Game fish loss in certain irrigation diversions of the West Gallatin River, Montana in relation to the physical characteritics of canal intakes

by John C Spindler

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for a degree of Master of Science in Fish and Wildlife Management
Montana State University

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GAME FISH LOSS IN CERTAIN IRRIGATION DIVERSIONS OF THE WEST GALLATIN RIVER, MONTANA IN RELATION TO THE PHYSICAL CHARACTERISTICS OF CANAL INTAKES

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Approved:

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Head, Major Department

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Chairman, Examining Committee

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Dean, Graduate Division

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ABSTRACT

The relationship between legal game fish loss and various physical characteristics of canal intakes was investigated on twelve irrigation diversions of the West Gallatin River, Montana during the summers of 1951 and 1952. The physical characteristics considered were: headgate location, construction and manipulation; intake velocity, volume, gradient, width, depth and angle with river; location of intake in relation to river flow, amount of water diverted in comparison to the amount retained by the river, diversion dams, bottom types and cover. No correlation was apparent between legal game fish loss and location, construction or manipulation of headgates and the linear regression of fish loss on velocity, gradient, width or depth of intakes did not prove significant by the analysis of variance test. The regression of fish loss on the angle of the intake with the river or the amount of cover at the intake and adjacent river area did not prove significant and bottom types in the intakes and adjacent river areas or the existence of diversion dams at the intake had no observable influence on fish loss. Legal game fish loss was highest in canals with the higher volumes of flow and in those with intakes located on river bends and the highest loss in 1952 was sustained by a canal into which all but a negligible amount of water was diverted from the river.

INTRODUCTION

Numerous efforts have been made in the United States to prevent fish loss in irrigation diversions. One of the earliest attempts was on Caldonia Creek, New York (Leitritz, 1952) in 1865. The most intensive effort has probably been in California (Wales, 1948; Leitritz, 1952) where a large number of ditches have been screened.

A fish screening policy was adopted in Montana in 1893 but was discontinued in 1897 (Clothier, 1953a) and the maintenance of screens was abandoned by the Fish and Game Department in 1942 (Montana Fish and Game Department, 1942). Most of the work has been directed toward the development of fish screens which are known to be effective, but the cost of installation and maintenance has limited their use.

Clothier (1953a) reported a variation in the fish loss between irrigation diversions of the West Gallatin River. He also found much diversity in the physical characteristics of the canals. The present study deals with the relationship between the physical characteristics of canal intakes and fish loss. If a relationship exists, then feasible alterations of existing and proposed diversions might reduce fish losses. The U. S. Fish and Wildlife Service and the Montana Fish and Game Department (1952) in a joint report on the Pishkun Supply Canal, suggested that the design, location and operation of canal headings may have a direct effect on fish loss. The present investigation was conducted June through October, 1951 and 1952.

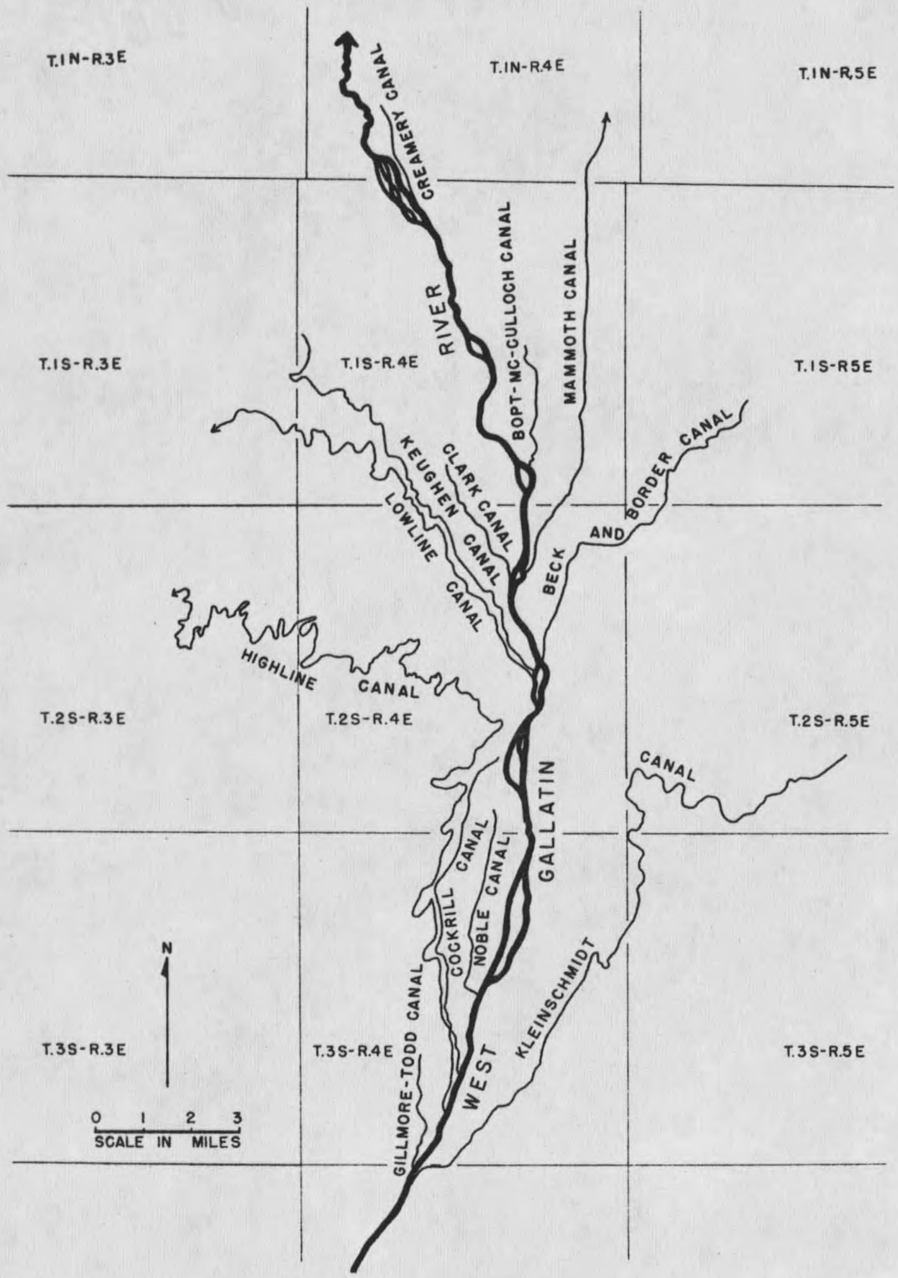

Figure 1. A 20-mile section of the West Gallatin River, showing the 12 canals studied.

Acknowledgements

The writer wishes to express appreciation to Dr. C. J. D. Brown who directed the project and aided in the preparation of the manuscript and to Mr. William Clothier for his assistance in the field. Thanks are also due Mr. Melvin Papke for information on diversion flows and to the ranchers of Gallatin Valley for their cooperation. Dr. Bernard Ostle supervised the statistical analysis of the data. Financial assistance was furnished by the Montana Fish and Game Department under the Federal Aid to Fish Restoration Act (Project number F-3-R).

