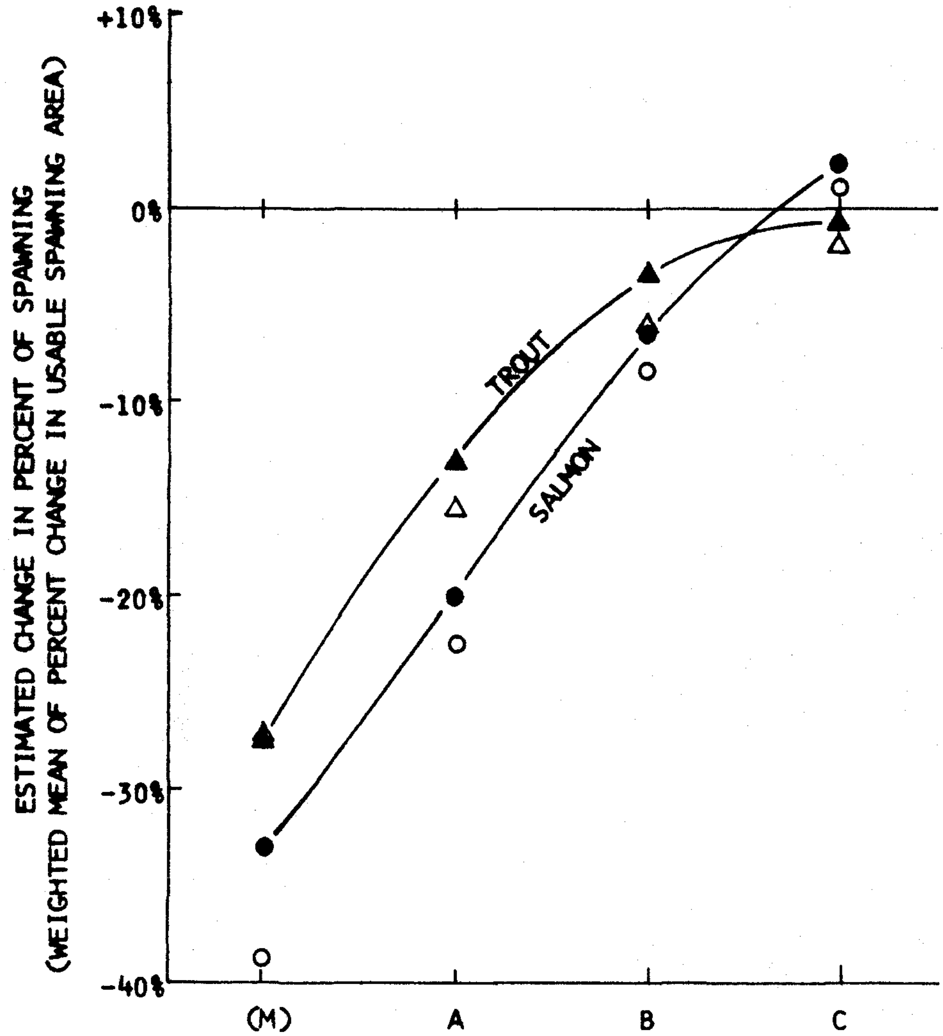
(2) No new spawning gravel areas will be made usable at lower discharges that were not previously available and utilized at mean discharges. This assumption holds true since observed distribution of gravel in the lower Deschutes River is unusually stable and limited. We found no significant areas of presently un-utilized or unavailable gravel that could be utilized or made available at lower than average river discharges.

(3) More efficient utilization of presently used spawning areas will not occur. The validity of this assumption is based on past years' observations -- all apparently high quality spawning gravels were typically so densely covered by redds that superimposition occurred at even the usual river discharges.

Photographic records of the effects changing discharges had on spawning gravel bars are portrayed in Figures 3.6.2 through 3.6.18.

FIG. 3.6.1

ESTIMATED CHANGES IN TROUT AND SALMON SPAWNING UNDER 4 DIFFERENT MINIMUM DISCHARGE REGIMENS, LOWER DESCHUTES RIVER.



Discharge Regimen		Pelton Project Minimum Releases March-June	July-September	From Table
Minimum Allowed	(M)	3500 cfs	3000 cfs	1.3.5
Hypothetical Regimen	A	4000	3500	1.3.6
" "	B	4500	4000	1.3.7
" "	C	5000	4500	1.3.8

Percent of area usable weighted by proportion of spawning occurring by location and by time to estimate changes in actual spawning induced by minimum discharges. Changes estimated are derived by comparing conditions under mean discharges of recent years with predicted discharges under listed regimens. Open symbols indicate raw means of changes in area usable, from Fig. 3.5.2.

STREAM SECTION II

FIG. 3.6.2 STATION 10 (DRY CREEK CAMP) SPAWNING GRAVEL BAR AT 4,500 CFS, APRIL 16, 1963. NUMBERS REFER TO INTRAGRAVEL STAND-PIPES.

FIG. 3.6.3 STATION 10 AT 3,150 CFS, JANUARY 3, 1964. DOTTED LINE OUTLINES AREA USED FOR TROUT SPAWNING IN 1963. BIOLOGIST PICTURED IS MONTY MONTGOMERY.

FIG. 3.6.4 STATION 10 AT ABOUT 5100 CFS, MARCH 16, 1967. THE 1964-65 FLOODS REDUCED THE VOLUME OF WATER FLOWING THROUGH THIS SIDE CHANNEL AND LAID A HIGH GRAVEL BAR BETWEEN THE NEAR SHORE AND MID-CHANNEL. COMPARE THIS PHOTOGRAPH WITH THE TWO PREVIOUS PHOTOGRAPHS. TROUT SPAWNING IN 1965 AND 1966 OCCURRED ALONG THE EDGE BETWEEN THE NEAR EXPOSED GRAVEL BAR AND MID-CHANNEL.

FIG. 3.6.5 STATION 19 (ABOVE TROUT CREEK) AT 5,250 CFS, MAY 8, 1963. IN 1963 AND 1964 TROUT SPAWNED IN THE AREA AROUND AND DOWNSTREAM FROM THE TWO BIOLOGISTS (JIM HUTCHISON AND MONTY MONTGOMERY)

FIG. 3.6.6 STATION 19 AT 3,100 CFS, JULY 7, 1964. BIOLOGIST IN PICTURE IS DON KING.

STREAM SECTION III

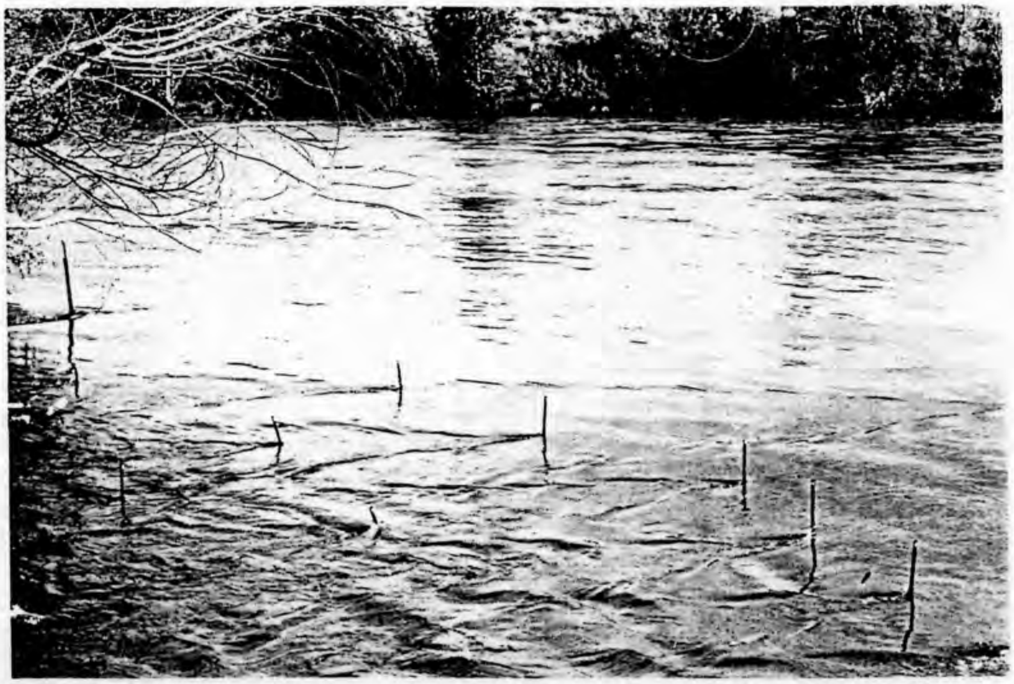


FIG. 3.6.7 STATION 47 (UPPER WHISKY DICK) AT 4,500 CFS, MAY 2, 1963. TROUT SPAWNED IN AREA COVERED BY STANDPIPES.

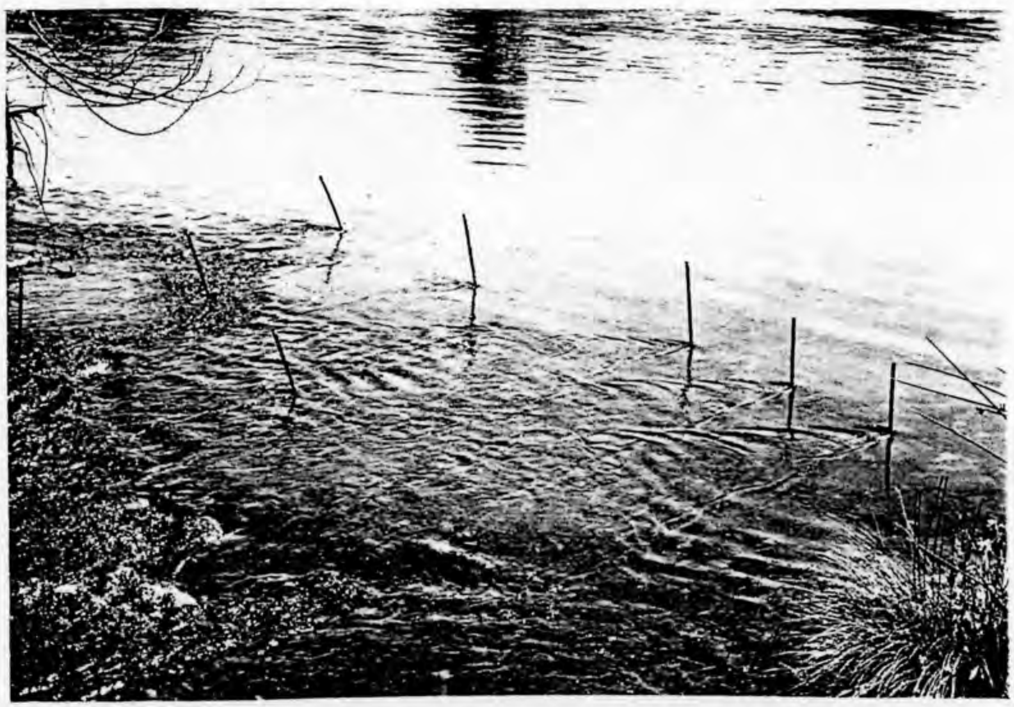


FIG. 3.6.8 STATION 47 AT 3,100 CFS, JULY 10, 1964. THIS BAR WAS COMPLETELY REMOVED BY THE 1964-65 FLOODS.

FIG. 3.6.9 STATION 58B (EAST RIM ROCK CHATEAU) AT 4,500 CFS, JANUARY 14, 1964. TROUT SPAWNED IN THE AREA AROUND AND DOWN-STREAM FROM THE RIGHT STANDPIPE.

FIG. 3.6.10 STATION 58B AT 3,500 CFS, JANUARY 3, 1964.

FIG. 3.6.11 STATION 58B AT ABOUT 8,700 CFS, JANUARY 15, 1965. PEAK DISCHARGE DURING THE 1964-65 FLOODS WAS OVER 25,000 CFS AT THIS POINT.

FIG. 3.6.12 STATION 58B AT ABOUT 5,000 CFS, MARCH 20, 1967. THESE STANDPIPES ARE REPLACEMENTS, SINCE THE 1964-65 FLOODS BURIED THE ORIGINAL GRAVEL UNDER 15-20 INCHES OF NEW GRAVEL.

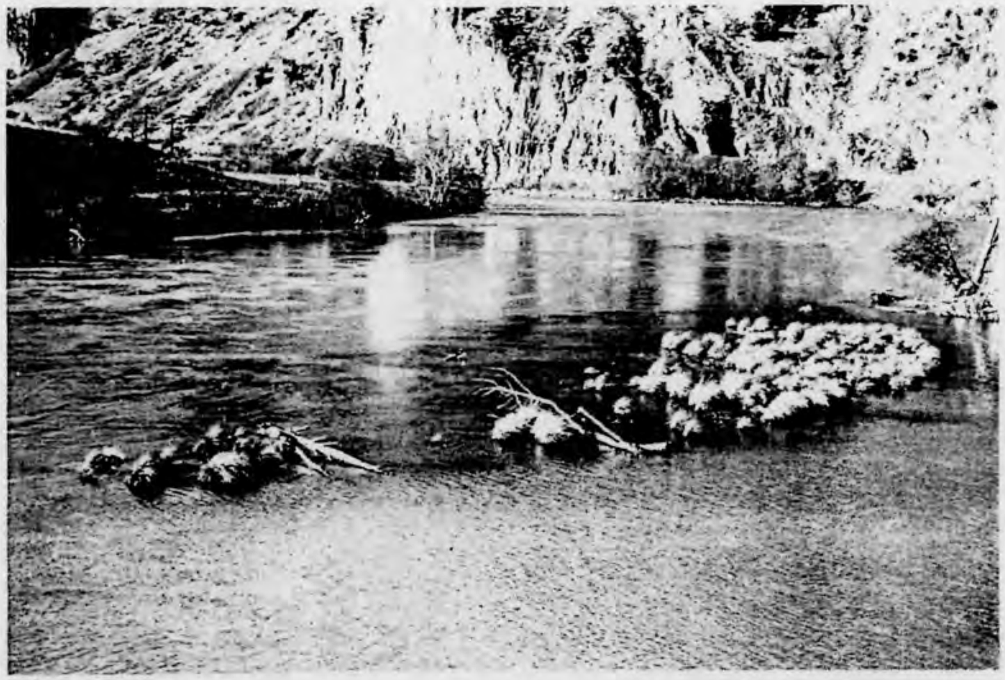


FIG. 3.6.13 STATION 64 (RATTLESNAKE PIT) AT 4,500 CFS, JANUARY 24, 1964.

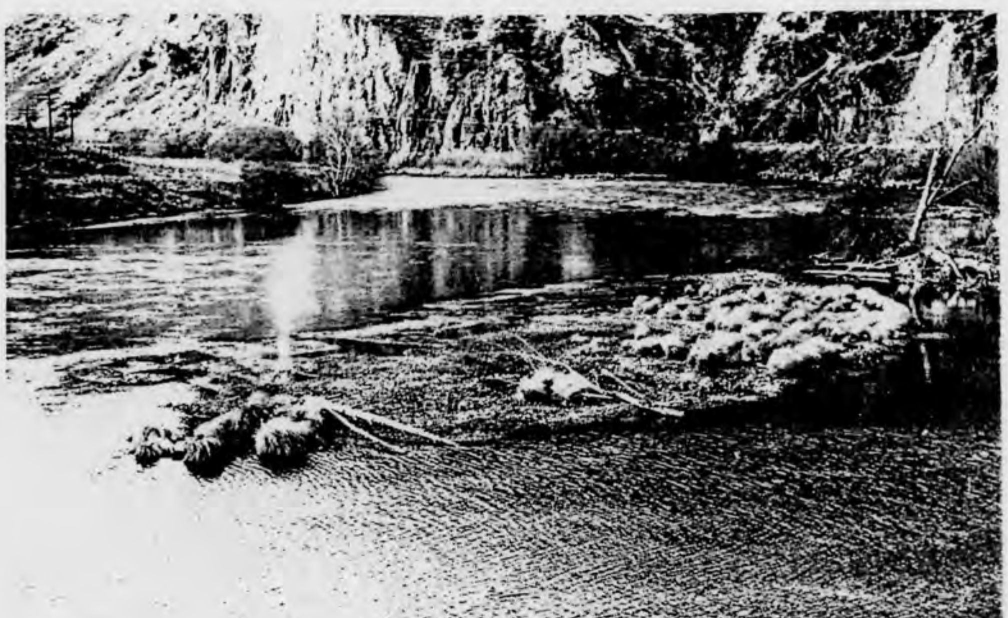


FIG. 3.6.14 STATION 64 AT 3,500 CFS, JANUARY 3, 1964.

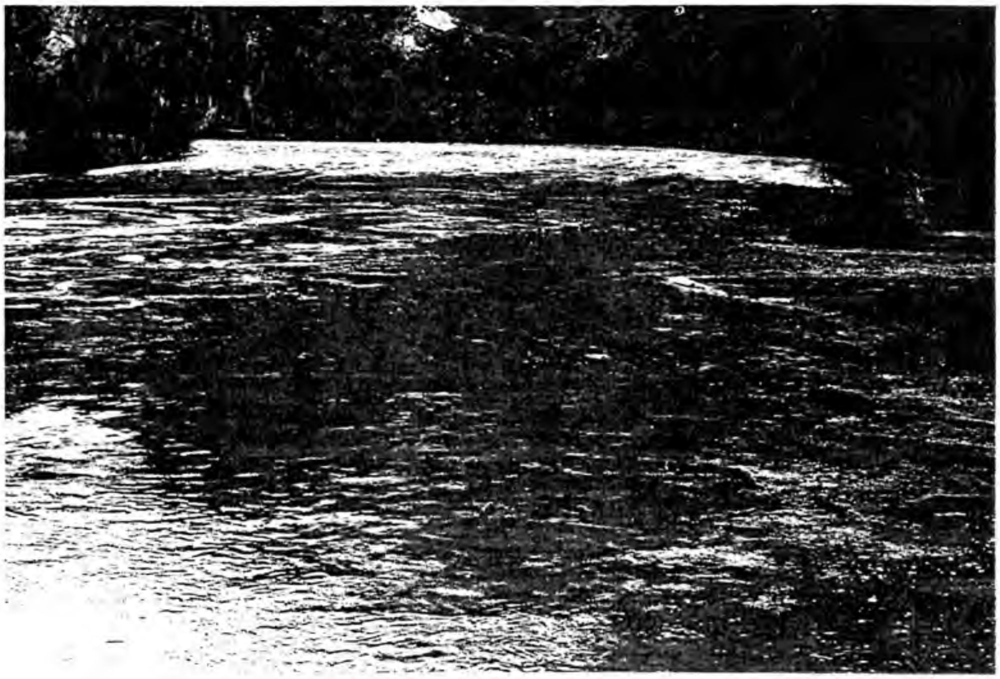


FIG. 3.6.15 STATION 64 AT ABOUT 8,700 CFS, JANUARY 15, 1965.

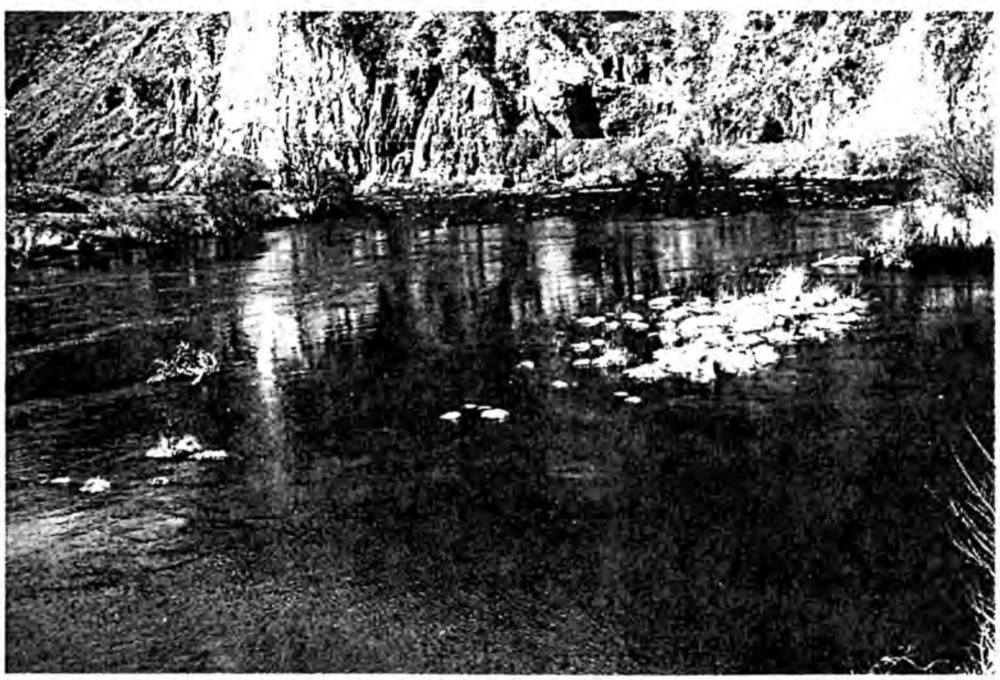


FIG. 3.6.16 STATION 64 AT ABOUT 5,000 CFS, MARCH 20, 1967.

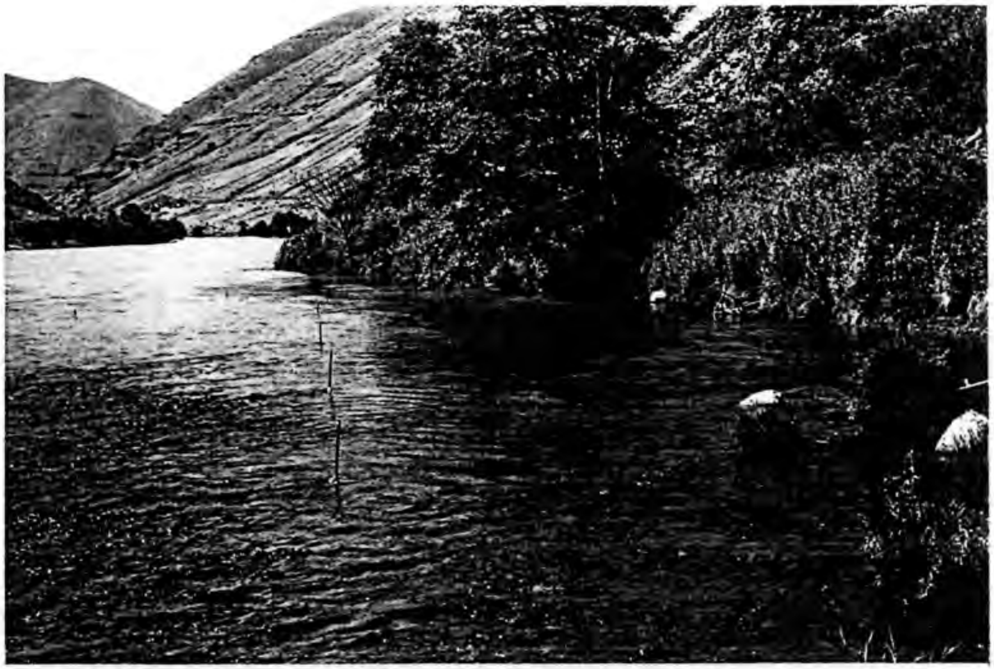


FIG. 3.6.17 STATION 114A (BELOW DIKE) AT 4,920 CFS, JUNE 6, 1963. IN 1963 TROUT SPAWNED IN THE AREA NEAR THE STANDPIPE TO THE FAR RIGHT. IN 1963 AND 1964 SALMON SPAWNED ALONG THE FAR LEFT MARGIN OF THE GRAVEL BAR.

