A STUDY OF THE CHANNELIZATION OF THE WEBER RIVER, SUMMIT COUNTY, UTAH

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James R. Barton, Department of Civil Engineering

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Final Report

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Utah Division of Wildlife Resources

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ABSTRACT

Construction of Interstate 80 in Henefer Valley, Utah resulted in channelizaiton of 1.6 miles of Weber River. In an attempt to alleviate some fo the adverse effects of channelization, instream rehabilitation structures in the form of deflectors and check dams were installed in the altered sections.

Because of these structures, hydrologic features in the changed portions of the river were similar to those of the unchanged areas. Holes were scoured around the structures and material was deposited below, forming riffle areas. There were as many holes and riffles in the changed sections as in the unchanged.

Channelized portions of the Weber River were rapidly populated by macroinvertebrates. After six months with substantial stream flows and stabilization of the substrate, no difference in numbers, weight, or species diversity could be detected between the benthos of the changed and the unchanged sections.

Fish population estimates were difficult to obtain due to the size of the river, high mobility of the fish, and low shocking efficiency especially at high discharges. Howeber, shocking data did indicate that fish populations were essentially the same in the changed and unchanged areas as a result of the rehabilitation measures taken. DeLury population estimates collected in 1972 indicate that the fish populations were similar in changed and unchanged areas and that shocking efficiency decreases as the number of holes and amount of cover increase. Fish populations were composed mainly of whitefish (80%) with cutthroat, rainbow, brown, suckers, and carp, making up the rest of the population.

Rehabilitation structures did provide holes and riffles in the changed sections, nevertheless, channelization should be avoided if at all possible since other deleterious effects still occur such as loss in stream length, loss of cover, loss in streamside vegetation and loss in aesthetic value.

INTRODUCTION

In 1968 construction was started on a new section of Highway I-80 in the area near Henefer, Utah. Five different sections of the Weber River were channelized as a result of this construction. In an attempt to alleviate some of the disastrous effects of channelization, a number of instream structures were placed in the new channels to create holes and riffle areas.

In order to evaluate the effectiveness of the channel rehabilitation measures, a research grant was awarded to Brigham Young University by the Utah Division of Wildlife Resources and the Utah State Department of Highways. This report is the result of studies carried on from June 1968 to July 1972. No pre-study on the Weber River was possible, since the research and construction began at the same time. For this reason channelized or changed sections were compared with sections of the river that were not altered by the present highway construction.

Originally eight study reaches were selected; 4 in changed sections and 4 in unchanged sections. However, due to access problems only five of the original sections were used throughout the study.

The main objectives of this study were:

1. To study the effects of the channel changes on the fish and invertebtate populations of the river.
2. To evaluate the hydraulic effectiveness of the various structures in creating a good fish habitat.
3. To compare the various types of structures used and make recommendations on their relative effectiveness.

4. To develop concepts that can be used in designing future projects where river channel changes are needed.

Review of Literature

Detrimental Effects of Channelization

The disastrous effect of channelization on the aquatic habitat is becoming a very prominant issue throughout the United States, and only recently, congressional subcommittee hearings were held concerning this problem (Reuss, 1971). Copious literature substantiates that channel alteration and realignment are detrimental to rivers and streams in all geographical areas (Arthur, 1936; Alexander, 1960; Alvord and Peters, 1963; Bagby, 1969; Bayless and Smith, 1964; Beland, 1953; Berryman, et al., 1962; Blackwelder, 1971; Broach, 1969; Buntz, 1969; Calhoun, 1966, 1967; Carter and Jones, 1969; Clark, 1944; Davidson, 1971; Davis, 1941; Einsele, 1957; Engehard, 1951; Fulton, 1970; Gangmark and Bakkala, 1959; Gebhards, 1970; Greene, 1950; Hales, 1960; Hynes, 1960; Irizarry, 1969; Peters and Alvord, 1964; Phenicie, 1954; Scheidt, 1967; Smith, 1968, 1971; Stuart, 1959; Swedberg and Nevala, 1964; Trautman, 1939; Warner and Porter, 1960; Welker, 1967; Whitney and Bailey, 1959). Probably one of the most detrimental effects of channelization is the loss in stream length (Peters and Alvord, 1964). Many states have lost numerous miles of stream as a result of channelization (Irazarry, 1969; Davidson, 1971; Gebhards, 1970; Larkin, et al., 1959). The loss of streamside vegetation, cover and shelter for fish is also an important aspect of channelization (Beland, 1953; Boussu, 1954). Channelization exposes a new substrate to the current, thus increasing sedimentation and siltation (Saunders and Smith, 1965;

