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THE EFFECT OF VARIOUS STREAM FLOWS ON CONDITION FOR TROUT IN THE MIDDLE BRANCH OF THE ONTONAGON RIVER, ONTONAGON COUNTY, MICHIGAN

by

Paul Eschmeyer

Introduction

During the summer of 1937 the Copper District Power Company built a storage dam on the Middle Branch of the Ontonagon River just upstream from Bond Falls. A diversion canal was constructed to divert water from this reservoir to the South Branch of the Ontonagon River through tributaries of that stream. The purpose was to store flood waters of the Middle Branch and to divert these waters to the South Branch utilizing the power generating facilities already constructed on this branch at Victoria dam.

Considerable controversy has existed since the diversion of water was begun as to the amount of water required by trout in the Middle Branch between Bond and Agate Falls, and as to the relative value of the following flows in cubic feet per second; 25, 35, 40 and 62½. These flows have been permitted at various times by the power company in agreement with the Conservation Department. The purpose of the present investigation was to determine the effect of these various flows on condition for trout in the river below, especially their effect on area of stream bed covered, depth in pools and riffles and temperature.

The investigation herein reported was carried on from March 5 to August 22, 1942.

Bond Falls Reservoir and Connecting Waters.

Bond Falls Dam, on the Middle Branch of the Ontonagon River, is situated in sections 1 and 12, T. 46N., R. 39W., Haight Township, Ontonagon County, Michigan. It is $2\frac{1}{2}$ miles east of Paulding, Michigan, and is accessible from that village by a county road. The structure impounds eastward from it a total of about 2,160 acres of water when the reservoir is full. Although large areas of the impoundment are very shallow and are covered with dead trees, stumps and brush, some parts of it reach a depth of about 40 feet.

Water in the reservoir is slightly bog-stained, ranges from somewhat acid to slightly alkaline (pH 6.5 to 7.1), and is moderately soft (methyl orange alkalinity 54-58 p.p.m.). It undergoes chemical and thermal stratification during the summer, but appears not to stratify chemically, to an appreciable degree, during the winter.

Bond Falls Reservoir has been in existence for the proper length of time to have reached, or to be about to reach, its maximum biological productivity, if it is following the ecological cycle of many impoundments which have been studied in the past. Although no detailed studies have been made, on this water, it seems logical to assume that food in the lake is plentiful, that growth of the indigenous species is good, and that no single species has yet reached the point where overpopulation and stunting has occurred. The excellent condition of many of the perch taken from the water (one of the first species which would be expected to show the effects of overcrowding and lack of food) bears out this assumption. The principal species in the lake, which are caught at times in considerable numbers by anglers, are perch, crappies, and largemouth bass. Bluegills also occur, and, as might be expected, occasional large trout are taken. The reservoir is becoming increasingly popular among cane-pole fishermen, as well as among those who enjoy casting or trolling for largemouth bass. Excellent catches of large perch and good-sized bass are not uncommon.

Being part of the Ontonagon River System, the reservoir exerts a certain influence on the species composition of the fish in the waters above and below it. Crappies and largemouth bass, and occasional bluegills and perch are found in the stream below the falls, as well as in the section of stream immediately above the reservoir. Large numbers of dead crappies were found in the stream immediately below Bond Falls during the spring of 1942. The mortality had resulted either from disease in the reservoir, or from injuries received while passing through the dam. Both crappies and largemouth bass have been taken by the writer on dry flies in the section of stream below the falls, and both species occur occasionally in anglers' catches throughout the area of stream between Bond and Agate Falls. They normally inhabit the more sluggish waters which are not generally preferred by trout. The actual numbers of these centrarchids in the stream and the extent of their damage in competing with trout for food and in feeding on young trout has not been determined. Since trout are so highly predominant numerically in the stream, and since such large stretches of excellent trout water in the stream are not at all suited to these warm water species, the situation should not be viewed with undue alarm.

Although the reservoir is probably responsible for the increase of crappies and bass in the river above and below it, it may possibly function as a wintering place for trout which enter from the stream above it. During cool summers, it is probable that considerable numbers of trout remain in the lake throughout the year except when spawning. Occasional large trout were reported taken in the reservoir by anglers during the summer of 1942 which was unusually cool.

Some trout which presumably enter the reservoir from the stream above may continue on through the dam to populate the stream below it. Partial proof of this is the considerable number of trout which are caught each year in the short stretch of stream between the dam and the falls. These quite evidently come from the reservoir, since Bond Falls cannot under any circumstances be negotiated in an upstream direction by the fish. Further proof was furnished recently when a tagged rainbow trout which had been planted near the Ontonagon Rearing Station, 1 mile east of Watersmeet, on April 14, 1942, was recaptured by an angler in late August, over 16 miles downstream, between Bond Falls Dam and Bond Falls.

Besides the effect on the fish populations of the stream of which it is a part, the reservoir exerts certain slight chemical and thermal effects on the stream below. Its effect on stream temperatures are discussed later in this report. Reference to Table I indicates that the reservoir has ample oxygen to support fish life (4 p.p.m. or more) at all depths, during the period of ice cover in winter, as shown by the oxygen analysis of March 5, 1942. During the late summer, however, oxygen at the depths from which the water is drawn for the Middle Branch (about 30 feet) has insufficient oxygen to support trout. This might have serious effects on the stream below, if it were not for the fact that the water apparently becomes recharged with oxygen while passing through the dam. A check made at the lower by-pass (through which most of the water passes which enters the Middle Branch) showed 6.5 p.p.m. of oxygen on September 1.

A similar check on August 24 showed that over 5.5 p.p.m. were present. (An exact determination could not be made on that date due to the unexpected deterioration of an indicator solution used in the final titration). On the latter date, the water showed over 7.5 p.p.m. just below Bond Falls. As the water becomes recharged with oxygen, it releases hydrogen sulfide (a decomposition product which accumulates in the deeper waters of the reservoir above). The odor of this gas is discernible in the area below the dam throughout the summer months. By the time the water reaches Bond Falls, it appears to have lost all traces of this gas. The reservoir appears to exert no permanent chemical effect upon the water in the stream which might be considered harmful to trout.

An analysis of the daily flow of water from Bond Falls Reservoir into the Middle Branch of the Ontonagon River for the period from September 1, 1941 to August 31, 1942, is made in Table II and Figure 1 (graph). The figures were supplied by the Copper District Power Company. Essentially, these show a moderate flow of 30 to 35 c.f.s. during September and part of October, somewhat greater, fluctuating flows from mid-October until early January (to accommodate fall rains) and flows of from 25 to 40 c.f.s. from early January until mid-April. There follows a period of high water levels and severe fluctuations, from mid-April until mid-June. Lower levels persist from that time on, except where interrupted, in late July, by unusual rains. Except for the latter period of high water in mid-summer, the flows from the dam could be expected to follow this same general pattern during most years.

There are insufficient data available as yet to make a meaningful comparison between the water entering the reservoir and that permitted to continue down the Ontonagon River. A temporary staff gauge was placed in the stream near Interior about 1 mile above the reservoir, by the U. S. Geological survey, during the summer of 1942. A few preliminary figures, supplied by the Survey, show that for the period extending from August 6 to 21, 1942, inflow ranged from 106 to 155 c.f.s., and averaged 126.5 c.f.s. The waters were receding throughout most of the period during which these measurements were made, indicating perhaps that the river was still being affected by the abnormal precipitation of late July, and that the average shown is not a safe criterion for the average flow during this period in a normal year.

The backwaters of Bond Falls Reservoir extend into a portion of Deadman Creek, a stream which enters from the southeast. This has been a source of some complaint by fishermen, who can no longer wade their favorite stretches of what was and still is a very fine trout stream. No detailed study has been made of the effect of the reservoir on this stream. It is quite possible, however, that, although the convenience of the angler who fishes the stream may have been impaired, the deepening of portions of the stream may act to the advantage of the trout which makes it his habitat. On the other hand the increase in warm-water fish which no doubt followed this flowage is a disadvantage.

The portion of the water which enters the reservoir, but is not again released into the Middle Branch of the Ontonagon River is sent through a diversion canal, to the South Branch of the same stream, and is ultimately used for power development by the Copper District Power Company. The canal leaves the reservoir in Section 12, T. 46 N., R. 38W., and enters the headwaters of the South Branch in Section 8, T. 46 N., R. 39W., slightly over 1 mile west of Paulding, Michigan. An analysis of the flow of water through the canal for a period of one year, from September 1, 1941 to August 31, 1942, is shown in Table II and Figure 2 (graph). In the 179 days during the year when it was in use (excluding the periods from July 18 to 30 and August 23 to 31, when only 6 and 9 c.f.s. per day, respectively, were being passed) the average daily flow was 171 c.f.s. The maximum was 311 (July 15).

The diversion canal was built exclusively for water transport purposes. It is subject to extreme fluctuations in water level, dependent upon the needs for power development purposes. It was not planned as a fishing stream; it is not now a good fishing stream; it will have little importance in this capacity in the future. It is at the present time very lightly fished and a few trout (some quite large) are sometimes reported taken by anglers. Other than the few trout present, the upper section of the canal contains large numbers of crappies, sticklebacks, and a few common shiners and other minnows. Temperatures were taken in the stream at its origin below the reservoir, and about $\frac{1}{2}$ mile downstream, on August 20. With an air temperature of 79° F., the former temperature was 64.5°, and the latter was 66° F., both suitable for trout.

Besides the fluctuation in water levels in the South Branch, brought about by the waters of the diversion canal, there is some disturbance of the water levels in the lower reaches of certain of its tributary streams, with some areas becoming too deep to wade during periods of high water in the canal. No detailed study of the effect of these fluctuations on condition for trout in the streams concerned has been made, Opinions heard concerning such effect are highly controversial, and none is based on adequate data. The existing situation of fluctuating water levels cannot readily be remedied as long as the diversion canal continue to serve its primary purpose.

Object and Methods of Study

The primary objective of the investigation with which this paper deals was to determine the effect of several different volumes of flow on condition for trout in the section of the Middle Branch of the Ontonagon River which extends from Bond Falls to a point 3 miles (by stream) below Agate Falls. The lower limit marks the downstream end of state ownership.

The volumes of flow which were tested were 25, 35, 40, and $62\frac{1}{2}$ cubic feet per second, as measured at Bond Falls Dam. A schedule of the various flows was originally drawn up for the period extending from July 6 to 29. The section of stream extending from Bond Falls to Agate Falls was mapped in detail during the first 10 days of this period. Further work was interrupted when an especially severe rain made it necessary to spill a large amount of excess water from Bond Falls Reservoir, during the period extending from July 18 to August 2. A second schedule of flows was arranged and the work was completed in August. The following flows were maintained during the period of investigation:

August 5 - 12,	inclusive	............Flow	25 c.f.s.
" 13 - 15,	"	.... "	35 c.f.s.
" 16 - 18,	"	.... "	40 c.f.s.
" 19 - 23,	"	.... "	$62\frac{1}{2}$ c.f.s.

The rates of flow were checked by gauges installed by the U. S. Geological Survey in the upper and lower by-passes. All water which entered the river from the reservoir during the period of investigations was measured by these gauges. The exact discharges during the period, both at Bond Falls, and at Agate Falls, as measured by the U. S. Geological Survey gauges, are shown in Table III.

Table III

Total Flow to Middle Branch of the Ontonagon River through the Weirs of Bond Falls Dam, and Total Flows as measured at a Point 800 feet Above Agate Falls, During the Period from August 5 - 23, 1942.

(From preliminary figures [Subject to Revision] supplied by the U. S. Geological Survey).

Date	Total Flow to Middle Branch from Weirs	Total Flow as measured 800 feet above Agate Falls
August	(c.f.s.)	(c.f.s.)
5	25.08	43
6	25.08	43
7	25.08	43
8	25.08	43

Table III Continued

Date	Total Flow to Middle Branch from Weirs	Total Flow as measured 800 feet above Agate Falls
August	(c.f.s.)	(c.f.s.)
9	25.08	43
10	25.08	43
11	25.08	42
12	26.78*	42
13	35.28	48
14	35.28	49
15	36.28*	51
16	40.08	56
17	40.08	56
18	43.55*	57
19	62.6	80
20	62.6	80
21	62.3	80
22	62.6	134**
23	62.6	99**

During the first 25 c.f.s. flow period, 25 measuring stations were established in the stream, at points ranging from just below Bond Falls to a point almost 2 miles below Agate Falls. At each station, blazes (generally at an elevation of about 2 feet above the level of the water) on directly opposed trees, on opposite sides of the stream, marked the points between which a steel tape was stretched. A record was kept of the exact point on the tape at which it intercepted the edges of the two shorelines. Depth measurements were made at each 5-foot mark along the section of the tape beneath which the river flowed. This procedure was repeated during each flow period, at all stations. No measurements were made until at least 12 hours had elapsed, after a change in flow had been made. Detailed reproductions of the field data collected for each station are shown in Table IV, and the results are summarized in Tables V, VI, and VII.

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* Change of flow over by-pass weirs was made in the late evening. Flow before change was the same as the previous day. Figure listed is 24 hour average.