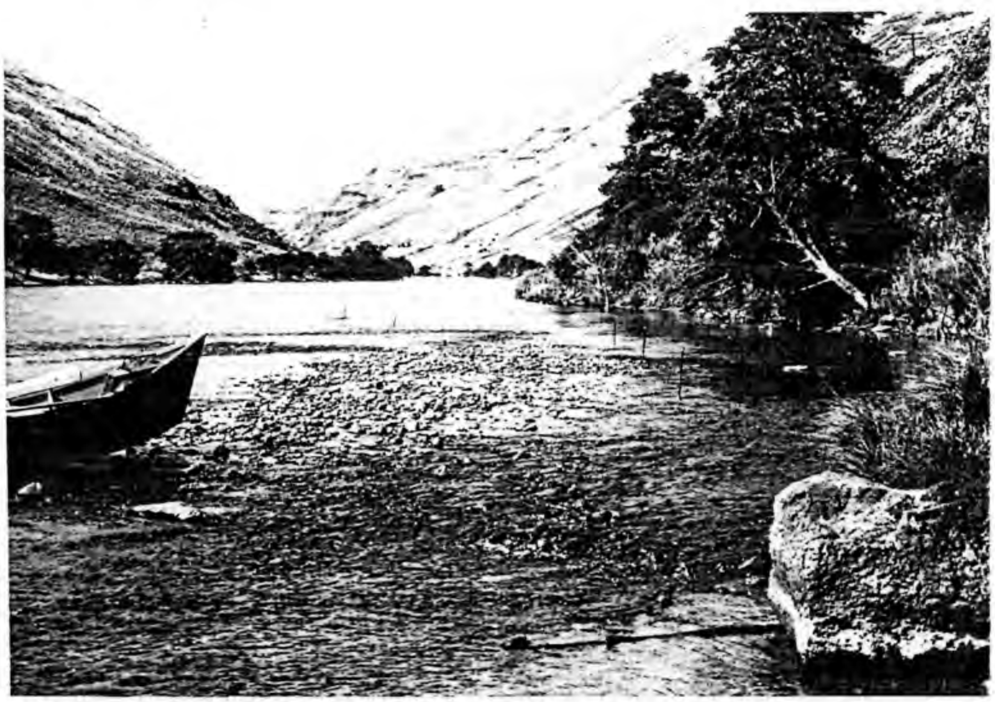


FIG. 3.6.18 STATION 114 AT 3,720 CFS, JULY 8, 1964.

3.7 Optimum River Discharges

Examination of the graphs relating stream discharge to percent of gravels usable for spawning can also lead to certain conclusions as to optimum river discharge for each river section. Points plotted in these graphs tended to follow an S-shaped or sine curve (Figs. 3.4.4 through 3.4.6). These graphs could be useful in determining an optimum discharge where further increases in discharge would have a diminishing effect in increasing the amount of usable area. Methods of this nature were utilized in making stream flow recommendations for spawning in reports on Oregon's South Coast (Hutchison, 1962), Umatilla (Hutchison et al, 1963a), and Middle Willamette basins (Hutchison et al, 1963b).

By this method, examination of Fig. 3.4.3, for river Section I, showed that insufficient points have been plotted to adequately determine an optimum river discharge, although it would be in excess of 4,200 cfs, highest discharge during which we measured cross section water conditions.

Examination of Fig. 3.4.4, for river Section II, indicated optimum river discharge of about 5,000 cfs. Decreasing river discharges below 5,000 cfs rapidly reduced the amount of spawning gravel within usable water depth and velocity ranges. Above 5,000 cfs there appeared to be a diminishing effect of increased river discharge on water velocities and depths over spawning gravel.

Fig. 3.4.5, for river Section III, indicated an optimum discharge of about 5,000 cfs. In river Section IV, Fig. 3.4.6, examination of the graph indicated an optimum river discharge in excess of 6,000 cfs.

These approximations of optimum discharge are summarized in Table 3.7.1. It would appear that more measurements would be needed to establish the relationship between spawning gravel usability and higher river discharges (above 6,000 cfs) in the lower Deschutes River.

TABLE 3.7.1

Optimum River Discharge, Based on an Examination of Graphs Relating River Discharge to Percent of Gravel Cross Section Length Usable for Spawning, Lower Deschutes River

Stream Section	Chart	Optimum Discharge
I	Fig. 3.4.3	at least 4,200 cfs
II	Fig. 3.4.4	about 5,000 cfs
III	Fig. 3.4.5	about 5,000 cfs
IV	Fig. 3.4.6	at least 6,000 cfs

LOWER DESCHUTES RIVER, OREGON;

DISCHARGE AND THE FISH ENVIRONMENT

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Monty L. Montgomery and
Allan B. Lichens

Oregon State Game Commission
Portland, Oregon

PART FOUR
Intragravel Environment of Spawning Beds

Lower Deschutes Flow Study Final Report (Draft)

November 1967

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Part Four. Intragravel Environment of Spawning Beds

Methods

4.1 Measuring Dissolved Oxygen Content of Intragravel Water

Semi-permanent plastic intragravel standpipes of a type developed in Alaska (McNeil, 1962) were used to obtain water samples from the intragravel environment. These standpipes were 3 or 5 foot lengths of 0.75 inch rigid plastic water pipe open at both ends. Twenty holes, 0.078 inch diameter, were drilled in the lower 3 inches (see Fig. 4.1.1). We used a collared steel driving rod fitted to the inside diameter of the standpipes to drive them into the gravel to a depth of 9 to 12 inches.

Standpipes were placed in random and selected locations in gravel bars throughout the study area, both in natural redds and in undisturbed gravel areas. See Table 4.1.1 and Fig. 4.1.2. Most standpipes were 3 feet in length although several 5-foot standpipes were used in deep water. After placing the standpipe and removing the driving rod, a hand operated suction pump was used to remove silt within the standpipe. Removal of accumulated silt and dirt was also required periodically.

Samples of intragravel water were collected in 30 milliliter (ml.) vials using a mouth suction assembly consisting of flexible rubber tubing, glass tubing and a two-hole rubber stopper. These samples were collected, fixed and analyzed according to the semi-micro dissolved oxygen analysis method described by Harper (1953). For this purpose the following chemicals were used:

0.0125 N sodium thiosulfate solution

Manganous sulfate solution (Winkler method)

Alkaline-iodide-azide reagent (Alsterberg modification)

Concentrated sulfuric acid

Stabilized starch indicator solution

Standard iodate-iodide solution equivalent to 10 $mgO_2/l.$ dissolved oxygen (for titer standardization)

For analysis a 5 ml. automatic semi-micro buret was used. All analyses were done in the field as soon after sampling as possible, usually within one hour. Standardization of sodium thiosulfate was accomplished at least twice monthly and frequently more often.

All intragravel dissolved oxygen data and related observations were recorded on a standard form which included such items as station number, date, weather during sampling, time of sampling, river discharge, river turbidity, air temperature, water temperature, normality of titer, date titer standardized, time of analysis, standpipe number, intragravel water temperature, standpipe depth, water depth at standpipe, and volume of titer required to titrate sample (Fig. 4.1.3).

Absolute quantity of dissolved oxygen present in the water sample was calculated using the following formula:

$$M = 8000\left(\frac{V_t\ N_t}{V_s}\right)$$

Where: $M = mgO_2/l.$ = absolute dissolved oxygen content of water sample in milligrams per liter (mg./l.)

V_t = volume of titer used in titration, in milliliters.

N_t = normality of titer, usually around 0.0125.

V_s = volume of water sample titrated, in milliliters.

This procedure is generally considered capable of measuring true dissolved oxygen with an error of less than 10%. Percent saturation of oxygen in water was calculated from this absolute dissolved oxygen content based on water temperature measured either at the surface or within the standpipe at the point of sampling:

$$S' = \frac{M}{S\left(\frac{P}{760}\right)}$$

Where: S' = Percent saturation of dissolved oxygen in water

S = Solubility of oxygen in water in milligrams per liter (Table 19, APHA, 1962)

P = Barometric pressure correction for altitude above sea level in millimeters of mercury.

M = $mgO_2/l.$ = absolute dissolved oxygen content of water sample in milligrams per liter

All absolute dissolved oxygen and percent saturation calculations were made by computer. Fig. 4.1.4.

4.2 Measurement of Permeability

Gravel permeability is defined as the ability of gravel to pass water. It is directly related to the amount and size of gravel interstices. Gravel beds composed of small particles with high proportions of fine material have low permeability, whereas coarser gravels containing little silt and other fine material have high permeability.

Permeability is expressed as the rate water will pass through gravel under a given head -- usually this rate is given in centimeters per hour (cm/hr) at a standard head of one inch.

The Mark VI ground water standpipe used for measuring permeability in this study was developed in British Columbia (Terhune, 1958). It consisted of a 1.25 inch diameter metal tube 34.25 inches long with 48 drilled holes in the lower 3.5 inches just above the attached 2.5 inch driving point (Fig. 4.1.1). The lower end of the tube was closed by the driving point and the upper end of the tube was open and extended above the water after placement. The standpipe was driven into the gravel a predetermined distance using an inside driving rod.

The measurement apparatus consisted of a hand vacuum pump, a graduated plastic reservoir and a brass sampling probe connected to the reservoir by means of a flexible rubber hose. See Figs. 4.2.2 and 4.2.3. The brass probe was inserted into the driven standpipe until it touched the water surface within the standpipe. A sliding marker was then adjusted until it was exactly one inch above the open top of the standpipe. When taking the actual permeability sample the marker rested on top of the standpipe, placing the end of the probe one inch below the water surface within the standpipe. The rubber tube was then pinched off, the hand pump operated until a vacuum is established within the plastic reservoir, and the pinched tube was released for a measured time period, usually five seconds, while pumping continued. The first water pumped was the one inch needed to establish a head within the standpipe. Thereafter the only water entering the reservoir was equivalent to that entering the 48 holes near the bottom of the standpipe (seven to eight inches below the gravel surface). Subtracting the volume of the one inch head (25 ml.) left an amount equivalent to the volume of water that flowed through the gravel during the sampling period. This amount was directly related to gravel permeability. In-flow was expressed in mililiters per second which we converted to gravel permeability expressed in centimeters per hour by use of Table 4.2.1.

During this study we measured gravel permeability at random locations on selected gravel bars and systematically in relationship to natural redds. Information recorded during the conduct of these measurements included gravel bar location, date, weather, water temperature, river discharge, water turbidity, actual sample location, standpipe depth, water depth at standpipe and the actual results of permeability sampling -- time (seconds) and volume (ml.). Fig. 4.2.1.

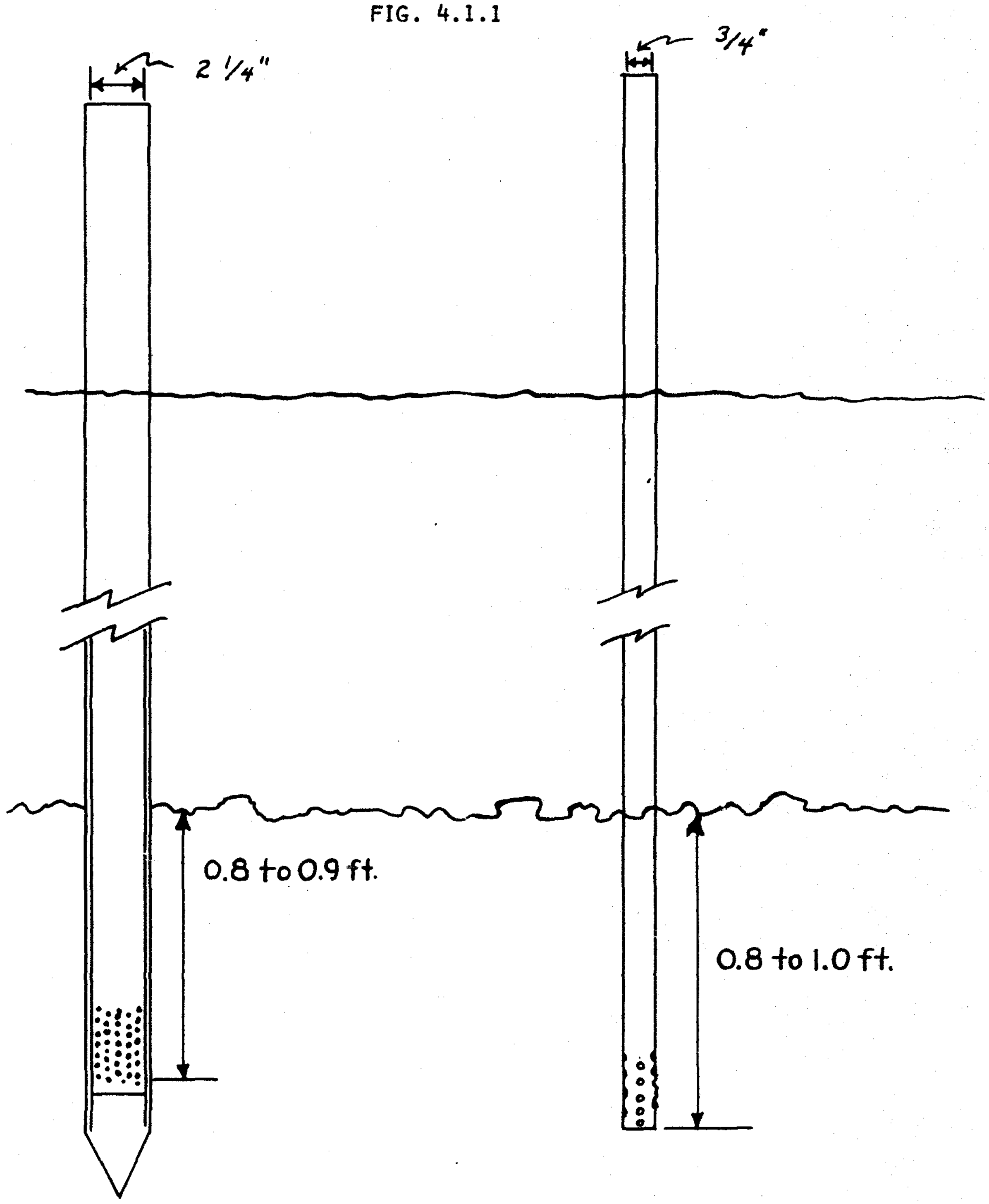
We also established an index of permeability by using the same method of measuring flow into plastic intragravel standpipes instead of metal Mark VI standpipes.

4.3 Measuring Intragravel Water Temperatures

Early in the study we tried to measure intragravel water temperatures by lowering a pocket thermometer into the standpipes. The method proved impractical.

In mid-1964 a thermister equipped electronic thermometer was obtained and this was used throughout the rest of the study to measure intragravel water temperature. This thermometer had an absolute accuracy of ± 0.25 °F. and was readable to ± 0.1 °F.

FIG. 4.1.1



Mark VI Groundwater Standpipe

McNeil's Plastic Intragravel Standpipe

SCHEMATICS OF STANDPIPES USED IN THE LOWER DESCHUTES INTRAGRAVEL ENVIRONMENT STUDY

TABLE 4.1.1

Distribution of Effort, Intragravel Water Quality Sampling (Dissolved Oxygen), Lower Deschutes River

	Station Number	Station Visits for Intragravel Water Quality Sampling 1963	1964	1965	1966	Total	Intragravel Water Dissolved Oxygen Analyses Made 1963	1964	1965	1966	Total
STREAM SECTION I	501	0	8	22	11	41					
	504	0	3	13	8	24					
	505	0	1	0	5	5					
	Totals	0	12	0	5	5	0	35	229	175	439
STREAM SECTION II	6A	3	0	0	0	3					
	9	0	0	18	5	23					
	9B	0	5	0	0	5					
	9D	0	1	0	8	9					
	10	21	18	5	8	52					
	11A	0	0	4	2	6					
	15A	0	0	5	0	5					
	19	18	11	0	2	31					
	25B	0	0	0	6	6					
	29B	0	0	0	2	2					
	Totals	42	35	32	33	142	218	201	129	84	632
STREAM SECTION III	47	14	18	0	0	32					
	47A	0	0	0	5	5					
	47B	18	17	18	8	61					
	56	0	0	13	0	13					
	58A	12	22	0	7	41					
	58B	20	23	22	11	76					
	58C	10	17	0	0	27					
	58D	11	15	0	0	26					
	62	18	15	0	0	33					
	72B	0	0	2	0	2					
	73	0	0	14	11	25					
	89	3	0	0	0	3					
	Totals	106	127	69	42	344	646	821	262	274	2003
STREAM SECTION IV	109B	0	0	2	0	2					
	114A	12	12	2	0	26					
	122	13	14	3	4	34					
	123	13	15	14	4	46					
	Totals	38	41	21	8	108	176	211	77	56	520
	Overall Totals	186	215	157	168	664	1040	1268	697	589	3594

Biased samples not included (see text, Section 4.4).

Oregon State Game Commission — Basins Investigations

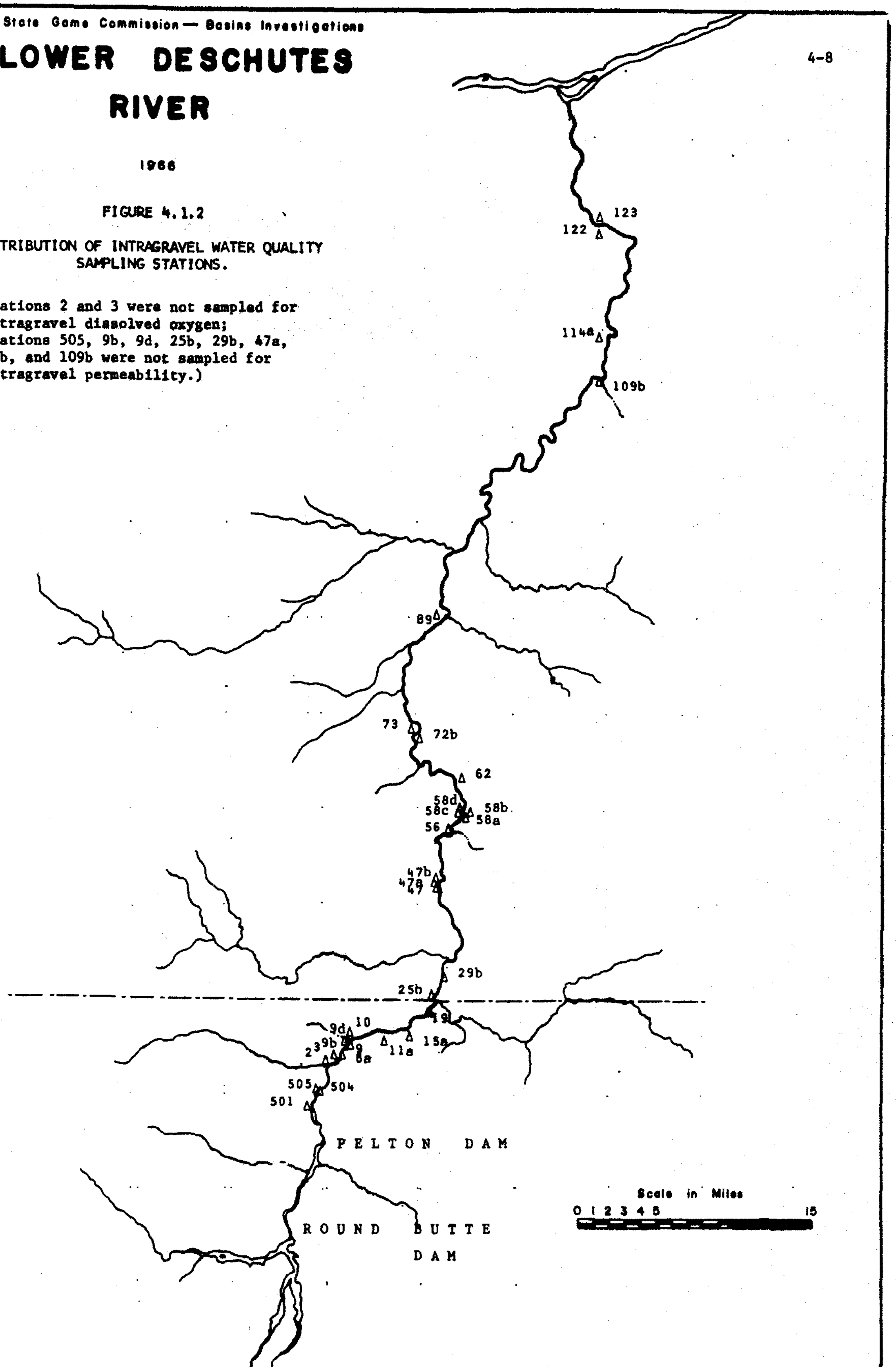
LOWER DESCHUTES RIVER

1966

FIGURE 4.1.2

DISTRIBUTION OF INTRAGRAVEL WATER QUALITY SAMPLING STATIONS.

(Stations 2 and 3 were not sampled for intragravel dissolved oxygen; Stations 505, 9b, 9d, 25b, 29b, 47a, 72b, and 109b were not sampled for intragravel permeability.)



FORM 1061-1b

INTRAGRAVEL DISSOLVED OXYGEN
OSGC - Basins

Project [1061] Stream [05A] Section [3] Station No. [47 B] Date (M D Y) [4 : 13 : 66]

Location Lower Whisky Dick Time Sampling Started [14:30] Finished 14:55

Weather [2] High haze Air Temperature 63.3° Water Temperature [48.4]

Stream conditions: Flow volume [5400] Turbidity [SL] Slight

Crew Aney, King, and Behrens Remarks [100] 1 small redd below #15, larger redd right of #21

Analysis: Normality of titer 0.[01197] Date Standardized 4/13

Vs 24.854 Time Analysis Started [15:10] Finished 15:45 By [4] King

Mean DO_2 Content

Vial No.	Stand pipe No.		I-G Water Temp.	Stand pipe Depth	Water Depth	DO_2 Analysis V_t	DO_2 Analysis MgO_2/l.	Remarks	
A	12	B	47.1	1.00	1.3	0.20	0.77	012	1" silt in standpipe, turbid
B	15		47.3	1.00	1.2	0.40	1.54		
C	16		47.2	1.00	1.0	1.24	4.78		
D	17		47.2	1.00	1.2	0.95	3.66		
E	18		47.2	1.00	1.2	0.30	1.16	007	turbid sample, overrun
F	19		46.9	1.00	1.4	0.33	1.27	010	1" silt
G	13		47.2	0.80	0.8	0.14	0.54	002	turbid sample
H	20		47.4						
I	21		47.3						
Ø	22		47.3					5	overrun
CC	23		47.2						1" silt
W	25		47.2	1.00	1.5	0.80	3.08	005	overrun
X	SW		—	—	—	3.24	12.48		

FIGURE 4.1.3

FORM USED FOR FIELD RECORDING OF INTRAGRAVEL WATER SAMPLING AND ANALYSIS DATA.

LOWER DESCHUTES STUDY PROJECT NO 1061

STREAM SECTION NO 3 STATION NO 47B

STREAM DISCHARGE 5400 CFS WATER TURBIDITY SL STATION REMARKS CODE 100

DATE 4/13/66 WEATHER CODE 2 SURFACE WATER TEMP 48.4 DEG.F

TITER NORMALITY 0.01197 TIME OF SAMPLING 14:30 TIME OF ANALYSIS 15:10 ANALYSIS BY 4

CLUSTER NUMBER	STANDPIPE NUMBER	INTRAGRAVEL WATER TEMP.	STANDPIPE DEPTH	WATER DEPTH	MGO2/L (PPM)	PERCENT SATURATION	WATER COL.HT	STANDPIPE REMARKS	M
2	12B	47.1	1.00	1.3	.77	6.9	2.30	12	
9	13	47.2	.80	.8	.54	4.8	1.60	2	
9	15	47.3	1.00	1.2	1.54	13.8	2.20		
9	16	47.2	1.00	1.0	4.78	42.9	2.00		
1	17	47.2	1.00	1.2	3.66	32.8	2.20		
1	18	47.2	1.00	1.2	1.16	10.4	2.20	7	
3	19	46.9	1.00	1.4	1.27	11.1	2.40	10	
9	20	47.4	1.10	.8	3.35	30.0	1.90		
1	21	47.3	1.05	1.2	4.39	39.3	2.25		
1	22	47.3	1.00	1.4	4.32	38.7	2.40	5	
1	23	47.2	1.00	1.5	.15	1.3	2.50	10	
1	25	47.2	1.00	1.5	3.08	27.6	2.50	5	
	SW				12.48	113.4*			

* DENOTES CALCULATION USING SURFACE WATER TEMPERATURE

FIGURE 4.1.4

COMPUTER OUTPUT, INTRAGRAVEL WATER DISSOLVED OXYGEN ANALYSIS

FIG. 4.1.5 DRAWING INTRAGRAVEL WATER SAMPLES AT RIM ROCK CHATEAU, STATION 58D, LOWER DESCHUTES RIVER.

FIG. 4.1.6 30 ML. INTRAGRAVEL WATER SAMPLE SHORTLY AFTER ADDING OXYGEN FIXING CHEMICALS.