General Description of the Study Area

A rather complete description of the West Gallatin River and the diversions was given by Clothier (1953a). Of the 52 diversions on the West Gallatin, nine (Figure 1) were selected for study in 1951. These were as follows: Kleinschmidt, Highline, Lowline, Keughen, Beck and Border, Creamery, Clark, Gillmore-Todd and Cockrill. In 1952, the Mammoth, Noble and Bopt-Mc Culloch ditches were included in addition and the Gillmore-Todd was deleted since access was not permitted.

METHODS

Stations were established at comparable locations near the head of each canal intake and velocities, depths, widths and gradients were taken. A detailed map of the intake and adjacent river area was prepared for each of the twelve ditches (see supplement, Figures 2-12). The canal intake is defined as that part of an irrigation diversion from its origin at the river to the first or primary headgate.

Observations were made on primary headgates in relation to the type of materials used in construction and the method of regulating the volume of flow into the diversions.

<u>Velocities</u>, <u>volumes</u> <u>and</u> <u>gradients</u>: Clothier (1953b) reported that the greatest movement of fish into irrigation diversions occurred during the high-water period. Intake velocities were taken July 7-9 (near the end of the high-water period for 1952). A water level station was established in the river near the Keughen canal intake. A variation in level of eight and one-half inches was recorded during the three days required to obtain the velocity readings at all stations.

Water velocity was determined by the float method (Welch, 1948) since high water levels prevented the use of the current meter. A 25-50 foot range was established at each intake and surface floats were timed from the upper to the lower end of the range. Three readings were taken at each station and the average velocity determined. A comparison was made between velocities taken by the float method and by a Leupold and Stevens "Midget Current Meter" when levels permitted. In these comparisons, the float method showed higher velocities in all cases with a percentage difference ranging from 10 at the lower velocities to 23 at the higher; the average was 16.6.

Information on volume of flow was secured from the river commissioner and the decreed rights (cubic feet per second) were used for the study of the relationship between fish loss and volume. Gradients were determined at each canal intake by the use of a hand level.

Widths and depths: In 1952, average widths and depths across the canal intakes were obtained as soon as water levels permitted (July 24-31). The water level fluctuation at the Keughen station during this period was three inches. Three measurements of width were taken at each station and the average determined. Depths were obtained by measuring the distance from the water surface to the canal bottom at each one-foot interval of width and the average determined by totalling the readings and dividing by one more than the number of observations.

Mapping: Plane table maps were completed during the periods June 20-August 21, 1951 and July 23-August 15, 1952 (supplement, Figures 2-12). In 1951, the angle between each intake and the river (Figure 4) was determined. In 1952, each canal intake and the river adjacent to the diversion from 150 feet downstream to 300 feet upstream was mapped in detail and measurements of physical characteristics obtained. The physical characteristics determined were as follows: locations of primary headgates, location of the canal intakes in relation to the direction of river flow, angle between the intake and the river, bottom types, bottom contours, bank cover and location of diversion dams if present.

Fish loss: Clothier (1953a) estimated the legal game fish (total length, seven inches or over) loss in certain diversions of the West Gallatin River for 1951. His figures (Table 1) were used for the study of the relationship between fish loss and the various physical characteristics of the intakes for that year. He found the greatest number of

Table 1. Game fish loss and various physical characteristics of canal intakes for 1951 and 1952.

Name of diversion	Estimated legal game fish loss 1951 No.	Estimated legal game fish loss 1951 Lb.	Estimated game fish loss 1952 Legal No.	Estimated game fish loss 1952 Legal Lb.	Estimated game fish loss 1952 Sub-legal No.	Velocity (ft/sec)	Volume (cfs)	Gradient (ft/mi)	Width (feet)	Depth (feet)	Cover (percent)	Angle of intake 1951	Angle of intake 1952
Kleinschmidt	560[1]	227[1]	11	3.5	11	3.37	151	4.3	20.0	3.6	68	--	0
Highline	61[2]	23[2]	21	11.1	14	4.60	148	19.8	18.8	2.5	33	--	53
Lowline	132	71	8[2]	1.6[2]	28[2]	----	148	----	----	---	--	33	--
Mammoth	---	---	51	22.4	44	3.61	74	15.3	11.3	3.0	2	--	40
Keughen	167	44	13	10.4	34	3.09	70	2.1	25.0	2.1	1	75	60
Beck & Border	368[1]	176[1]	22	10.0	44	2.37	50	5.5	47.5	1.2	9	--	30
Noble	---	---	7	2.5	14	2.55	23	3.2	25.0	1.2	52	--	42
Creamery	44	33	0	0.0	79	1.78	20	----	37.5	1.1	16	46	31
Clark	77	20	19	5.9	34	4.91	16	15.3	11.3	1.2	24	0	0
Gillmore-Todd	22	6	--	----	--	----	15	----	----	---	--	0	--
Bopt-Mc Culloch	---	---	14	3.3	76	2.56	12	3.2	26.0	1.8	0	--	30
Cockrill	16	5	10	3.7	22	2.47	6	1.5	19.0	1.3	36	0	0

[1] Loss influenced by creeks entering canals (Clothier, 1953a).

[2] Sharp reductions in rate of flow before sampling may have influenced loss (Clothier, 1953a).

fish in the first one-half mile of canal. In 1952, 900 feet of each canal immediately downstream from the headgate was sampled by an alternating-current "shocker". This was divided into three sections by the use of blocking nets for convenience in sampling. All fish collected were counted, weighed and measured and the results were used for the 1952 comparisons. Very few fish smaller than three inches were included since the net openings (one-half inch stretch) were too large to retain them. All diversions were sampled during the period July 14 to August 8 except the Highline and the Lowline canals which were sampled August 21 and September 13 respectively.

PHYSICAL CHARACTERISTICS OF CANAL INTAKES AND FISH LOSS

An attempt was made to determine what relationship, if any, existed between fish loss and the various physical characteristics of canal intakes. The headgate characteristics considered were location, construction and manipulation. The intake characteristics were velocity, volume, gradient, width, depth, location in relation to river flow, angle with river, diversion dams, bottom types, cover.

Headgates: The primary headgates of some canals are located directly on the river while in others, they are at varying distances downstream. The legal game fish loss in 1951 averaged 18.8 pounds (70.5 fish) in the Keughen, Clark, Gillmore-Todd and Cockrill diversions which had headgates on the river and 52.0 pounds (88.0 fish) in the Lowline and Creamery canals which had headgates downstream. Other ditches studied were excluded from this comparison since loss was known to be influenced by water manipulations or other causes (Clothier, 1953a). In 1952, the legal loss averaged 7.1 pounds (15.9 fish) in the Kleinschmidt, Highline, Mammoth, Keughen, Noble, Creamery, Bopt-Mc Culloch and Cockrill diversions which have headgates on the river and 8.0 pounds (20.5 fish) in the Beck and Border and Clark canals which have headgates downstream. The sublegal game fish loss averaged 36.8 fish in the former and 39.0 in the latter. The loss in the Lowline ditch was not used in the 1952 comparisons since water manipulations may have influenced it (Clothier, 1953a).