** Abnormal inflow due to precipitation.

The decrease in distance from the blaze to the shoreline during successively higher flows was converted to increase in stream width by the simple summation of the differences (on the two sides of the stream) between the distance at a given flow and the one which preceded it. The results for each station are summarized in columns 4, 5, and 6 of Tables V (pools) and VI (riffles). Columns 7, 8, and 9 were derived by averaging the difference between depth measurements taken at a given flow and the lower flow which preceded it. An average of 9.3 measurements were taken at each station. The accuracy of individual measurements varied considerably with the nature of the stream bottom, since it was not possible to place the measuring stick at precisely the same spot during the 4 flow periods. The average increase in depth for all measurements at a given section, however, represents what in most cases is believed to be very close to a true value. In the case of one riffle (Sta. 25) and one pool (Sta. 3) no increase in depth was shown by an increase in flow from 35 to 40 c.f.s. Unquestionably there was an increase, but it was too small to be detected by the technique which was used.

In general, the location of the measuring stations depended on accessibility. Sufficient points of access to the river were found so that there was some representation of all basic types of stream bed found in the river within the area under study. Location of the individual stations was determined chiefly by the presence of trees on each side which might serve as points between which the tape could be stretched, and not with regard to the amount of area which might be expected to be covered by subsequent higher flows. In the latter respect they may be considered as having been selected at random.

In addition to the cross-sectional measurements, temporary depth gauges were placed in 25 pools chosen at intervals between Bond Falls and a point about 1.6 miles below Agate Falls. These consisted of stakes (1 inch x 1 inch x 48 inches) which were driven firmly into the stream bottom. During each flow period, a record was made of the distance from the level of the water to the top of the stake. These measurements are summarized in Table VIII.

Besides the cross-sectional measurements and pool gauges, a number of photographs of the stream at various levels of the water were taken. In most cases, one photograph was taken downstream and one upstream from identified points above and below each station. Pictures of several representative stations are included in this report.

EFFECTS OF CHANGE IN FLOW ON THE STREAM.

Effect of Changes in Flow on Area of Bottom Covered.

In the Ontonagon River, the annual occurrence during the spring months of the year (and at times of exceptional rains, during other seasons) of flows of from 300 to 1200 c.f.s. has served to gouge out a stream bed which in many sections of the river has relatively steep sides. As a result, the increase in area of bottom covered by an increase in flow is not very great. This is shown in tables V, VI, and VII and in Fig. 3 (graph). The riffle areas have been considered separately from the pool areas so that the effect of changes in flow on each stream situation may be better observed. The field data from which these tables have been derived are included in Table IV.

In the riffle areas, the increase in width of the stream with an increase in flow from 25 to 35 c.f.s. ranged from 1½ to 29 1/4 inches, and averaged 9.6 inches. In the pools, the increase ranged from 4 to 20½ inches and averaged 10.2 inches.

With an increase in flow from 35 to 40 c.f.s., the riffles increased from 0 to 54 inches in width and had an average increase of 8.63 inches. Increases in width of pools ranged from 0 to 39 3/4 inches, and averaged 6.9 inches.

An increase in flow from 40 to 62½ c.f.s. produced increases in width of riffles ranging from 0 to 112½ inches, which averaged 23.6 inches. Increases in width of pools ranged from 1 to 58 inches and averaged 19.1 inches.

It is seen that an increase in flow from 25 to 35 c.f.s. caused a greater increase in width of pools than of riffles, while in the case of the two higher flows, the reverse was true.

If one averages the figures for the entire 25 stations, including 12 pools and 13 riffles, it is found that an increase in stream flow from 25 to 35 c.f.s. increases the average width of the stream by 9.9 inches; a 40 c.f.s. flow adds an additional 7.74 inches, and the 62½ c.f.s. flow adds 21.5 inches to this total.

Interesting results are obtained if these figures are applied in terms of area to the stream as a whole. The average of 143 width measurements taken between Bond and Agate Falls during the survey work, at a flow of 25 c.f.s. was 45.6 feet. The stream distance between Bond and Agate Falls is 44,360 feet. The area of stream between Bond and Agate Falls, at a flow of 25 c.f.s. thus becomes approximately 46.2 acres. There follow the facts that (1) an increase in flow from 25 to 35 c.f.s. adds 0.85 acres, or 1.84% to the area of the stream between the two falls; (2) an increase from 35 to 40 c.f.s. adds a further 0.66 acres, or 1.4% to the area at 35 c.f.s.; and (3) an increase from 40 to 62½ c.f.s. adds 1.82 acres and increases the area between the two falls by 3.81%, over the 40 c.f.s. flow. In other words, assuming an average width of 45.6 feet, it requires about 955 feet of stream to equal an acre. A 35 c.f.s. flow adds the equivalent of 812 additional feet in (between the two falls) to the stream as it is at 25 c.f.s.; a 40 c.f.s. flow adds 630 feet to this total, and a 62½ c.f.s. flow contributes an additional 1,738 feet.

In the above calculations, the data obtained for 6 stations below Agate Falls are included in those applied to the stream above the falls. However, the stream is ofsuch similar general character above and below Agate Falls that the effect of these data on the averages for the 19 stations above the falls would not be highly significant.

The effect of an increase in flow on the area of bottom covered and velocity on a few representative sections of the stream is shown in figures 4 to 15. Figures 4 to 7 refer to the pool just below Bond Falls, at the various stages of flow. (The arrow in the 25 c.f.s. flow photograph indicates a temporary depth gauge, earlier described). The water in the pool rose 1 5/8, 5/8, and 3 inches with increases in flow from 25 to 35, 35 to 40, and 40 to 62½ c.f.s. respectively. Small portions of the sand bars present gradually become covered with increasing flows.

Figures 8 to 11 show the gradual submergence of a rubble bar just upstream from Station 8, 3.1 miles below Bond Falls. In the riffle below the bar, the stream increased in width 6½, 2½, and 14½ inches, and increased in depth 0.82, 0.22, and 1.69 inches with changes in flow from 25 to 35, 35 to 40, and 40 to 62½ c.f.s. respectively.

Figures 12 to 15 were taken downstream toward Station 1. Besides showing a readily observed increase in velocity with each increase in flow, the stream at this point increased 3 1/4, 1 3/4 and 19 inches in width, and 0.46, 1.0, and 2.32 inches in depth, with increases in flow from 25 to 35, 35 to 40, and 62½ c.f.s. respectively.

Effect of Change in Stream Flow on Depth.

The effect of change in stream flow on depth of water is shown in Tables V, VI, VII, and VIII, and in figure 3 (graph)

The nature of the outlet, or downstream end, of a given pool is the factor upon which the extent of rises with increased water volume chiefly depends. Since outlets are extremely varied, each pool reacts individually, with respect to increase in depth, with an increase in water volume. Increases of depth in riffles would not be expected to be as great as in most pools, and would depend largely on the amount of drop in the riffle and the degree of its confinement. Increased flows would tend to exhibit themselves more in the form of increased velocity than in increased depth.

Very accurate determinations of increases in depth of pools with increased water volumes were obtained by means of the temporary pool gauges previously described. In 25 pools of varying types and depths, located between Bond Falls and a point 1.6 miles below Agate Falls, there was an average rise of 1.14, 0.48 and 2.21 inches with increases in flow of from 25 to 35, 35 to 40, and 40 to 62½ c.f.s. respectively. Pools measured by the cross-section method showed increases of 1.2, 0.61, and 2.03 inches during the successive flows. Average increases in the depth of riffles were uniformly less by slight margin, being 0.96, 0.45, and 1.78 inches during the successively greater flows. The general average for increase in depth of both pools and riffles was 1.12 inches, 0.53 inches, and 1.9 inches for the change in flow from 25 to 35, 35 to 40, and 40 to 62½ c.f.s. respectively. Roughly speaking, in the section of river studied, between the flows of 25 and 62½ c.f.s., any increase in flow of 5 c.f.s. results in an average rise in the water of the stream of about one-half inch.

<u>Effect of Change in Stream Flow on Velocity of Current.</u>

Very little information was obtained on the effect of an increase in flow on velocity of the current. Due to the very great differences in current velocities among the various riffles, among the pools, and between the riffles and pools, an extremely large amount of data would have to be obtained in order to arrive at any conclusions regarding the stream as a whole. Mean velocities at a given point are rarely representative of velocities in other portions of the stream.

Several check measurements of discharge were made by members of the U. S. Geological Survey during the various rates of flow, at two stations in the stream. One of these was located near Bond Falls and the other about 1/4 mile above Agate Falls. The latter group of readings was taken at exactly the same spot in the stream, and there is probably a definite relation between stage and velocity for the various measurements taken during the 4 flow periods. The station was located in the same pool with Pool Gauge C, which showed an increase in depth during the period of investigation of 1.0, 3/8, and 2 3/8 inches with an increase in flow of from 25 to 35, 35 to 40, and 40 to 62½ c.f.s. respectively. The data on mean velocity for this one station, which are not in any sense representative of other portions of the stream, show increases in mean velocity of 13.8 percent, 21 percent, and 20 percent, with increases in flow from 25 to 35, 35 to 40, and 40 to 62½ c.f.s., respectively.

The effect of an increase in flow on velocity in a typical stretch of fast water can be observed in figures 12 to 15, looking downstream on Station 1. A moderately fast current at 25 c.f.s. becomes quite fast at 35 c.f.s. and is extremely fast ("white" water) at 62½ c.f.s.. It would be difficult to demonstrate the effect of stream velocity, within the limits of 25 and 62½ c.f.s., on condition for trout, and that is not here attempted. It might be stated that, from the practical standpoint of the fisherman, many stretches of the stream become extremely difficult to wade at a flow of 62½ c.f.s..

Known Effect and Probable Effect of Stream Flow on Temperature.

Water flowing from Bond Falls Reservoir into the Middle Branch leaves the reservoir through an intake structure which is located at a depth of 30 feet (when the reservoir is full). The importance of the temperature at the point at which it is withdrawn from the reservoir is quite obvious. If the temperature were quite warm, for example, it might make several miles of stream below it uninhabitable during the summer months. Table I shows the temperature of the water in Bond Falls Reservoir at various depths, on March 5, August 9, and 24 and September 1, 1942. On the latter three dates, the average temperature at 30 feet was 52.7° F., while at 27 feet it was 59.8° F.. All temperature series were taken at a point about 300 feet out from the spillway.

Temperatures at the lower by-pass, through which flows the major portion of the water which enters the stream from the reservoir, were 35.4° F. on March 6, and 61.2°, 61.5°, 62°, and 63° F., on August 9, 12, 20, and September 1, respectively. These summer figures average 61.9° F.. It appears that the warmer temperatures extend down to a lower depth right near the spillway than at a distance of 300 feet from it, where the temperature series were taken, or else the intake structure which is located at a 30 foot depth draws water from the stratum immediately above this point, rather than directly from it. It is possible, of course, that some warming of the water occurs during its passage through the dam. In any event, throughout the hotter portions of the summer of 1942, water entered the river from the reservoir at a temperature of about 62° F.. This approximate temperature would be expected to prevail throughout the average northern Michigan summer. If thermal stratification at a distance of 300 feet from the spillway is the same as at the spillway*, and the intake structure draws its

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* In most lakes this would certainly be true where a single depression is involved, but water currents are doubtless present in the lower depths of the reservoir, as a result of the release of water into the river. This makes it difficult to predict with certainty the conditions at the spillway from the data which thus far have been made available.

water from a stratum between the 27 and 30 foot levels, the temperature would remain equally low during the warmest of summers. This would be true because the intake structure functions below the thermocline.*/ The temperature at the lower by-pass (62° F.) makes it difficult to believe that this is true. It is more reasonable to suppose that the water is taken from the uppermost portions of the thermocline or the lower portion of the epilimnion (an area of warm circulating water above the thermocline). In this event, a long period of very warm weather, accompanied by high winds, would raise the temperature of the water entering the intake structure to a degree dependent upon the duration of these weather conditions. However, existing data make it appear doubtful that a temperature would ever be attained at this low level which would be lethal to trout.

The temperature of the water immediately below Bond Falls was 63.7° F. on August 9 and 12, and 63° F. on August 20 (air temperatures ranged between 78 and 80° F.). At Agate Falls, on the latter date, the temperature was 62.5. One mile above the point where the Ontonagon River enters the reservoir, the temperature was 68.2° on August 9, 64.8° on August 12, and 71° on August 20. Considering the temperatures above the reservoir and in the by-pass just below it, the body of water is observed to have exerted a cooling effect on the stream, to the extent of 7°, 3.3° and 9° F. during the 3 days for which records are available.

There was insufficient warm weather during the summer of 1942 to permit the collection of data on the effect of the several flow stages on stream temperature. If it is assumed that the temperature of the water as it enters the river at the dam remains about the same, irrespective of high atmospheric temperatures, the volume of flow probably does have a significant effect on the temperature of the stream below the dam. The larger volumes of water of the higher flows, carried at a greater velocity, would be warmed less rapidly by high air temperatures than would the smaller volume of, for example, the 25 c.f.s. flow. However, for a distance of somewhat over 4 miles below Bond Falls, the stream is, for the most part, quite rapid, with almost no sluggish, slow moving reaches which might readily become too warm for trout. In this area, it is not thought that the volume of flow, as long as it remains at 25 c.f.s. or above, would have a critical bearing on the maintenance of suitable temperatures for trout, during a normal Upper Peninsula summer. Whether or not the increased velocity and greater volume of the higher flows would greatly improve temperature conditions in certain slow, sluggish sections of the stream is difficult to determine in the absence

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*/ A stratum of water of rapidly changing temperature, e.g. 1° C. per meter of depth, which does not freely mix with the upper waters and thus is not subject to changea in atmospheric temperature.

of further data. While on the surface it appears that a beneficial effect would be exerted, a factor which should be remembered is that the greater the volume of the water already in the stream, the less is the total cooling effect exerted by cold inflowing springs. Table III shows that during a period of apparently normal inflow between August 5 and August 22, the daily discharge at Agate Falls averaged 16.75 c.f.s. greater than at Bond Falls dam. Although a few very small streams enter the river between these points, the greater part of this increase is made up of spring water, entering the stream from the river bed itself or from its banks. During the period when this section of stream was mapped (July 8-18), temperatures taken in 13 typical springs ranged from 44 to 54°F., and averaged 49°F.. The average inflow for the period from August 5-22 would form 40.3 percent, 32.6 percent, 29.7 percent and 21.3 percent of the total flow at Agate Falls, when there is a discharge at Bond Falls of 25, 35, 40 and $62\frac{1}{2}$ c. f. s. respectively. The precise effect of the inflow of this spring water, at the rate of about 2 c. f. s. per mile, on the temperature during the various flow stages was not determined, and could not easily be determined with certainty. However, it seems logical to suppose that it would have a somewhat greater effect on the lower than the higher flows.