FIG. 4.1.7 FIELD ANALYSIS OF DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES. ITEMS IN PHOTOGRAPH INCLUDE UNTITRATED WATER SAMPLES (LEFT FOREGROUND), FIELD RECORDING FORM (CLIPBOARD), SEMI-MICRO BURET (CENTER, WITH BLACK RESERVOIR BOTTLE), 25 ML. MEASURING FLASK (IN FRONT OF RESERVOIR BOTTLE), STARCH INDICATOR SOLUTION (PLASTIC BOTTLES BEHIND BURET) AND TITRATION FLASK WITH SAMPLE BEING TITRATED.

GRAVEL PERMEABILITY
OSGC - Basins

Stream Deschutes Station No. 10 Date Jan. 27, 1965

Location Dry Creek camp Time 2:00 P.M.

Weather Overcast Air Temperature ____ Water Temperature 42°F

Stream conditions: Vol. of flow about 7,500 Turbidity High

Crew Haxton and Aney Mean Permeability 655 cm/hr.

Remarks staff gage placed

Sample No.	Location	Sampling Depth	Water Depth	Rate of Inflow Time	Rate of Inflow Vol.	Rate of Inflow Ml./sec	Permeability cm/hr Sample	Permeability cm/hr Mean	Remarks
1	131½' at 75½°	—	—						Water too deep
2	122½' at 76½°	—	—						" " "
3	108' at 85½°	—	—						" " "
4	76' at 83½°	7¼"	2.0'	5 sec.	60	12	1070		
"	"	"	"	"	65	13	1180	1125	
5	57' at 77½°	"	0.15'	"	25	5	360		
"	"	"	"	"	25	5	360	360	
6	48' at 80°	"	0.1'	"	50	10	830		
"	"	"	"	"	65	13	1180	1005	
7	24½' at 80½°	"	0.3'	"	5	1	0		
"	"	"	"	"	20	4	260	130	
8	62' at 105°	—							Water too deep
9	58½' at 118½°	—							" " "
10	51½' at 122½°	—							" " "
11	72½' at 170½°	—							" " "

FIGURE 4.2.1

FORM USED FOR FIELD RECORDING OF GRAVEL PERMEABILITY SAMPLING DATA.

FIG. 4.2.2 GRAVEL PERMEABILITY MEASUREMENT IN SHALLOW WATER, USING THE MARK VI GROUNDWATER STANDPIPE.

FIG. 4.2.3 GRAVEL PERMEABILITY MEASUREMENT IN DEEPER WATER. LENGTH OF THE MARK VI GROUNDWATER STANDPIPE LIMITED ITS USE IN DEEP WATER.

TABLE 4.2.1

Permeability Calibration
for Mark VI Groundwater Standpipe.

Q ml/sec	K cm/hr	Q ml/sec	K cm/hr	Q ml/sec	K cm/hr
2	100	43	6,200	84	24,600
3	170	44	6,450	85	25,500
4	260	45	6,700	86	26,400
5	360	46	7,000	87	27,300
6	460	47	7,250	88	28,200
7	550	48	7,500	89	29,100
8	640	49	7,750	90	30,000
9	730	50	8,000	91	31,200
10	830	51	8,300	92	32,400
11	950	52	8,600	93	33,600
12	1,070	53	8,900	94	34,800
13	1,180	54	9,200	95	36,000
14	1,290	55	9,500	96	37,200
15	1,400	56	9,800	97	38,400
16	1,520	57	10,100	98	39,600
17	1,640	58	10,400	99	40,800
18	1,760	59	10,700	100	42,000
19	1,880	60	11,000	101	44,100
20	2,000	61	11,400	102	46,300
21	2,150	62	11,800	103	48,400
22	2,300	63	12,200	104	50,600
23	2,450	64	12,600	105	52,700
24	2,600	65	13,000	106	54,900
25	2,750	66	13,400	107	57,000
26	2,900	67	13,800	108	59,200
27	3,050	68	14,200	109	61,300
28	3,200	69	14,600	110	63,500
29	3,350	70	15,000	111	65,600
30	3,500	71	15,600	112	67,800
31	3,670	72	16,200	113	69,900
32	3,850	73	16,800	114	71,100
33	4,040	74	17,400	115	73,200
34	4,230	75	18,000	116	75,400
35	4,420	76	18,600	117	77,600
36	4,610	77	19,200	118	79,800
37	4,800	78	19,800	119	82,00
38	5,000	79	20,400	120	84,200
39	5,200	80	21,000	121	86,800
40	5,400	81	21,900	122	89,200
41	5,650	82	22,800	123	91,600
42	5,900	83	23,700	124	94,000

Derived from Figure 6, page 1039, Terhune (1958); assuming a straight line (nearly) between points on the Figure, by Robert W. Phillips, Oregon State Game Commission.

TABLE 4.2.2

Distribution of Effort, Mark VI Gravel Permeability Sampling, Lower Deschutes River

	Station Number	Station Visits for Gravel Permeability Sampling					Number of Gravel Permeability Samples Taken				
		1963	1964	1965	1966	Total	1963	1964	1965	1966	Total
STREAM SECTION I	501	0	2	6	0	8	0	17	72	0	89
	504	0	1	2	0	3	0	4	16	0	20
	Totals	0	3	8	0	11	0	21	88	0	109
STREAM SECTION II	2	1	0	0	0	1	1	0	0	0	1
	3	1	0	0	0	1	5	0	0	0	5
	6A	1	0	0	0	0	3	0	0	0	3
	9	0	0	6	0	6	0	0	28	0	28
	10	2	2	1	0	5	27	12	4	0	43
	11A	0	0	1	0	1	0	0	2	0	2
	15A	0	0	4	0	4	0	0	7	0	7
	19	4	1	0	0	5	32	11	0	0	43
	Totals	9	3	12	0	24	68	23	41	0	132
STREAM SECTION III	47	1	1	0	0	2	20	11	0	0	31
	47B	0	0	6	0	6	0	0	21	0	21
	56	0	0	5	0	5	0	0	21	0	21
	58A	2	2	0	0	4	27	25	0	0	52
	58B	6	2	2	0	10	69	20	11	0	100
	58C	1	0	0	0	1	25	0	0	0	25
	58D	1	2	0	0	3	16	14	0	0	30
	62	2	2	0	0	4	18	16	0	0	34
	73	0	0	4	0	4	0	0	36	0	36
	89	1	0	0	0	1	6	0	0	0	6
	Totals	14	9	17	0	40	181	86	89	0	356
STREAM SECTION IV	114A	2	2	0	0	4	40	16	0	0	56
	122	2	2	0	0	4	22	16	0	0	38
	123	2	2	5	0	9	20	18	26	0	64
	Totals	6	6	5	0	17	82	50	26	0	158
	Overall Totals	29	21	42	0	92	331	180	244	0	755

Results

4.4 Dissolved Oxygen Content of Intragravel Water

Over 3,500 individual measurements of intragravel water dissolved oxygen were made during the course of this study. This excludes measurements discarded because of possible biasing due to excessive silt in standpipes (three or more inches), surface water contamination of intragravel water samples (cracked or flooded standpipes) and disturbance of gravel around standpipes (usually by spawning fish). Also, no measurements were used when the gravel at the standpipe location was not under water.

Data from standpipes in current redds were treated separately from measurements made from standpipes in undisturbed gravel. (Redds were considered "current" during the period between spawning and probable emergence of all fry). Sampling effort from undisturbed gravels is summarized in Table 4.4.1.

Monthly means and their confidence intervals were computed and graphed for each stream section, as in Figs. 4.4.1, 4.4.2, 4.4.3 and 4.4.4. These means, portrayed by solid lines in the graphs, illustrate seasonal fluctuations in the dissolved oxygen content of intragravel water. The broken lines on each side of solid line portray the 90% confidence interval of the mean, computed by formula 2, Table 4.4.2 (these limits describe the interval which would include the true mean unless a one in ten chance has occurred in sampling). In a few cases the confidence interval was not computed because of too few measurements. To give a general indication of trends in these cases, only the mean is graphed. If only one measurement was made, it alone is graphed.

Data was obtained from 488 surface water samples measured concurrently with the intragravel water samples. Monthly means of these surface water measurements are portrayed on the dissolved oxygen graphs by a single broken line.

Summarized intragravel water dissolved oxygen data for the entire study area is listed in Table 4.4.3 for each of the 38 months during which measurements were made. Fig. 4.4.5 portrays this data, a summary of surface water dissolved oxygen data, and river discharge means over the entire study period.

The following points of discussion pertain to the five dissolved oxygen graphs and associated tables:

1. Mean intragravel dissolved oxygen varied from a high of 9.6 $mgO_2/l.$ in Stream Section II, March 1964 to a low of 1.3 $mgO_2/l.$ in the same Section in the late summer of 1964.

2. In all stream sections, intragravel dissolved oxygen tended to be lowest in late summer (August and September) and highest in late winter (February and March).

3. Dissolved oxygen levels were lowest in 1964. In Section II, the intragravel mean remained below 4.0 $mgO_2/l.$ from June through December 1964 (seven months) while in 1963 it was below this level three months, in 1965 at least three months and in 1966 only two months. In Section III, intragravel dissolved oxygen was below 4.0 $mgO_2/l.$ only once -- in 1964 -- for a five month period. In Section IV, intragravel dissolved oxygen was below 4.0 $mgO_2/l.$ for six months in 1964, two months in 1963, five months in 1965 and two months in 1966.

4. Surface water dissolved oxygen fluctuated seasonly much less than intragravel water dissolved oxygen. Monthly section means ranged from 8.2 $mgO_2/l.$ (Section IV, July 1965) to 14.8 $mgO_2/l.$ (Section II, March 1966).

5. Surface water dissolved oxygen levels were lowest between July and October and highest in March and April.

6. Surface water dissolved oxygen measurements over any one year were not obviously higher or lower than measurements over any other year -- there were few differences among yearly data records.

Fig. 4.4.6 portrays a construction of how the dissolved oxygen content of surface and intragravel water fluctuated over a year's time. These curves are based on monthly means, summarized over all years of the study period, as listed in Tables 4.4.4 and 4.4.5.

Because 1963 discharge patterns were typical of that occurring under unregulated conditions, monthly data from that year were used to construct a curve representing hypothetically optimum intragravel dissolved oxygen levels. Measurements for 1963 began in April, so hypothetically optimum values for January, February and March were defined as those values resulting if intragravel oxygen content approached surface water oxygen content in late winter.

Data from standpipes in natural and artificial redds were treated separately. Since developing embryos are in the gravel environment for only a limited and critical period, we attempted to describe any changes in environment quality over time by correlating measured dissolved oxygen with redd age by days. See Tables 4.4.6 and 4.4.7. We obtained a high number of significant negative correlations in the case of steelhead and rainbow trout redds but relatively few correlations in examining chinook salmon redds. This was anticipated since trout redds were constructed during a period of declining intragravel environmental quality while salmon redds were constructed at a time when this same quality was on the upswing (see Figs. 4.4.6 and 4.4.7).

During the course of this study, standpipes were placed in several redds apparently constructed during a time when river discharge was higher than that prevailing during the remainder of the spawning and incubation season. Using the criteria that river discharge at time of spawning was at least 500 cfs higher than the mean for the ensuing 60 days (month of spawning and following month), data from ten standpiped redds were analyzed to determine the effect reduction in discharge had on the quality of the embryo environment. Results of this analysis are summarized in Fig. 4.4.8 and Table 4.4.8. From these results it is apparent that reductions in flow after spawning critically depressed the amount of oxygen available to the developing embryos.

Data from artificial redds showed a significant correlation between intragravel dissolved oxygen and redd age, particularly in the case of the first series of redds constructed. See Table 4.4.9 and Fig. 4.4.9. Generally, this data revealed that intragravel environment quality in the artificial redds was quite similar to that found in natural redds, at least as far as dissolved oxygen is concerned.

A study of the 24-hour fluctuations in surface and intragravel water dissolved oxygen content revealed the effect time of day has on oxygen concentrations. Surface water oxygen content appears to be highest about 2 p.m. and lowest around 9 a.m., while intragravel water oxygen content was highest about 7 p.m. and lowest about 4 a.m. During 24 hours, intragravel dissolved oxygen means changed 1.4 $mgO_2/l.$, and surface water dissolved oxygen changed 1.7 $mgO_2/l.$ See Fig. 4.4.10.

TABLE 4.4.1

Distribution of Sampling Effort for Measurement of the Dissolved Oxygen Content of Intragravel Water, Lower Deschutes River, 1961-1966

Year:	1963					1964					1965					1966					Grand
Stream Section:	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total	Total
Number of Measurements, by Month																					
Jan			No measurements			0	33	118	0	151	0	0	0	0	0	9	0	9	0	18	169
Feb			made prior to			0	17	76	11	104	0	3	6	0	9	6	0	0	0	6	119
Mar			April 1963			0	25	48	21	94	0	19	5	4	28	25	13	44	8	90	212
Apr	0	12	34	0	46	0	23	91	38	152	0	19	24	11	54	39	15	51	16	121	373
May	0	28	34	0	62	2	27	92	18	139	0	0	16	6	22	36	15	54	0	105	328
June	0	23	46	15	84	2	21	95	29	147	8	0	25	6	39	44	21	100	32	197	467
July	0	25	88	27	140	1	9	46	19	75	12	0	24	6	42			No measurements			257
Aug	0	22	95	20	137	0	7	72	26	105	5	12	15	0	32			made after			274
Sept	0	21	73	18	112	11	25	83	19	138	6	6	26	6	44			June 1966			294
Oct	0	24	99	31	154	0	0	27	18	45	30	3	17	5	55						254
Nov	0	13	34	12	59	4	5	39	0	48	19	1	12	1	33						140
Dec	0	11	67	12	90	7	5	34	12	58	18	2	16	7	43						191
Total by Stream Section	0	179	570	135	884	27	197	821	211	1256	98	65	186	52	401	159	64	258	56	537	3078

Number of water samples (taken from standpipes in undisturbed gravel) and analyzed for dissolved oxygen content. Measurements were not included if excessive silt was present in standpipe (over 3 inches), if gravel at base of standpipe was not covered by water, if surface water was entering standpipe, or if an included sample had been taken within 24 hours from the same standpipe.

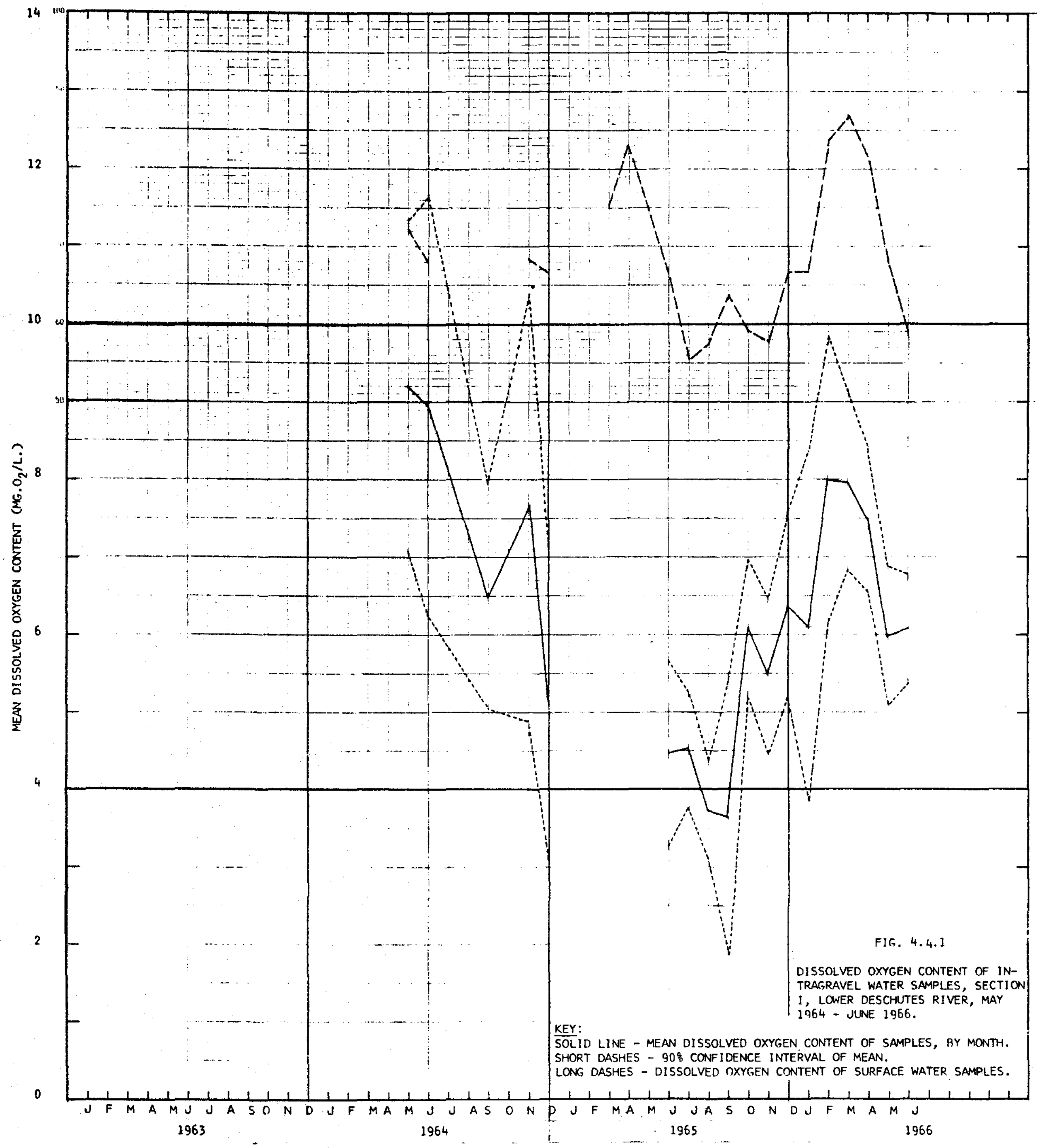


FIG. 4.4.1

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES, SECTION I, LOWER DESCHUTES RIVER, MAY 1964 - JUNE 1966.

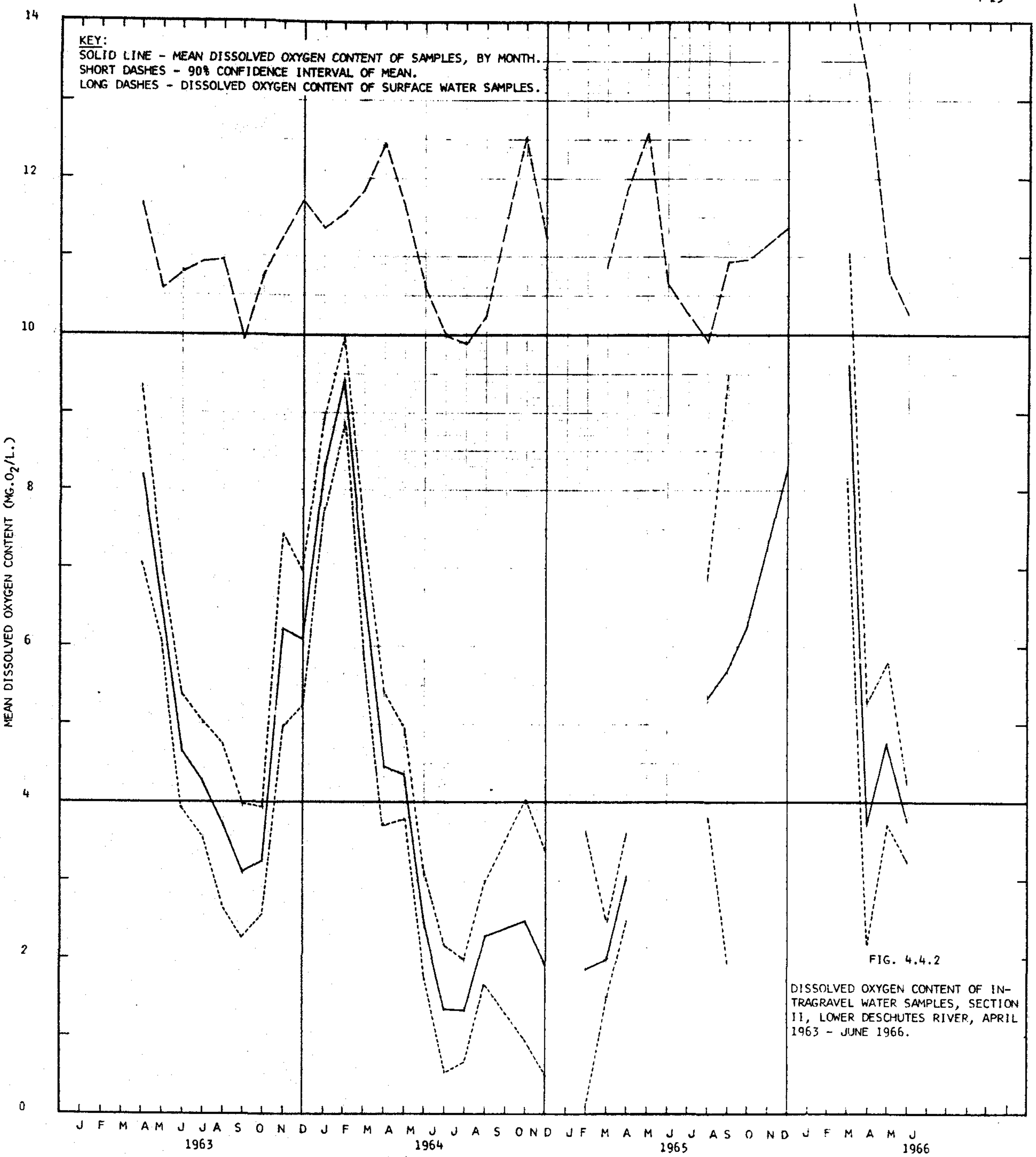


FIG. 4.4.2

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES, SECTION II, LOWER DESCHUTES RIVER, APRIL 1963 - JUNE 1966.

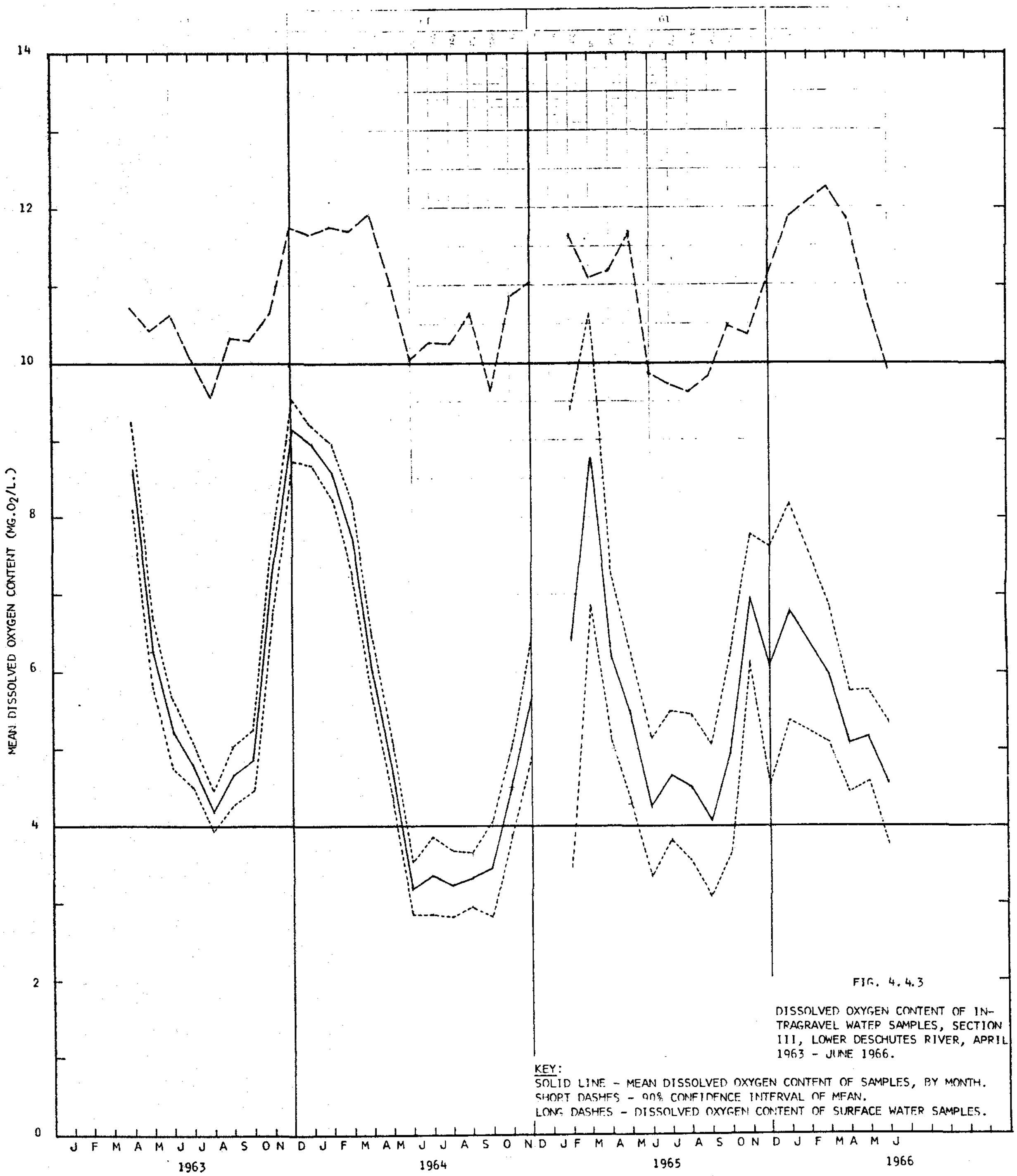


FIG. 4.4.3

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES, SECTION III, LOWER DESCHUTES RIVER, APRIL 1963 - JUNE 1966.