The headgates of some canals are constructed of concrete while others are built of wood. In 1951, the legal game fish loss averaged 34.8 pounds (88.4 fish) in the Lowline, Keughen, Creamery, Clark and Gillmore-Todd diversions which have headgates constructed of concrete and was 5 pounds (16.0 fish) in the Cockrill canal which has a headgate built of wood. In 1952, the legal loss averaged 8.3 pounds (18.9 fish) in the Kleinschmidt, Highline, Mammoth, Keughen, Beck and Border, Creamery, Clark and Bopt-Mc Culloch diversions which have concrete headgates and 3.1 pounds (8.5 fish) in the Noble and Cockrill canals which have wooden headgates. The sublegal game fish loss averaged 42.0 fish in the former group of diversions and 18.0 in the latter.

Water flow into each of the diversions studied is regulated by vertical manipulation of a wooden gate in the headgate opening except for one canal which is regulated by placing planks on end from side to side across the opening. In 1951, the legal game fish loss averaged

34.6 pounds (82.8 fish) in the Lowline, Keughen, Clark, Gillmore-Todd and Cockrill ditches which have vertically manipulated headgates and was 33 pounds (44 fish) in the Creamery canal which has a horizontally manipulated headgate. In 1952, the legal loss averaged 8.1 pounds (18.7 fish) in the Kleinschmidt, Highline, Mammoth, Keughen, Beck and Border, Noble, Clark, Bopt-Mc Culloch and Cockrill diversions which have vertically manipulated headgates while there was no legal loss in the Creamery canal which has a horizontally manipulated headgate. The sub-legal loss averaged 32.6 fish in the former and was 79.0 in the latter.

Velocity, volume and gradient: A comparison was made between fish loss in those diversions having above average and those having below average velocity, volume and gradient at the intake (Table 1). In 1952, the average velocity in all canal intakes was 3.13 feet per second. The legal game fish loss averaged 10.7 pounds (25.5 fish) in the Kleinschmidt, Highline, Mammoth and Clark ditches which had velocities above average and 5.0 pounds (11.0 fish) in the Keughen, Beck and Border, Noble, Creamery, Bopt-Mc Culloch and Cockrill canals which had velocities below average. The sublegal game fish loss averaged 24.8 fish in the former and 44.8 in the latter.

In 1951, the average volume of flow at the headgate was 45.8 cubic feet per second. The legal game fish loss averaged 57.5 pounds (150 fish) in the Lowline and Keughen canals which had above average volumes and 16.0 pounds (39.8 fish) in the Creamery, Clark, Gillmore-Todd and Cockrill diversions which had volumes below average. In 1952, the average volume was

57.0 cubic feet per second. The legal loss averaged 11.0 pounds (24.0 fish) in the Kleinschmidt, Highline, Mammoth and Keughen canals which had volumes above average and 4.2 pounds (12.0 fish) in the Beck and Border, Noble, Creamery, Clark, Bopt-Mc Culloch and Cockrill ditches which had volumes below average. The sublegal loss averaged 25.8 fish in the former and 44.8 in the latter.

The gradients of all canal intakes averaged 7.8 feet per mile. The legal loss averaged 13.1 pounds (30.3 fish) in the Highline, Mammoth and Clark diversions which had gradients above average and 5.6 pounds (12.8 fish) in the Kleinschmidt, Keughen, Beck and Border, Cockrill, Noble and Bopt-Mc Culloch canals which had gradients below average. The average sublegal loss was 30.7 fish in the former and 33.5 in the latter. The gradient of the Creamery intake was not included due to alteration resulting from highway construction.

<u>Width and depth</u>: A comparison of fish loss in the diversions in relation to the widths and depths across the canal intakes was made in 1952 (Table 1). The average width across all canal intakes was 24.1 feet. The legal game fish loss averaged 5.2 pounds (11.2 fish) in the Keughen, Beck and Border, Noble, Creamery and Bopt-Mc Culloch diversions which have intakes wider than average and 9.3 pounds (22.4 fish) in the Kleinschmidt, Highline, Mammoth, Clark and Cockrill ditches which have intakes narrower than average. The average sublegal loss was 49.4 fish in the former and 25.0 in the latter.

The average depth across all canal intakes was 1.9 feet. The legal loss averaged 11.9 pounds (24.0 fish) in the Kleinschmidt, Mammoth and Keughen diversions which have intakes deeper than average and 4.2 pounds (12.0 fish) in the Beck and Border, Noble, Creamery, Clark, Bopt-Mc Culloch and Cockrill ditches which have intakes shallower than average. The sublegal loss averaged 25.8 fish in the former and 44.8 in the latter.

Location in relation to river flow: Some intakes are located on bends and others on straight sections of the river. A comparison of fish loss was made between diversions having intakes on river bends and those having intakes on straight-a-ways. In 1951, the legal game fish loss averaged 49.3 pounds (114.3 fish) in the Lowline, Keughen and Creamery ditches which have intakes on river bends and 10.3 pounds (38.3 fish) in the Clark, Gillmore-Todd and Cockrill canals which have intakes on straight-a-ways. In 1952, the legal loss averaged 8.3 pounds (17.7 fish) in the Highline, Mammoth, Keughen, Noble, Creamery and Bopt-Mc Culloch diversions which have intakes on bends and 5.8 pounds (15.5 fish) in the Kleinschmidt, Beck and Border, Clark and Cockrill ditches which have intakes on straight-a-ways. The sublegal loss averaged 43.5 fish in the former and 27.8 in the latter.

Angle with river: Some canal intakes are parallel with the river from their origin to at least 150 feet downstream while others leave the river at an angle (Table 1). Those which are parallel are referred to as forming an angle of zero degrees with the river. A comparison of fish loss was made between diversions which form above average angles and those which form below average angles with the river. In 1951, the average angle between the intake and the river for all canals was 25.7 degrees. The legal game fish loss averaged 49.3 pounds (114.3 fish) in the Lowline, Keughen and Creamery diversions which form greater than average angles with the river and 10.3 pounds (38.3 fish) in the Clark, Gillmore-Todd and Cockrill ditches which form less than average angles. In 1952, the average angle between the intakes and the river was 28.6 degrees. The legal loss averaged 8.5 pounds (18.3 fish) in the Highline, Mammoth, Keughen, Beck and Border, Noble, Creamery and Bopt-Mc Culloch diversions which form greater than average angles with the river and 4.4 pounds (13.3 fish) in the Kleinschmidt, Clark and Cockrill canals which form less than average angles. The sublegal loss averaged 43.6 fish in the former and 22.3 in the latter.