Effect of Stream Flow on Food Supply

Food production in a trout stream depends at least in part upon the area of bottom covered. Increased flows, which cover portions of the stream bottom which were previously exposed, add to the productive area of the stream. The extent to which increased area increases food production cannot be precisely stated. The fact that a 35 c. f. s. flow increases the area of stream bottom covered by 1.8% does not necessarily mean that food production is increased by that percentage. However, all the new area is of shallow depth and would be logically expected to support aquatic organisms. While the 0.85 acre which is added to the productive bottom with an increase in flow from 25 to 35 c. f. s. does not seem large, it might add significantly to the total food production in the stream. Further increases in flow would further increase production.

In appraising the effect of increased stream flows on food production, it should be remembered that an increased flow also implies an increased depth. Judging by work which has been done in other streams, bottom food production drops considerably in water of greater depth than 14 inches. Hence, although a given flow may add a certain area to the stream, it will decrease production in other areas by increasing the water depth above 14 inches. Two hundred thirty-three measurements of stream depth were made at 25 selected stations during the 4 flow periods discussed in this report. With an increase in flow of from 25 to 35 c. f. s., 5.6 percent of the measurements made changed from a depth below 14 inches to one above that depth; an increase in flow to 40 c. f. s. caused an additional 5.6 percent of the measurements to cross the 14-inch limit; with an increase to $62\frac{1}{2}$ c. f. s., a further 9.4 percent underwent the critical change in depth. Of the 233 measurements made, 48, or 20.6 percent, had increased from below 14 to above 14 inches with an increase in flow from 25 to $62\frac{1}{2}$ c. f. s..

Reference to Figure 3 will show that increase in depth over 14 inches at higher flows occurred almost entirely in the pools. Since the riffles have been shown to be the "larders" of the stream, food production at the higher flows would undoubtedly be greater since the area of riffle bottom is considerably increased and the amount of water deepened beyond 14 inches is negligible.

In connection with the study of food conditions in the Ontonagon River, a number of square-foot samples of bottom organisms were obtained to determine the quantitative and qualitative nature of the bottom fauna. Table IX shows the contents of each sample collected. Identifications and measurements were made by Dr. J. W. Leonard, in charge of the Hunt Creek Experiment Station, to whom the writer is indebted for much of the material included in this section of this paper.

Since the samples were taken very late in the season, many of the insects had emerged, and the very early growth stages of the nymphs and larvae which were found lacked sufficient volume to reach the probable spring and early summer standards for the stream. The 6 samples for which a record is shown averaged 552 organisms in number and 1.592 c.c. in volume. However, the large number of blackfly larvae in Sample Number 6 had a considerable effect upon this average. Judged by a standard commonly employed to evaluate food production in a stream, one of the samples was exceptionally rich (volume greater than 2 c.c., number of organisms greater than 50), three were of average richness (volume from 1 to 2 c.c., number greater than 50) and two were poor in food (volume less than 1 c.c.). It should be noted that all samples had at least three times more organisms (in number) than is required to meet the common standard for "exceptional richness". The samples are insufficient in number to permit conclusions for the stream as a whole. General observations made by the writer and others during the course of the summer lead to the conclusion that the samples taken are representative and that this stream in the area studied is considerably better than average in food production.

It cannot be stated that any given orgamism or organisms found in the bottom samples would thrive better at one flow than another (between the limits of 25 and $62\frac{1}{2}$ c. f. s.). Although no intensive data were obtained, general observation of the stream makes it appear evident that there remain suitable ecological conditions for all, and the continuation of any flow over a period of time would permit the bottom fauna to satisfactorily adapt itself.

It should be emphasized that fluctuation in water level, within the 25 to $62\frac{1}{2}$ c. f. s. flow range, or within greater range, is decidedly destructive to much of the bottom fauna. The extent of the harm is probably roughly proportional to the amount, suddenness and frequency of the fluctuation.

At a given water level which has continued for a period of time, insects normally adjust themselves to their environment by seeking out the proper water depths, speed of current, and bottom type most favorable to them. Any fluctuation in the depth of the water and velocity of the current brings about changes in a given habitat for which the bottom fauna must make readjustments. Besides a general disturbance to the entire ecological set-up of the stream, a sudden drop in the water level may cause the immediate destruction of some portion of the bottom fauna. Among the insects found in the Ontonagon River, certain Caddis (such as Mystrophora americana, the Molannidae, and the Sericostomatidae) which occupy cases of sand or other materials, cemented to submerged objects, and marl or mud-burrowing forms, (such as marl beetles and certain cranefly larvae) are left stranded to die or are otherwise adversely affected by suddenly decreasing water levels. All of these have some importance in trout diet (although the marl beetle is not frequently directly available to trout). Large numbers of insects which live in very shallow water near shore are also likely to be left to perish by suddenly lowered water levels. Many species of the midge family (Chironomidae) for example (generally speaking the most important single group of insects in the diet of trout)* are most abundant in very shallow water, and cannot but suffer severe losses with suddenly lowered water levels.

Although it is of course true, that water fluctuation occurs in all streams, to various degrees, it is generally a rather gradual process, which is much less destructive to insect life than is sudden fluctuation. It should be stressed that it would be a distinct advantage to the bottom fauna of the Ontonagon River if fluctuations were held to a minimum, and if necessary fluctuations, particularly drops in water level were made somewhat gradually, rather than abruptly. An inspection of the graph (Figure 1) showing the flow of water into the Ontonagon River from Bond Falls Reservoir reveals a few striking examples of what should be avoided if possible, if the establishment and maintenance of optimum conditions for trout in the stream is to be achieved. On April 17, for example, water rose from 29 c. f. s. to 815 c. f. s., and 1230 c. f. s. a day later. By April 21, the flow had dropped to little more than half its previous flow

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*The relatively small numbers of Chironomidae found in the Ontonagon samples is probably explained by the fact that, at the time the samples were taken, most species had very recently emerged as adults. Later or earlier samples would doubtless reveal their presence in quantity in both still and fast areas, in gravel and in silt bars.

(730 c.f.s.); on the 26th it was down to 205; on the 28-30th it was back up to 930, but had again dropped to 280 c.f.s. by May 2. On May 6 it was back up to 1230, only to be dropped to a mere 30 c.f.s. on May 12 and 13. On May 18 it went back up to 930 c.f.s.. It dropped to 205 for several days, from May 24-29; it was pushed up to 930 for the period from June 6-11, finally settling down to about 40 c.f.s. for the subsequent month. It is fluctuation such as this which most seriously disturbs ecological conditions in the stream, and is highly destructive to bottom organisms. Sudden recession of the water level may leave many forms stranded and sudden increases in flow may wash a high percentage of organisms away.

In addition to the study of the possible effects of stream flow on the bottom fauna in the stream, a number of stomachs of trout taken by angling during August and September were examined, to determine the availability of terrestrial insects to trout during late summer, and to determine the relationship in trout diet between insects of aquatic origin and those of terrestrial origin. The results, as compiled by Dr. Leonard, are shown in Table XI. The table shows that terrestrial insects and spiders made up only 3.3 percent of the total volume of food taken by 11 trout. Over 85 percent of the total volume was made up of the larvaie, pupae, and adults of _Hydropsyche_ sp.*. (Aquatic Diptera would doubtless be more important earlier in the summer and during the winter than they are in late summer or fall. Mayflies would probably also bulk larger in these seasons).

The large amount of bottom food in the stomachs indicates that even in summer, terrestrial insects may be of minor importance; they cannot be depended upon to make up for losses in bottom food which might be brought about by disturbed ecological conditions. This requirement of bottom food throughout the year reflects again the desirability of controlling excessive water fluctuation.

Effect of Stream Flow on Vegetation.

Vegetation in a stream derives its chief importance from food production and the provision of shelter for fish. In the case of the Middle Branch, throughout the 11 miles of stream studied, it is so scant that it is of negligible value to the stream. It is estimated that well over 90 percent of the vegetation which is present and is covered at a flow of $62\frac{1}{2}$ c.f.s.

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* The larvae of this species, which reach a large size, construct a sort of pen of gravel with an opening upstream across which they spin a net. The larva lies behind the net and feeds on small organisms caught therein. Largely a riffle type, they are abundant on stones, submerged logs, and other debris large enough to support their nets.

is likewise adequately covered and thriving at 25 c. f. s.. It is true however, that a flow of 62½ c. f. s. causes the spread of water over a restricted number of quiet, silty areas which would eventually produce beds of vegetation. Promotion of the growth of vegetation cannot, however, be pointed out as being highly beneficial to the stream. The examination of stomach and bottom samples, previously discussed, reveals that the stream can safely be considered essentially a "caddis" stream. As such, its riffles areas are always doubtless more productive than silt bars, weed beds and other quiet water areas. Although aquatic vegetation may harbor valuable fish-food supplies in predominantly quiet-flowing stream, vegetation is not regarded as being highly important, either actually or potentially, in the attainment and maintenance of good conditions for trout in the section of stream with which this paper deals.

Effect of Stream Flow on Fishing.

Most creel census returns for the fishing in the Ontonagon River during the 1942 season were collected by Conservation Officers as part of the general creel census, and have not yet been tabulated. It is highly probably that the stage of the water level, between the limits of 25 and 62½ c. f. s., once it becomes stabilized, has less effect upon anglers' success than have other factors, such as weather, time of day, water temperature, presence or absence of a "hatch", etc. In any event, it would be extremely difficult to demonstrate the effect of stage of flow on quality of the fishing. It is not attempted here.

The summary of a few creel census records collected by the writer is included here to give a general idea of the quality of fishing in the Middle Branch during some portions of the summer of 1942.

From June 26 to July 4, when the water was at a flow stage of about 40 c. f. s., 22½ hours of angling produced 97 trout, or 4.3 fish per hour. These included 72 brook trout (average size, 7.6 inches) 23 rainbows (8.7 inches) and 2 brown trout (8 inches).

From July 7-14, during a flow stage of 25 c. f. s., 28 3/4 hours of fishing yielded 114 trout, or 4 fish per hour. Included were 43 brook trout (8 inches), 64 rainbows (9 inches) and 7 browns (6 inches).

During the high water period from July 19 to August 1, 14½ hours of fishing produced 25 fish, or 1.7 fish per hour. Five brook trout (8 inches) and 20 rainbows (8.4 inches) made up the catch.

It is the opinion of the writer that, on the average, during the 1942 season, trout fishing on the section of the Middle Branch with which this paper deals, left little to be desired by any fair-minded angler.

Because it properly comes in this section of the report, and not for particular re-emphasis, it should perhaps be repeated that some sections of the stream become very difficult to wade at flows of over 40 c. f. s.. The somewhat greater depth and considerably increased current velocity of the $62\frac{1}{2}$ c. f. s. flow, for example (as compared to the 40 c. f. s. flow) adds very materially to the treacherousness of a slippery, boulder-strewn, rubble-covered bottom.

No data for comparison of the effect of the various flows on the clearness of the water were obtained. During August, after the 25 c. f. s. flow had been in progress for a full week, and no intervening rain had occurred, two fishermen who have fished the stream a great deal during the past 15 years were heard to agree that the river was then the clearest they had ever seen it. Higher flows caused an obvious reduction in transparency. However, none of the higher flows was maintained for a sufficient period to allow silt, debris, etc., removed from the newly submerged shore areas, to settle out. No doubt once a stabilized condition prevailed, the water would be almost equally clear at the higher flows. The water transparency, in the ranges within which it normally occurs in the Middle Branch probably has little significant effect upon condition for trout, clearness of the water is frequently thought to affect quality of fishing, in that extremely clear water makes deception of trout with artificial lures somewhat more difficult than would otherwise be the case. It is for this reason that it has been briefly discussed here.

Effect of Stream Flow on Conditions for Trout in Winter.

Figure 16 is a photograph taken downstream toward Station 1 (see Figures 12-15) on March 25, 1942, during a flow of 27 c.f.s.. An ice shelf is seen to have formed along both shores of the river. This occurred in a number of sections of the river, and the ice persisted for a period of months. At Station 1, on March 6, 1942, the shelf was 18 feet wide along the left (s.w.) shore in the photograph, and 8 feet 9 inches wide along the other. Station 2 showed no ice shelf, but Station 18 had an ice shelf of 11 feet, 4 inches in width along one shore and one 4 feet wide along the other. The ice shelf at Station 19 was 4 feet wide along one shore and 6 feet wide along the other. This ice shelf has some function in offering shelter and protection for trout during the winter months, when cold water temperatures (making the trout less active than in other seasons) and (usually) very clear water combine to the advantage of some of the trout's natural enemies. The effect of stream flow (within the limits of the 25 and $62\frac{1}{2}$ c.f.s. stages) on the formation of an ice shelf is not known. Although the high current velocities of the $62\frac{1}{2}$ c. f. s. flow might be expected to inhibit the formation of an ice shelf, some of the best-developed ice shelves at the 27 c. f. s. flow were found in the faster reaches of stream. Insofar as it affects condition for trout, ice shelf formation would be expected to be equally satisfactory at any of the flows studied.