KEY:
SOLID LINE - MEAN DISSOLVED OXYGEN CONTENT OF SAMPLES, BY MONTH.
SHORT DASHES - 90% CONFIDENCE INTERVAL OF MEAN.
LONG DASHES - DISSOLVED OXYGEN CONTENT OF SURFACE WATER SAMPLES.

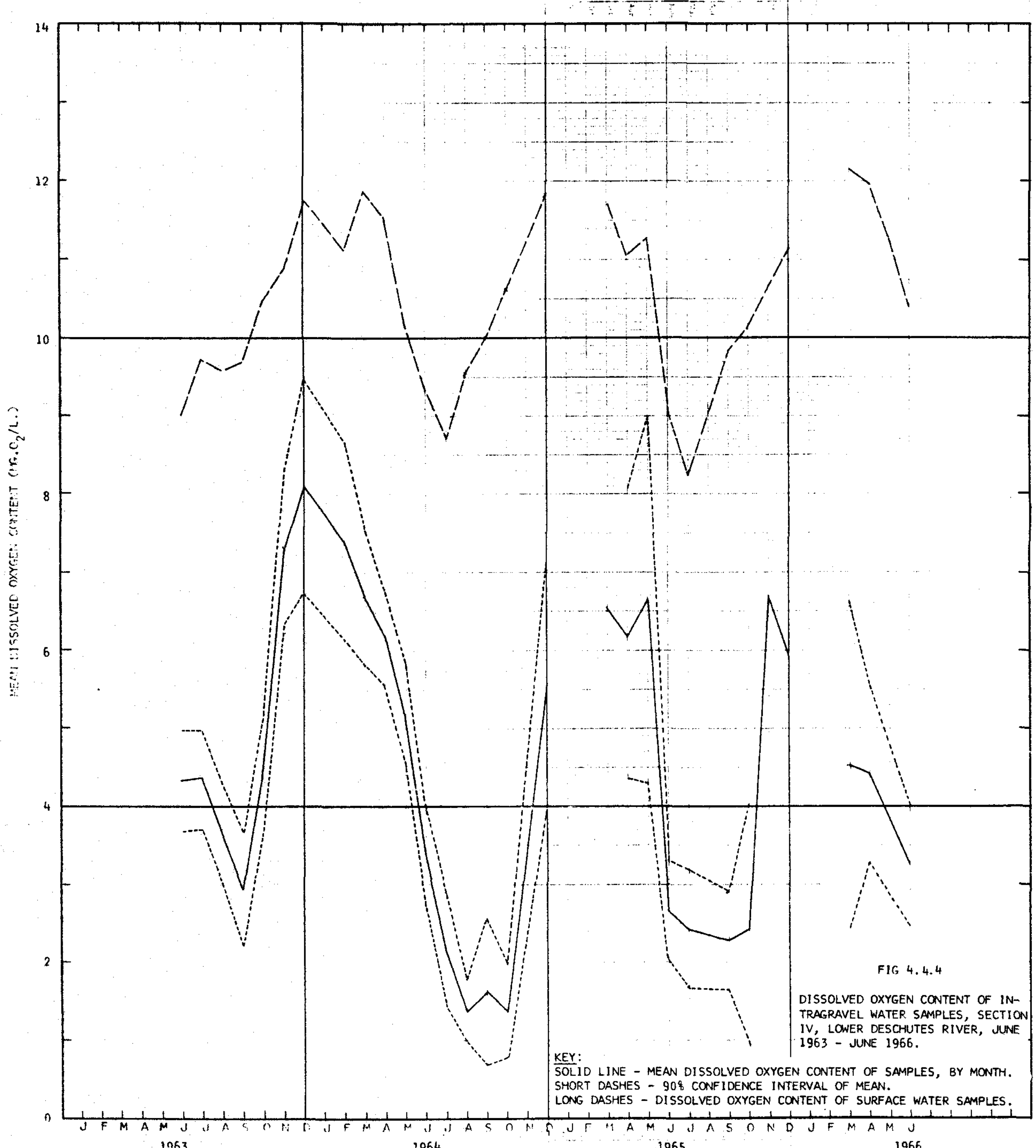


FIG 4.4.4

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES, SECTION IV, LOWER DESCHUTES RIVER, JUNE 1963 - JUNE 1966.

TABLE 4.4.2

Computational Formulas Used in Part Four

1. Mean: $\bar{y} = \frac{\Sigma y}{n}$

2. 90% Confidence Interval of the Mean:

$$\bar{y} \pm t_{.05}\sqrt{\frac{s^2}{n}}$$

3. Variance:

$$s = \sqrt{\frac{\Sigma (y - \bar{y})^2}{n-1}}$$

4. Standard deviation (in linear correlation):

$$s^2 = \frac{\Sigma (y - \bar{y}_x)^2}{n - 2}$$

5. F - ratio (in linear correlation):

$$F = \frac{\Sigma (\bar{y}_x - \bar{y})^2}{s^2}$$

6. Correlation coefficient:

$$r = \frac{\Sigma (x-\bar{x}) \ (y-\bar{y})}{\sqrt{\Sigma (x-\bar{x})^2 \ \Sigma (y-\bar{y})^2}}$$

7. Regression formula:

$$\bar{y}_x = \bar{y} + b \cdot (x-\bar{x})$$

where: $\bar{y}_x$ = estimated mean of y at value x.

$$b = \frac{\Sigma (x-\bar{x}) \ (y-\bar{y})}{\Sigma (x-\bar{x})^2}$$

$\bar{x}$ = mean of x

x = a given value of x

TABLE 4.4.3

Statistical Summary of Intragravel Water Dissolved Oxygen Measurements, by Month and Year, Lower Deschutes River, April 1963 through June 1966

1963

Month	Measurements (n)	Mean mg.O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
April	46	8.51 ± 0.46	1.87
May	62	6.37 ± 0.31	1.47
June	84	4.90 ± 0.34	1.86
July	140	4.62 ± 0.25	1.81
Aug	137	4.03 ± 0.16	1.14
Sept	112	4.09 ± 0.33	2.08
Oct	154	4.50 ± 0.32	2.40
Nov	59	7.04 ± 0.42	1.93
Dec	90	8.61 ± 0.39	2.24

1964

Month	Measurements (n)	Mean mg.O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
Jan	151	8.78 ± 0.24	1.76
Feb	104	8.60 ± 0.31	1.93
Mar	94	7.21 ± 0.38	2.22
April	152	5.84 ± 0.31	2.29
May	139	4.75 ± 0.29	2.10
June	147	3.19 ± 0.28	2.04
July	75	2.78 ± 0.40	2.06
Aug	105	2.63 ± 0.32	1.95
Sept	138	3.15 ± 0.33	2.34
Oct	45	2.61 ± 0.50	2.00
Nov	48	4.55 ± 0.58	2.40
Dec	58	5.26 ± 0.62	2.82

1965

Month	Measurements (n)	Mean mg.O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
Feb	9	4.91 ± 2.29	3.69
March	28	3.84 ± 1.10	3.43
April	54	5.09 ± 0.70	3.06
May	22	5.79 ± 1.00	2.74
June	39	4.05 ± 0.63	2.33
July	42	4.30 ± 0.55	2.12
Aug	32	4.69 ± 0.70	2.34
Sept	44	3.99 ± 0.76	3.00
Oct	55	5.42 ± 0.70	3.12
Nov	33	6.15 ± 0.69	2.34
Dec	43	6.28 ± 0.83	3.23

1966

Month	Measurements (n)	Mean mg.O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
Jan	18	6.44 ± 1.22	2.97
Feb	6	8.00 ± 1.85	2.25
March	90	6.92 ± 0.64	3.66
April	121	5.60 ± 0.50	3.34
May	105	5.40 ± 0.45	2.80
June	197	4.60 ± 0.46	3.94

See Table 4.4.2 for formulas used in computed Confidence Interval of mean ($\bar{y}$ ± 90% Conf. Int.) and Standard Deviation (s).
No measurements could be made during January 1965 because of high water.

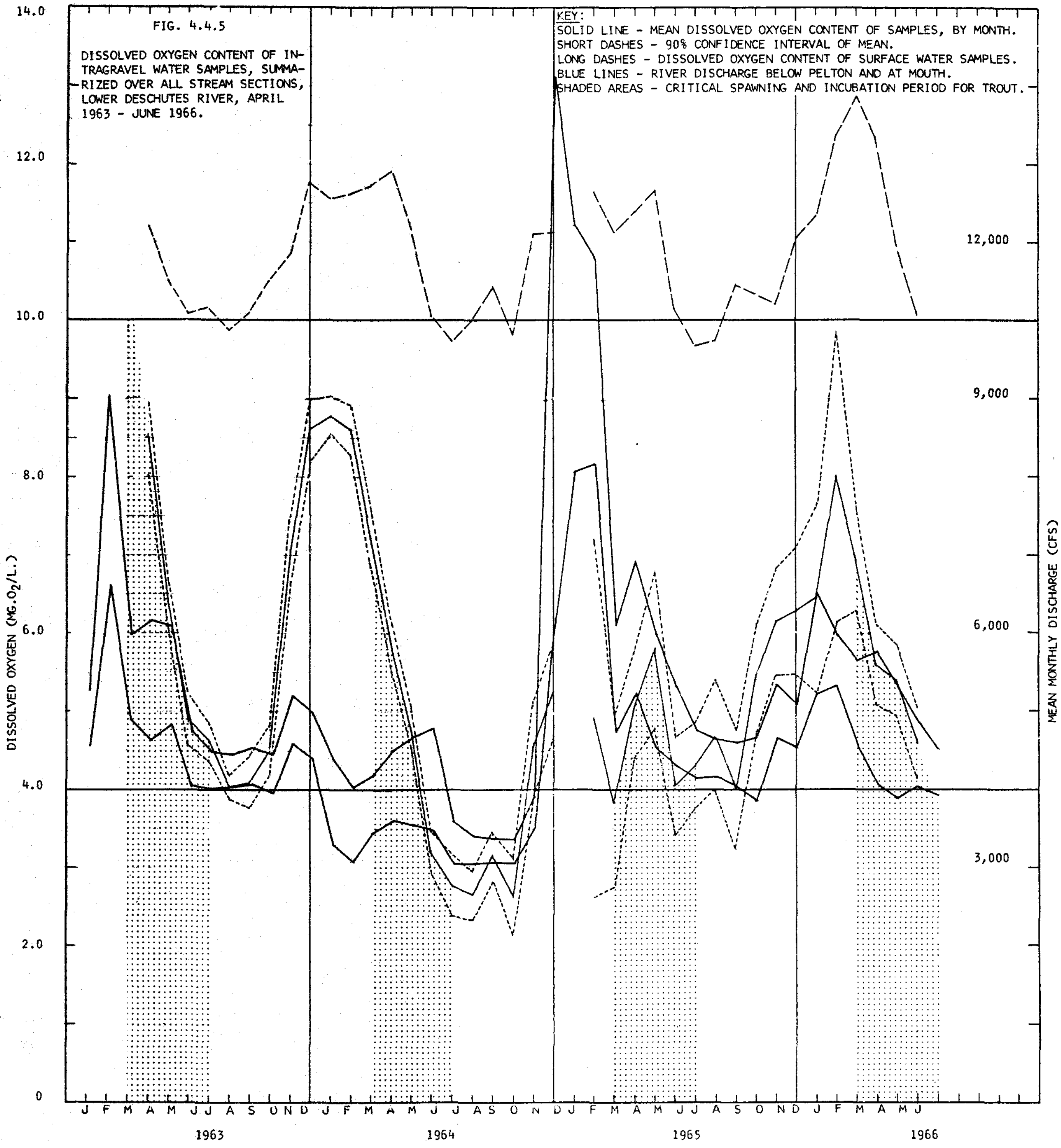
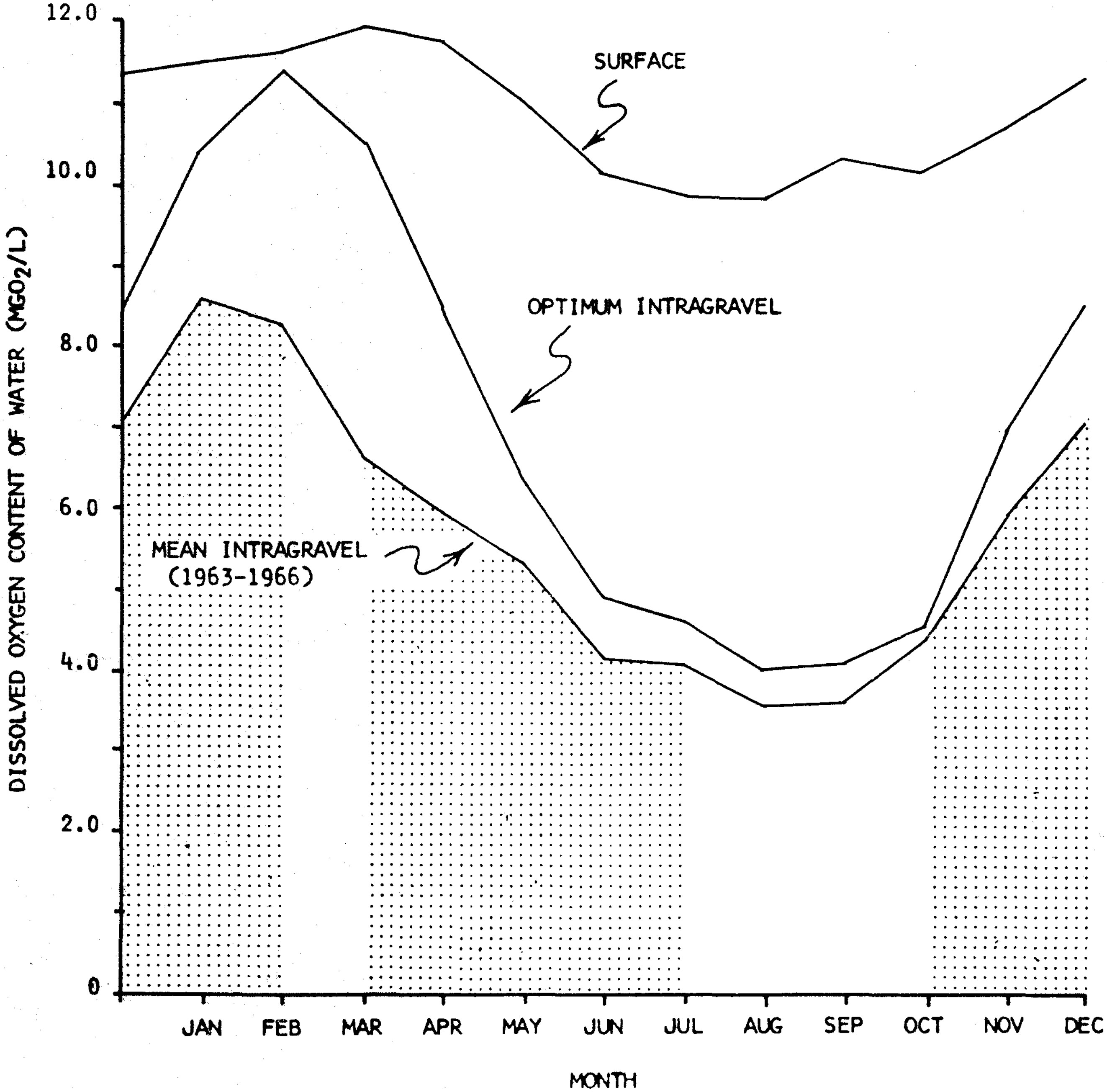


FIG. 4.4.5
DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES, SUMMARIZED OVER ALL STREAM SECTIONS, LOWER DESCHUTES RIVER, APRIL 1963 - JUNE 1966.
KEY:
SOLID LINE - MEAN DISSOLVED OXYGEN CONTENT OF SAMPLES, BY MONTH.
SHORT DASHES - 90% CONFIDENCE INTERVAL OF MEAN.
LONG DASHES - DISSOLVED OXYGEN CONTENT OF SURFACE WATER SAMPLES.
BLUE LINES - RIVER DISCHARGE BELOW PELTON AND AT MOUTH.
SHADED AREAS - CRITICAL SPAWNING AND INCUBATION PERIOD FOR TROUT.
DISSOLVED OXYGEN (MG.O_2/L.)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
MEAN MONTHLY DISCHARGE (CFS)
12,000
9,000
6,000
3,000
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1963
1964
1965
1966

FIG. 4.4.6

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL AND SURFACE WATERS, BY MONTH, LOWER DESCHUTES RIVER



Monthly means of all surface water and intragravel water sample measurements of dissolved oxygen ($mg.O_2/l.$), in undisturbed gravels, April 1963 through June 1966. See Tables 4.5.4 and 4.5.5.

Optimum intragravel water dissolved oxygen mean construction based on 1963 sampling.

Shaded areas include periods of spawning and incubation (trout - spring; salmon - fall and winter).

TABLE 4.4.4

Dissolved Oxygen Content of Intragravel Water Samples, by Month
Summarized over All Years of Study,
Lower Deschutes River

Month	Measurements (n)	Mean mg O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
January	169	8.54 ± 0.26	2.04
February	119	8.29 ± 0.35	2.31
March	212	6.64 ± 0.37	3.25
April	373	5.98 ± 0.25	2.90
May	328	5.33 ± 0.22	2.37
June	467	4.16 ± 0.23	3.06
July	257	4.03 ± 0.22	2.09
August	274	3.57 ± 0.18	1.82
September	294	3.63 ± 0.23	2.39
October	254	4.37 ± 0.27	2.65
November	140	5.98 ± 0.34	2.44
December	191	7.07 ± 0.36	3.05
Overall	3078	5.24 ± 0.09	3.01

See Table 4.4.2 for formulas used in computing Confidence Interval of the mean ($\bar{y}$ ± 90% Conf. Int.) and Standard Deviation (s).

TABLE 4.4.5

Dissolved Oxygen Content of Surface Water Samples, by Month Summarized Over All Years of Study, Lower Deschutes River

Month	Measurements (n)	Mean mg O_2/l. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation (s)
January	15	11.50 ± 0.27	0.598
February	12	11.65 ± 0.31	0.596
March	36	11.97 ± 0.37	1.301
April	50	11.80 ± 0.19	0.797
May	62	11.08 ± 0.16	0.738
June	83	10.12 ± 0.16	0.859
July	55	9.88 ± 0.20	0.878
August	38	9.87 ± 0.24	0.876
September	41	10.34 ± 0.19	0.708
October	47	10.20 ± 0.17	0.686
November	21	10.78 ± 0.25	0.666
December	28	11.36 ± 0.16	0.511
Overall	488	10.71 ± 0.08	1.103

See Table 4.4.2 for formulas used in computing Confidence Interval of mean ($\bar{y}$ ± 90% Conf. Int.) and Standard Deviation (s).

TABLE 4.4.6

Summary of Linear Correlations of Intragravel Dissolved Oxygen With Redd Age for Trout and Salmon, Lower Deschutes River

Section	Year	Trout Redds n	Trout Redds r	Trout Redds F	Salmon Redds n	Salmon Redds r	Salmon Redds F
I	1964	8	-0.73	6.89	0		
	1965	0			22	-0.67	15.92
	1966	16	-0.65	10.36	0		
	Total	24	-0.59	12.00			
II	1963	39	-0.38	6.26	0		
	1964	4	-0.45	0.50	0		
	1965	0			4	0.04	0.00
	1966	20	-0.19	0.68	0		
	Total	63	-0.32	6.84			
III	1963	72	-0.61	41.67	4	0.20	0.08
	1965	0			8	0.44	1.40
	1966	16	-0.17	0.41	0		
	Total	88	-0.56	38.41	12	-0.04	0.01
IV	1963	1			40	0.22	1.97
	1965	0			3	-0.16	0.03
	Total	.			43	0.20	1.79
Total	1963	112	-0.53	43.41	44	0.24	2.56
	1964	12	-0.55	4.37	0		
	1965	0			37	-0.48	10.48
	1966	52	-0.32	5.64	0		
Grand Total		176	-0.44	42.11	81	-0.10	0.77

Underlined F-ratios are significant at the 10% level using the test for a correlation described in Table 4.4.2.

Formula for correlation coefficient (r) also given in Table 4.4.2.

TABLE 4.4.7

Estimated Mean Intragravel Water Dissolved Oxygen Content at Various Redd Ages, Based on Linear Correlation, Lower Deschutes River

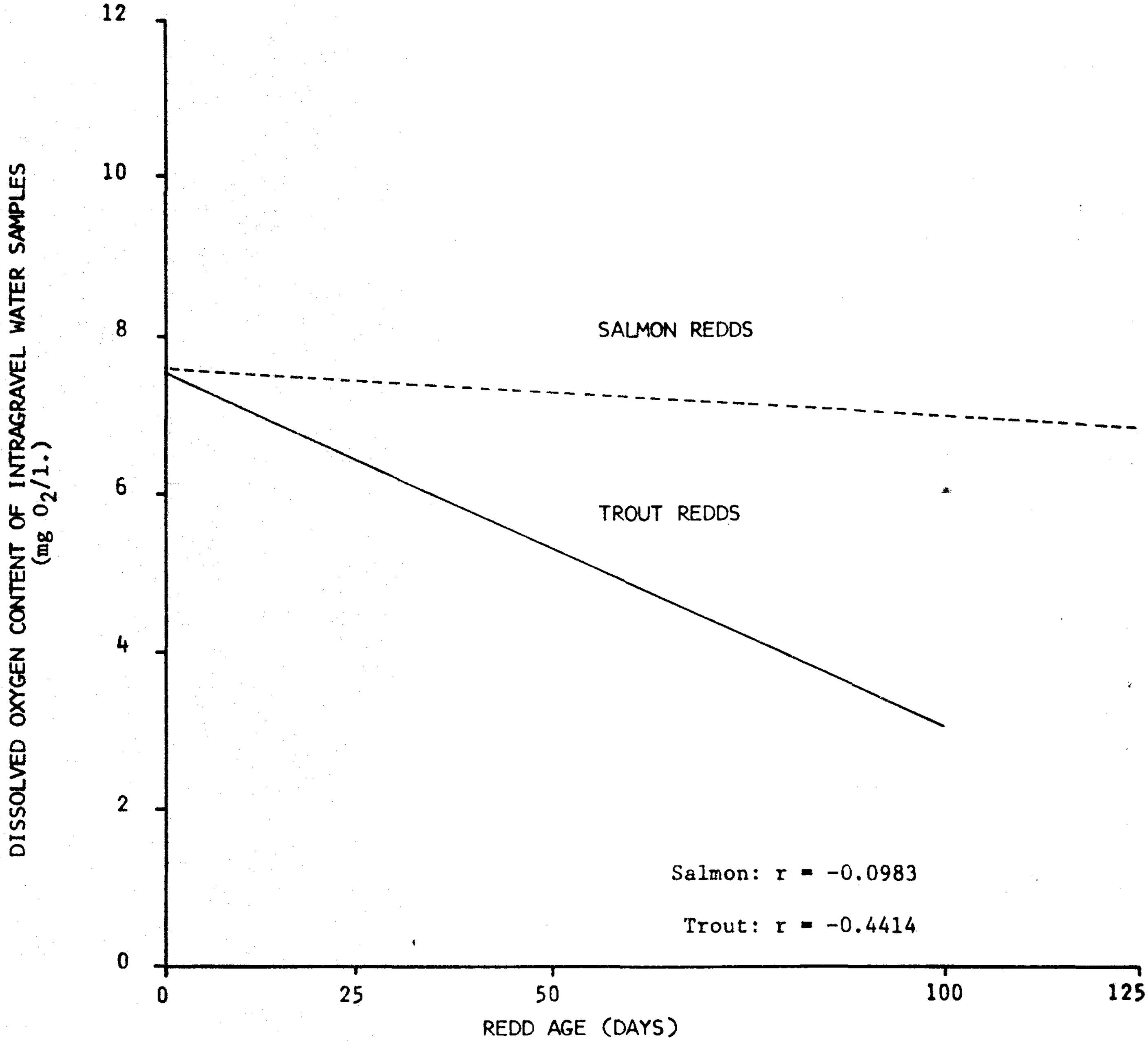
		Redd Age in Days					
		Trout			Salmon		
Section	Year	0	25	100	0	50	125
I	1964	9.0	8.2	5.9	-	-	-
	1965	-	-	-	9.4	6.7	2.7
	1966	10.3	8.0	0.7	-	-	-
	Overall	9.7	8.0	2.7	-	-	-
II	1963	7.1	6.2	3.8	-	-	-
	1964	(7.3)	(5.8)	(1.4)	-	-	-
	1965	-	-	-	(5.0)	(5.9)	(6.1)
	1966	(6.3)	(5.6)	(3.5)	-	-	-
	Overall	6.9	6.0	3.4	-	-	-
III	1963	7.8	6.6	3.0	(7.6)	(7.9)	-
	1965	-	-	-	(4.8)	(6.8)	(9.8)
	1966	(6.2)	(5.6)	(3.6)			
	Overall	7.7	5.2	2.8	(6.7)	(6.6)	(6.3)
IV	1963	-	-	-	(7.6)	(7.9)	(8.4)
	1965	-	-	-	(7.0)	(5.5)	(3.2)
	Overall	-	-	-	(7.4)	(7.7)	(8.3)
	1963 Overall	7.5	6.4	3.2	(7.5)	(7.9)	(8.4)
	1964 Overall	8.8	7.4	3.3	-	-	-
	1965 Overall	-	-	-	8.5	6.1	2.7
	1966 Overall	7.6	6.3	2.6	-	-	-
	Entire Study	7.5	6.4	3.1	(7.6)	(7.3)	(6.9)

Estimates are enclosed in parenthesis if the correlation was not significant at the 10% level (see Tables 4.4.2 and 4.4.6)

For trout redds analysis of covariance was not able to show any differences in the rate of dissolved oxygen reduction over time between the years 1963, 1964 and 1966 (F-test of homogeneity of regression coefficients, 10% level of significance).