Cordone and Kelley, 1961; Hansen and Muncy, 1971). This also produces an unstable substrate which hinders the establishment of algae and macroinvertebrate organisms (Ballinger and Mckee, 1971; Cummins and Lauff, 1969; Patrick, 1959). Increased sedimentation and silt are detrimental to the fisheries due to the abrasive and smothering action (Warner and Porter, 1960; Allen, 1960, 1961; Agnew, 1962; Hamilton, 1961). Increased sedimentation and siltation may also cause an increase in the instability of the substrate (Chutter, 1968). The loss in streamside vegetation which usually accompanies channelization can cause an increase in sedimentation (Scheidt, 1967; Fredericksen, 1970) as well as an increase in the stream temperature (Warner and Porter, 1960; Hansen and Muncey, 1971). The loss of streamside vegetation may effect the trophic structure of the acquatic environment due to a significant loss of basic food material entering the stream (Egglishaw, 1964; Warner and Porter, 1960). The overall aesthetic value of a channeled stream is effected, and the recreational utilization is reduced (Beland, 1953). Altered stream channels may show the effects for extended periods, and some may never recover (Bayless and Smith, 1964; Larimore, et al., 1959).

The recovery and establishment of invertebrates in channeled areas are dependent upon the stability of the substrate (Ballinger and McKee, 1971; Cummins and Lauff, 1969; Elder, 1969; Morgans, 1956; Patrick, 1959). Stream flow, season of the year, and life cycles of the organisms also play an important role in the establishment of organisms in denuded areas (Patrick, 1959). Colonization of denuded or channeled areas is accomplished mainly by invertebrate drift from undisturbed areas upstream (Waters, 1964; Crisp and Gledhill, 1970; Kennedy, 1955).

Rehabilitation of Altered Areas

Many attempts have been made to rehabilitate altered or unproductive stream channels. These attempts have often shown favorable results (Aitken, 1936; Burghduff, 1934; Burkhard, 1967; Clark, 1945; Croemiller, 1955; Cumming and Hill, 1971; Edminister, et al., 1949; Ehlers, 1956; Gard, 1961; Gee, 1952; Greely and Tarzwell, 1932; Hale, 1969; Harrison, 1962, 1963, 1964, 1965; Hazzard, 1935; Howard, 1971; Hubbs, 1932; Hubbs, Greely and Tarzwell, 1932; Hunt, 1968, 1971; Jester and McKirdy, 1966; Johnson, 1967; Leonard, 1940; Little, 1965; Mueller, 1954; Mullan, 1962; Mullan and Barrett, 1962; O'Donnell and Threinen, 1960; Otis (no date); Richards, 1963; 1964; Robinson and Mendendez, 1964; Saunders and Smith, 1962; Schuyler, 1971; Shetter, et al., 1946; Swedberg and Nevala, 1964; Tarzwell, 1932, 1937, 1938; Taube, 1967; Trautman, 1939; Warner and Porter, 1960; White and Brynidson, 1967; Wilkins, 1960).

The most common rehabilitation method used is the placement of structures in the stream channel to alter the current (Warner and Porter, 1960; Saunders and Smith, 1962; Hubbs, Greely and Tarzwell, 1932). These structures divert the current and cause the water to dig holes and deposit the material in riffle areas, thus providing a riffle-pool complex which is important to the stream environment (Gee, 1952; Hazzard, 1935). Piles of gravel placed in the channel to form riffle areas have proved effective in some areas and were still functioning several years after their placement (Stuart, 1953).