On March 6, 1942, temperature of the water as it flowed from the lower (principal) by-pass below the dam was 35.2° F.. It is possible that the flow of somewhat warmer water from the lower levels of the reservoir (temperatures in the reservoir during winter are shown in Table I) impedes to some degree the formation of anchor ice in the stream below during extremely cold weather in mid-winter. In this respect the higher flows would be expected to exert a somewhat greater effect than the lower volumes of flow, since the former would cool less readily than the latter to freezing temperatures.

CONCLUSIONS AND RECOMMENDATIONS

An inspection and analysis of the data which have been collected during the 4 stages of flow discussed above reveals that the margin of superiority of any one flow over any other, in providing good condition for trout, is not outstanding. However, each higher flow contributes somewhat to the value of the stream for trout, by increasing the area of bottom covered, and thus presumably, the food production in the stream. Since the higher flows tested showed no harmful effects to the stream which would nullify this favorable effect, the logical choice of flow for providing the best condition for trout in the Middle Branch, would be the 62½ c.f.s. flow.

As compared to the 25 c.f.s. flow, it adds 39.1 inches to the width of the stream, which adds 3.3 acres, or 7% to the area of covered stream bottom, between Bond and Agate Falls. This should increase significantly the total food production in the stream. Increase in depth of pools, though not very great (3.83 inches over the 25 c.f.s. flow, judging by 25 pool gauge readings) contributes substantially to the shelter provided by at least some of the pools in the river. Population studies on other Michigan streams have shown that the deeper the pool the greater the number of legal sized trout present.

The greater volume and current velocity of the 62½ c.f.s. flow very probably would have a beneficial effect on temperature, reducing somewhat the effect of warm air temperatures on the relatively cold water entering the stream from Bond Falls Reservoir. However, the part which spring water would play in having a cooling effect on the river would be reduced by the greater volume of flow, as has been discussed above.

Though of secondary importance in turbulent waters (as has been explained above) the 62½ c.f.s. flow would, in general, facilitate the growth of vegetation in quiet areas which it floods.

The condition of the stream for trout in winter would be little affected, as near as can be determined, by any of the 4 flows studied.

The increased difficulty in wading the stream at a 62½ c.f.s. flow would perhaps be some disadvantage to fishermen.

Advantages of the 62½ c.f.s. flow over the 35 and 40 c.f.s. flow are of the same character as those shown for the 25 c.f.s. flow, except that they are less pronounced. Each successive higher flow has similar advantages over the preceding lower flow.

In concluding that the 62½ c.f.s. flow is best for trout, water requirements of the Copper District Power Company have not been considered. If it is established that the Company has the right to divert water from the Middle Branch, the problem is to determine how this may be accomplished with the least disadvantage to trout fishing.

As previously mentioned, the average flow into Bond Falls Reservoir for the period from August 6 to 21 was 126.5 c.f.s. However, the discharge for the last day (August 21) was the lowest of the group (106 c.f.s.), and there was a decrease in discharge for the entire period following August 6. The river was quite evidently still somewhat swollen due to excessive rains in mid-July. Normal average summer inflow probably is well under 100 c.f.s. The average daily discharge of the diversion canal during the period from Sept. 1, 1941 to August 31, 1942, was 64 c.f.s. If 62½ c.f.s. are used for the Middle Branch, and 64 c.f.s. are required for power purposes, an extended dry period (with inflow going below 100 c.f.s.) would certainly severely tax the storage facilities of the reservoir. An evaluation of the possible effects of a power shortage on the industry of the area concerned is not meant to be a part of this paper. However, from the fisheries standpoint, it is highly advantageous to have the reservoir as nearly full as possible at all times especially in mid-summer. A substantial decrease in level of the reservoir during a long dry period (doubtless accompanied by much warm weather) might very possibly cause a significant warming of the water in the stratum of the reservoir from which water for the Middle Branch is drawn, with serious effects upon the trout population in the stream.

If the belief is shared by Power Company Officials that a 62½ c.f.s. flow might jeopardize the maintenance of reasonably high water levels in the reservoir in summer, it is recommended that a 40 c.f.s. flow be maintained in the river, rather than a 62½ c.f.s. flow.

The 40 c.f.s. flow adds 17.6 inches to the average width of the stream (as compared to a 25 c.f.s. flow), thus contributing an estimated 1.5 acres, or 3.24 percent, to the area of stream bottom covered between Bond and Agate Falls. The depth of the stream is increased about 1.6 inches. It is presumed that a 40 c.f.s. flow could be readily maintained, since the average flow for the 5 months (in year Sept., 1941-August, 1942) during which no water passed over the spillway, was 41 c.f.s. (Sept., 31 c.f.s.; Oct., 77 c.f.s.; Jan., 39 c.f.s.; Feb., 30 c.f.s.; Mar., 28 c.f.s.).

Although the margin of superiority of the 40 c.f.s. flow over the 35 c.f.s. flow is slight, the additional 5 c.f.s. are well worth retaining since it so happens that they contribute more to the area of stream bottom covered than any other given 5 c.f.s. between the limits of 25 and 62½ c.f.s. (insofar as can be determined from existing data). This is shown in Table XI. With respect to depth, all flows contribute roughly equal amounts, per 5 c.f.s. of increased flow.

Even though a $62\frac{1}{2}$ c.f.s. flow has certain advantages over the 40 c.f.s. flow, as discussed above, the latter still appears to be a very good second choice. This opinion is based upon the fact that the stream is almost undoubtedly from "high average" to exceptionally rich in bottom food, as judged by general observations and the several bottom samples examined which were earlier discussed. All trout observed by the writer during the summer of 1942 were in excellent condition, and almost all showed rich supplies of mesenteric fat. Under conditions of a stabilized 40 c.f.s. flow, it seems highly probable that food supply would not be a major limiting factor in determining numbers and condition of the trout population of the section of the river with which this report is concerned.

It is recommended that officials of the Copper District Power Company be asked to use all possible means to stabilize the flow of water into the Middle Branch at whatever volume is chosen, whether it be 40 or $62\frac{1}{2}$ c.f.s.. Return to normal flows after the spring run-off should be a relatively gradual process, roughly paralleling the gradually decreasing flows of a natural stream during the same period. This is equally true of changes in flow at other times of the year. Large, sudden and frequent changes in flow which were made during the spring of 1942 should be avoided. By making use of the daily flow measurements which will be recorded by instruments of the U. S. Geological Survey at a point about 1 mile above the reservoir, in the Middle Branch, it should be possible to judge more accurately than heretofore the needs of the reservoir, and to better regulate the flow into the river from it. The maintenance of a stabilized flow whenever that is possible - the reduction of fluctuation to a minimum- is one outstanding contribution which the Copper District Power Company can make to the improvement of condition for trout in the section of the Middle Branch of the Ontonagon Reservoir with which this paper has dealt.

INSTITUTE FOR FISHERIES RESEARCH

by Paul Eschmeyer

Report approved by: A. S. Hazzard

Table I

Water Temperatures and Dissolved Oxygen in Bond Falls Reservoir

	3/5/42		8/9/42	8/24/42	9/1/42	
Depth	Temp.	O_2	Temp.	Temp.	Temp.	O_2
Surface	32.2	...	70.9	66.7	...	...
3	...	...	69.4	...	70.2	...
6	...	...	69.3	...	70.2	...
9	...	...	68.7	65.7	69.4	...
10	32.4	11.2	...	...	...	...
12	...	...	68.0	64.8	69.3	...
15	...	...	66.7	64.6	68.7	...
18	...	...	66.0	64.2	67.4	7.4
20	34.5	10.0	...	...	...	...
21	...	...	65.5	64.0	64.8	6.5
24	...	...	64.4	64.0	64.0	...
26	35.2	...	...	...	...	...
27	...	...	55.6	60.8	63.0	2.9
30	36.3	5.4	51.4	52.3	54.3	0.7
Pond elevation, feet	136.9		140.5	139.5	140.2	

Table II

A Record of Daily Flows from Bond Falls Reservoir
into the Middle Branch of the Ontonagon River
and into the South Branch Diversion Canal
from September 1, 1941 to August 31, 1942.
(From figures provided by the
Copper District Power Company).

Date	Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
1941		
September 1	40	0
2	40	0
3	35	0
4	35	0
5	35	0
6	35	0
7	30	0
8	30	0
9	30	0
10	30	0
11	30	0
12	30	0
13	30	0
14	30	0
15	30	0
16	30	0
17	30	0
18	30	0
19	30	0
20	30	0
21	30	0
22	30	0
23	30	0
24	30	0
25	30	0
26	30	0
27	30	0
28	30	0
29	30	0
30	30	0
Total for month	940	0
Average daily flow	31	0
October 1	30	0
2	30	0
3	30	0
4	30	0
5	30	0
6	30	0
7	30	0
8	30	0
9	30	0

(Continued)

Table II

(Continued)

Date		Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
October	10	30	0
	11	55	0
	12	55	0
	13	90	0
	14	90	0
	15	105	0
	16	105	0
	17	105	0
	18	105	0
	19	105	50
	20	105	57
	21	105	58
	22	105	80
	23	105	89
	24	105	90
	25	105	90
	26	105	90
	27	105	108
	28	105	129
	29	105	136
	30	105	166
	31	105	166
Total for month		2,375	1,309
Average daily flow		77	42
November	1	305	166
	2	355	166
	3	355	166
	4	355	73
	5	255	60
	6	255	60
	7	125	60
	8	105	60
	9	105	60
	10	105	60
	11	105	60
	12	80	60
	13	202	0
	14	202	0
	15	202	0
	16	202	0
	17	202	0
	18	202	0
	19	202	0
	20	252	0
	21	252	0
	22	252	0
	23	252	0

(Continued)

Table II

(Continued)

Date	Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
November 24	254	0
25	252	0
26	252	0
27	252	0
28	252	0
29	252	0
30	212	0
Total for month	6,653	1,051
Average daily flow	222	35
December 1	202	0
2	152	0
3	90	0
4	40	0
5	40	0
6	40	0
7	40	0
8	115	0
9	115	0
10	115	0
11	115	0
12	115	0
13	115	0
14	115	0
15	115	0
16	120	0
17	82	0
18	52	53
19	52	97
20	52	104
21	52	104
22	52	104
23	202	124
24	74	130
25	74	130
26	74	130
27	74	130
28	74	130
29	74	70
30	74	70
31	39	56
Total for month	2,735	1,432
Average daily flow	88	46
1942		
January 1	39	52
2	39	52
3	39	52

(Continued)

Table II

(Continued)

Date	Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
January 4	39	52
5	39	52
6	39	112
7	39	202
8	39	44
9	39	16
10	39	27
11	39	52
12	39	92
13	39	96
14	39	112
15	39	52
16	39	36
17	39	36
18	39	36
19	39	36
20	39	36
21	39	36
22	39	36
23	39	36
24	39	36
25	39	36
26	39	36
27	39	52
28	39	65
29	39	84
30	39	109
31	39	144
Total for month	1,209	1,915
Average daily flow	39	62
February 1	39	153
2	39	195
3	39	197
4	39	197
5	39	197
6	39	197
7	39	197
8	39	197
9	39	197
10	29	197
11	25	197
12	25	197
13	25	197
14	25	197
15	25	193
16	25	190
17	25	190

(Continued)

Table II

(Continued)

Date	Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
February 18	25	190
19	25	187
20	25	187
21	25	187
22	25	187
23	25	187
24	25	184
25	25	184
26	25	184
27	25	181
28	25	181
Total for month	830	5,324
Average daily flow	30	190
March 1	25	181
2	25	178
3	25	178
4	25	178
5	30	178
6	30	178
7	30	178
8	30	175
9	30	172
10	30	172
11	30	169
12	30	166
13	30	166
14	30	163
15	30	163
16	30	163
17	30	160
18	30	160
19	30	160
20	30	160
21	27	160
22	27	160
23	27	160
24	27	119
25	27	79
26	27	79
27	27	79
28	27	17
29	27	0
30	27	0
31	27	0
Total for month	877	4,251
Average daily flow	28	137

(Continued)

Table II

(Continued)

Date		Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
April	1	27	0
	2	27	0
	3	27	0
	4	27	0
	5	27	0
	6	27	0
	7	27	0
	8	127	0
	9	27	0
	10	27	0
	11	27	0
	12	27	0
	13	27	0
	14	27	0
	15	27	0
	16	30	0
	17	815	0
	18	1,230	0
	19	1,230	0
	20	1,230	0
	21	730	0
	22	630	0
	23	625	0
	24	618	0
	25	205	0
	26	205	0
	27	355	0
	28	930	0
	29	930	0
	30	930	0
Total for month		11,198	0
Average daily flow		373	0
May	1	780	0
	2	280	0
	3	280	0
	4	280	0
	5	795	0
	6	1,230	0
	7	930	0
	8	930	0
	9	930	0
	10	930	0
	11	605	0
	12	30	0
	13	30	0
	14	205	0

(Continued)

Table II

(Continued)