Diversion dams: Most of the canals have diversion dams constructed either of rock or concrete which extend out into the river and divert water into the intake. In 1952, a comparison of fish loss was made between ditches with diversion dams at the intake and those without. The Kleinschmidt and Keughen canals have concrete diversion dams which were not operated; therefore, they were excluded from the comparison. The legal game fish loss averaged 9.9 pounds (23.0 fish) in the Highline, Mammoth, Beck and Border, Noble and Bopt-Mc Culloch ditches which have diversion dams and 3.2 pounds (9.7 fish) in the Creamery, Clark and Cockrill canals which do not have diversion dams. The sublegal loss averaged 38.4 fish in the former and 45.0 in the latter.

Bottom types and cover: Some intakes and the adjacent river bottoms were predominantly silt-sand while others were gravel-rubble. In 1952, a comparison of fish loss in the diversions was made in relation to these two bottom types. Legal game fish loss averaged 4.3 pounds (11.5 fish) in the Beck and Border, Creamery, Bopt-Mc Culloch and Cockrill diversions which have silt-sand bottoms in the intake and adjacent river and 9.3 pounds (20.3 fish) in the Kleinschmidt, Highline, Mammoth, Keughen, Noble and Clark canals which have bottoms of gravel-rubble. The sublegal loss averaged 55.3 fish in the former and 25.2 in the latter.

Cover was classified as pools, overhanging brush and undercut banks and the area of each type was determined (Table 1). The total percentage of cover for the intake and adjacent river area was obtained by adding the square feet of area occupied by water three feet and greater in depth; the area covered by overhanging brush; the area covered by overhanging bank and dividing by the total square feet of water area. In 1952, a comparison of fish loss was made between diversions having above average and those having below average cover on the intakes and adjacent river areas. The average percentage of cover was 24.1 percent. The legal game fish loss averaged 5.2 pounds (12.3 fish) in the Kleinschmidt, Highline, Noble and Cockrill diversions which have above average cover and 8.7 pounds (19.8 fish) in the Mammoth, Keughen, Beck and Border, Creamery, Clark and Bopt-Mc Culloch ditches which have below average cover. The sublegal loss averaged 15.3 fish in the former and 46.8 in the latter.

DISCUSSION

An attempt was made to correlate legal game fish loss with the various physical characteristics of canal intakes. Sublegal game fish loss was not used since the method of sampling did not permit a true estimation of the number of fish smaller than seven inches. The number of ditches studied is small but they are believed to be representative of the irrigation diversions of the West Gallatin River, Montana.

While some of the characteristics of headgates, such as location, construction and manipulation, could be correlated with fish loss, no confidence is placed in this information since other factors may have greater effect. Among these other factors are volume of flow in ditches, amount of water diverted as compared to the amount retained by the river and location of intakes in relation to river flow.

The legal game fish loss was proportional to the volume of flow in the ditches except for the Kleinschmidt canal. To determine the significance of this relationship, the regression of fish loss on volume was computed for both the 1951 and 1952 comparisons. In both cases, the regression was significant at $P = 0.05$, therefore; it appears that a reasonably high degree of linear association exists between legal game fish loss and volume of flow in the diversions.

The measurements for the Mammoth and Kleinschmidt canals were not included in the regression computations. The Mammoth ditch is located on a lateral branch of the Gallatin River and from early in the irrigation season until the headgate is closed in the autumn, approximately July 1 to October 15, all but a negligible amount of water is diverted from the river into the canal. In 1952, the Mammoth ditch sustained the highest legal game fish loss and it is believed to be the result of this dewatering practice. Although the Kleinschmidt canal had the largest volume of flow of the ditches studied, it sustained a very low fish loss in 1952. This diversion is on the upper part of the study area (Figure 1) and the river adjacent to the intake is not subject to dewatering. The intake is also on a straight section of the river and apparently, few fish are present in this area, possibly accounting for the low loss in the canal.

The linear regressions of fish loss against velocity, gradient, depth or width did not prove to be significant. It is therefore assumed that these physical characteristics influence fish loss in irrigation diversions only when in combination.

In considering canal intakes in relation to river flow, the highest legal game fish loss was sustained by those on river bends, but in 1951, these canals (Lowline, Keughen and Creamery) also had higher volumes of flow. However, if the Lowline and Keughen diversions were excluded from the comparison, making the canals with intakes located on bends more comparable in volume of flow to those with intakes located on straight-a-ways, the loss in the former would still be almost three times that in the latter. In 1952, the average volume of flow for the diversions with intakes on river bends was practically the same as those with intakes on straight-a-ways. The legal game fish loss was highest in canals with intakes on river bends.

The regressions of fish loss against the angle of the intake with the river did not prove to be significant. The information gained from this study does not support the inference that the angle by which the intake leaves the river has any influence on legal game fish loss.

When comparing legal game fish loss in canals having diversion dams with that in canals not having dams, the former group of canals sustained the highest loss. However, this higher loss is thought to be a result of other factors, particularly volume of flow.

In considering fish loss in relation to bottom types in the intakes and adjacent river areas, the diversions which have gravel-rubble bottoms sustained a higher loss than those which have silt-sand bottoms. Again, this higher loss is thought to be a result of other factors including volume of flow.

Regarding the effect of cover at the intakes and adjacent river areas, the regression of fish loss on the three types of cover, individually and collectively, was tested and found not significant. It is thought that cover may not effect legal game fish loss other than what influence it exerts in combination with intakes which are located on river bends.

SUMMARY

1. Fish loss was determined and the various physical characteristics of the canal intakes and headgates were measured during the summers of 1951 and 1952 for 12 irrigation diversions of the West Gallatin

River, Montana.

2. The physical characteristics considered were: headgate location, construction and manipulation; intake velocity, volume, gradient, width, depth and angle with river; location of intakes in relation to river flow, diversion dams, bottom types, cover and amount of water diverted in relation to the amount retained by the river.

3. No correlation was apparent between legal game fish loss and location, construction or manipulation of headgates.

4. The linear regression of legal game fish loss on velocity, gradient, width or depth of intakes did not prove significant with the analysis of variance test.

5. The regression of legal game fish loss on the angle of the intake with river or amount of cover at the intake or adjacent river areas did not prove significant.

6. Bottom types in the intake and adjacent river areas or the existence of diversion dams at the intake apparently had no observable influence on legal game fish loss.

7. Legal game fish loss was highest in canals with the higher volumes of flow and in those with intakes located on river bends.

8. The highest legal loss in 1952 occurred in a canal into which all but a negligible amount of water was diverted from the river channel on which it was located.

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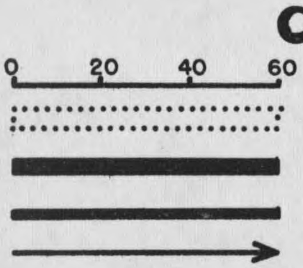
SUPPLEMENT

Maps of eleven irrigation canal intakes and adjacent areas of the West Gallatin River, Montana (Figures 2-12) showing the following physical characteristics: location and construction of primary headgates; intake width and angle with river; depth contours, location of intakes in relation to river flow, diversion dams and cover.