HYDROLOGIC ASPECTS OF THE WEBER RIVER

The Weber Basin area covers approximately 2,500 square miles, 3 percent of the state of Utah. Great Salt Lake forms the western boundary of the area and the north, east, and south boundaries are the divides between the Bear, the Provo, and the Jordan River drainages, respectively. The Weber River originates near the west end of the Uinta Mountain range (elevation 11,900 feet) and flows approximately 50 miles northwesterly between the Uinta and Wasatch Mountains and then turns west and flows 90 miles to the Great Salt Lake (elevation 4,200 ft.). It is joined by its major tributary, the Ogden River just west of Ogden City about 15 miles upstream from the Lake. The total stream flow in the Weber Basin area averages 640,000 acre feet annually. (USBR, 1951 Weber Basin Project).

A Description of the Study Area

The original area involved in this report was a 10 mile stretch of river located below Echo Reservoir and continuing downstream to the Devil's Slide Area in Summit County, Utah. The drainage area is 732 square miles (USGS, Water Supply Paper 1244).

Interstate 80 was built between the river and the railroad and this location required five sections of the Weber River to be straightened near Henefer, Utah. The location of the Weber River and the study area are shown in Figure 1.

During the past 30 years the river channel in this area has been altered in several places as a result of flood control or agricultural practices. Consequently, this stretch of the Weber River is not a pristine environment. For the purpose of this study, all sections which underwent changes during the present construction of I-80 are referred to as changed sections while those sections not touched by the construction are referred to as unchanged sections.

Five sections of river were channelized. The total length of the altered channel was 8,800 feet or 1.6 miles. The channelization resulted in a loss of about 0.4 of a mile in channel length in the seven or eight mile section of river where the changes occurred.

Hydrology of the Weber River

Discharge Records

In 1931 the Echo Dam with a reservoir capacity of 73,940 acre feet was completed, and the flow of the river through the present study area has been regulated artifically since that time. In 1957, Wanship Dam, with a reservoir capacity of 60,860 acre feet, was completed a few miles upstream from Echo Dam. There are not adequate data available to compare the river flows with those before construction of Echo Dam, but the flow records of the river at Echo for the 35-year period from 1932 to 1967 are summarized in Table 1. The maximum average monthly discharge was 2180 cfs in May of 1952. During this month the maximum mean daily flow was 3060 cfs and the minimum mean daily flow was 250 cfs.