FIG. 4.4.7

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES FROM NATURAL TROUT AND SALMON REDDS CORRELATED WITH REDD AGE IN DAYS, LOWER DESCHUTES RIVER, 1963-1966



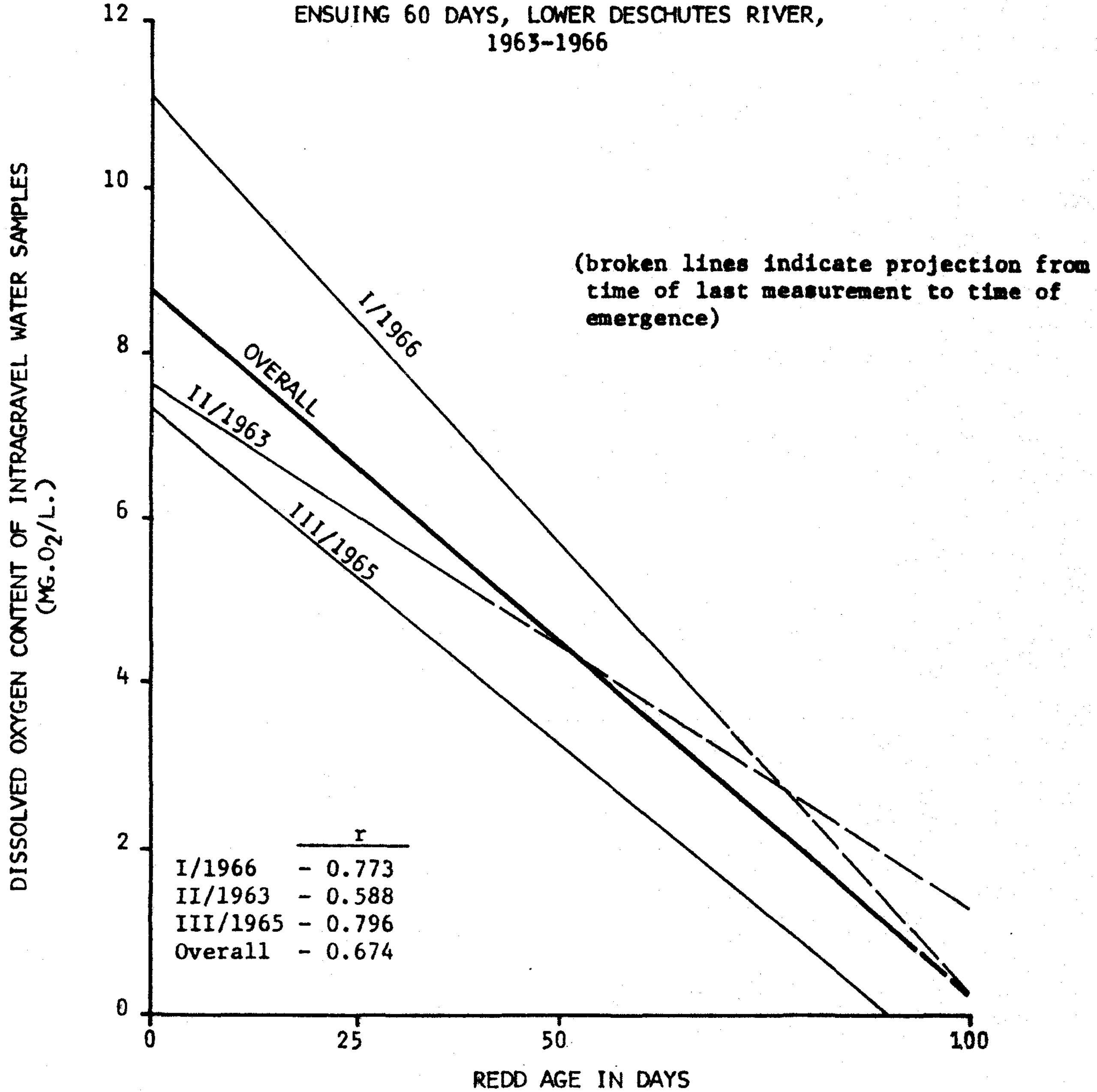
$$\bar{y}_x = \bar{y} + b\,(x - \bar{x})$$

	$\bar{y}$	b	$\bar{x}$	n
Salmon	7.3785	-0.0057	41.9629	81
Trout	6.1638	-0.0444	31.0511	176

Salmon regression line not significant, trout line significant at the 10% level.

FIG. 4.4.8

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES FROM NATURAL TROUT REDDS CORRELATED WITH REDD AGE IN DAYS, WHERE SPAWNING OCCURRED DURING PEAK DISCHARGES AT LEAST 500 CFS ABOVE THE MEAN FOR THE ENSUING 60 DAYS, LOWER DESCHUTES RIVER, 1963-1966



$$\bar{y}_x = \bar{y} + b\ (x-\bar{x})$$

	$\bar{y}$	b	$\bar{x}$	No. of redds	No. of observations
Stream Section I (1966)	7.70	-0.108	31.27	4	15
" " II (1963)	6.13	-0.074	19.78	5	18
" " III (1965)	3.45	-0.080	47.62	1	8
Overall	6.18	-0.086	29.41	10	41

See Table 4.4.8

TABLE 4.4.8

Linear Correlations of Intragravel Water Dissolved Oxygen Content With Ages of Natural Redds Constructed During Discharge Peaks, Lower Deschutes River

Stream Section	I	II	III	Overall
Date standpipes placed	4/14/66	5/7/63	5/5/65	-
Discharge when standpipes placed	4675 cfs	5200 cfs	6500 cfs	-
Number of redds	4	5	1	-
Number of measurements	15	18	8	41
Redd age in days (x) correlated with mg O_2/l. (y):				
Correlation coefficient (r)	-0.77	-0.59	-0.80	-0.67
F-ratio	19.30	8.46	10.38	32.54
Estimated mean ($\bar{y}$) at:				
0 days	11.1mg/l.	7.6mg/l.	7.3mg/l.	8.7mg/l.
25 days	8.4	5.8	5.3	6.6
100 days	0.3	0.2	-0.8	0.1
Redd age in days (x) correlated with percent saturation of dissolved oxygen (y):				
Correlation coefficient (r)	-0.73	-0.54	-0.78	-0.68
F-ratio	14.66	6.66	9.33	34.02
Estimated mean ($\bar{y}$) at:				
0 days	97.8%	74.1%	71.8%	82.3%
25 days	75.6	57.7	52.5	62.8
100 days	9.1	7.5	-5.2	4.2
Mean discharges:				
Month of spawning	4055 cfs	5000 cfs	5000 cfs	
Month following spawning	3889	4200	4700	

All F-ratios were significant at the 10% level.

See Table 4.4.2 for formulas used.

TABLE 4.4.9

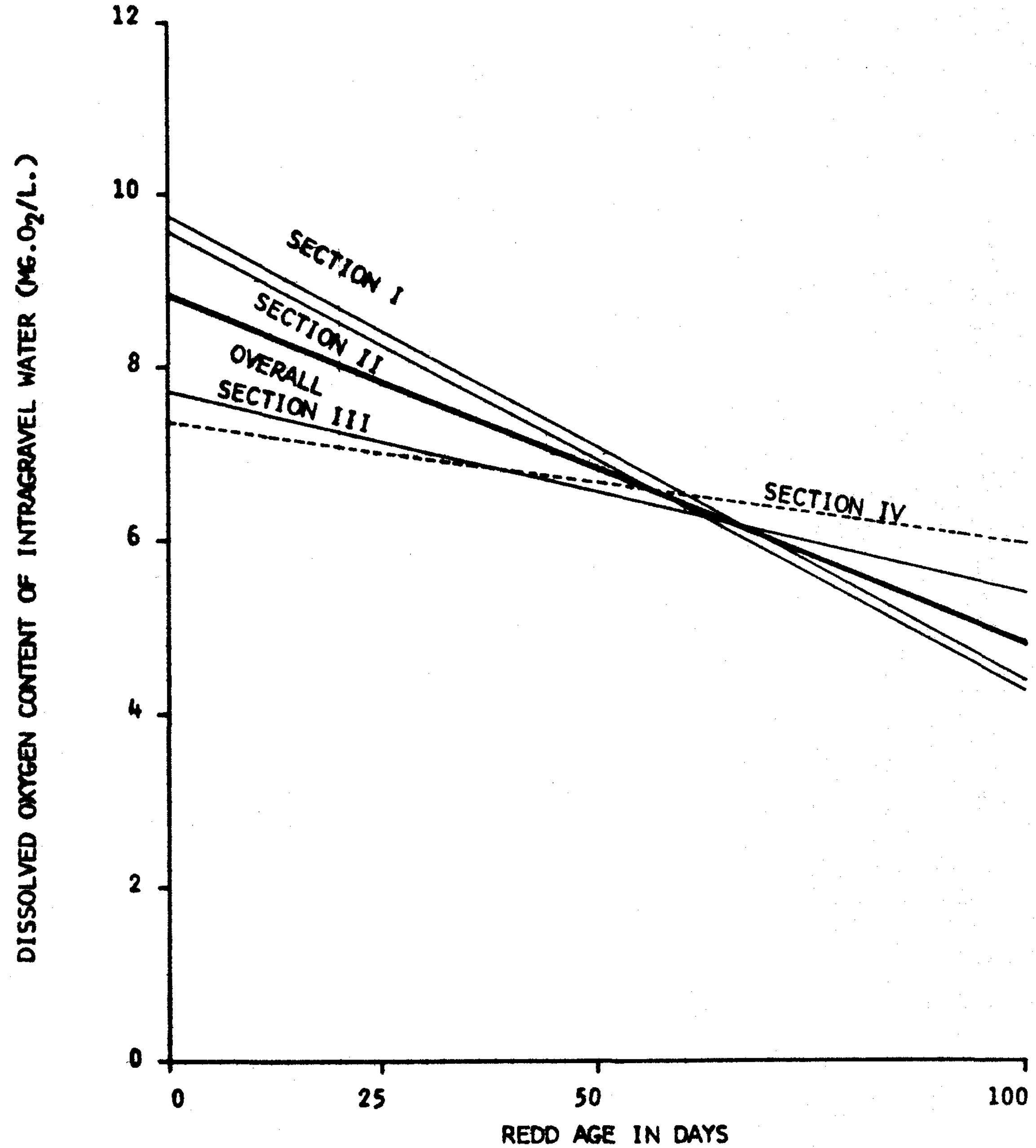
Linear Correlations of Intragravel Dissolved Oxygen With Age of Artificial Redds and Estimated Mean Dissolved Oxygen Content at Various Redd Ages, Lower Deschutes River

	Stream Section				
	I	II	III	IV	Overall
First Series					
Number of observations	62	21	32	12	127
Correlation coefficient	-0.66	-0.77	-0.69	-0.53	-0.66
F-ratio	47.26	27.71	27.73	3.83	96.49
Estimated mean DO_2 at:					
0 days	11.6	10.8	11.4	9.6	11.1
25 days	10.0	9.2	9.6	8.1	9.5
100 days	5.1	4.3	4.4	3.7	4.8
Second Series					
Number of observations	47	39	36	10	132
Correlation coefficient	-0.39	-0.35	0.16	0.47	-0.14
F-ratio	8.05	5.06	0.94	2.32	2.45
Estimated mean DO_2 at:					
0 days	8.0	8.3	(4.9)	(4.7)	(6.6)
25 days	6.7	7.5	(5.4)	(5.3)	(6.3)
100 days	3.1	4.9	(6.7)	(7.1)	(5.2)
Combined					
Number of observations	109	60	68	22	259
Correlation coefficient	-0.45	-0.55	-0.20	-0.18	-0.37
F-ratio	27.63	25.36	2.83	0.64	40.94
Estimated mean DO_2 at:					
0 days	9.8	9.6	7.7	(7.4)	8.9
25 days	8.4	8.3	7.2	(7.0)	7.9
100 days	4.4	4.4	5.5	(6.0)	4.9

Underlined F-ratios are significant at the 10% level using the test for a correlation described in Table 4.4.2. Estimates are enclosed in parenthesis if the correlation was not significant.

FIG. 4.4.9

DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL WATER SAMPLES FROM ARTIFICIAL REDDS CORRELATED WITH REDD AGE IN DAYS, BY STREAM SECTION LOWER DESCHUTES RIVER, 1963-2966



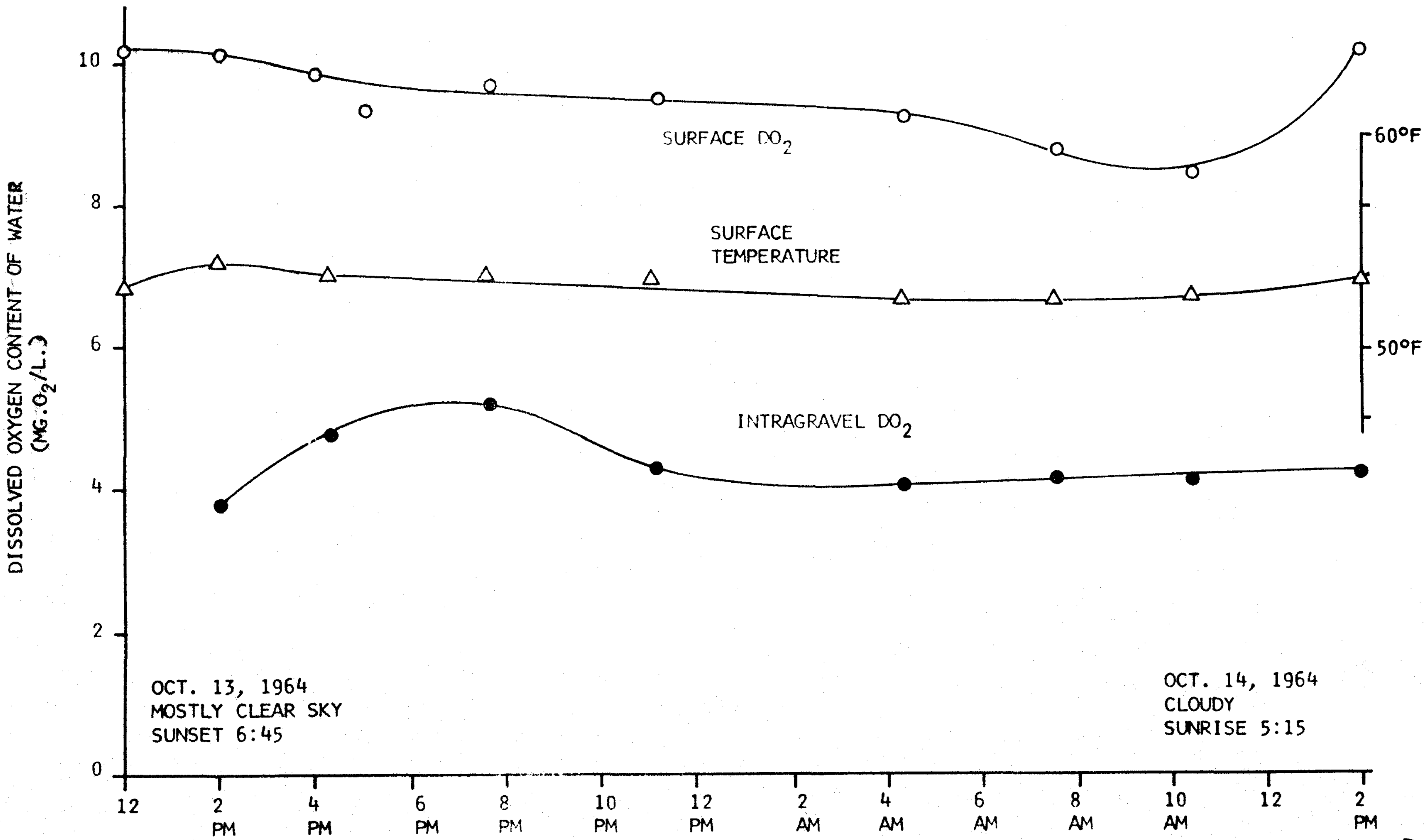
$$\bar{y}_x = \bar{y} + b\,(x - \bar{x})$$

	$\bar{y}$	b	$\bar{x}$	n
Stream Section I	7.2411	-0.0532	47.4678	109
II	7.2266	-0.0524	45.2666	60
III	6.8076	-0.0227	40.2647	68
IV	6.7586	-0.0141	44.1363	22
Overall	7.0837	-0.0397	44.7837	259

All correlations significant (10% level) except Section IV.
See Table 4.5.9

FIG. 4.4.10

24-HOUR FLUCTUATIONS IN DISSOLVED OXYGEN CONTENT OF INTRAGRAVEL AND SURFACE WATER SAMPLES, MEASURED AT STATIONS 58A AND 58B, LOWER DESCHUTES RIVER



CURVES FITTED BY EYE.

4.5 Gravel Permeability

More than 1,200 measurements were made of the permeability of Deschutes River streambed gravels using the Mark VI groundwater standpipe. Usually two measurements were taken for each sample (each location at which the standpipe was driven was considered a sample). Deschutes River gravel permeabilities ranged from 0 to over 35,000 cm/hr with an overall study period average of 1,604 cm/hr. See Table 4.5.1.

Examination of summarized gravel permeability data led us to the following observations:

1. Gravel permeability measurements over all years averaged highest in Section I and lowest in Section IV.

2. Gravel permeability measurements over all sections averaged lowest in 1964.

3. Gravel permeability was significantly lower in 1964 than in 1963 in all river sections measured (Sections II, III and IV).

During the course of the study we also observed that gravel permeabilities in areas used for spawning tended to be over 1,000 cm/hr and that permeability in all gravels decreased steadily from early spring through late summer. In a near-typical discharge year such as 1963, permeability increased quite rapidly in early winter.

In 1965 an additional 306 measurements were made of the rate of water flow into uncalibrated plastic standpipes. These measurements, expressed in milliliters per second (ml/sec), are usable indexes of actual gravel permeability at that sampling location. As in sampling using the Mark VI standpipe, usually two measurements were taken at each sampling location during each visit.

These measurements, summarized in Table 4.5.2 and Fig. 4.5.1, led to the following observations:

1. Gravel permeabilities in artificial redds were high at the outset but decreased rapidly to relatively low plateaus within 40 to 60 days.

2. Gravel permeabilities in artificial redds remained highest at station 501 (Section I) and were lowest at stations 9, 56 and 123 (Sections II, III and IV, respectively).

3. In general, all gravel permeability indexes were initially highest and remained so in Section I.

4. Early in the season gravel permeability indexes in artificial redds were much higher than in undisturbed gravels but by the end of spawning and most incubation (July) both indexes were practically identical, except in Section I.

TABLE 4.5.1

Measurements of Gravel Permeability, By Stream Section and Year, Lower Deschutes River, 1963-1965

(Using Mark VI Permeability Standpipe, Terhune, 1958)

Section	Year	Measurements (n)	Mean cm./hr. ($\bar{y}$ ± 90% Conf. Int.)	Standard Deviation(s)
I	1964	40	1916 ± 551	2068
	1965	76	4090 ± 1374	7179
	Overall	116	3340 ± 926	6011
II	1963	136	1437 ± 560	3262
	1964	46	690 ± 251	1013
	1965	32	956 ± 431	1437
	Overall	214	1204 ± 306	2713
III	1963	359	2322 ± 313	3592
	1964	172	1188 ± 358	2347
	1965	60	996 ± 269	1248
	Overall	591	1857 ± 214	3150
IV	1963	165	810 ± 247	1924
	1964	101	431 ± 86	523
	1965	18	758 ± 537	1308
	Overall	284	672 ± 151	1541
Total	1963	660	1762 ± 208	3245
	1964	359	993 ± 163	1875
	1965	186	2230 ± 596	4929
Grand Total		1205	1604 ± 156	3276

Formulas used are listed in Table 4.4.2

Number of measurements made does not equal number of samples (Table 4.2.2) since two or more measurements were made at each sampling site. Also, in 1965, 150 additional samples were taken using uncalibrated plastic intragravel standpipes. These measurements are summarized in Table 4.5.2.

Each measurement was treated as a separate random observation.