LEGEND



SCALE IN FEET
UNDERWATER CONCRETE APRON
CONCRETE HEADGATE
WOODEN HEADGATE
DIRECTION OF WATER FLOW
++++++++++++++++ UNDERCUT BANK

CHARACTERS OF BANK	SHADING
HA- HIGH ABRUPT	O - OPEN
HS- HIGH SLOPING	PS- PARTLY SHADED
GS- GENTLY SLOPING	DS- DENSLY SHADED
LA- LOW ABRUPT	
G - GRASS	
SH- SHRUBS	
T - TREES	
RD- ROCK DAM	
RP- ROCK PILING	

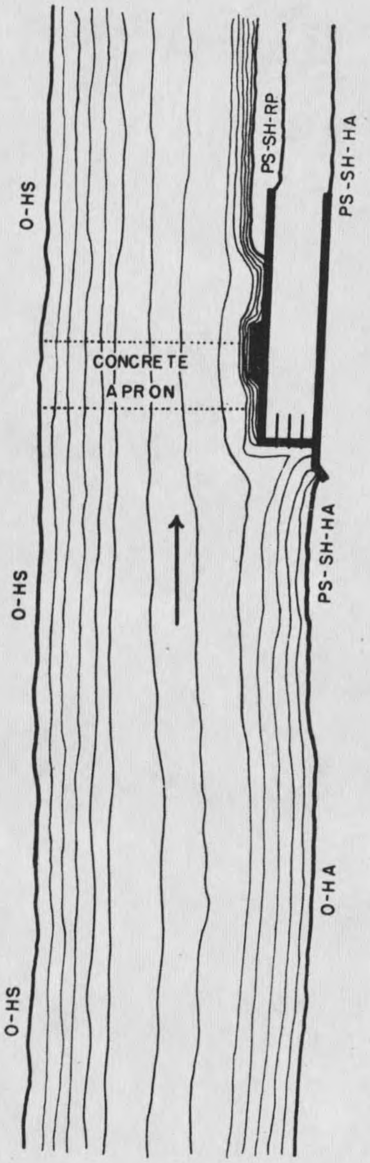


Figure 2. Kleinschmidt canal.

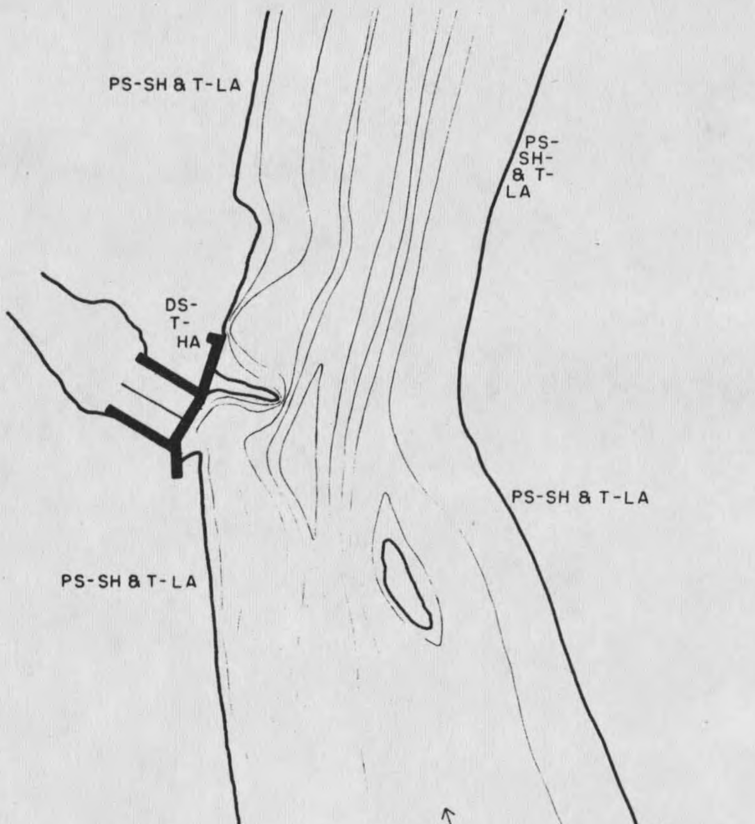


Figure 3. Highline canal.

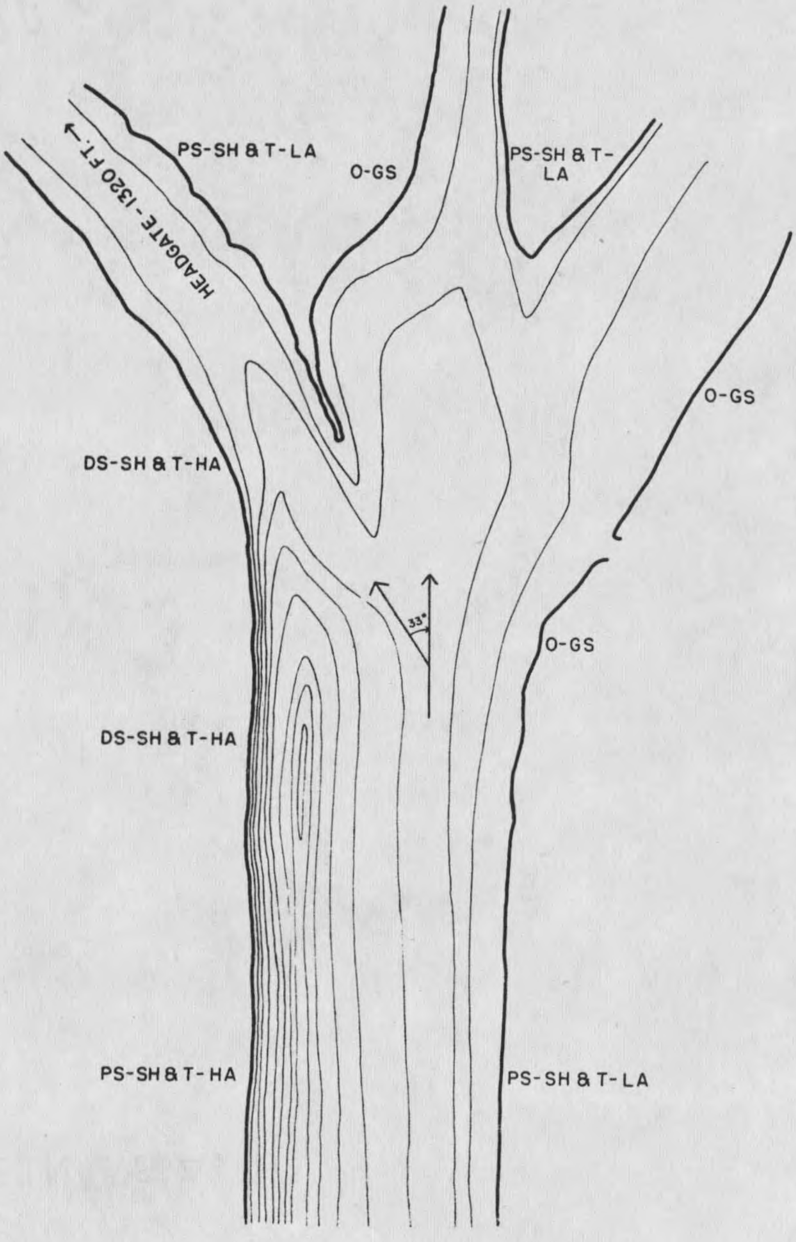


Figure 4. Lowline canal.