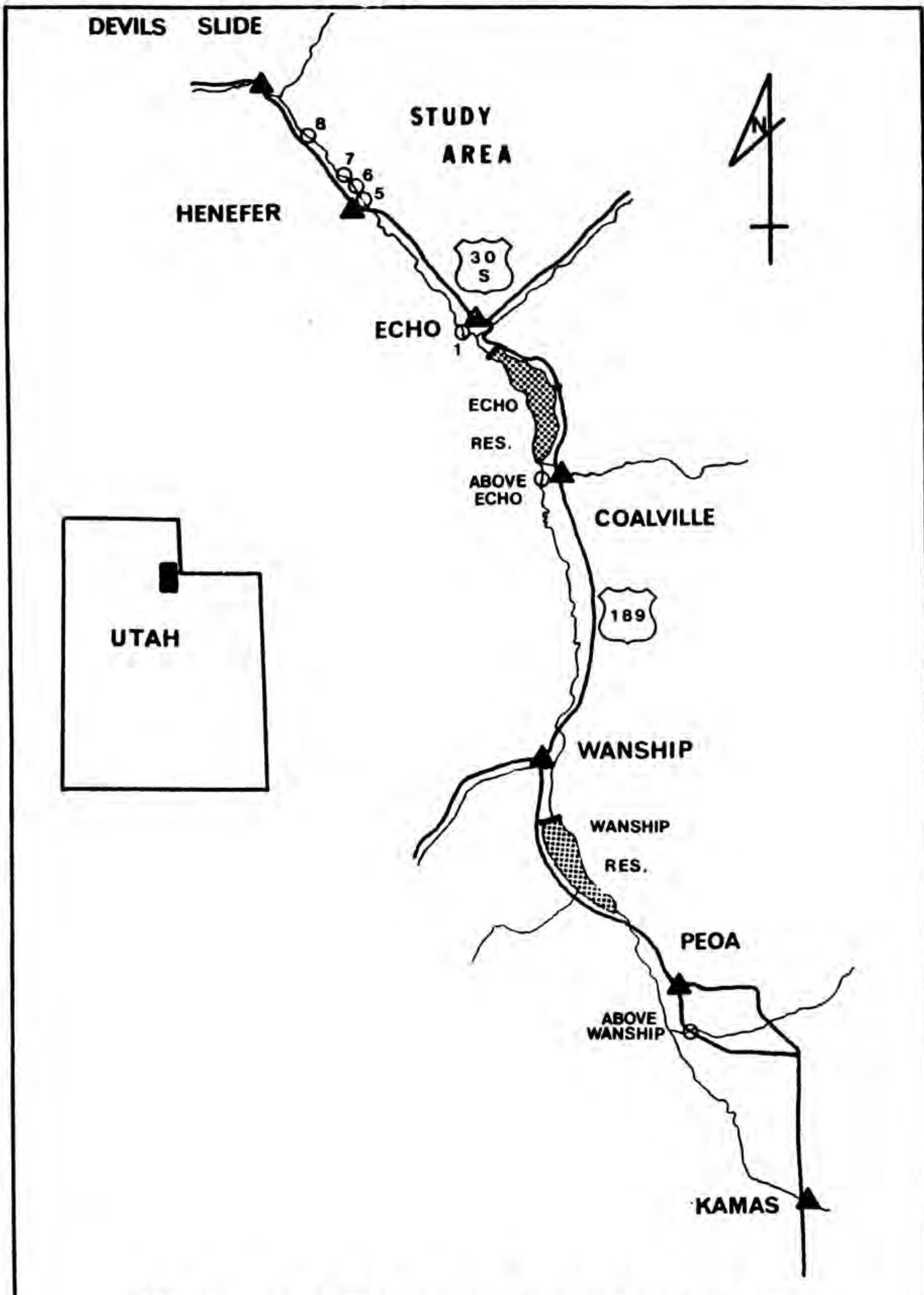

Fig. 1. Map of Utah showing location of Weber River, Summit County, Utah, and the location of the study area

TABLE 1. Mean, maximum and minimum average monthly discharges in cubic feet per second as measured at Echo, Utah, 1932-1967.

Month	35 Year Mean	Maximum	Minimum
October	118	270 (1966)	6 (1962)
November	94	183 (1939)	0.5 (1962)
December	83	179 (1958)	0.44 (1955)
January	86	173 (1951)	0.44 (1955)
February	86	215 (1952)	0.5 (1962)
March	83	505 (1952)	0.5 (1962)
April	141	580 (1938)	0.5 (1962)
May	513	2180 (1952)	8 (1933)
June	686	1682 (1950)	235 (1934)
July	502	702 (1967)	321 (1937)
August	408	623 (1962)	97 (1934)
September	261	372 (1964)	23 (1934)

During the 30-year period from 1931 to 1970 the flow of the river in this area has fallen below 30 cfs for 84 months or an average of 2.2 months per year. The flow has been below 10 cfs for 53 months or an average of 1.4 months per year. Table 2 indicates the severity of some of the low flow periods since 1953.

In addition to these low flows, there have been many days when the flow at Echo was 0 and the flow in the river at Henefer was a result of seepage into the channel and the flow of Echo Creek.

TABLE 2. Summary of periods of low flows, Weber River at Echo, Utah.

Year	Months Less than 30 cfs	Months Less than 10 cfs
1953	1	1
1954	2	1
1955	5	5
1956	4	3
1957	2	2
1968	0	0
1959	4	3
1960	5	0
1961	3	0
1962	6	0
1963	2	0
1964	6	2
1965	3	0
1966	1	0
1967	5	0
1968	1	0
1969	2	2
1970	2	2

The minimum flows during the winter months were a result of shutting off the outlet works of Echo Dam so that little or no flow was coming out of the reservoir. The summer minimums were established in 1934 which was an exceptionally low water year for all of Utah.