TABLE 4.5.2

Summary of Gravel Permeability Measurements Using Uncalibrated Plastic Standpipes, Lower Deschutes River, 1965

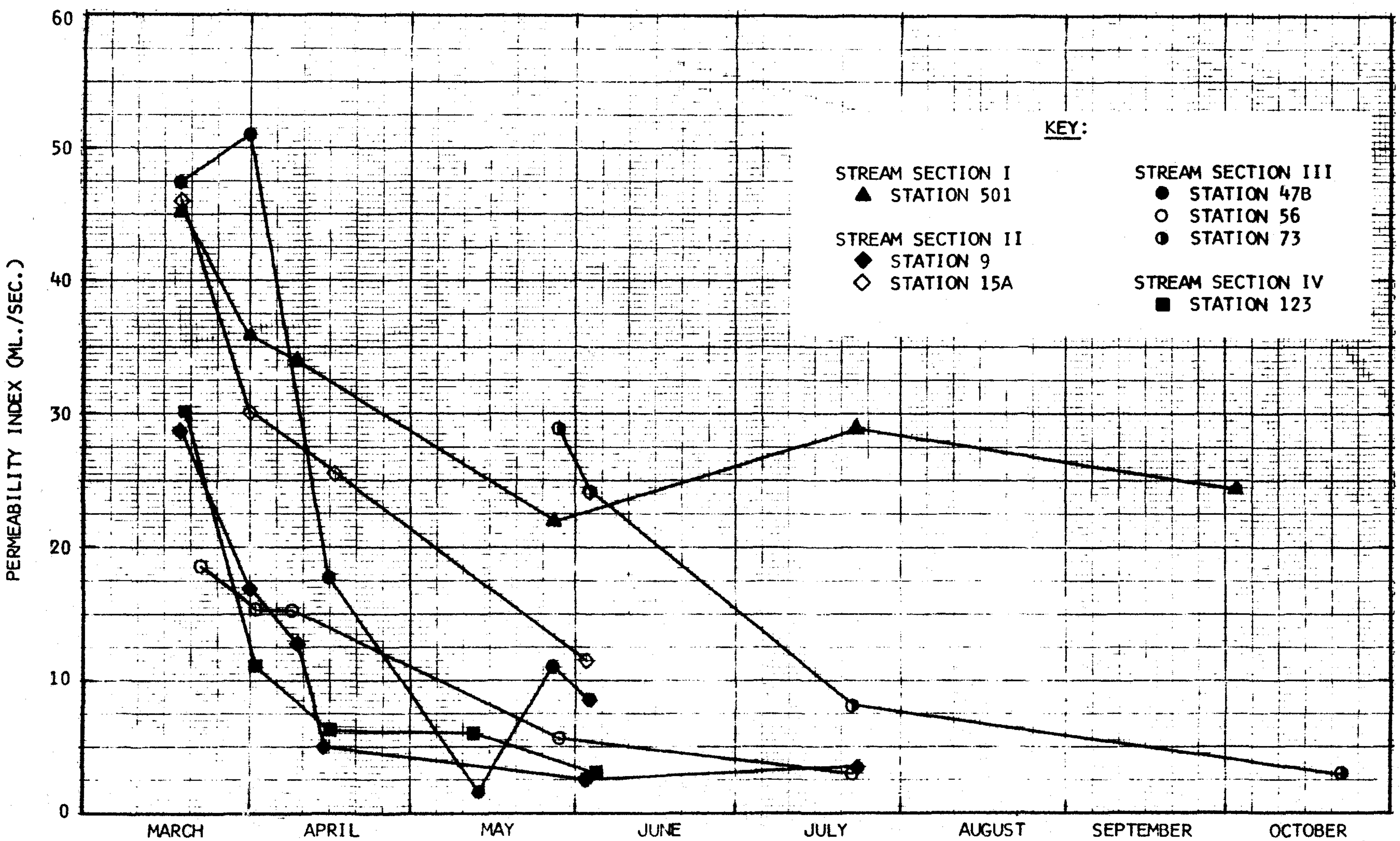
		Artificial Redds 1st Series			Artificial Redds 2nd Series			Natural Chinook Redds			Standpipes in Undisturbed Gravels		
Stream Section	Month	No. of Measurements (n)	Permeability Index, Mean ml./sec. ($\bar{y}$±90% CI)	Standard Deviation (s)	No. of Measurements (n)	Permeability Index, Mean ml./sec. ($\bar{y}$±90% CI)	Standard Deviation (s)	No. of Measurements (n)	Permeability Index, Mean ml./sec. ($\bar{y}$±90% CI)	Standard Deviation (s)	No. of Measurements (n)	Permeability Index, Mean ml./sec. ($\bar{y}$±90% CI)	Standard Deviation (s)
I	Mar.	26	41.0 ± 7.4	22.073									
	Apr.	12	33.8 ± 9.2	17.724									
	May	10	22.0 ± 6.9	11.981	6	28.5 ± 15.3	18.641						
	June	10	28.9 ± 7.8	13.461	6	24.3 ± 7.2	8.733				2	8.0 ± 6.3	1.414
	July	10	28.9 ± 7.8	13.461	10	24.9 ± 7.9	13.617				6	2.7 ± 1.9	2.338
	Oct.	4	19.5 ± 5.6	4.796				8	20.5 ± 11.2	16.673	8	1.2 ± 0.7	1.035
	Overall	62	33.2 ± 4.1	19.168	22	25.7 ± 5.0	13.544	8	20.5 ± 11.2	16.673	16	2.6 ± 1.2	2.705
II	Mar.	18	26.8 ± 3.9	9.534									
	Apr.	10	13.7 ± 4.2	7.304									
	June	4	7.0 ± 6.2	5.228	4	15.5 ± 2.4	2.082						
	July	2	3.0 ± 0	0	8	13.1 ± 4.4	6.600						
	Overall	34	20.1 ± 3.1	10.567	12	13.9 ± 2.9	5.501						
III	Mar.	12	24.4 ± 7.4	14.330									
	Apr.	16	15.5 ± 3.2	7.348							10	2.9 ± 0.8	1.449
	May	8	5.9 ± 3.1	4.643	14	24.6 ± 7.0	14.804						
	June	2	8.5 ± 3.2	0.707	14	17.4 ± 7.2	15.144				8	4.4 ± 1.8	2.669
	July	4	2.8 ± 1.8	1.500	4	8.2 ± 1.1	0.957				8	5.2 ± 3.1	4.621
	Oct.				4	3.0 ± 1.0	0.816				14	2.4 ± 1.7	3.565
	Overall	42	14.7 ± 3.0	11.730	36	17.6 ± 4.2	14.864				40	3.5 ± 0.9	3.343
IV	Mar.	4	30.0 ± 8.3	7.024							8	1.6 ± 0.5	0.744
	Apr.	8	8.6 ± 4.7	7.029									
	May	2	6.0 ± 6.3	1.414									
	June	2	3.0 ± 0	0	4	2.2 ± 0.6	0.500				6	2.0 ± 0	0
	Overall	16	12.9 ± 5.2	11.840	4	2.2 ± 0.6	0.500				14	1.8 ± 0.3	0.579

Formulas for mean and its 90% Confidence Interval ($\bar{y}$ ± 90% CI) and standard deviation (s) are given in Table 4.4.2.

Each measurement was treated as a separate, random observation.

FIG. 4.5.1

CHANGES IN GRAVEL PERMEABILITY OVER TIME, AS MEASURED USING UNCALIBRATED PLASTIC STANDPIPES IN ARTIFICIAL REDDS, LOWER DESCHUTES RIVER, 1965.



4.6 Intragravel Water Temperatures

On any given day, surface water temperatures are highest in late afternoon and lowest in mid-morning. We found that intragravel temperature fluctuations had a smaller range and a definite time-lag when compared to surface temperatures. These differences appeared to depend on such factors as gravel permeability and rate of interchange. Highest intragravel temperatures typically occurred in the evening and lowest temperatures occurred shortly before noon.

During daytime hours when we did most of our sampling, intragravel water temperature deviations from surface water temperature tended to range from 0°F in early morning to as much as 5°F in mid-afternoon. See Table 4.6.1.

TABLE 4.6.1

Comparisons of Surface Water and Intragravel Water Temperatures Recorded in Stream Section IV, 1965, Lower Deschutes River

Month	Time	Surface Water Temperature	Intragravel Water Temperatures			
			Mean	Minimum	Maximum	Mean Difference
March	13:45	44.5°F.	44.73°F.	43.4°F.	49.6°F.	+0.23
April	9:08	49.7	49.85	49.8	50.0	+0.15
	14:30	50.0	49.88	49.7	50.3	-0.12
May	8:25	48.8	49.25	49.2	49.3	+0.45
	10:45	55.8	54.10	53.8	54.3	-1.70
June	13:11	62.1	59.28	58.2	60.6	-2.82
July	9:10	62.0	61.92	61.7	62.2	-0.08
	10:05	64.2	63.52	63.1	63.9	-0.68
Sept.	8:50	57.8	58.65	58.2	59.2	+0.85
	11:08	55.4	55.55	55.1	56.2	+0.15
Oct.	12:05	55.1	55.44	54.9	55.7	+0.34
	13:50	55.9	55.25	55.2	55.3	-0.65
Nov.	12:30	49.9	50.70	50.2	51.2	+0.80
Dec.	13:05	47.2	48.10	47.8	48.4	+0.90
	14:43	47.1	47.15	47.1	47.2	+0.05
	15:00	47.1	47.32	47.1	47.9	+0.22

4.7 Other Intragravel Environment Factors

Intragravel movement of silt particles may be an important factor affecting quality of the intragravel environment in some gravels. All plastic intragravel standpipes were pumped clean of silt and sand when first installed and as required later on. Certain standpipes required pumping out much more frequently than others, suggesting movement of intragravel silt in their vicinity.

Discussion

4.8 Relation Between River Discharge and Intragravel Dissolved Oxygen

We initially attempted to analyze the relationship between river discharge and intragravel dissolved oxygen through linear correlation. Each individual oxygen measurement was correlated with measured or estimated discharge at the time and location of sampling.

We succeeded in obtaining significant correlations in several of our analyses—more than would be expected by chance alone--but their occurrence was inconsistent and unpredictable. Table 4.8.1 lists the analyses of data from standpipes in undisturbed gravel and Table 4.8.2 lists corresponding data from standpipes in redds. At the 90% level used, only one in ten of these correlations would be expected to be significant by chance alone. Since 59 out of 141 (1 out of 2.4) correlations were significant, we concluded that these analyses indicated discharge had some effect on intragravel oxygen.

In our correlations of intragravel dissolved oxygen with redd age (Tables 4.4.6 and 4.4.7) we found that redds constructed during the low discharge year of 1964 exhibited little environmental difference from redds constructed during the high flow years of 1963 and 1965. Therefore, discharge at time of spawning does not seem to be a critical factor unless it is much higher than the season average, since fish apparently select spawning sites that will give developing embryos the best possible intragravel environment at the discharge prevailing during spawning. In 1964 fish were severely restricted in their choice of spawning sites (as was shown in Part Two, Section 2.5) but they still tended to choose sites that would provide approximately the same environmental quality as would have been present in redd sites chosen during a time of higher discharge.

Critical factors then would seem to be those occurring after spawning. The effect of one critical factor, reducing discharge after spawning, was discussed in Section 4.4 and supporting data was summarized in Table 4.4.8.

Therefore, these following factors seem to be most important in determining the dissolved oxygen content of intragravel water:

1. Surface water dissolved oxygen content
2. Rate of interchange between surface and intragravel water
3. Gravel permeability
4. Intragravel biological and chemical oxygen demands
5. Water temperature
6. Stream discharge

Using present methodology and facilities, only stream discharge can be controlled on the Lower Deschutes River.

In Table 4.8.3 we attempt to show the correlation between mean monthly discharges and the means of each month's intragravel dissolved oxygen measurements. Since 1963 and early 1966 showed near-typical stream discharge patterns, a combining of these two years' data produced the regression line shown in Fig. 4.8.1 (solid line).

The dotted lines in Fig. 4.8.1 represent the confidence limits for predicted intragravel dissolved oxygen values at various levels of probability. These can be interpreted as follows:

1. Assuming that the regression line (solid) adequately describes the relationship between stream discharges and intragravel dissolved oxygen in undisturbed gravels; and assuming also that this straight-line relationship can be extrapolated beyond the available data to provide estimates for discharges below 3900 cfs and above 5300 cfs, then

2. At a given point on a particular broken line we would expect at least that particular percentage of the intragravel water oxygen means to fall would above this point (with a confidence of 90%). For example at 4,500 cfs (vertical line A)

a. 99% of the actual mean intragravel oxygen values would be expected to be above 2.4 mgO_2/l,

b. 95% would be expected to be above 3.5 mgO_2/l,

c. 90% would be expected to be above 4.0 mgO_2/l,

d. 75% would be expected to be above 4.9 mgO_2/l,

e. 50% would be expected to be above 6.2 mgO_2/l (6.2 being on the line of regression).

3. At a discharge of 3,500 cfs from the Pelton-Round Butte complex we would expect about 75% of the downstream mean intragravel dissolved oxygen levels to be above 2.1 mgO_2/l, and about 50% would be above 4.0 mgO_2/l.

4. At a discharge of 3,000 cfs, we would expect about 75% of the mean intragravel dissolved oxygen levels to be above 0.3 mgO_2/l and about 50% would be above 2.8 mgO_2/l.

5. If we desired a mean intragravel dissolved oxygen level of 4.0 mgO_2/l, at 3,500 cfs this would occur with a probability of 50%, at 4,500 cfs it would occur with a probability of 90% and at 5,500 cfs it would occur with a probability of better than 95%.

6. If we desired a mean intragravel dissolved oxygen level of 5.0 mgO_2/l, at 4000 cfs this would occur with a probability of 50%, at 5000 cfs this would occur with a probability of 95%, and at 5750 cfs it would occur with a probability of 99%.

7. If the optimum late winter intragravel dissolved oxygen content is near 11 mgO_2/l (see Fig. 4.4.6), then by extrapolation of the line of regression we find that

$$\bar{y}_x = \bar{y} + b(x - \bar{x})$$

$$11 = 5.975 + .0023(x - 4382.4)$$

$$x = 6567 \text{ cfs.}$$

That is, a discharge of about 6600 cfs would be expected to provide mean intragravel dissolved oxygen levels of 11 mgO_2/l (with approximate 90% confidence limits of ± 1.5 mgO_2/l).

TABLE 4.8.1

Frequency Distribution of Correlation Coefficients from Correlations of River Discharge With Intragravel Dissolved Oxygen, Undisturbed Gravels, Lower Deschutes River

Correlation Coefficient (r)	Dissolved Oxygen Measurement Used: $mgO_2/l.$ Significant (f')	$mgO_2/l.$ Total (f)	Percent Saturation Significant (f')	Percent Saturation Total (f)	Grand Total (Σf)
0.81 to 1.00	1	1	1	1	2
0.61 to 0.80	2	2	5	5	7
0.41 to 0.60	9	9	6	6	15
0.21 to 0.40	7	17	5	13	30
0.01 to 0.20	5	22	0	9	31
-0.19 to 0.00	1	15	0	10	25
-0.39 to -0.20	0	3	0	2	5
-0.59 to -0.40	3	3	3	3	6
-0.79 to -0.60	2	2	1	1	3
-0.99 to -0.80	0	0	0	0	0
Totals	30	74	21	50	124

See Table 4.4.2 for formula used in computing the correlation coefficient (r).

Frequency of occurrence of significant correlations listed as f', total number of correlations tested listed as f.

River discharge (x) was correlated with dissolved oxygen measurements (y) from individual standpipes, all the standpipes in a stream section, or all subject standpipes in the entire river over varying periods of time. Sample sizes for individual correlations ranged from 13 to 1,854.

TABLE 4.8.2

Frequency Distribution of Correlation Coefficients from Correlations of River Discharge With Intragravel Dissolved Oxygen, Lower Deschutes River

Correlation Coefficient (r)	Measurements From Redds Significant (f')	Measurements From Redds Total (f)	Measurements From Undisturbed Gravels a/ (f)	Total Significant (Σf')	Grand Total (Σf)
0.81 to 1.00	0	0	2	2	2
0.61 to 0.80	0	0	7	7	7
0.41 to 0.60	0	0	15	15	15
0.21 to 0.40	4	4	30	16	34
0.01 to 0.20	0	8	31	5	39
-0.19 to 0.00	0	1	25	1	26
-0.39 to -0.20	3	3	5	3	8
-0.59 to -0.40	1	1	6	7	7
-0.79 to -0.60	0	0	3	3	3
-0.99 to -0.80	0	0	0	0	0

a/ From Table 4.8.1

Formulas used - See Table 4.4.2

River discharge (x) was correlated with intragravel dissolved oxygen measurements (y) from individual standpipes, all the subject standpipes in entire stream sections, and all subject standpipes in the entire river over varying periods of time. Sample size for individual correlations ranged from 33 to 294 in the case of measurements from redds.

f = total number of correlations tested.

f' = frequency of occurrence of significant correlations (at 10% level).

Table 4.8.3

Linear Correlations of Mean Monthly Discharge at Pelton a/ With Mean Monthly Oxygen Content of Intragravel Water, by Year, Lower Deschutes River, 1963-1966

Year	1963	1964	1965	1966	1963+1966	Overall
No. of months (n)	9 b/	12	11 c/	6 d/	15	38
Regression coefficient (b)	0.0042	0.00296	0.00051	0.0015	0.0023	0.00425
Mean discharge ($\bar{x}$)	4291 cfs	3534 cfs	4778 cfs	4519 cfs	4382 cfs	4245 cfs
Mean oxygen content ($\bar{y}$)	5.85 mg./l.	4.95 mg./l.	4.96 mg./l.	6.16 mg./l.	5.98 mg./l.	5.36 mg./l.
Correlation coefficient (r)	0.758	0.109	0.070	0.832	0.690	0.253
Variance ($\bar{s}^2$)	1.642	5.542	0.841	0.566	1.399	2.808
F-ratio	<u>9.455</u>	0.121	0.044	<u>9.015</u>	<u>11.821</u>	2.457
Estimated mean oxygen content at:						
3000 cfs	0.4 mg/l.	(4.8)mg/l.	(4.9)mg/l.	3.9 mg/l.	2.8 mg/l.	(4.8)mg/l.
3500	2.5	(4.9)	(4.9)	4.6	3.9	(5.0)
4000	4.6	(5.1)	(4.9)	5.4	5.1	(5.3)
4500	6.7	(5.2)	(4.9)	6.1	6.2	(5.5)
5000	8.8	(5.4)	(5.0)	6.9	7.4	(5.7)
6000	13.0	(5.7)	(5.0)	8.4	9.7	(6.1)

a/ As measured by USGS at gage below Pelton Regulating Dam. All dissolved oxygen measurements from standpipes in undisturbed gravel. F-ratios are underlined where the correlations were significant at the 10% level. For formulas used, see Table 4.4.2.

b/ April - December.

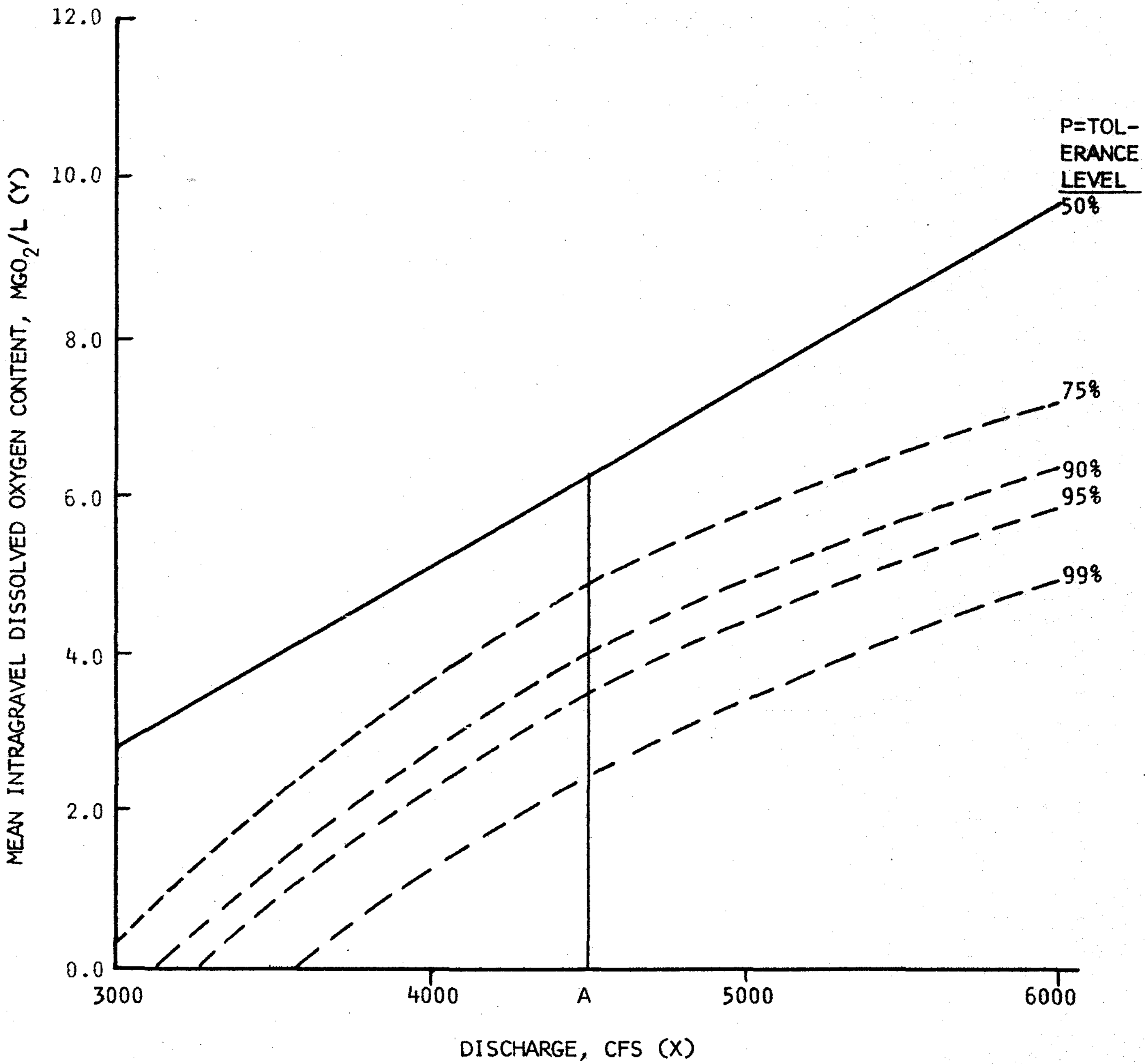
c/ February - December.

d/ January - June.

FIG. 4.8.1

OVERALL CORRELATION AND ONE-SIDED TOLERANCE LIMITS, MEAN MONTHLY INTRAGRAVEL WATER DISSOLVED OXYGEN CONTENT WITH MEAN MONTHLY DISCHARGE, LOWER DESCHUTES RIVER, 1963 AND 1966.

SEE TABLE 4.8.3



Solid line: $\bar{y}_x = \bar{y} + b(x - \bar{x}) = 5.975 + 0.0023(x - 4382.4)$

Broken lines: $L = \bar{y}_x - ks$, where k is obtained from Owen's Tables (1963) for a given tolerance level with a confidence of 90%, and

$s = \sqrt{1.3994}$

4.9 Relationship Between River Discharge and Gravel Permeability

Based on the data described in previous sections, we made the following observations:

1. Consistently high permeability in stream Section I indicates a low silt and sand content in the streambed. The presence of Pelton-Round Butte complex reservoirs tends to maintain this condition by allowing settling of most suspended materials.

2. Low gravel permeability in Section IV indicates a high silt and sand content in the streambed. This is undoubtedly caused by high sediment loads contributed by such tributaries as White River, Buck Hollow Creek, Bakeoven Creek and Trout Creek. White River is probably the chief and most significant contributor since its highest sediment loads usually occur in late summer when Deschutes discharges are lowest and least able to carry this material in suspension and thereby flush it out of the system.

3. High fall and winter flows seemed instrumental in flushing the streambed of accumulated sediments acting to depress gravel permeability. Absence of such flows in the fall of 1963 and the winter and spring of 1964 resulted in 1964 showing abnormally low gravel permeability in all stream sections.

4. Fish purposefully select gravels of higher permeability for spawning.

5. The act of redd construction for spawning increases gravel permeability in redds by rearranging gravel particles and allowing the washing out of most finer materials.

6. An adequate stable discharge, if relatively free of silt, will maintain redd permeability at a higher level longer than sediment-laden, fluctuating inadequate discharges.

LOWER DESCHUTES RIVER, OREGON;

DISCHARGE AND THE FISH ENVIRONMENT

PART FIVE

Conclusions and Recommendations

Table of Contents

Part Five. Conclusions and Recommendations

Results

5.1 Physical Description.

The Deschutes River is characterized by an unusually stable discharge of high quality water. Only in its lower reaches is it subjected to erratic and turbid tributary inflows of relative severity. See sec. 1.1, 1.3 and 1.4.

5.2 Biological Description.

The most highly valued fish species of the lower Deschutes River are steelhead trout, resident rainbow trout, and chinook salmon. The Deschutes River is an unusually high quality rearing ground for these species because of the unique combination of a rich food supply in a basically stable environment. See sec. 1.5 and 1.7.

Since the completion of Pelton Dam, Warm Springs River has assumed primary importance as a tributary vital for anadromous fish spawning. Shitike Creek, Trout Creek, Bakeoven Creek and Buckhollow Creek also contain valuable spawning runs of steelhead and rainbow trout.

5.3 Social, Economic and Recreational Development.

The Deschutes River, historically and currently, is a key factor to the life and economy of central Oregon (see sec. 1.9, 1.10 and 1.11). The lower Deschutes River sports fishery currently provides nearly 100,000 1/ angler-days of recreation each year. There has been a definite upward trend in chinook salmon angling and catch in recent years, while the steelhead and

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1/ 1965-1966 data.

resident trout catches have remained relatively stable in the face of ever-increasing angling pressure.