Date		Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
May	15	400	0
	16	530	0
	17	530	0
	18	930	0
	19	930	0
	20	530	0
	21	530	0
	22	530	0
	23	330	0
	24	205	0
	25	205	0
	26	205	0
	27	205	0
	28	205	0
	29	205	0
	30	330	0
	31	330	0
Total for month		14,435	0
Average daily flow		496	0
June	1	530	0
	2	530	0
	3	530	0
	4	630	0
	5	745	0
	6	930	0
	7	930	0
	8	930	0
	9	930	0
	10	930	0
	11	930	0
	12	930	0
	13	380	0
	14	359	0
	15	365	19
	16	200	47
	17	215	22
	18	78	14
	19	65	11
	20	45	11
	21	40	0
	22	40	0
	23	145	0
	24	40	50
	25	40	70
	26	40	105
	27	40	130
	28	40	160

(Continued)

Table II

(Continued)

Date		Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
June	29	40	191
	30	40	252
Total for month		11,687	1,082
Average daily flow		390	36
July	1	42	252
	2	42	252
	3	42	154
	4	42	154
	5	25	154
	6	25	154
	7	25	154
	8	25	154
	9	25	154
	10	25	154
	11	25	154
	12	25	154
	13	25	208
	14	25	289
	15	25	311
	16	25	273
	17	25	75
	18	25	6
	19	366	6
	20	861	6
	21	930	6
	22	930	6
	23	640	6
	24	432	6
	25	472	6
	26	518	6
	27	518	6
	28	346	6
	29	130	6
	30	257	6
	31	277	43
Total for month		7,191	3,321
Average daily flow		232	107
August	1	277	57
	2	189	58
	3	27	123
	4	26	137
	5	25	175
	6	25	197
	7	25	198
	8	25	198
	9	25	198

(Continued)

Table II

(Continued)

Date		Flow to Ontonagon River, in c.f.s.	Flow to South Branch, in c.f.s.
August	10	25	198
	11	25	198
	12	30	198
	13	35	198
	14	35	198
	15	38	197
	16	40	196
	17	40	196
	18	50	196
	19	63	195
	20	63	198
	21	63	198
	22	63	69
	23	63	9
	24	52	9
	25	40	9
	26	40	9
	27	40	9
	28	40	9
	29	40	9
	30	40	9
	31	40	9
Total for month		1,603	3,857
Average daily flow		52	124

(Continued)

Table II

(Continued)

Summary of Monthly Totals and Daily Averages

Month	River		Canal	
	Monthly total	Daily average	Monthly total	Daily average
September, 1941	940	31	0	0
October	2,375	77	1,309	42
November	6,653	222	1,051	35
December	2,735	88	1,432	46
January, 1942	1,209	39	1,915	62
February	830	30	5,324	190
March	877	28	4,251	137
April	11,198	373	0	0
May	14,435	496	0	0
June	11,687	390	1,082	36
July	7,191	232	3,321	107
August	1,603	52	3,857	124
Totals for year	61,733	2,058	23,542	779
Monthly average	5,144	...	1,962	...
Daily average for year	...	169	...	64

Table IV

Width and Depth Measurements Taken at 25 Stations in the Ontonagon River During Flows of 25, 35, 40 and $62\frac{1}{2}$ c.f.s., August, 1942.

Station 1 (Riffle)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet:								
		45	40	35	30	25	22	14	9	6
		Depths in inches:								
25	4 ft. 7 1/4 in.	7/8	11	20	16 3/4	17 3/4	16 1/4	2 1/4	5	11
35	4 ft. 7 1/4 in.	2 1/4	13 1/2	21 1/2	18	16	13 3/4	3 1/2	7 3/4	8 3/4
40	4 ft. 6 in.	3 1/4	13	22 3/4	18	17 1/4	14	4 1/4	9 1/4	12 1/4
62 1/2	4 ft. 6 in.	5 7/8	16	25 1/2	21	20 1/2	16 1/2	6	11	12 1/2
*30	2 ft. 6 in.	4	12	19 1/2	20	12	7 3/4	8	...	9

* March 6, 1942. Spring run-off had obviously made some changes in the stream bottom, between the time of this measurement and those made for the other flows.

Station 2 (Pool)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet:								
		40	35	30	25	20	15	10	5	
		Depths in inches:								
25	6 ft. 2 in.	4	8	17	19 3/4	22	23	23 1/2	11 1/2	
35	5 ft. 9 1/2 in.	5 1/8	10 1/4	18 3/4	21	23	24 1/2	25	13 1/4	
40	5 ft. 8 in.	6	11	19 1/2	22 1/4	24 1/2	24 1/2	24 1/4	15 3/4	
62 1/2	5 ft. 2 1/2 in.	8 1/2	14	23	25 1/4	29	29 1/4	28 1/2	18 3/4	
*30	6 ft. 8 in.	3 1/2	10	19 1/2	18 3/4	22	24 3/4	25	5 3/4	

* March 6, 1942. See footnote for Station 1.

Table IV
(Extension)

Station 1

Distance in feet and inches from blaze on tree to water's edge
5 ft. 1 3/4 in.
4 ft. 10 1/2 in.
4 ft. 10 in.
3 ft. 3 in.
4 ft. 0 in.

Station 2

Distance in feet and inches from blaze on tree to water's edge
1 ft. 4 in.
1 ft. 0 1/2 in.
1 ft. 0 in.
0 ft. 7 in.
1 ft. 10 in.

(Continued)

Table IV

(Continued)

Station 3 (Pool)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 5	10	15	20	25	30	35	40	45	
		Depths in inches:									
25	2 ft. 0 in.	7 1/2	11 1/2	11 1/4	12 3/8	14	13 1/4	10 1/4	10 1/2	6 1/4	
35	1 ft. 9 3/4 in.	9	12 1/2	11 3/4	12 3/4	14 3/4	16 1/2	13 1/2	10	9 1/2	
40	1 ft. 9 3/4 in.	6 1/2	13	12 3/4	13	15	16 1/2	13 1/2	10	10	
62 1/2	1 ft. 3 1/2 in.	8	16	15	15 3/4	18	20	17	13 1/4	...	

Station 4 (Pool)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 10	15	20	25	30	35	40	45	50	55
		Depths in inches:									
25	14 ft. 3 in.	...	1 3/4	6 1/2	7 3/8	13 1/4	11 1/2	11 7/8	19	13 1/2	4 7/8
35	13 ft. 7 3/4 in.	...	2 3/4	7 3/4	10	12 1/2	13	14 1/2	20 1/4	14 3/4	5 7/8
40	11 ft. 1 in.	...	2 3/4	8 1/4	12	15 1/4	16	16 1/4	21	16 3/4	6 1/8
62 1/2	8 ft. 10 in.	1/2	3 1/2	10	12 1/4	17	15	18	20 1/2	15 1/2	7 7/8

Station 5 (Riffle)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 45	40	35	30	25	20	15	10		
		Depths in inches:									
25	2 ft. 1 3/4 in.	1 3/4	7	17 3/8	21 1/4	20 1/2	17 3/4	1 5/8	3/4		
35	1 ft. 10 1/2 in.	3 1/8	7 3/4	19	22 1/2	22	19	3	1 3/4		
40	1 ft. 10 1/2 in.	3 3/4	7	19 1/4	22 3/4	21 1/4	19 1/2	3 1/2	2 1/2		
62 1/2	1 ft. 9 1/2 in.	...	11	21 1/2	24 3/4	23 1/4	22 1/4	5 1/4	4 3/4		

Table IV
(Extension)

Station 3

	Distance in feet and inches from blaze on tree to water's edge
	2 ft. 8 in.
	1 ft. 9 in.
	1 ft. 9 in.
	1 ft. 9 1/4 in.

Station 4

	Distance in feet and inches from blaze on tree to water's edge
	2 ft. 7 1/2 in.
	1 ft. 11 1/2 in.
	1 ft. 2 1/2 in.
	1 ft. 2 1/2 in.

Station 5

	Distance in feet and inches from blaze on tree to water's edge
	8 ft. 5 in.
	7 ft. 9 in.
	7 ft. 9 in.
	7 ft. 5 in.

(Continued)

Table IV
(Continued)

Station 6 (Riffle)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5
		Depths in inches:									
25	5 ft. 0 in.	...	3 1/2	2	8 1/4	9 3/4	7 1/2	3/8	9 3/8	5 3/8	1 1/8
35	5 ft. 0 in.	...	5	3	9 1/4	11	10	1 1/2	11 3/4	6 1/4	1 3/4
40	5 ft. 0 in.	...	5 1/2	2 1/8	9 1/2	11 1/2	...	3	10	7	1 3/8
62 1/2	4 ft. 3 1/2 in.	1	7	2 3/4	11	14 1/2	15 1/2	3 1/2	13 3/4	8 3/4	4 1/4

Station 7 (Pool)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 5	10	15	20	25	30	35	40	45	
		Depths in inches:									
25	4 ft. 9 1/2 in.	3/8	12	25 1/2	22 1/2	12 5/8	12	10	5 3/4	1 3/4	
35	4 ft. 2 in.	1 1/2	14 3/4	26 1/2	24 1/8	13 1/2	14	11	7	3 1/8	
40	4 ft. 0 in.	1 7/8	14	27 1/2	25 1/8	15 1/2	14 1/2	12 1/4	7 3/4	3 7/8	
62 1/2	3 ft. 3 in.	3 3/4	14	29 1/4	27	18	17	14 1/2	9 7/8	5 1/2	

Station 8 (Riffle)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 60	55	50	45	40	35	30	25	20	15	10
		Depths in inches:										
25	6 ft. 11 in.	3 1/2	6 1/2	2 1/2	5 1/4	3 1/2	3 1/2	4	3 1/2	6 1/2	8 3/4	17 1/2
35	6 ft. 10 in.	4 1/4	7 1/8	5 1/2	5	4 1/4	3 3/4	5 1/2	7	7 1/2	11	17 1/4
40	6 ft. 9 in.	4 1/4	6 3/4	5 3/4	6	3 3/4	4 1/2	5 1/2	6 1/2	7 1/2	10	18 1/2
62 1/2	5 ft. 9 1/2 in.	5 3/4	8 1/2	6 3/4	7	5 1/4	5 1/2	7 3/4	9 1/4	11	13 1/4	19

Table IV
(Extension)

Station 6

	Distance in feet and inches from blaze on tree to water's edge
	3 ft. 3 1/2 in.
	3 ft. 2 in.
	2 ft. 1 in.
	1 ft. 4 1/2 in.

Station 7

	Distance in feet and inches from blaze on tree to water's edge
	5 ft. 10 in.
	4 ft. 9 in.
	4 ft. 0 in.
	2 ft. 10 in.

Station 8

5	Distance in feet and inches from blaze on tree to water's edge
8 3/4	3 ft. 4 in.
8 1/2	2 ft. 10 1/2 in.
10 1/4	2 ft. 9 in.
10	2 ft. 6 in.

(Continued)

Table IV
(Continued)

Station 9 (Pool)

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 45	40	35	30	25	20	15	10	5	
		Depths in inches:									
25	10 ft. 0 3/4 in.	1 1/2	6 7/8	10 1/2	12	11 1/2	18 3/4	18 3/4	16	13 3/4	
35	9 ft. 5 in.	1 7/8	8 3/4	10 1/2	12 1/2	13 1/2	20 1/2	20 1/2	17	15	
40	9 ft. 5 in.	3	8	11	11 3/4	14 3/4	21 1/2	21	17	14 1/2	
62 1/2	8 ft. 8 1/2 in.	6	11 7/8	13 1/4	16	14 1/2	20 1/4	23	20	16	

Station 10

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 45	40	35	30	25	20	15	10	5	
		Depths in inches:									
25	6 ft. 8 in.	13	16 1/4	20 1/2	23 1/2	22 1/8	21 1/8	15 1/8	17 1/8	7 3/4	
35	6 ft. 5 in.	13 3/4	14 1/2	21 1/2	24 1/4	23 1/2	23	22 3/8	18	10 1/4	
40	6 ft. 5 in.	14 1/8	14 7/8	22	24	24	23 1/2	23	18	10 7/8	
62 1/2	6 ft. 5 in.	15 3/4	16 3/4	24 1/2	27	26	25	25	20 1/4	11	

Station 11

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5
		Depths in inches:									
25	3 ft. 7 in.	...	14 1/2	18	18 7/8	17 1/4	13 3/4	13	15	8 3/4	3 1/4
35	3 ft. 2 in.	1	16	19 1/4	19 1/2	18 1/4	14 1/4	14 1/2	16 1/2	10	4 1/2
40	3 ft. 0 in.	2	16 1/2	20 1/4	20	19	15 1/4	14 1/2	16 1/4	10 1/2	4 3/4
62 1/2	2 ft. 5 1/2 in.	4	18 3/4	22 1/2	22	21 1/4	17	17	18 1/4	12	6 3/4

Table IV
(Extension)

Station 9

	Distance in feet and inches from blaze on tree to water's edge
	2 ft. 8 in. 2 ft. 5 in. 2 ft. 4 in. 2 ft. 4 in.

Station 10

	Distance in feet and inches from blaze on tree to water's edge
	2 ft. 8 in. 2 ft. 7 in. 2 ft. 7 in. 1 ft. 7 1/4 in.

Station 11

	Distance in feet and inches from blaze on tree to water's edge
	2 ft. 8 in. 2 ft. 2 1/2 in. 2 ft. 1 1/2 in. 1 ft. 9 1/2 in.