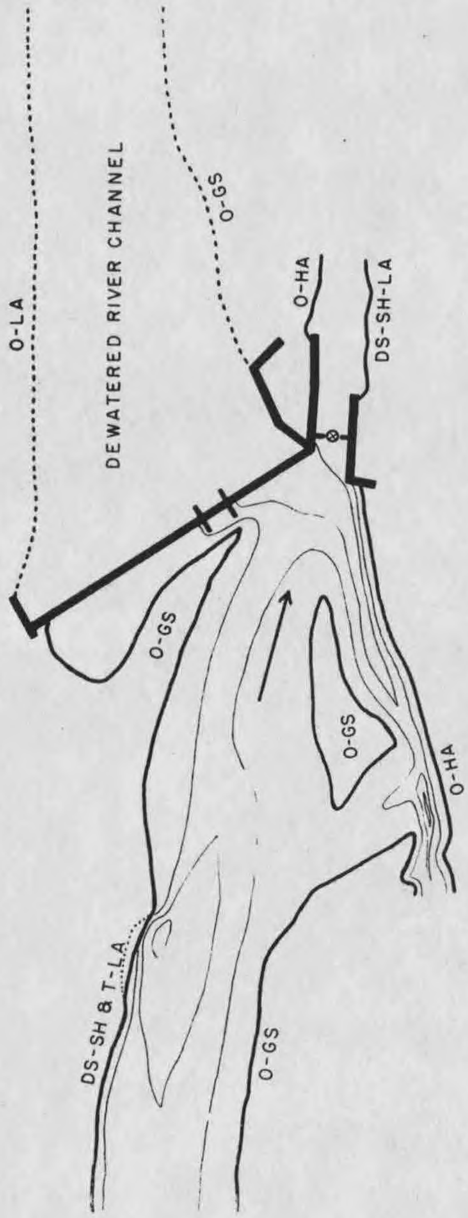


Figure 5. Mammoth canal.

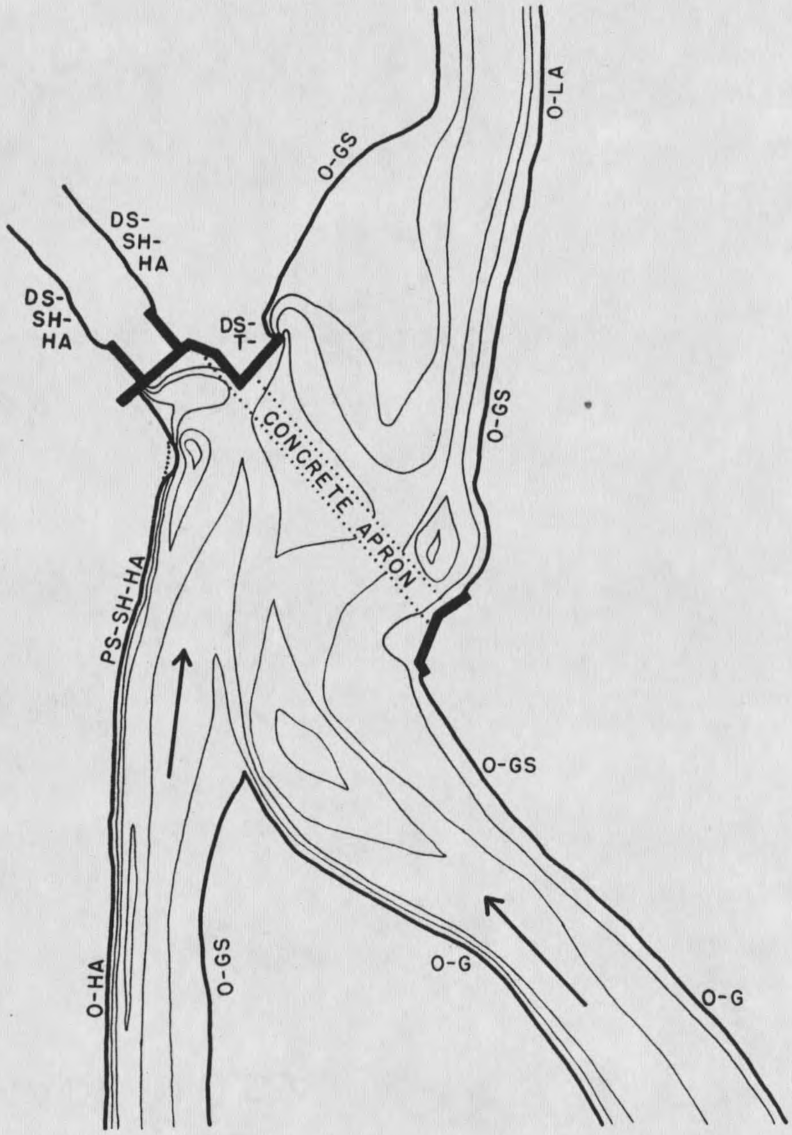


Figure 6. Keughen canal.