5.4 Relationship Between Spawning and Discharge.

Reduced discharges in the lower Deschutes River have a deleterious effect on salmon and trout spawning. High quality spawning beds become unavailable to the spawning fish, spawning appears to be thrown off schedule, and fish crowd onto limited and lower quality gravels (see sec. 2.3, 2.4 and 2.5). We therefore recommend that discharges during trout and steelhead spawning (March 15 thru July 15) and during salmon spawning (September 15 thru December 15) be maintained at level adequate to fully cover all normally used spawning beds with water of suitable velocities and depths. Minimum discharges of 4,800 cfs in the spring and 4,500 cfs in the fall would satisfy these requirements (see sec. 3.5 and 3.6).

If discharge is drastically reduced after trout have started spawning the environment of some completed redds will become deficient or fatal. We therefore recommend that every effort be made to keep discharge fluctuations below 600 cfs once spring trout spawning is well underway (see sec. 4.4). This can best be achieved by bringing discharges down to the recommended minimum by April 15 and by making an effort to reduce natural freshets of a magnitude greater than 600 cfs, i.e., if the recommended minimum is 4,800 cfs, discharges should not be allowed to go higher than 5,400 cfs. Any sudden discharge increases that would exceed this recommended range should be limited to as short a duration as possible to minimize redd construction under high water conditions.

Since fall spawning by chinook salmon occurs during a period of naturally increasing river discharge, the problem at this time may not be nearly so acute. Nevertheless, discharge reductions of a magnitude greater than 600 cfs should not occur once spawning has commenced and natural increases should be controlled to minimize the likelihood of subsequent excessive discharge reductions after prolonged periods of high water. This is, if discharges are at 4,500 cfs when salmon spawning starts, these discharges should be maintained well above 3,900 cfs during the duration of the spawning and incubating period; if discharges should subsequently increase to 5,200 cfs (for example) during spawning, discharges should then be kept well above 4,600 cfs for the rest of the spawning and incubation period.

5.5 Relation Between Intragravel Environment, Embryo Survival, and Discharge.

Embryo survival and development are adversely affected by silted gravels, low intragravel water dissolved oxygen levels, and subnormal discharges. In terms of these three factors, the steelhead and rainbow spawning months are the most critical period (see sec. 4.4). Evidence indicates that the initially higher amounts of oxygen available in fresh redds tends to converge downward to the lower concentrations present in adjacent undisturbed gravels as the incubation period progresses (see sec. 4.4 and 4.5). A critical period for embryo survival is at the time of fry emergence when oxygen requirements are highest. At this time the dissolved oxygen content of water from disturbed gravels (in the redd) has frequently degraded to the point that it is practically identical to that from adjacent undisturbed gravels, which in many cases may be inadequate for optimal fry survival and emergence.

Embryos exhibited high survival when minimum intragravel oxygen levels remained above 5.5 mgO_2/l. Low embryo survival rates occurred when minimum intragravel oxygen levels dropped below 4.0 mgO_2/l. (See sec. 2.4.) Based on a significant correlation of mean monthly discharges from Pelton with mean intragravel oxygen levels in undisturbed gravels (see sec. 4.8): A mean intragravel oxygen content of at least 4.0 mgO_2/l would be achieved 90% of the time if the mean monthly discharge were 4,500 cfs at Pelton; and a mean intragravel oxygen content of at least 5.5 mgO_2/l would be achieved 90% of the time if the mean monthly discharge were 5,400 cfs at Pelton.

In regard to these findings, two points need to be made:

1. Any established minimum discharge for the critical spring spawning period will probably be almost the same as the mean discharge during that period. In recent years, releases from the Pelton-Round Butte complex during spring months were frequently near the allowed minimum for extended periods of time; and

2. Maintaining a mean intragravel oxygen content of even 5.5 mgO_2/l would result in a certain portion of the individual values falling below the critical 4.0 mgO_2/l. (visualizing all possible oxygen values as being distributed in a manner similar to a normal or bell-shaped distribution curve). The higher this mean value is, the less likelihood there is that a given individual value will fall below the critical level. But if a mean intragravel oxygen content of only 4.0 mgO_2/l were maintained, by definition we would expect one-half of the individual values to fall below this critical level and only a minor portion would occur above the known safe level of 5.5 mgO_2/l (since the distribution of individual values tends to be non-skewed).

Slightly more than 17% of the individual dissolved oxygen levels recorded from disturbed gravels fell below 4.0 mgO_2/l. 1/ During the 1963 and 1966 spring spawning seasons, 28% of the dissolved oxygen measurements from undisturbed gravel fell below 4.0 mgO_2/l. 2/ Therefore, we assume that low survival due to this range of low oxygen values can be considered as natural attrition.

A mean stream discharge of 4,800 cfs at Pelton will result in a mean intragravel dissolved oxygen content of at least 5.0 mgO_2/l about 85% of the time (see Fig. 4.8.1). When the mean intragravel dissolved oxygen content is exactly 5.0 mgO_2/l, about 35% of the individual values will fall below 4.0 mgO_2/l. 3/

We established above that natural attrition results from 17% to 28% of the individual oxygen values being below 4.0 mgO_2/l under near-normal conditions. Therefore, we would expect a slight decrease in spawning survival exceeding that of natural attrition if the mean intragravel dissolved oxygen content were maintained at 5.0 mgO_2/l.

On the basis of these conclusions, we recommend a minimum discharge release from the Pelton-Round Butte complex of 4,800 cfs during the major trout spawning and incubation period, March 15 thru July 15; a minimum discharge of

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1/ 673 observations, mean = 6.69 mgO_2/l; standard deviation = 2.8571.

2/ 705 observations, mean = 5.63 mgO_2/l; standard deviation = 2.7173.

3/ This conclusion is based upon the following reasoning: If the monthly mean were established at 5.0 mgO_2/l, we are interested in finding out how many of the individual values are more than 1.0 mgO_2/l below this mean, i.e., below 4.0 mgO_2/l. During the execution of this study, 12 different months showed intragravel dissolved oxygen means between 4.5 and 5.5 mgO_2/l. Out of the 1,070 individual measurements made during these 12 months, 375 or 35% were more than 1.0 mgO_2/l below their respective monthly means. Therefore, if in the future individual measurements hold to this sort of distribution, we would expect 35% of them to be below 4.0 mgO_2/l if the mean were established at 5.0 mgO_2/l.

4,500 cfs during the major salmon spawning and incubation period, September 15 thru February 15; and a minimum discharge of 4,200 cfs at all other times.

Periodic high flushing discharges occur naturally in unregulated streams and are instrumental in maintaining a high quality intragravel environment. Discharges of this type occur in the Deschutes within the framework of its basically stable nature, particularly in those downstream reaches where silt accumulation tends to be most acute. Discharge regulation which eliminates or reduces the natural high water extremes will eventually degrade spawning gravels through accumulation of sedimentary material, gravel compaction and spread of rooted aquatic vegetation (see sec. 1.4, 1.8, 2.6, 4.7 and 4.9).

Study of intragravel oxygen data indicated that 6,600 cfs would be expected to provide near-optimum late winter oxygen levels (see sec. 4.8). However, a discharge of this magnitude would be insufficient to flush out accumulated silt and rooted vegetation. Tentatively, we recommend that a discharge of at least 8,500 cfs be released from the Pelton project (or be permitted to occur) each year, preferably at some time between January 15 and March 1 and for a period of at least 36 hours. To be most efficient, this release should coincide with naturally occurring high water in lower river tributaries to enhance the flushing effect in downstream sections; this would also minimize settling of sedimentary materials in these lower reaches. We also recommend that effects of these flushing discharges be closely monitored to determine if they are adequate in preventing long-term trends in habitat degradation.

Flood discharges from tributaries such as Trout Creek, Bakeoven Creek, While River and Buckhollow Creek are always loaded with sedimentary material and it is necessary that mainstem Deschutes discharges be sufficiently high to minimize the settling and accumulation of this material (see sec. 1.3, 1.4 and 4.9). If low mainstem discharges allow this material to settle out over the Deschutes riverbed much higher flushing discharges will be required to counteract degradation of gravel quality, as recommended in the pervious paragraph.

In order to identify trends in habitat quality, we propose to monitor gravel quality at key spawning areas. The results of this monitoring may be used to recommend future modifications in discharge regulation.

Methods

5.6 General

During the conduct of this study we used and evaluated these methods and devices: Drift boat and aerial spawning survey techniques, redd excavation as a method of sampling embryo survival, emergent fry traps, artificial redds, techniques for measuring water depths and velocities at redd sites, gravel bar cross section evaluation techniques, plastic intragravel standpipes, and the Mark VI groundwater standpipe.

5.7 Evaluation of Methods and Equipment.

Drift boat and aerial spawning surveys are both highly efficient methods of covering a stream the size of the Deschutes River (see sec. 2.1). Aerial observation was preferred for surveying chinook salmon spawning, while drift boats were best for steelhead and rainbow trout surveys.

Despite some rather obvious shortcomings, redd excavation with a shovel and net was a quick and convenient way to sample embryos (see sec. 2.2). In our experience, efficiency was relatively poor because of difficulty in digging out all embryos in a redd, the possibility of failing to catch all excavated embryos in the net, and high rates of embryo damage caused by shovelling. Also, we know of no way to estimate the number of fertilized eggs originally placed in a redd.

Emergent fry trapping techniques developed for use on small coastal streams failed in Deschutes River trials (see sec. 2.2. and 2.4). Reasons for failure included higher water velocities, coarser gravels, rapid build-up of algae and sediments on the trap, and deficient trap material (at least in relation to these other reasons).

Artificial redd trials involving the placing of fertilized green eggs into simulated redds also failed to produce useful data for reasons separate from the fact they were used in conjunction with the emergent fry traps (see sec. 2.2 and 2.4).

Methods used for measuring water depths and velocities at natural redd sites were well suited to our requirements, with the exception of their applicability to redds in water beyond wading depths (see sec. 3.1 and 3.3). We found it most efficient to make the measurement at a single location one foot above the upstream edge of the redd. No difficulty was experienced in locating enough fresh redds to measure. However, we had to expend extra effort to locate and measure redds in deeper water to compensate for a natural tendency to concentrate on redds in shallow, easily accessible locations.

Methods used in measuring gravel cross sections were also very suitable for the purposes of this study (see sec. 3.2 and 3.3). It made little practical difference whether water velocities were measured at 0.4 ft. from the bottom or at 6/10 of the water depth from the top.

The plastic intragravel standpipes developed by McNeil are highly efficient and easily used (see sec. 4.1). The Mark VI groundwater standpipe in its original design was not durable enough to withstand Deschutes River gravel bars (see sec. 4.2). A more durable form was made of stainless steel instead of aluminum and proved satisfactory throughout the project. The amount of physical effort expended in sampling with the Mark VI standpipe is considerable and the results are highly variable and difficult to interpret.

Discussion

5.8 Summary of Recommendations

This study's original purpose was to determine discharge minimums for the Deschutes River below Pelton Dam. This we did---the results are outlined in Tables 5.8.1 and 5.8.2: Table 5.8.1 summarizes discharge relationships reported on in the body of this report (Parts One thru Four); Table 5.8.2 summarizes the minimum discharge recommendations described in Part Five.

We emphasize that these minimum discharge recommendations are not based on only one criterion. All criteria used to determine proper discharge recommendations provided the same basic conclusions:

1. Primary criteria
   a. Minimal change in actual spawning gravel usable area (sec. 3.5 and 3.7);
   b. Adequate intragravel dissolved oxygen levels (sec. 4.8);
2. Supplementary and related criteria
   a. Minimal disruption of observed spawning behavior (sec. 2.5);
   b. Optimum embryo survival and condition (sec. 2.6); and
   c. Minimal gravel quality degradation over time (sec. 4.9).

Recommended minimum discharges of 4,800 cfs in the spring, 4,500 cfs in the fall, and 4,200 cfs in the summer and winter are an interpretation of our observations and measurements in terms of the amount of water needed to provide a satisfactory salmon and trout environment in the mainstem of the lower Deschutes River. More water would be beneficial, less water will certainly reduce and degrade the fish environment.

Table 5.8.1
Summary of Discharge Relationships, Lower Deschutes River

Period	Location	Discharge	Effect	Reference
March-June	Pelton	Between 4500 and 5000 cfs	Least change in amount of usable trout spawning area	Sec. 3.5 (Fig. 3.5.2)
July-February	Pelton	Between 4000 and 4500 cfs	Least change in amount of usable salmon spawning area	Same
March-June	Pelton	Between 4500 and 5000 cfs	Least change in estimated trout spawning	Sec. 3.6 (Fig. 3.6.1)
July-February	Pelton	Between 4000 and 4500 cfs	Least change in estimated salmon spawning	Same
During spawning	Section I	In excess of 4200 cfs	Optimum discharge in terms of gravel area available for spawning	Sec. 3.4 and 3.7
During spawning	Section II	5000 cfs	Same	Same
During spawning	Section III	5000 cfs	Same	Same
During spawning	Section IV	In excess of 6000 cfs	Same	Same
During incubation	Pelton	3000 cfs	Expected intragravel oxygen insufficient most of the time	Sec. 4.8 (Fig. 4.8.1)
During incubation	Pelton	3500 cfs	90% expectation that mean intragravel oxygen level will be at least 1.2 mgO_2/l in undisturbed gravels	Same
During incubation	Pelton	4500 cfs	90% expectation that mean intragravel oxygen level will be at least 4.0 mgO_2/l in undisturbed gravels	Same
During incubation	Pelton	5000 cfs	90% expectation that mean intragravel oxygen level will be at least 5.0 mgO_2/l in undisturbed gravels	Same
Late winter	Pelton	6600 cfs	To provide mean intragravel oxygen level of 11 mgO_2/l	Same

Table 5.8.2
Summary of Discharge Recommendations, Lower Deschutes River

Period	Location	Recommended Discharge	Reason	Reference
March 15 thru July 15	Pelton	4800 cfs	To fully cover all normally used spawning beds with water of suitable velocities and depths; and to maintain an intragravel water mean oxygen content of at least 5.0 $mgO_2l/$ about 85% of the time.	Sec. 5.4 & 5.5
September 15 thru February 15	Pelton	4500 cfs	To fully cover all normally used spawning beds with water of suitable velocities and depths; and to provide initially optimum intragravel oxygen levels within salmon redds.	Same
July 16 thru September 14 and February 16 thru March 14	Pelton	4200 cfs	To minimize deterioration of the intragravel environment and to enhance survival of residual trout and salmon incubation.	Same
36 hours during some time between January 15 and March 1	Pelton	8500 cfs	Maintenance of intragravel environment quality by "flushing" out accumulated silt and rooted vegetation.	Same

Appendix I

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Appendix II, Part 1
Summary of U.S.G.S. Discharge Records,
Lower Deschutes River, by Water Year, 1898-1965

	Gage 925 Near Madras				Gage 935 at Mecca			
Water Year	Total a/ Runoff	Maximum b/ Discharge	Minimum c/ Discharge	Mean d/ Discharge	Total a/ Runoff	Maximum b/ Discharge	Minimum c/ Discharge	Mean d/ Discharge
1898								
1899								
1907								
1908								
1909								
1910								
1911								
1912					3,720	8,490	3,300	5,130
1913					3,690	9,410	4,200	5,100
1914					3,650	8,430	3,900	5,040
1915					3,180	7,470	3,470	4,390
1916					3,960	11,700	3,680	5,450
1917					3,770	11,600	4,070	5,200
1918					3,600	9,300	3,740	4,970
1919					3,470	10,300	3,840	4,800
1920					3,230	10,100	3,170	4,460
1921					3,980	9,820	3,850	5,510
1922					3,830	10,600	3,760	5,290
1923					3,490	15,200	3,410	4,820
1924	2,980	7,440	--	4,100	3,040	7,570	3,310	4,190
1925	3,370	10,700	3,350	4,650	3,530	12,200	3,400	4,870
1926	2,920	6,940	3,230	4,030	3,010	7,570	3,200	4,150
1927	3,340	10,500	3,400	4,620				
1928	3,400	8,320	3,540	4,690				
1929	2,900	5,820	3,270	4,010				
1930	2,800	6,190	3,230	3,870				
1931	2,600	6,600	2,990	3,590				
1932	2,840	8,940	3,060	3,900				
1933	2,910	6,400	3,180	4,020				
1934	2,824	7,820	3,260	3,901				
1935	2,988	6,090	3,380	4,127				
1936	3,034	8,280	3,330	4,179				
1937	2,938	9,730	3,290	4,058				
1938	3,461	11,300	3,340	4,761				
1939	2,907	7,770	3,250	4,015				
1940	2,829	8,960	3,110	3,897				
1941	3,690	5,500	3,090	3,716				
1942	2,866	6,680	3,110	3,958				
1943	3,703	1,330	3,100	5,115				
1944	2,942	6,590	3,160	4,052				
1945	2,811	6,050	3,160	3,883				
1946	3,262	12,000	3,270	4,505				
1947	3,048	6,700	3,370	4,210				
1948	3,265	7,820	3,400	4,497				
1949	3,279	8,720	3,580	4,529				
1950	3,346	7,920	3,610	4,621				
1951	3,986	11,300	3,760	5,506				
1952	3,837	12,700	3,910	5,285				
1953	3,667	9,570	3,730	5,065				
1954	3,759	9,430	4,010	5,192				
1955	3,182	5,490	3,760	4,395				
1956	4,089	13,100	3,740	5,632				
1957	3,685	11,000	3,700	5,090				
1958	3,776	13,100	2,440	5,216				
1959	3,317	7,640	3,750	4,581				
1960	3,153	7,430	3,590	4,343				
1961	3,132	10,500	3,300	4,326				
1962	3,294	6,470	3,770	4,550				
1963	3,394	8,030	3,920	4,688				
1964	2,583	5,660	3,040	3,558				
1965	3,617	15,800	3,040	4,995				

a/ Thousands of acre-feet per year.
b/ Momentary maximum, in cubic feet per second (cfs).
c/ Daily minimum, in cfs.
d/ Cfs

Appendix II, Part 2
Summary of U.S.G.S. Discharge Records,
Lower Deschutes River, by Water Year, 1898-1965

Water Year	Gage 1020 at Sherars Bridge: Total a/ Runoff	Maximum b/ Discharge	Minimum c/ Discharge	Mean d/ Discharge	Gage 1030 at Moody: Total a/ Runoff	Maximum b/ Discharge	Minimum c/ Discharge	Mean d/ Discharge
1898					4,870	11,700	--	8,730
1899					5,580	16,000	4,100	7,670
1907					5,700	30,600	5,080	7,870
1908					4,940	22,200	--	8,800
1909					4,670	14,700	--	6,450
1910					5,690	26,900	--	7,860
1911					4,420	10,800	--	6,110
1912					5,100	17,900	4,080	7,020
1913					4,840	15,700	4,780	6,690
1914					4,410	11,200	4,300	6,090
1915					3,600	9,850	3,680	4,980
1916					5,160	27,000	3,920	7,110
1917					4,510	14,500	4,350	6,230
1918					4,200	17,500	4,080	5,800
1919					3,950	13,500	4,100	5,460
1920					3,820	16,900	3,510	5,270
1921					4,800	14,600	4,200	6,630
1922					4,730	22,900	4,200	6,530
1923					4,410	46,600	4,120	6,090
1924					3,560	8,660	3,670	4,900
1925					4,270	19,200	3,820	5,900
1926	3,420	12,300	3,680	4,730	3,410	13,300	3,600	4,710
1927	4,420	32,000	3,860	6,110	4,340	32,400	3,820	6,000
1928	4,290	11,700	3,890	5,910	4,290	11,500	4,040	5,910
1929	3,480	7,060	3,640	4,800	3,450	7,400	3,640	4,770
1930	3,260	8,650	3,530	4,300	3,240	8,550	3,550	4,470
1931	3,070	13,300	3,450	4,240	3,030	15,700	3,380	4,190
1932	3,520	11,200	3,510	4,850	3,520	12,400	3,460	4,850
1933					3,600	10,000	3,660	4,980
1934					3,466	13,300	3,620	4,788
1935					3,590	9,400	3,690	4,958
1936					3,744	11,200	3,760	5,158
1937					3,550	13,300	3,810	4,904
1938					4,507	15,200	3,810	6,225
1939					3,406	9,760	3,690	4,704
1940					3,392	11,500	3,560	4,672
1941					3,111	6,400	3,530	4,296
1942					3,496	13,400	3,560	4,829
1943					5,113	32,900	3,560	7,063
1944					3,409	7,490	3,510	4,696
1945					3,363	8,760	3,600	4,646
1946					4,150	25,400	3,760	5,733
1947					3,802	16,200	3,880	5,252
1948					4,245	19,000	3,930	5,847
1949					4,455	19,000	4,180	6,154
1950					4,424	15,200	4,240	6,111
1951					5,367	19,500	4,410	7,413
1952					4,694	15,000	4,520	6,466
1953					4,666	19,700	4,270	6,446
1954					4,864	15,600	4,550	6,718
1955					3,916	8,380	4,390	5,409
1956					5,580	28,900	4,390	7,686
1957					4,565	14,300	4,600	6,305
1958					4,740	17,900	2,880	6,548
1959					4,026	9,640	4,280	5,561
1960					3,849	9,960	4,080	5,301
1961					4,102	34,700	4,200	5,667
1962					4,080	10,000	4,360	5,636
1963					4,100	18,600	4,380	5,663
1964					3,124	6,860	3,350	4,303
1965					4,869	75,500	3,320	6,725

a/ Thousands of acre-feet per year.
b/ Momentary maximum, in cubic feet per second (cfs).
c/ Daily minimum, in cfs.
d/ Cfs

Appendix III, Part 1
Monthly Discharges During Execution of the
Lower Deschutes Flow Study, Deschutes River
Gage near Madras (River Mile 100.1),
January 1961 through December 1966

Year	Parameter	Month											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Mean	4,318	5,486	5,076	4,350	4,054	4,179	3,979	3,947	3,945	3,980	4,499	4,693
1961	Minimum	3,300	4,450	4,370	4,000	3,970	4,020	3,880	3,880	3,830	3,820	3,770	4,380
	Maximum	4,640	8,800	5,410	5,160	4,200	4,400	4,020	4,070	4,120	4,620	5,300	5,320
	Mean	4,865	5,263	5,267	5,461	4,298	4,153	4,069	4,120	3,992	4,309	4,802	5,530
1962	Minimum	4,350	4,760	4,900	4,240	4,050	3,870	3,870	3,950	3,900	3,970	4,030	5,050
	Maximum	5,180	5,660	5,600	6,100	4,740	4,350	4,220	4,600	4,190	4,740	6,360	5,880
	Mean	4,575	6,626	4,902	4,629	4,840	4,048	4,020	4,039	4,081	3,971	4,598	4,395
1963	Minimum	4,180	5,240	4,360	4,100	4,100	3,940	3,920	4,000	4,000	3,750	3,840	3,600
	Maximum	5,570	7,630	6,620	5,520	5,880	4,150	4,120	4,150	4,360	4,120	5,160	4,860
	Mean	3,305	3,094	3,455	3,613	3,554	3,492	3,059	3,064	3,081	3,085	3,521	6,090
1964	Minimum	3,080	3,060	3,200	3,490	3,510	3,460	3,040	3,040	3,040	3,040	3,100	3,100
	Maximum	4,330	3,140	3,630	3,670	3,630	3,550	3,120	3,100	3,120	3,120	5,600	15,100
	Mean	8,097	8,182	4,744	5,243	4,530	4,307	4,144	4,171	4,047	3,872	4,672	4,645
1965	Minimum	6,260	5,880	3,600	4,180	3,600	3,900	3,840	3,920	3,920	3,540	4,100	3,520
	Maximum	12,300	12,200	6,710	6,800	6,230	5,410	4,590	4,590	4,490	4,450	5,020	6,090
	Mean	5,242	5,323	4,567	4,055	3,889	4,039	3,917	3,715	3,841			
1966	Minimum	3,988	4,200	3,410	3,450	3,720	3,840	3,630	3,500	3,720			
	Maximum	6,460	6,750	6,750	4,780	3,980	4,600	4,150	3,860	3,960			

Appendix III, Part 2
Monthly Discharges During Execution of the Lower Deschutes Flow Study,
Deschutes River Gage at Moody (River Mile 1.4)
January 1961 through December 1966