(Continued)

Table IV
(Continued)

Station 12

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 65	60	55	50	45	40	35	30	25	20	15
		Depths in inches:										
25	7 1/2 in.	3 5/8	9 1/2	10 3/4	11 1/4	10	7 7/8	6	6 5/8	5 3/8	4 3/8	4
35	7 in.	3 3/8	9 1/4	12 1/2	13 1/4	10 1/2	9	7	7 1/4	5 5/8	5 1/8	4 3/4
40	4 in.	4 1/8	10	13	13 3/4	11	7 1/2	7 3/4	7	6 1/4	5 1/2	4 3/4
62 1/2	3 1/2 in.	4 1/2	12 1/4	14 3/4	15	11 1/2	11	9 1/2	8 1/2	7 1/2	6 7/8	6

Station 13

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 55	50	45	40	35	30	25	20	15	10	5
		Depths in inches:										
25	6 ft. 10 in.	...	5 1/2	9 1/4	12 1/4	10 3/4	10 1/2	11	10 3/4	8 1/2	3	3 3/4
35	6 ft. 5 in.	...	6 1/2	10 1/8	13 1/4	12 1/2	11 3/4	12	12 1/4	9 1/2	3 1/8	5 3/8
40	6 ft. 1 1/4 in.	...	7 3/8	10 3/4	14 1/4	13	12	12 3/4	12 1/2	10 1/2	9 1/4	6
62 1/2	3 ft. 8 in.	1 1/2	10	13	16 1/2	15 3/4	14 1/4	15 1/4	15 1/4	12 1/4	10 1/2	8 1/2

Station 14

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 45	40	35	30	25	20	15	10	5		
		Depths in inches:										
25	4 ft. 2 in.	...	3 1/4	6	9 3/4	14 1/2	15 3/4	12 3/4	5	...		
35	3 ft. 10 in.	1 1/4	4	7	9 3/4	14	16 3/4	14	6	...		
40	3 ft. 7 in.	...	4 1/2	7 1/4	11 1/4	15 1/2	16 3/4	14 3/4	6 1/2	...		
62 1/2	1 ft. 11 in.	5	8	10	14 1/2	17	20 1/2	17 3/4	8 1/4	1/8		

(Extension)

Table IV

Station 12

	Distance in feet and inches from blaze on tree to water's edge
	13 ft. 11 in. 13 ft. 10 in. 13 ft. 8 in. 13 ft. 7 in.

Station 13

	Distance in feet and inches from blaze on tree to water's edge
	3 ft. 4 in. 2 ft. 11 in. 2 ft. 7 in. 2 ft. 7 in.

Station 14

	Distance in feet and inches from blaze on tree to water's edge
	7 ft. 9 in. 7 ft. 2 1/2 in. 6 ft. 5 in. 4 ft. 7 in.

(Continued)

Table IV
(Continued)

Station 15

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5	
		Depths in inches:										
25	19 ft. 7 in.	...	...	7	14 1/4	21 1/4	22	30 1/4	20 1/4	11 3/8	8 1/4	
35	17 ft. 11 in.	...	1/2	10	13	22	23	32	18 1/2	12 1/2	11	
40	13 ft. 5 in.	...	1/2	10 1/2	18 1/2	22 1/2	23 1/2	32	19 1/2	11	7 7/8	
62 1/2	9 ft. 10 in.	1 1/2	2 1/2	13	21 3/4	23	24 1/2	34 1/4	20 3/4	15	10 1/4	

Station 16

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5	
		Depths in inches:										
25	0 ft. 11 1/2 in.	20 1/4	30	32 1/2	29	25 1/2	21	13 1/8	8 3/8	3 1/4	...	
35	0 ft. 9 in.	21 1/2	32	35	31 1/4	27 3/4	21 1/2	12 3/4	8 7/8	4 3/4	...	
40	0 ft. 9 in.	21	31 1/4	35	31 3/4	28 1/8	21 3/4	12 7/8	9 1/4	5 1/4	...	
62 1/2	0 ft. 2 in.	23 1/4	34 3/4	38	33 3/4	30 1/8	23	16 1/2	12	8 3/4	1 1/4	

Station 17

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 65	60	55	50	45	40	35	30	25	20	15
		Depths in inches:										
25	5 ft. 10 in.	2 3/4	2 1/2	2 1/4	4 1/4	6 1/2	7	9 1/2	11	10 1/4	6 1/2	10 1/4
35	5 ft. 5 in.	4	2 7/8	3 1/2	5 3/4	8	8	11	12 1/2	11 1/2	7	10 3/4
40	5 ft. 4 1/2 in.	4 1/2	4 3/8	4 1/4	6 1/4	8	9 1/4	13	13	12	8	11 1/4
62 1/2	5 ft. 0 in.	6	6 1/2	5 1/2	7	10 1/2	10	13	13	13 1/4	9 1/4	12 3/4

See next page

Table IV
(Extension)

Station 15

		Distance in feet and inches from blaze on tree to water's edge
		3 ft. 3 in.
		3 ft. 3 in.
		3 ft. 3 in.
		3 ft. 3 in.

Station 16

		Distance in feet and inches from blaze on tree to water's edge
		8 ft. 3 in.
		7 ft. 5 in.
		6 ft. 9 1/2 in.
		4 ft. 2 1/2 in.

Station 17

		Distance in feet and inches from blaze on tree to water's edge
10	5	
12 1/2	3 1/8	3 ft. 8 in.
11	4	3 ft. 5 in.
12 1/2	4	3 ft. 4 1/2 in.
13	6	3 ft. 2 in.

(Continued)

Table IV
(Continued)

Station 18

See next page

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 65	60	55	50	45	40	35	30	25	20	15
		Depths in inches:										
25	1 ft. 1 1/2 in.	...	17 1/4	20	12 1/4	12 1/4	15	15 3/4	7 7/8	23 1/2	31 3/4	24 1/4
35	1 ft. 1 1/4 in.	...	18 1/2	16 1/2	17 3/4	13 1/4	15	17 1/4	8 1/2	19 1/4	32 3/4	25
40	1 ft. 1 in.	2 1/4	20 1/4	21 1/4	14 1/2	14 3/4	15 1/2	16 1/2	8 1/2	22	33 1/2	25 1/2
62 1/2	1 ft. 0 in.	4	22	22	19 1/4	15 1/2	16	18 3/4	10	21 3/4	34	27 1/2
*30	0 ft. 4 in.	3	13	15 1/2	22	17	2	5 1/2	15	26	28 1/2	15 1/2

*March 6, 1942. See footnote for Sta. 1.

Station 19

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 55	50	45	40	35	30	25	20	15	10	5
		Depths in inches:										
25	0 ft. 9 in.	5	14 1/2	7	1 1/2	2 3/4	3 1/4	3/8	1 1/4	4 1/4	7	10 1/2
35	0 ft. 8 1/2 in.	7	13	8 1/4	1 1/2	3	5 3/4	1 1/2	2 1/4	4 1/2	8 1/2	11 1/4
40	0 ft. 3 in.	6 1/2	14	8 1/4	1 3/4	3 1/4	6	1 7/8	2	5 1/2	8 1/2	11 5/8
62 1/2	0 ft. 3 in.	6 1/4	12	10 1/4	2 1/2	3 1/4	6 3/4	2 3/4	3 1/4	7 1/4	10 3/4	14
*30	0 ft. 8 in.	...	15 1/2	9 1/2	2	2 1/2	6 1/2	3	2 1/2	6	10 1/2	13

*March 6, 1942. See footnote for Sta. 1.

Station 20

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 55	50	45	40	35	30	25	20	15		
		Depths in inches:										
25	0 ft. 9 1/2 in.	13 1/4	26 1/2	26	24 1/2	17	16 1/8	8 7/8	1 3/8	...		
35	0 ft. 4 in.	15	31	26 1/2	25 1/2	20 3/4	17 1/2	9 1/8	3 3/8	...		
40	0 ft. 1 in.	15 1/4	32	26	25 1/2	21	18	10 1/2	3 1/2	...		
62 1/2	0 ft. 5 in.	17 1/2	34	29 3/4	28 1/2	23 1/2	20 1/2	11 3/4	5 3/4	1		

Table IV
(Extension)

Station 18

10	Distance in feet and inches from blaze on tree to water's edge
14 1/2	6 ft. 2 in.
15 3/4	5 ft. 11 in.
16 1/8	5 ft. 8 1/2 in.
18	5 ft. 8 1/2 in.
15	5 ft. 0 in.

Station 19

	Distance in feet and inches from blaze on tree to water's edge
	0 ft. 5 in.
	0 ft. 3 in.
	0 ft. 2 in.
	0 ft. 2 in.
	0 ft. 0 in.

Station 20

	Distance in feet and inches from blaze on tree to water's edge
	17 ft. 10 in.
	16 ft. 7 1/2 in.
	16 ft. 5 in.
	11 ft. 11 in.

(Continued)

Table IV
(Continued)

Station 21

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 40	35	30	25	20	15	10	5		
		Depths in inches:									
25	10 ft. 11 in.	3 1/2	10 1/2	12 1/2	9	7 1/4	11	6	4 1/4		
35	8 ft. 8 in.	6	14	...	10 3/4	8 1/4	12	6 1/4	4		
40	8 ft. 7 in.	4 3/4	13 3/4	18 3/4	9 1/2	9 1/2	12 1/2	7	5		
62 1/2	8 ft. 2 in.	6	14	19	13	10 1/2	15	8 1/2	6 3/4		

Station 22

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 40	35	30	25	20	15	10	5		
		Depths in inches:									
25	4 ft. 7 in.	6 1/2	14 1/4	19 1/2	27 1/4	27	26	9 1/4	...		
35	4 ft. 3 in.	8	13 1/2	19 1/2	29	28 1/4	26 1/4	10 3/4	...		
40	4 ft. 0 1/2 in.	8 1/2	13 3/4	19 3/4	29 1/2	28	26 1/2	11 1/4	...		
62 1/2	3 ft. 1 in.	10 1/4	15 1/4	21 3/4	31 1/2	29 1/2	22	13 1/2	1		

Station 23

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5
		Depths in inches:									
25	3 ft. 2 1/2 in.	2 1/4	12 1/2	9 1/2	9 1/2	6 3/4	7 1/2	3 1/4	1 1/4	1/2	4 1/4
35	3 ft. 1 in.	3	13	10 1/2	10	8	8 1/2	3 1/4	2	1 1/2	6
40	3 ft. 0 in.	3 1/8	13	10 3/4	10	8	9	3 3/4	2 1/4	2 3/4	6
62 1/2	2 ft. 11 in.	4 1/2	15 1/4	13	11	9 1/2	9	5 3/4	3 1/2	5 1/4	9

Table IV

(Extension)

Station 21

Distance in feet and inches from blaze on tree to water's edge
1 ft. 6 1/2 in.
1 ft. 4 1/4 in.
1 ft. 0 1/2 in.
0 ft. 9 in.

Station 22

Distance in feet and inches from blaze on tree to water's edge
6 ft. 1 in.
6 ft. 0 in.
5 ft. 7 in.
4 ft. 8 in.

Station 23

Distance in feet and inches from blaze on tree to water's edge
2 ft. 3 in.
2 ft. 0 in.
1 ft.11 in.
1 ft. 5 in.

(Continued)

Table IV
(Continued)

Station 24

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	5
		Depths in inches:									
25	4 ft. 10 in.	...	13 3/4	17 1/4	20 1/4	25 1/2	30 1/2	33 3/4	25 1/4	13 1/4	2 1/4
35	4 ft. 1 3/4 in.	...	14 3/4	19	20 3/4	26 1/4	32 1/2	32	24 3/4	12	1 1/2
40	4 ft. 1 1/2 in.	...	14 3/4	19	20 3/4	27 1/2	32 1/2	35 1/8	26 1/2	16 3/8	2
62 1/2	3 ft. 4 in.	2 1/4	17	20 3/4	23 1/4	28 3/4	34 1/2	37	28 3/4	17	4 1/2

Station 25

Flow period, c.f.s.	Distance in feet and inches from blaze on tree to water's edge	Tape readings, feet: 50	45	40	35	30	25	20	15	10	
		Depths in inches:									
25	3 ft. 5 in.	7 1/2	14	15 1/2	12	7	6 1/2	3	...	...	
35	3 ft. 1 1/2 in.	9	15 1/2	16 1/2	14 1/2	10 1/2	6 1/2	4 3/4	...	...	
40	3 ft. 1 in.	8 1/4	16	17	13 1/2	10	7 1/2	4 3/4	...	...	
62 1/2	2 ft. 11 1/2 in.	12	17 3/4	19 1/4	15 1/2	12 1/4	10	6 1/2	1/4	1	

Station 24

Distance in feet and inches from blaze on tree to water's edge
3 ft. 11 in.
3 ft. 10 in.
3 ft. 10 in.
3 ft. 7 in.

Station 25

Distance in feet and inches from blaze on tree to water's edge
17 ft. 4 in.
16 ft. 3 in.
16 ft. 2 in.
6 ft. 11 in.