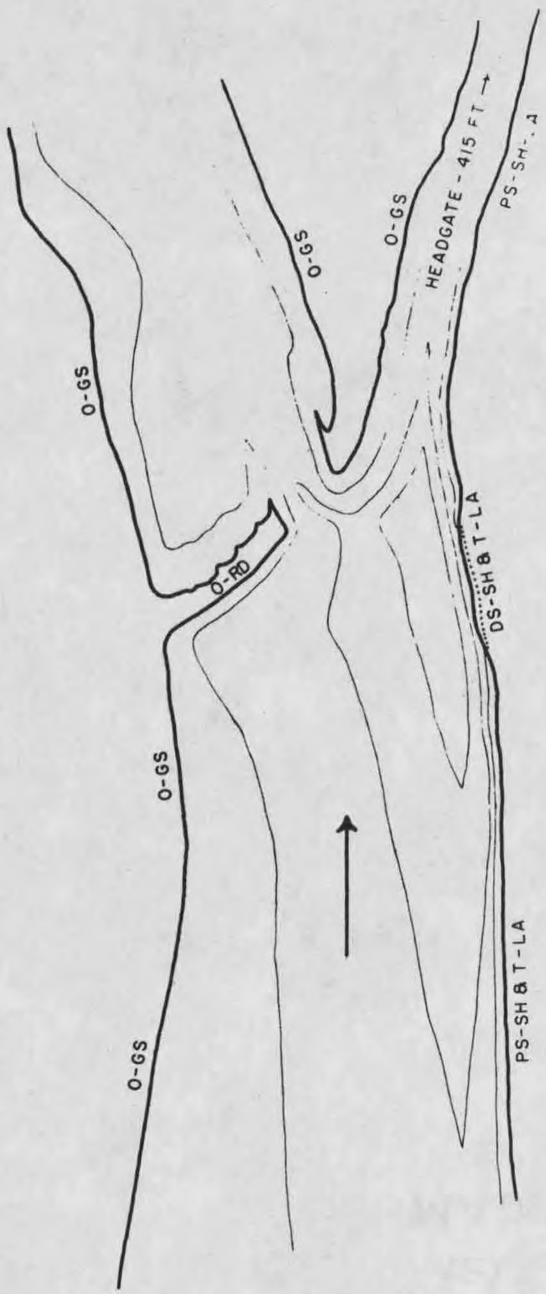


Figure 7. Beck and Border canal.

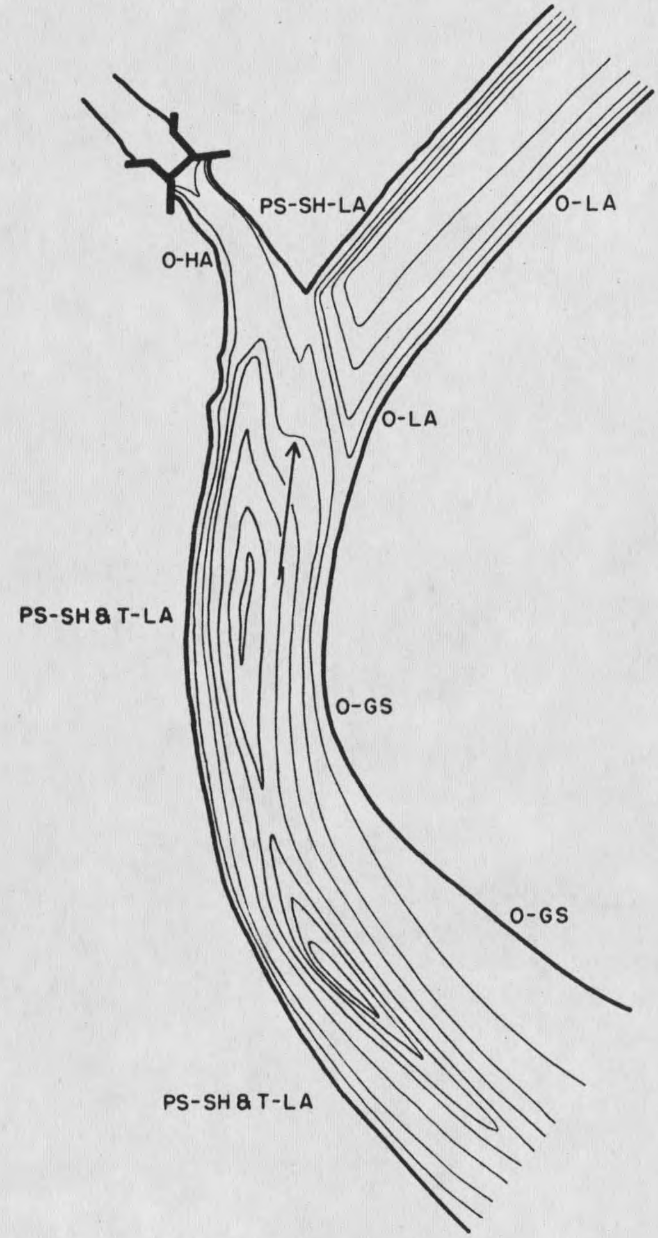


Figure 8. Noble canal.

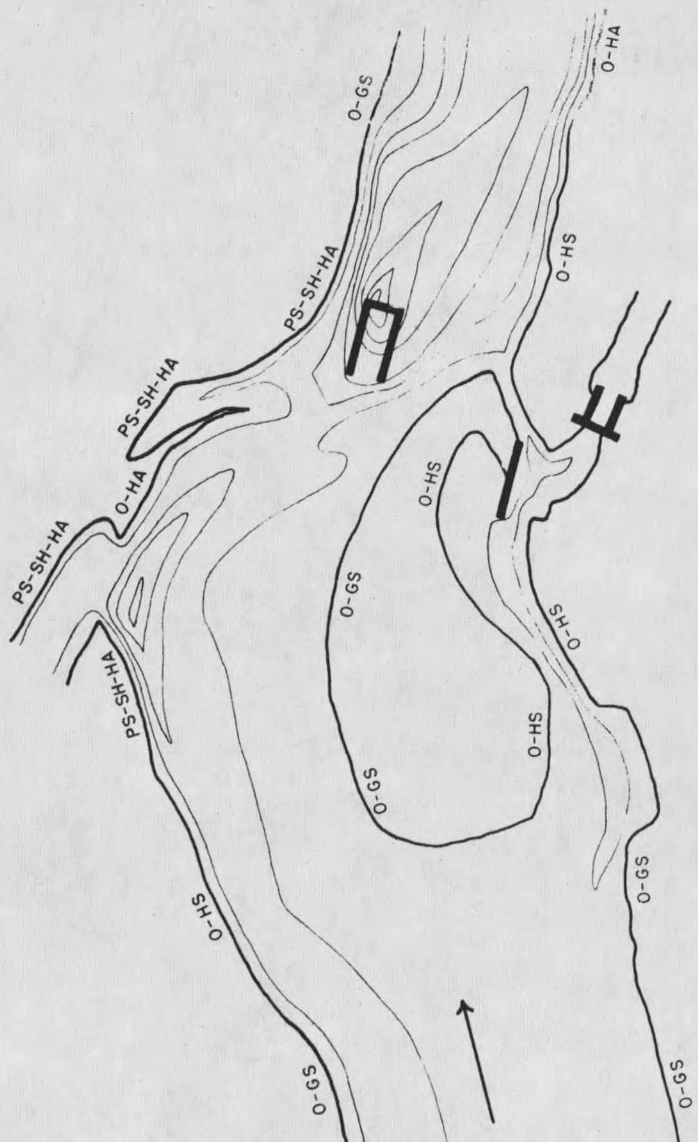


Figure 9. Creamery canal.