		Month											
Year	Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Mean	5,373	9,725	7,451	6,160	5,528	5,314	4,635	4,452	4,434	4,546	5,190	5,929
1961	Minimum	4,300	5,600	6,490	5,300	5,340	4,810	4,550	4,390	4,330	4,360	4,390	4,910
	Maximum	6,000	28,400	8,430	7,730	5,810	5,780	4,810	4,550	4,840	4,940	6,560	9,250
	Mean	6,176	6,545	6,599	7,663	5,894	5,238	4,734	4,695	4,513	4,992	5,706	6,711
1962	Minimum	5,250	5,430	5,930	5,970	5,340	4,950	4,560	4,500	4,410	4,590	4,620	6,320
	Maximum	7,950	7,630	7,750	9,550	6,650	5,680	5,010	5,100	4,800	5,770	8,620	7,790
	Mean	5,277	9,052	6,002	6,177	6,099	4,747	4,493	4,451	4,526	4,451	5,224	4,989
1963	Minimum	4,590	5,250	5,400	5,620	5,130	4,620	4,380	4,380	4,410	4,230	4,290	4,530
	Maximum	6,320	16,300	8,300	6,860	7,480	4,980	4,650	4,620	4,890	4,590	6,680	5,370
	Mean	4,378	4,021	4,192	4,512	4,682	4,795	3,597	3,411	3,394	3,385	3,910	13,150
1964	Minimum	3,720	3,810	3,810	4,440	4,440	4,230	3,460	3,350	3,350	3,320	3,380	3,780
	Maximum	5,770	4,560	4,470	4,650	5,190	5,370	4,140	3,520	3,430	3,430	5,740	62,400
	Mean	11,230	10,810	6,121	6,950	6,102	5,330	4,764	4,637	4,514	4,675	5,354	5,195
1965	Minimum	8,050	7,620	4,840	5,350	5,000	4,660	4,510	4,390	4,390	4,330	4,300	4,010
	Maximum	21,800	20,200	8,630	9,310	8,410	6,280	5,150	5,000	5,000	5,150	5,850	6,690
	Mean	6,513	5,980	5,671	5,757	5,311	4,894	4,512	4,135	4,223			
1966	Minimum	4,800	4,920	4,530	4,840	4,920	4,510	4,060	3,920	4,070			
	Maximum	11,300	7,340	7,370	6,850	5,950	5,530	5,020	4,330	4,420			

Appendix IV
Description of Lower Deschutes River Tributaries

Part A. Major Tributaries

ajor Tributaries a/	River Mile	Drainage Area (sq. mi.)	Discharge (cfs) Mean	Minimum	Maximum	Annual Discharge (Ac.ft. per yr.)	Water Temperatures (°F) Range of Monthly Means	Min.	Max.	Primary Sources
Above Study Area										
PPER DESCHUTES R.	120.6	2,705	919	418	4,790	665,300	42-58	38	64	Runoff & lakes
ROOKED R.	113.75	4,330	1,478	920	8,260	1,071,000	49-58	40	63	Runoff & springs
ETOLIUS R.	111.3	347+	1,483	1,080	7,530	1,074,000	41-49	38	55	Springs
Study Area										
ESCHUTES MAINSTEM	100.1	7,820	4,427	2,990**	15,800	3,205,000	46-56	43	59	
HITIKE CR.	96.8	105	107	32	3,000*	77,300				Runoff
	83.8	550+	461	166	14,000*	334,000				Runoff & springs
HITE R.	46.4	370	433	7.5	13,300	313,500	40-61	32	72	Runoff & glacial
ESCHUTES MAINSTEM	1.4	10,500	5,835	3,380**	75,500	4,224,000	42-67	33	74	

* approximate
** before Pelton Dam

PART B. MINOR TRIBUTARIES

inor Tributaries a/	River Mile	Source West Side	East Side	Approximate Drainage Area (sq.mi.)	Approximate Discharge Range (cfs)	Notes on b/ Stream Discharges	Stream Section	Watershed Type c/	Remarks
nnamed draw	99.7		X	1	0 - ?	1,A,B	I	I,R,G	
" "	97.8		X	2	0 - ?	1,A	I	I,R,G	
" "	94.7		X	1	0 - ?	1,A	II	I,R,G	
ry Creek	94.3	X		28	0 - 700	2,B	II	G	
ecca Grade Can.	93.1		X	3	0 - ?	1,A	II	I,R,G	
rog Springs Can.	90.6		X	5	0 - ?	1,A	II	R,I,G	
ROUT CR.	87.2		X	600	0 - 10,000	3,A,B	II	G,I,D,W,R	Some diversion for irrigation
wans Cr.	79.5		X	4	0 - ?	1,B	III	G	
kookum Cr.	78.1	X		10	< 1 - ?	2,B,C	III	G	
ak Cr.	78.0	X		5	0 - ?	1,B	III	G,W	
nnamed draw	75.2	X		1	< 1 - ?	C	III	G,R	
ntoken Cr.	73.0	X		3	0 - ?	2,B	III	G,W,R	
ove Cr.	72.0		X	8	0 - 500	2,B	III	G,R	
wo Springs Can.	69.0		X	6	0 - 400	2,B	III	G,R,D	
AGLE CR.	64.5	X		15	0 - 400	3,B	III	W,G,R	Presence of salmonids unverifi
ENA CR.	57.8	X		40	0 - 1,000	3,B	III	G,W,R,D	Anadromous fish use unverified
evil Can.	57.2		X	5	0 - 300	1,B	III	G,R,D,	
APINITIA CR.	54.7	X		70	0 - 2,000	3,A,B	III	D,I,G,W,R	
hicken Springs Can.	52.9		X	4	0 - ?	1,B	III	G,D,R	
tag Can.	52.5		X	14	0 - ?	2,B	III	G,D,R	
aupin Spr.	52.0	X		0	10 - ?	D	III	Town	Town water supply
AKEOVEN CR.	51.4		X	157	0 - 4,000	3,B	III	G,D,R	
nnamed Spr.	50.8	X		0	5 - ?	D	III	G,I,D,R	
ak Spr.	47.5	X		1	80 - 100	A,D	III	G,I,R	Hatchery water supply
inter Water Can.	44.3	X		7	0 - ?	2,B	IV	G,D	
hicken Springs Can.	43.8	X		3	0 - ?	1,B	IV	G	
UCK HOLLOW CR.	43.0		X	187	0 - 5,000	3,B	IV	G,D,R,I	
lder Cr.	42.3		X	4	0 - ?	2,B	IV	G,R,D	
ak Can.	36.1	X		20	0 - ?	2,B	IV	G,D,R	
ones Can.	34.3		X	18	0 - 1,000	2,B	IV	G,D,R	

Appendix IV (continued)

Minor Tributaries a/	River Mile	Source West Side	Source East Side	Approximate Drainage Area (sq.mi.)	Approximate Discharge Range (cfs)	Notes on b/ Stream Discharges	Stream Section	Watershed Type c/	Remarks
Rattlesnake Can.	30.3		X	3	0 - ?	1,B	IV	G,R,D	
Box Elder Can.	26.9		X	2	0 - ?	1,B	IV	G,R,D	
Ferry Can.	25.7	X		6	0 - ?	1,B	IV	G,R,D	
Craft Can.	24.1	X		4	0 - ?	1,B	IV	G,R,D	
Macks Can.	23.6		X	17	0 - ?	2,B	IV	G,D,R	
Sixteen Can.	22.0		X	6	0 - ?	1,B	IV	G,R,D	
Dry Can.	21.7	X		3	0 - ?	1,B	IV	G,R,D	
Bull Run Can.	18.1	X		6	0 - ?	1,B	IV	G,R,D	
Unnamed Can.	15.6			3	0 - 600	1,B	IV	G,R,D	
Harris Can.	12.2		X	8	0 - 700	2,B	IV	G,D,R	
Fall Can.	10.7	X		4	0 - ?	1,B	IV	G,D,R	
Burr Can.	9.3	X		1	0 - ?	1,B	IV	G,R,D	
Stecker Can.	7.8	X		3	0 - ?	1,B	IV	G,D,R	
Gordon Can.	4.0		X	10	0 - 1,000	2,B	IV	G,D,R	
Ferry Springs Can.	2.0		X	1	0 -?	1,B	IV	G,R.D	

a/ Streams listed in CAPITALS are known to contain resident trout, streams underlined are reported to contain anadromous salmonids.

b/ Notes on Stream Discharge:

1. Dry practically all year except during period of rapid runoff. Maximum discharges may reach several hundred cfs.

2. Usually dry in summer and fall with average winter discharges less than 10 cfs. Maximum discharges during flash floods and rapid runoff can reach several hundred cfs.

3. Summer and fall discharges about 2 to 20 cfs, winter and spring discharges usually about 10 to 40 cfs, with yearly maximums around 500 cfs. although periodic flash floods may reach several thousand cfs.

A. Irrigation waste water drains through this stream in the amount of 1 to 10 cfs. This waste water is heavily loaded with silt, discoloration and agricultural contaminants such as fertilizer and pesticides.

B. Any discharge higher than the seasonal norm will carry heavy silt and turbidity loads.

C. Springs maintain a steady, year round "trickle" sized flow to mouth.

D. Flow predominantly from springs, maintaining a fairly constant level year-round.

c/ Watershed types, listed by stream in order of relative area:

W Coniferous woodland
G Grass and shrub rangelands
D Cultivated - dry land
I Cultivated - irrigated
R Rimrock wasteland

Appendix V
Percentage Distribution of Fish Species Checked from Angler's Creels, Lower Deschutes River, 1961-1965

Species	Percent
Rainbow trout, *Salmo gairdneri* Rich.	75.3
Steelhead trout, *S. g. gairdneri* Rich.	21.3
Chinook salmon, *Oncorhynchus tsawytsche* Walb.	1.6
Mountain whitefish, *Prosopium williamsoni* Girard	0.9
Brown trout, *Salmo trutta* Linnaeus	0.3
Northern squawfish, *Ptychocheilus oregonensis* Rich.	0.2
Dolly Varden, *Salvelinus malma* Walb.	0.1
Coho, *Oncorhynchus kisutch* Walb.	0.1
White sturgeon, *Acipenser transmontanus* Rich.	0.05
Brook trout, *Salvelinus fontinalis* Mitchill	0.04
Suckers, *Catostomus* spp.	0.01

Total number of fish examined: 8,235

Appendix VI
Summary of Lower Deschutes River Creel Census Data, 1952, 1962-1966;
Trout, Steelhead and Salmon Anglers

	1966	1965	1964	1963	1962	1952
Trout Anglers:						
Anglers checked	1959	1640	1541	818	346	2,261
Fish per angler	1.9	1.6	0.9	1.9	1.9	1.5
Hours per fish	1.8	2.2	4.3	2.4	2.2	2.5
Steelhead Anglers:						
Anglers checked	1587 b/	1201	1940	765	1498	1,054
Fish per angler	0.2 b/	0.3 a/	0.2	0.3	0.3	0.4
Hours per fish	20.4 b/	11.4	19.2	15.2	15.7	9.7
Salmon Anglers:						
Anglers checked	437	129	47	124	87	228
Fish per angler	0.3	0.6	0.3	0.1	0.2	0.2
Hours per fish	16.0	6.7	14.9	72.9	37.6	15.4

a/ Does not include 37 chinook caught by steelhead anglers.

b/ A new method of checking was initiated that included some less productive areas as well as a higher percentage of incomplete anglers.

Appendix VII

Summary of Computer Linear Correlation Analyses, Lower Deschutes Flow Study (April 1963 through June 1966)

(See Note 3)

Run No.	Sect. No.	Month	Year	Gravel	Cluster No.	Station No.	N	$\bar{X}$ cfs	$\bar{Y}$ MG/1	$\bar{Y}$ % Sat.	B	R	S^2	F	Sign. at 5%
0-A1A1-1	All	03-07	All	All	All	All	703	4528	6.32		0.0037	0.3603	25.23	104.604	Yes
0-A1A1-1	"	"	1963	"	"	"	507	4657	6.65		0.0040	0.3683	31.59	79.231	Yes
0-A1A1-3	"	"	1964	"	"	"	707	3919	5.48		0.00002	0.0030	9.57	0.006	No
0-A1A1-4	"	"	1965	"	"	"	481	4903	5.81		0.00003	0.0071	11.09	0.024	No
0-A1A1-5	"	"	1966	"	"	"	687	4478	6.14		-0.0002	-0.0511	13.15	1.793	No
0-A1A2-1	"	"	1965	"	"	"	481	4903		54.2	-0.0006	-0.0167	899.40	0.133	No
0-A1A2-2	"	"	1966	"	"	"	687	4478		56.2	-0.0025	-0.0634	1079.58	2.765	No
0-A1A3-1	"	"	1965	AR	"	"	263	4661	7.04		0.0005	0.1134	10.05	3.398	
0-A1A3-2	"	"	"	"	"	"	"	"		65.6	0.0041	0.0998	794.04	2.624	No
1-A1A1	"	"	1963	UND	"	"	425	4638	5.66		0.0020	0.4858	3.58	130.656	Yes
1-A1A2	"	"	1964	"	"	"	633	3930	4.91		0.0002	0.0247	7.07	0.385	No
1-A1A3	"	"	1965	"	"	"	407	4910	5.86		-0.0001	-0.0261	11.00	0.277	No
1-A1A4	"	"	1966	"	"	"	577	4538	5.37		-0.0003	-0.0697	10.16	2.810	No
1-A2A1	"	"	1963	"	"	"	425	4638		56.0	0.0150	0.4019	329.36	81.462	Yes
1-A2A2	"	"	1964	"	"	"	633	3930		45.5	0.0014	0.0256	550.26	0.415	No
1-A2A3	"	"	1965	"	"	"	407	4910		54.4	-0.0018	-0.0482	872.92	0.944	No
1-A2A4	"	"	1966	"	"	"	577	4538		49.2	-0.0040	-0.0936	811.90	5.085	Yes
1-A3A1	"	"	1965	AR	"	"	230	4666	6.97		0.0003	0.0655	10.83	0.982	No
1-A3A2	"	"	"	"	"	"	"	"		64.6	0.0026	0.0576	842.04	0.760	No
2-A1A1	3	All	All	UND	"	58B	601	4351	5.26		0.0007	0.2068	8.14	26.767	Yes
2-A1A2	"	"	"	"	9	"	129	4717	4.24		0.0008	0.3135	7.76	13.844	Yes
2-A1A3	"	"	"	"	"	All	393	4411	4.52		0.0005	0.1401	8.39	7.829	Yes
2-A1A4	All	"	"	"	"	"	764	4346	5.05		0.0002	0.0624	8.25	2.979	No
2-A1A5	"	"	"	"	1,3,5	"	1272	4245	6.01		0.0003	0.0743	8.76	7.045	Yes
2-A1A6	3	"	"	"	"	"	580	4188	6.20		-0.00008	-0.0179	6.70	0.186	No
2-A1A7	All	"	"	"	7,9	"	938	4331	5.18		0.00009	0.0258	8.56	0.624	No
2-A1A8	3	"	"	"	"	"	438	4373	4.79		0.00027	0.0757	8.93	2.511	No
3-A1A1	1	"	"	All	All	All	494	4309	6.64		0.0003	0.0652	9.55	2.101	No
3-A1A2	2	"	"	"	"	"	578	4067	4.94		0.00006	0.0134	9.10	0.103	No
3-A1A3	3	"	"	"	"	"	2040	4228	5.50		0.0005	0.1238	8.09	31.735	Yes
3-A1A4	4	"	"	"	"	"	550	4569	4.73		0.0009	0.2257	8.31	29.407	Yes
3-A2A1	1	All	All	UND	All	All	200	4164	6.21		0.0005	0.1121	9.24	2.519	No
3-A2A2	"	"	"	DIS	"	"	294	4407	6.92		0.000004	0.0008	9.60	0.0002	No
3-A2A3	2	"	"	UND	"	"	481	3991	4.71		-0.0002	-0.0553	8.91	1.471	No
3-A2A4	"	"	"	DIS	"	"	97	4445	6.12		0.0006	0.1320	8.29	1.684	No
3-A2A5	3	"	"	UND	"	"	1854	4173	5.40		0.0004	0.0880	8.10	14.455	Yes
3-A2A6	"	"	"	DIS	"	"	186	4781	6.52		0.0014	0.2588	7.13	13.203	Yes
3-A2A7	4	"	"	UND	"	"	454	4545	4.27		0.0010	0.2746	7.74	36.867	Yes
3-A2A8	"	"	"	DIS	"	"	96	4686	6.89		-0.00097	-0.2613	6.89	6.890	Yes

Appendix VII (Continued)

Run No.	Sect. No.	Month	Year	Gravel	Cluster No.	Station No.	N	$\bar{X}$ cfs	$\bar{Y}$ MG/1	$\bar{Y}$ % Sat.	B	R	S^2	F	Sign. at 5%
3-A3A1	1	03-07	All	UND	All	All	118	4254	6.68		0.0006	0.1185	9.34	1.653	No
3-A3A2	"	"	"	DIS	"	"	190	4354	7.15		0.0004	0.0787	10.33	1.172	No
3-A3A3	2	"	"	UND	"	"	289	4140	4.69		0.0001	0.0286	7.63	0.234	No
3-A3A4	"	"	"	DIS	"	"	86	4466	6.18		0.0006	0.1301	8.07	1.447	No
3-A3A5	3	"	"	UND	"	"	921	4404	5.03		0.0005	0.1256	6.92	14.732	Yes
3-A3A6	"	"	"	DIS	"	"	150	4830	6.41		0.0016	0.3078	7.87	15.485	Yes
3-A3A7	4	"	"	UND	"	"	244	4815	4.42		0.0003	0.0996	6.49	2.427	No
3-A3A8	"	"	"	DIS	"	"	44	4777	6.68		-0.0009	-0.3113	4.76	4.506	Yes
3-A4A1	1	"	"	UND	"	"	118	4254		61.0	0.0033	0.0759	733.68	0.673	No
3-A4A2	"	"	"	DIS	"	"	190	4354		65.6	0.0017	0.0401	827.24	0.302	No
3-A4A3	2	"	"	UND	"	"	289	4140		44.5	0.0011	0.0300	650.34	0.258	No
3-A4A4	"	"	"	DIS	"	"	86	4466		58.6	0.0060	0.1440	650.04	1.779	No
3-A5A1	1	"	"	UND	ODD	ALL	107	4228	6.63		0.0005	0.0992	9.38	1.043	No
(Note 1)	"	"	"	"	"	"	101					0.1144	6.99	1.31	No
3-A5A3	2	"	"	"	"	"	201	4210	4.84		-0.0003	-0.0782	6.58	1.225	No
3-A5A5	3	"	"	"	"	"	456	4397	4.87		-0.0003	-0.0729	6.91	2.424	No
3-A5A7	4	"	"	"	"	"	115	4748	4.52		0.0007	0.2364	5.64	6.690	Yes
3-A6A1	2	"	"	"	7,9	"	117	4205	5.03		-0.0003	-0.0956	4.78	1.061	No
3-A6A2	"	"	"	DIS	"	"	40	4552	6.15		0.0006	0.1966	4.14	1.528	No
(Note 2)	"	"	"	"	"	"	40				0.0006	0.1981			
3-A6A3	2	"	"	UND	1,3,5	"	34	4356	5.96		0.0005	0.0663	12.31	0.141	No
(Note 2)	"	"	"	"	"	"	34	4356	5.96						

Note 1: Incorrect observations removed and recomputation made on desk calculator.
Note 2: Recomputations made on desk calculator.
Note 3: First nine runs made with raw data deck (unsorted for surface water, replicated and other anomalous observations).

Key: Sect. No. = Stream Section Number
Gravel = Condition of gravel at sampling site (Undisturbed, disturbed, or artificial redd)
Cluster No. = (1,3,5,7,9 refer to clusters in areas actually used for spawning; 7,9 referring to clusters in deeper water and 1,3,5 referring to clusters in shallower water less than about 1.5 ft. at normal discharges.

N = Number of observations

$\bar{X}$ = Mean stream discharge in cubic feet per second

$\bar{Y}$ MG/1 = Mean intragravel dissolved oxygen in $MGO_2/1$

$\bar{Y}$ SAT = Mean intragravel dissolved oxygen in percent saturation

B = Slope of line of regression

R = Regression coefficient

S^2 = Variance

F = F-Ratio testing hypothesis that slope of line of regression equals zero.

Sign at 5% - Significant at 5%? Yes if slope of line of regression is signicantly different from zero with 95% probability.

Aney, Warren W., Monty L. Montgomery and Allan B. Lichens. 1967. Lower Deschutes River, Oregon; Discharge and the Fish Environment. Oregon State Game Commission, Portland, Oregon.

ERRATA No. 1, July 11, 1968:

Page 1-10, change TABLE 1.2.2 to TABLE 1.2.1.

Page 1-67, line 24, change 25 1/2 to 25.5.

Page 1-68, line 3, change 22 1/2 to 22.5; line 5, change access if to access is.

Page 2-9, line 14, change usually recovered to usually re-covered.

Page 2-10, opposite March, change 1% to less than 1%.

Page 2-35, line 8, insert a comma (,) after observed and a semi-colon (;) after efforts.

Page 3-2, line 8, change 1.5 - 0.72 to 1.2 - 0.72.

Page 3-4, title, change Upstream Redd and to Upstream and (i.e., delete Redd).

Page 3-14, change titles so they read (for upper photo) FIGURE 3.2.4 MEASURING SPAWNING GRAVEL CROSS SECTION, STATION 504, FEB. 12, 1964 and (for lower photo) FIGURE 3.2.5 MEASURING SPAWNING GRAVEL CROSS SECTION, STATION 10 JAN. 27, 1965.

Page 4-17, line 16, change intragravel water to intragravel water in undisturbed gravels.

Page 4-18, line 7, change oxygen varied to oxygen in undisturbed gravels varied.

Page 4-22, add below Figure (FROM STANDPIPES IN UNDISTURBED GRAVEL).

Page 4-23, same as above.

Page 4-24, same as above.

Page 4-25, same as above.

Page 4-26, formula 2 should read $\bar{y} \pm t_{.05}\sqrt{s^2/n}$

Page 4-27, add below table (Standpipes in Undisturbed Gravel).

Page 4-28, add below Figure (FROM STANDPIPES IN UNDISTURBED GRAVEL)

Page 4-30, add below Table (Standpipes in Undisturbed Gravel).

Page 4-37, under Second Series F-ratio, the values 0.94, 2.32, and 2.45 should not be underlined. Under Third Series F-ratio, the value 0.64 should not be underlined.

Page 4-46, change column heading Time to Standard Time.

Page 4-50, line 4, change verticle to vertical.

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Aney, Warren W., Monty L. Montgomery and Allan B. Lichens, 1967. Lower Deschutes River, Oregon; Discharge and the Fish Environment. Oregon State Game Commission, Portland, Oregon.

ERRATA No. 2, December 24, 1968 (changes underlined):

Page 1-44, 3rd line from bottom, change 1965 to 1966.
1-48, line 12, change species of genera to species or genera.
1-52, last paragraph, capitalize k in kilowatt and kw (4 changes).
1-66, under Data Sources add after 1965 Statewide Angler Survey (unpublished data).
1-68, add after last sentence Some of this frontage which we defined as closed to public access may have some value in its present state if it can provide remote recreation as an unique attraction.
Page 2-9, line 2, change to read ... were found as early 1/ as...
line 12, change two weeks to seven to ten days.
add footnote 1/ In recent years (after 1965) chinook have been reported spawning just below the Regulation Dam prior to September.
Page 2-12, change last line to read (both records in 1965, see also footnote, page 2-9).
Page 2-16, change last sentnece to read This test was not able to show significant differences between the 1964, 1965 and 1966 data.
Page 2-18, line 18, change to ...and sampling methods 1/ may have...
add footnote 1/ In this year only, we marked redd sites at the time of observed spawning. There is a high likelihood that some of these redds were incomplete at the time of marking and the disturbed fish did not return to deposit eggs at the marked redd site.
Page 3-49, in table captions, change July-September to July-February.
Page 3-52, same as above
Page 4-1, line 5, change 1962 to 1962a.
4-49, line 19, delete confidence.
line 20, change intragravel dissolved oxygen....levels of probability to read mean intragravel dissolved oxygen...levels of tolerance.
last sentence change 3900 to 3,900 and 5300 to 5,300.
4-50 replace entire page.
Page 4-51, line 3, change to read with a probability of 90%, and at 6,000 cfs it would occur with a probability of nearly 99%.
line 2, change 4000 to 4,000 and 5000 to 5,000.
line 10, change 6600 to 6,600.
Page 4-54, change lower caption to read
All dissolved oxygen measurements from standpipes in undisturbed gravel. F-ratios are underlined where the correlations were significant at the 10% level. For formulas used, see Table 4.4.2.
a/ As measured by USGS at gage below Pelton Regulation Dam.
b/ April-December.
c/ February-December.
d/ January-June.