Table V

Increase in Width of Stream and Average Increase
in Depth, with an Increase in Flow

I. Pools

Station	Location: Distance below Bond Falls (Miles)	Width at 25 c.f.s. (ft. - in.)	Increase in width of stream (inches)			Average increase in depth (inches)		
			25 to 35	35 to 40	40 to 62½	25 to 35	35 to 40	40 to 62½
2	0.4	42 - 8	8	2	10 1/2	1.52	0.92	3.59
3	0.6	46 - 10	13 1/4	0	6 1/2	1.49	0	2.84
4	1.7	44 - 9	15 1/4	39 3/4	27	1.47	1.44	0.67
7	2.4	42 - 4	20 1/2	11	23	1.44	0.79	1.83
9	3.2	42 - 10	10 3/4	1	8 1/2	1.17	0.26	2.04
10	3.4	45 - 8	4	0	11 3/4	1.57	0.36	1.88
11	5.2	47 - 9	10 1/2	3	10 1/2	1.18	0.68	2.05
16	6.8	43 - 7	12 1/2	7 1/2	38	1.39	0.13	2.60
18	8.2	59 - 0	3 1/4	2 3/4	1	1.33	0.81	1.53
	(Below Agate Falls)							
20	0.1	41 - 5	10	7 1/2	58	1.83	0.25	2.44
22	1.4	36 - 11	5	7 1/2	22 1/2	0.79	0.21	1.07
24	1.8	35 - 8	9 1/4	1/4	12 1/2	0.19	1.22	1.89
	Sums of variates	529 - 7	122 1/4	82 1/4	229 3/4	137.50 ✓	65.38 ✓	215.50 ✓
	Averages	44 - 1	10.2	6.9	19.1	1.20	0.61	2.03

✓ Sum of the increases for all stations shown. For the 35 c.f.s. flow, 106 measurements were made; for the 40 c.f.s. flow, 107, and for the 62½ c.f.s. flow, 106.

Table VI

Increase in Width of Stream and Average Increase
in Depth, with an Increase in Flow

II. Riffles

Station	Location: Distance below Bond Falls (miles)	Width at 25 c.f.s. (ft. - in.)	Increase in width of stream (inches)			Average increase in depth (inches)		
			25 to 35	35 to 40	40 to 62½	25 to 35	35 to 40	40 to 62½
1	0.2	40 - 9	3 1/4	1 3/4	19	0.46	1.00	2.32
5	2.0	37 - 0	11 1/4	0	5 1/2	1.27	0.23	2.36
6	2.3	46 - 9	1 1/2	13	17	1.36	0.06	1.69
8	3.1	60 - 11	6 1/2	2 1/2	14 1/2	0.82	0.22	1.69
12	5.4	53 - 8	1 1/2	5	1 1/2	0.75	0.27	1.52
13	5.5	49 - 6	10	7 3/4	29 1/4	1.19	1.20	2.29
14	5.6	37 - 3	10 1/2	12 1/2	42	0.64	0.71	2.79
15	5.7	42 - 3	20	54	43	0.92	0.43	2.13
17	6.9	71 - 10	8	1	7	0.88	0.81	1.18
19	8.2	56 - 9	2 1/2	6 1/2	0	0.83	0.32	0.93
	(Below Agate Falls)							
21	0.14	38 - 5	29 1/4	4 3/4	8 1/2	1.39	0.11	1.50
23	1.5	48 - 6	4 1/2	2	7	0.85	0.29	1.71
25	1.9	35 - 8	16 1/2	1 1/2	112 1/2	1.68	0.00	2.32
	Sums of variates	619 - 3	125 1/4	112 1/4	306 3/4	118.00 ✓	55.50 ✓	220.40 ✓
	Averages	47 - 7	9.63	8.63	23.59	0.96	0.45	1.78

✓ Sum of the increases for the 13 stations. For the 35 c.f.s. flow, 123 measurements were made; for the 40 c.f.s. flow, 123; for the 62½ c.f.s. flow, 124.

Table VII

Summary of Increase in Width of Stream and Average Increase in Depth, with an Increase in Flow

III. Pools and Riffles

	Width at 25 c.f.s. (Ft. - In.)	Increase in width of stream (Inches) 25 to 35 c.f.s.	35 to 40 c.f.s.	40 to 62½ c.f.s.	Average increase in depth (Inches) 25-35	35-40	40-62½
Pools	44 - 1	10.20	6.90	19.10	1.20	0.61	2.03
Riffles	47 - 7	9.63	8.63	23.59	0.96	0.45	1.78
Average	46 - 0	9.90	7.74	21.50	1.12	0.53	1.90

Table VIII

Effect of an Increase in Flow on the Depth of 25 Pools in the Ontonagon River

Gage No.	Location: Distance below Bond Falls in miles	Distance from surface of water to top of gage, in inches				Increase in depth of pools (in inches)		
		25 c.f.s.	35 c.f.s.	40 c.f.s.	62½ c.f.s.	25 to 35 c.f.s.	35 to 40	40 to 62½
1	0.00	12	10 3/8	9 3/4	6 3/4	1 5/8	5/8	3
2	0.30	15 5/8	14 1/8	14 1/4	12 3/8	1 1/2	1/8	1 7/8
3	0.40	18 1/8	17	16 1/2	14	1 1/8	1/2	2 1/2
4	1.80	8 3/4	7 3/4	7 1/2	5 3/4	1	1/4	1 3/4
E	2.30	14 1/4	13 1/8	12 5/8	10 1/2	1 1/8	1/2	2 1/8
7	2.40	8 1/2	7 3/8	6 3/4	4 7/8	1 1/8	5/8	1 7/8
F	3.20	9 3/4	8 1/2	7 3/4	5 1/8	1 1/4	3/4	2 5/8
H	3.30	11 7/8	10 3/4	10 1/4	8	1 1/8	1/2	2 1/4
D	3.33	8 3/8	7 1/8	6 1/2	3 7/8	1 1/4	5/8	2 5/8
K	3.50	22 3/8	20 7/8	20 1/4	17 1/8	1 1/2	5/8	3 1/8
8	5.30	13 1/4	12 3/8	12	10 1/2	7/8	3/8	1 1/2
9	5.40	14 7/8	13 5/8	12 7/8	10 1/2	1 1/4	3/4	2 3/8
I	5.50	8 7/8	7 7/8	7 1/8	4 3/4	1	3/4	2 3/8
O	5.60	11 7/8	10 1/2	10 1/4	7 1/2	1 3/8	1/4	2 3/4
A	6.70	14 7/8	13 1/2	12 7/8	10	1 3/8	5/8	2 7/8
B	6.80	10 3/4	9 1/2	8 7/8	6 1/2	1 1/4	5/8	2 3/8
G	7.00	10	9 3/8	9	7 1/2	5/8	3/8	1 1/2
C	8.00	10	9	8 5/8	6 3/4	1	3/8	1 7/8
	Distance below Agate Falls							
M	0.00	27	26 3/8	26	25	5/8	3/8	1
J	0.15	14 7/8	14	13 3/8	11 3/4	7/8	5/8	1 5/8
X	0.20	11 5/8	10 3/4	10 1/4	8 1/4	7/8	1/2	2
P	0.30	13 7/8	13	12 5/8	11	7/8	3/8	1 5/8
N	1.40	15 1/8	14 1/4	14 3/8	11 3/4	7/8	1/8	2 5/8
L	1.50	17 5/8	16 1/4	15 7/8	13 1/4	1 3/8	3/8	2 5/8
T	1.60	11 1/8	9 1/2	9 1/8	6 3/4	1 5/8	3/8	2 3/8
				Sums of increases (inches)		28.5	12.00	55.375
				Average increases (inches)		1.14	0.48	2.21

Table IX

Contents of Six Square-foot Bottom Samples Taken in the Ontonagon River, August 24-September 3, 1942.
(Identifications and Measurements by Dr. J. W. Leonard)

Square-foot bottom sample No. 1.
Ontonagon River, 1/4 mile above Agate Falls.
Rubble, 12 inches deep.
September 3, 1942

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Mollusca (Snails and clams)			
Sphaerium sp.	1	1	Trace
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Stenonema rivulicolum	1	1	Trace
Rhithrogena sp.	1	15	0.025
Paraleptophlebia sp.	1	1	Trace
Ephemerella invaria	1	3	Trace
Baetis spp.	2	25	0.025
Plecoptera (Stoneflies)			
Acroneuria sp.	1	1	0.125
Coleoptera (Beetles)			
Elmidae - A	1	1	Trace
- L	1	10	0.025
Trichoptera (Caddisflies)			
Mystrophora americana	1	83	0.025
Hydropsyche spp.	2	14	0.025
Sericostomatidae	1	4	Trace
Brachycentrus nigrisoma	1	2	Trace
Diptera (Flies, midges, etc.)			
Simulium venustum - L	1	1	Trace
- P	1	1	Trace
Chironomidae	2	5	Trace
Hydracarina (Water mites)	1	1	Trace
Totals	18	169	0.250

A = Adult; L = Larva; P = Pupa.

Table IX

(Continued)

Square-foot bottom sample No. 2.
Ontonagon River, 1/2 mile above Agate Falls.
Rubble and gravel riffle, 8 inches deep.
September 3, 1942.

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Annelida (Worms)			
Oligochaeta	1	1	Trace
Mollusca (Snails and clams)			
Physa sp.	1	1	0.050
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Rhithrogena sp.	1	17	...
Paraleptophlebia sp.	1	2	...
Ephemerella invaria	1	8	0.025
Baetis spp.	2	15	...
Plecoptera (Stoneflies)			
Acroneuria sp.	1	3	Trace
Coleoptera (Beetles)			
Elmidae - A	1	4	Trace
- L	1	9	Trace
Trichoptera (Caddisflies)			
Mystrophora americana	1	36	0.025
Hydropsyche spp.	2	39	0.125
Leptoceridae	1	1	Trace
Limnephilidae	1	2	Trace
Sericostomatidae	1	3	Trace
Brachycentrus nigrisoma	1	2	Trace
Diptera (Flies, midges, etc.)			
Eriocera sp.	1	4	0.050
Chironomidae - L	4	16	Trace
- P	1	1	Trace
Ceratopogonidae	1	1	Trace
Totals	24	165	0.275

Sample also contained 1 Cottus, 44 mm. T. L.

(Continued)

Table IX

(Continued)

Square-foot bottom sample No. 3.
Ontonagon River, 1 mile below Bond Falls.
Riffle, 11 inches deep, gravel and rubble.
August 25, 1942.

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Mollusca (Snails and clams)			
Sphaerium sp.	1	3	0.025
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Stenonema rivulicolum	1	2	Trace
Rhithrogena sp.	1	1	Trace
Paraleptophlebia sp.	1	2	Trace
Ephemerella invaria	1	24	Trace
Baetis vagans	1	40	0.050
Baetis sp.	1	15	Trace
Neuroptera (Hellgrammites, etc.)			
Chauliodes nigricornis	1	2	0.500
Odonata (Dragonflies)			
Ophiogomphus sp.	1	1	Trace
Plecoptera (Stoneflies)			
Acroneuria sp.	1	1	Trace
Coleoptera (Beetles)			
Elmidae - A	2	2	0.025
- L	1	4	Trace
Trichoptera (Caddisflies)			
Mystrophora americana	1	123	0.050
Hydropsyche sp. 1	1	9	0.025
Hydropsyche sp. 2	1	39	0.075
Mollanidae	1	1	0.025
Sericostomatidae	2	4	Trace
Brachycentrus nigrisoma	1	3	Trace
Diptera (Flies, midges, etc.)			
Antocha saxicola	1	1	Trace
Eriocera sp.	1	8	0.200
Simulium venustum	1	8	Trace
Chironomidae	3	20	Trace
Atherix variegata	1	8	0.150
Totals	27	321	1.125

(Continued)

Table IX

(Continued)

Square-foot bottom sample No. 4.
Ontonagon River, 1 mile above Bond Falls
Gravel riffle, 8 inches deep.
September 3, 1942.

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Mollusca (Snails and clams)			
Sphaerium sp.	1	1	Trace
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Stenonema rivulicolum	1	5	Trace
Rhithrogena sp.	1	18	0.025
Paraleptophlebia sp.	1	1	Trace
Ephemerella invaria	1	7	Trace
Baetis vagans	1	66	0.075
Plecoptera (Stoneflies)			
Isogenus frontalis	1	1	Trace
Coleoptera (Beetles)			
Elmidae - A	1	7)	0.025
- L	1	30)	
Trichoptera (Caddisflies)			
Rhyacophila sp. - P	1	1	0.025
Mystrophora americana	1	35	0.025
Chimarrha aterrima	1	1	Trace
Hydropsyche spp.	2	190	0.600
Diptera (Flies, midges, etc.)			
Eriocera sp.	1	19	0.400
Simulium venustum	1	2	Trace
Chironomidae - L	3	11	Trace
- P	1	3	Trace
Atherix variegata	1	3	0.025
Totals	22	401	1.200

(Continued)

Table IX

(Continued)

Square-foot bottom sample No. 5.
Ontonagon River, 1/4 mile below Bond Falls.
Pool, gravel and rubble (near tail end of pool), 8 in. deep.
August 24, 1942.

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Mollusca (Snails and clams)			
Sphaerium sp.	1	4	0.025
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Baetis vagans	1	128	0.125
Ephemerella invaria	1	13	Trace
Coleoptera (Beetles)			
Elmidae - L	1	8	0.025
Trichoptera (Caddisflies)			
Hydropsyche sp. - L	1	104	0.850
Hydropsyche sp. - P	1	4	0.025
Psychomyiidae	1	3	Trace
Diptera (Flies, midges, etc.)			
Antocha saxicola	1	2	Trace
Eriocera sp.	1	9	0.350
Simulium venustum	1	52	0.050
Chironomidae - L	3	12	Trace
Chironomidae - P	1	3	Trace
Tabanus atratus	1	1	0.350
Atherix variegata	1	3	0.100
Totals	16	346	1.900

(Continued)

Table IX

(Continued)

Square-foot bottom sample No. 6.
Ontonagon River, 1/4 mile below Bond Falls.
Riffle, 9 inches deep.
August 24, 1942.