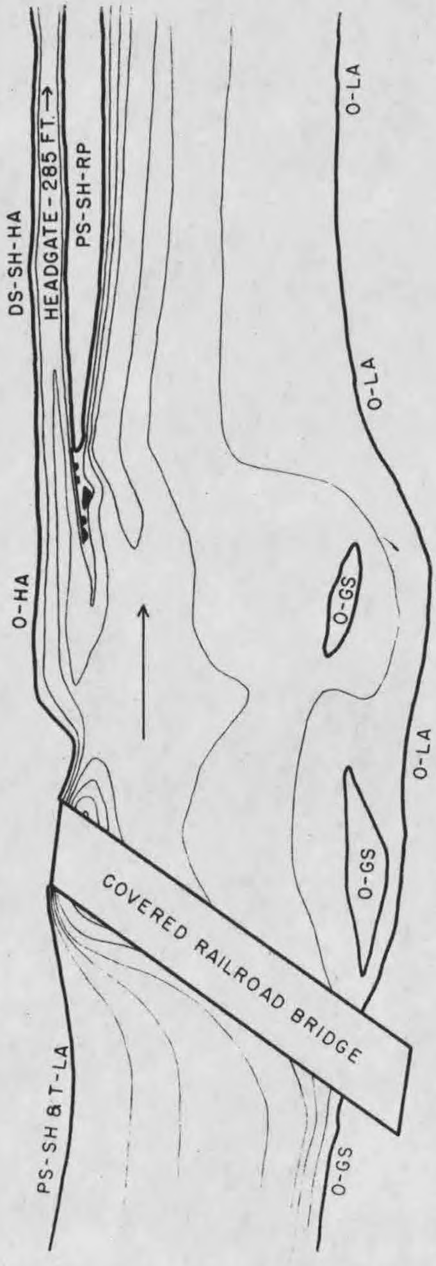


Figure 10. Clark canal.

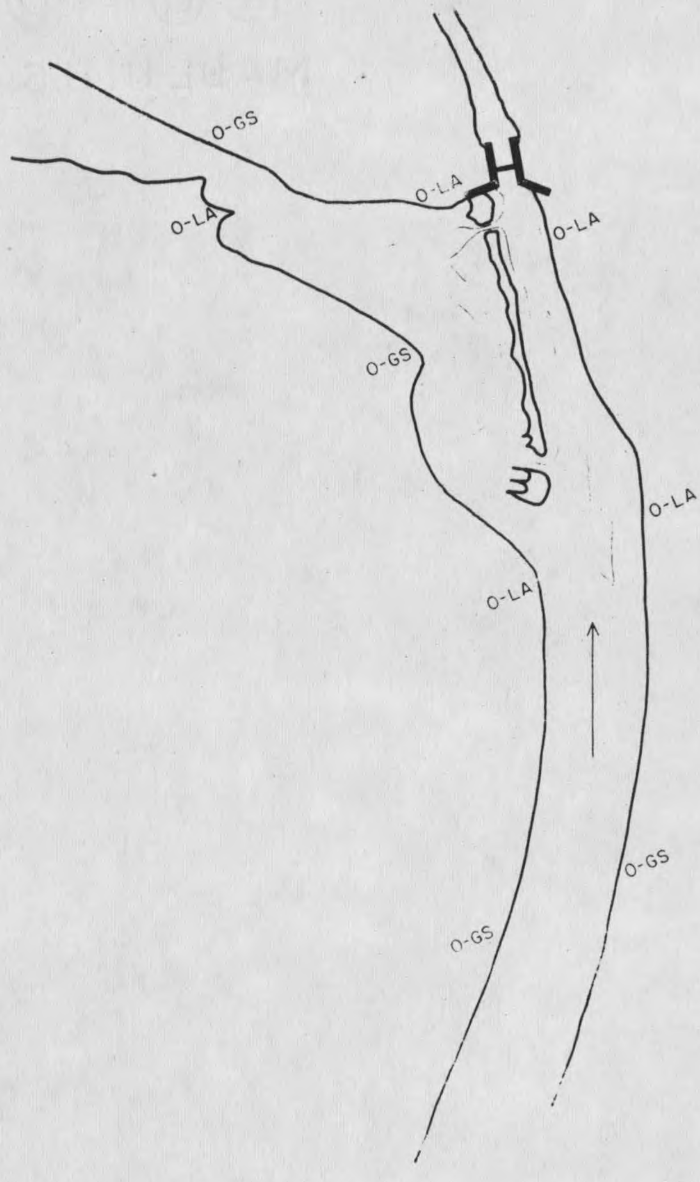


Figure 11. Bopt-Mc Culloch canal.

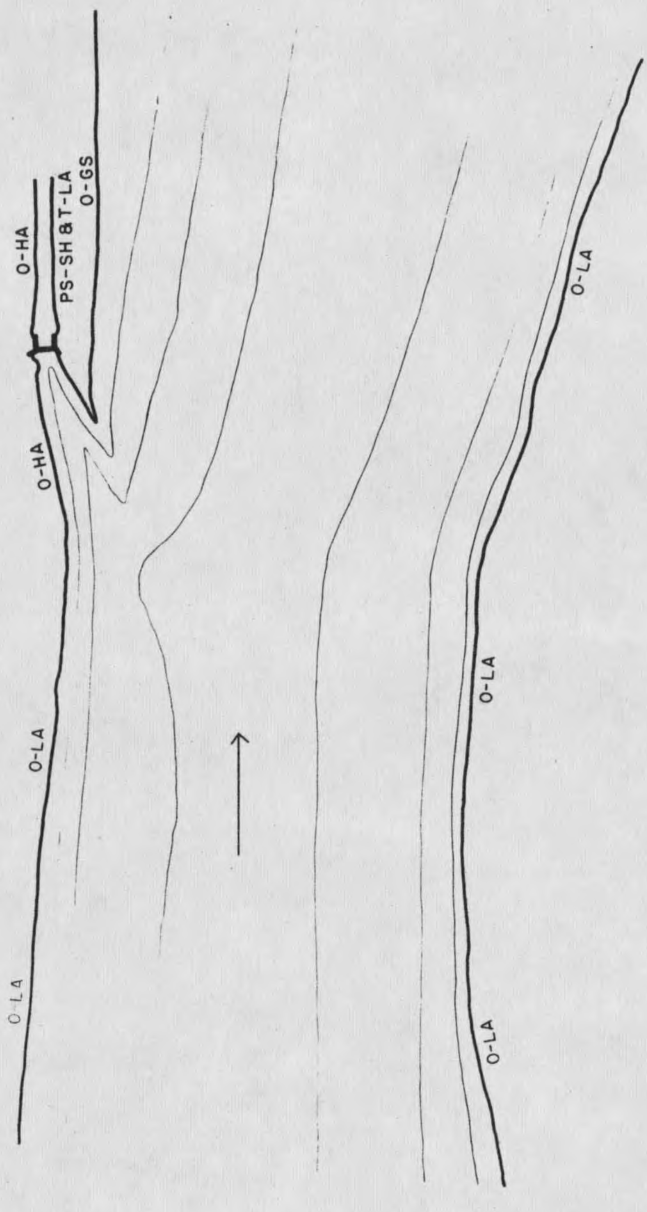


Figure 12. Cockrill canal.