Organism	Number of species	Number of individuals	Volume in cubic centimeters
Platyhelminthes (Free-living flatworms)			
Planaria sp.	1	10	0.075
Mollusca (Snails and clams)			
Sphaerium sp.	1	3	0.025
Insecta (Insects)			
Ephemeroptera (Mayflies)			
Baetis vagans	1	47	0.050
Ephemerella invaria	1	3	Trace
Trichoptera (Caddisflies)			
Mystrophora americana - L	1	13	0.025
Mystrophora americana - P	1	1	Trace
Hydropsyche sp.	1	63	0.400
Psychomyiidae	1	1	Trace
Diptera (Flies, midges, etc.)			
Antocha saxicola	1	1	Trace
Eriocera sp.	1	6	0.200
Simulium venustum - L	1	1,737	3.925
Simulium venustum - P	1	17	0.050
Chironomidae	1	6	Trace
Atherix variegata	1	2	0.050
Totals	14	1,910	4.800

Table X
Contents of stomachs of 11 brook, brown and rainbow trout from the Ontonagon River, taken between August 4 and September 3, 1942.
(All species combined, as there was no discernible specific difference in diet)
(Identifications and measurements by Dr. J. W. Leonard).

Organism	No. individuals	Number stomachs with organism	Most organisms in any stomach	Least organisms in any stomach	Av. no. organisms in stomachs containing them	Per cent of total volume
AQUATIC ORIGIN						
Mollusca						
Gastropoda (Snails)	37	6	17	1	3.4	8.3
Ephemeroptera (Mayflies)						
Stenonema sp. - A	14	1	14	14	14.0	0.3
Baetis sp. - N	37	8	16	1	4.6	0.3
Baetis sp. - A	9	4	6	1	2.5	0.3
Hemiptera						
Corixidae (Water boatmen)	1	1	1	1	1.0	Trace
Coleoptera (Beetles)						
Hydrophilidae	1	1	1	1	1.0	Trace
Bidessus sp.	1	1	1	1	1.0	Trace
Trichoptera (Caddisflies)						
Hydroptilidae - L	14	6	7	1	2.3	Trace
- A	2	2	1	1	1.0	Trace
Mystrophora americana - L	3	2	2	1	1.5	Trace
- A	16	4	8	1	4.0	0.3
Hydropsyche sp. - L	409	10	149	1	40.9	34.0
- P	148	5	52	1	29.6	33.7
- A	69	7	47	1	9.8	17.9
Psychomyiidae - L	1	1	1	1	1.0	Trace
Sericostomatidae - L	5	5	1	1	1.0	Trace
- A	1	1	1	1	1.0	Trace
Diptera (True flies)						
Tipulidae - L	1	1	1	1	1.0	Trace
- A	1	1	1	1	1.0	Trace
Simulium venustum - L	22	7	12	1	3.1	0.3
- P	2	2	1	1	1.0	Trace
- A	22	2	21	1	11.0	1.3
Chironomidae - L	42	7	26	1	6.0	0.3
- P	4	2	3	1	2.0	Trace
- A	2	1	2	2	2.0	Trace
Empididae - A	1	1	1	1	1.0	Trace
TERRESTRIAL ORIGIN						
Homoptera (Aphids, etc.)						
Aphididae	21	1	21	21	21.0	1.3
Cicadellidae	1	1	1	1	1.0	Trace
Cercopidae	1	1	1	1	1.0	Trace
Membracidae	1	1	1	1	1.0	0.7
Hemiptera (True bugs)						
Miridae	1	1	1	1	1.0	Trace
Coleoptera (Beetles)						
Staphylinidae	1	1	1	1	1.0	0.3
Diptera (Flies)						
Family?	1	1	1	1	1.0	Trace

(Continued)

Table X

(Continued)

Organism	No. individuals	Number stomachs with organism	Most organisms in any stomach	Least organisms in any stomach	Av. no. organisms in stomachs containing them	Per cent of total volume
Hymenoptera (Ants, etc.)						
Formicidae	13	6	8	1	2.2	1.0
Araneae (Spiders)	1	1	1	1	1.0	Trace
						100.0

Note: Above percentages calculated on total volume of identifiable organisms.
Total volume of stomachs was: 91.3 per cent identifiable material.
8.7 per cent debris (plant, animal and inorganic.)

After names, L = Larva, N = Nymph, P = Pupa, A = Adult.

Table XI

Comparison of Effect of River Stages on Area of Bottom Covered
(in units of 5 c.f.s.)

Flow increase	Total increase in width, inches	Average increase in width, per 5 c.f.s. increase in flow	Average increase in acreage, per 5 c.f.s. increase in flow
25 to 35 c.f.s.	9.90	4.95	0.425
35 to 40 c.f.s.	7.74	7.74	0.660
40 to $62\frac{1}{2}$ c.f.s.	21.50	4.78	0.404

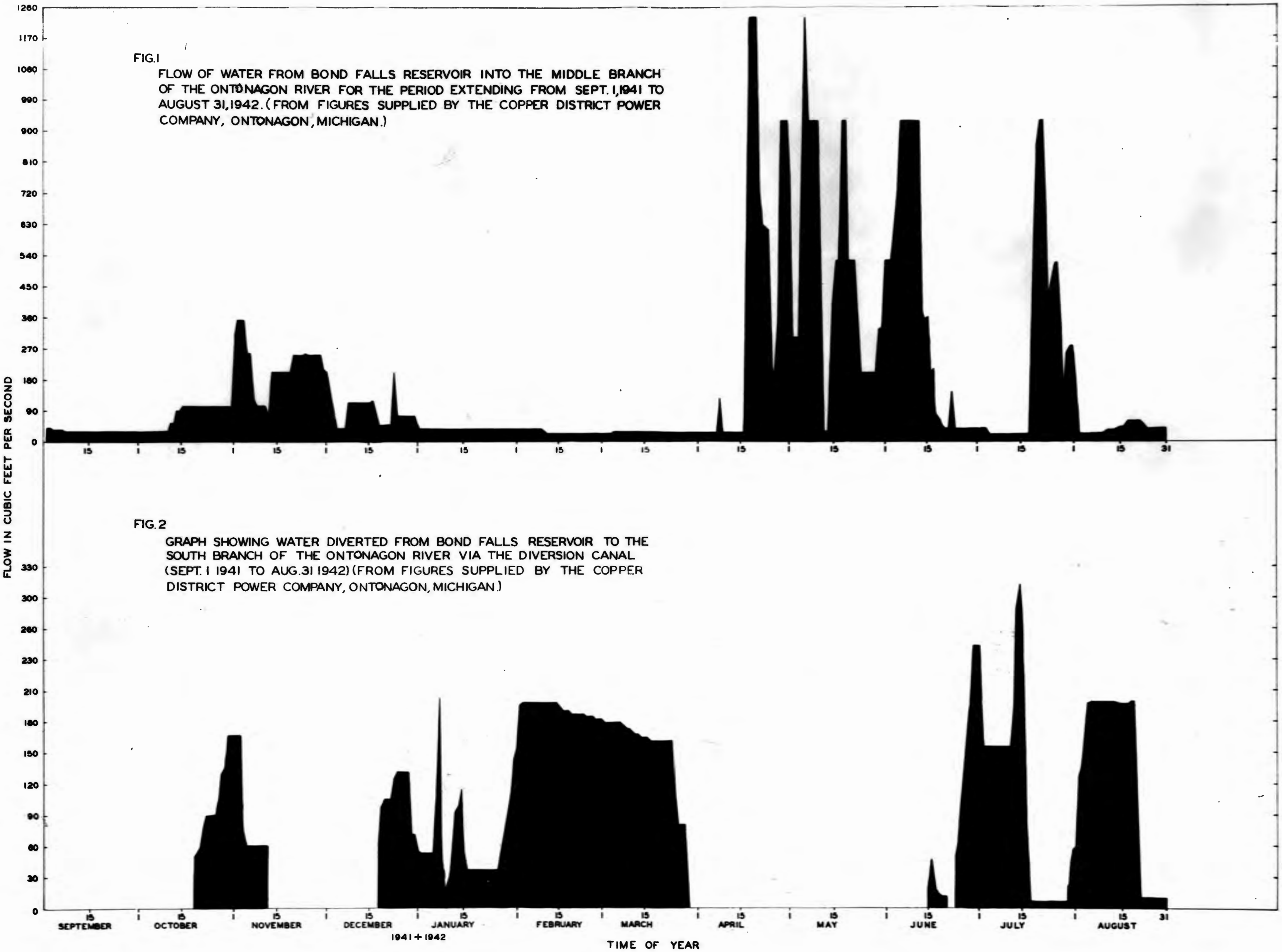

FIG. I
FLOW OF WATER FROM BOND FALLS RESERVOIR INTO THE MIDDLE BRANCH OF THE ONTONAGON RIVER FOR THE PERIOD EXTENDING FROM SEPT. 1, 1941 TO AUGUST 31, 1942. (FROM FIGURES SUPPLIED BY THE COPPER DISTRICT POWER COMPANY, ONTONAGON, MICHIGAN.)

FIG. 2
GRAPH SHOWING WATER DIVERTED FROM BOND FALLS RESERVOIR TO THE SOUTH BRANCH OF THE ONTONAGON RIVER VIA THE DIVERSION CANAL (SEPT. 1 1941 TO AUG. 31 1942) (FROM FIGURES SUPPLIED BY THE COPPER DISTRICT POWER COMPANY, ONTONAGON, MICHIGAN.)

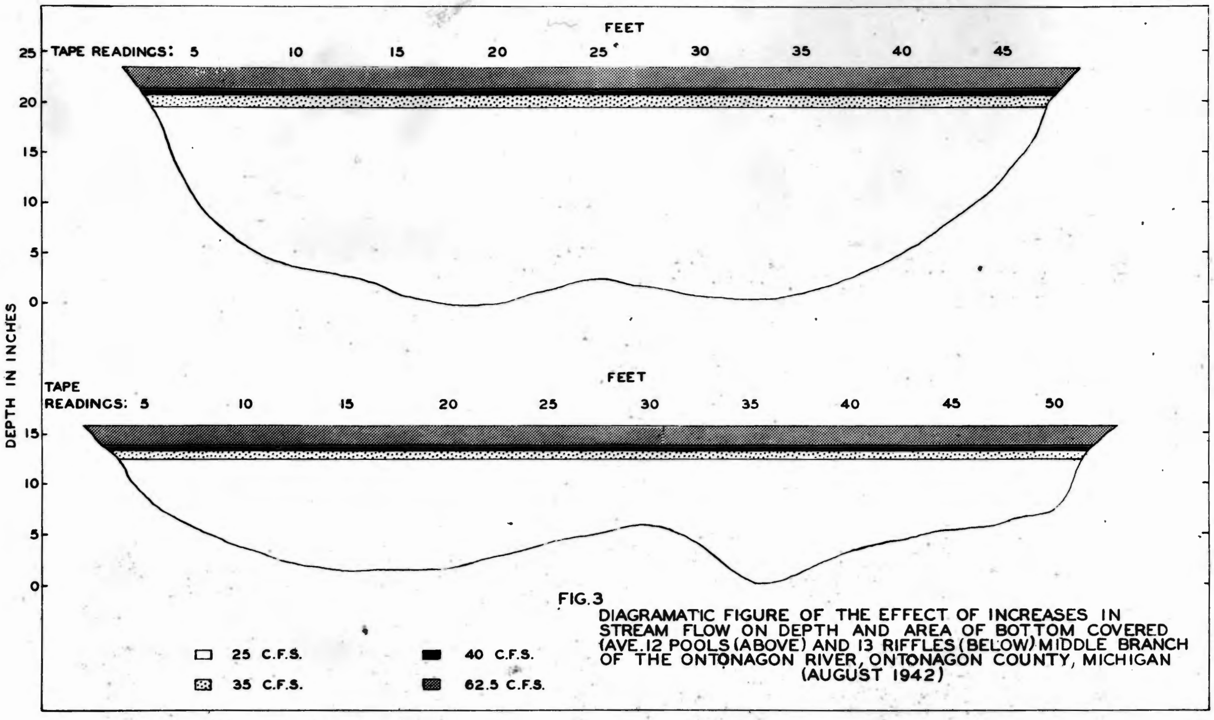

FIG.3
DIAGRAMATIC FIGURE OF THE EFFECT OF INCREASES IN STREAM FLOW ON DEPTH AND AREA OF BOTTOM COVERED (AVE. 12 POOLS (ABOVE) AND 13 RIFFLES (BELOW) MIDDLE BRANCH OF THE ONTONAGON RIVER, ONTONAGON COUNTY, MICHIGAN (AUGUST 1942)

Figure 4.-Pool below Bond Falls at a flow of 25 c.f.s.

Figure 5.-Pool below Bond Falls at a flow of 35 c.f.s.

Figure 6.-Pool below Bond Falls at a flow of 40 c.f.s.

Figure 7.-Pool below Bond Falls at a flow of 62 1/2 c.f.s.

Figure 8.-Station 8 at a flow of 25 c.f.s.

Figure 9.-Station 8 at a flow of 35 c.f.s.

Figure 10.-Station 8 at a flow of 40 c.f.s.

Figure 11.-Station 8 at a flow of 62 1/2 c.f.s.

Figure 12.-Station 1 at a flow of 25 c.f.s.

Figure 13.-Station 1 at a flow of 35 c.f.s.

Figure 14.-Station 1 at a flow of 40 c.f.s.

Figure 15.-Station 1 at a flow of 62 1/2 c.f.s.

Figure 16.-Looking downstream toward Station 1 on March 25, 1942. Note the extensive ice shelf on both sides of stream.