The discharges during the study period varied from 0 to 1800 cfs (Fig. 19, page 57). There were drastic fluctuations in discharge from Echo Reservoir during short periods of time. The discharge varied 400-500 cfs within a few hours on several occasions.

Tortuosity Studies

Since 1938, the river has undergone a number of channel changes which have slowly shortened the length of the channel. These changes were determined from a study of the aerial photographs taken of this area in 1938, 1952, and 1967. The results of these changes are summarized in Table 3.

TABLE 3. Changes in channel length, tortuosity and average slope of channel in the Weber River near Henefer, Utah; 1938-1969.

Year	Channel Length (Miles)	Tortuosity	Average Slope of Channel
1938	8.64	1.38	0.00356
1967	8.28	1.33	0.00370
1969	7.85	1.25	0.00391

In 1938 the distance along the channel thalweg from below Echo Reservoir down to the Devil's Slide area was 8.64 miles and by 1969 this had decreased to 7.85 miles. The change in length in 1968 due to the channelization resulted in a loss of 0.43 miles. The tortuosity of the channel decreased from 1.38 to 1.25. Tortuosity is defined as the distance from study reach 1 (Section A) to study reach 8 (Section J)

(Fig. 1) measured along the thalweg or the main thread of the current of the stream divided by the straight line valley length from reach 1 to reach 8. A high tortuosity ratio indicates a meandering stream while a tortuosity of 1.0 would imply a straight stream channel. The shortening of the river by 0.8 mile during the 31-year period demonstrates that a number of changes have been made in the channel over the last 30 years. Changes of this type in which no planned corrective measures are taken, are generally very detrimental to the habitat of a stream (Alvord and Peters, 1963). The decrease in channel length also resulted in an increase in the average slope of the river from 0.00356 to 0.00391 with slope being defined as difference in elevation between two points divided by the channel length between these same points.

Water Quality Records

A study of the U.S.G.S. water quality records for a number of years shows that the total dissolved solids in the study area were generally smaller than 300 mg/l. The water quality was within the limits of allowable impurities for domestic water set by the U.S. Public Health Service at 500 mg/l for total dissolved solids. The water is slightly alkaline with a pH varying between 7 and 8. No tests were made for pollution in this area of the river.

During the study period, the river was normally clear during the fall and winter but it became turbid during the spring and summer. When the water releases from Echo Reservoir were over 300 cfs, the water flowing from the reservoir was often quite turbid. Generally it was not possible to see the bottom of the river if the water depth exceeded 1.5 ft. or more. The turbidity was caused by fine materials in suspension in the release water from Echo Reservoir. Some of the turbidity was a result of sediment brought into the river by Echo Creek. During most of the summer, the turbidity of the water exceeded 40 JTU (Fig. 18, page 55). A summary of some of the water quality characteristics during the study period is given in the section on Aquatic Invertebrate Studies.

Hydraulics of the Weber River in the Study Area

Channel Characteristics

The average slope of the unchanged channel in the study area was 0.0028 or 2.8 feet change in elevation per 1000 feet. The maximum and minimum slope for the unchanged channels was 0.0038 and 0.0018. In the changed reaches, the slope was 0.0037 (3.7 feet per 1000 feet). An increase in slope usually results in an increase in the average velocity for that unit of stream.

The velocities and the average depth of flow are influenced greatly by the total discharge flowing in the river. However, during the months of May, June, July, August, and part of September, the discharge generally exceeds 400 cfs and occasionally reaches 800 cfs. In the study reach the average velocities normally varied from 3 feet per second to as high as 5 fps with the velocity averaging slightly higher in the changed sections. During periods of low flow, the velocities are greatly reduced. Velocity is an extremely variable flow characteristic, but except for short periods of spring runoff, the average cross sectional velocity in this area of the river, seldom exceeds 5 fps.

For the convenience of summarizing the data, the research area was divided into various sections labeled from A to J as shown in Figure 2. A summary of the slope, length and width for each section is included in Table 4.

TABLE 4. Average slope, length and width of each section in the study area on the Weber River, Summit County, Utah.

Section	Slope	(feet) Length	Ave.	Width (feet) Maximum	Min.
A	-	9,600	77 ft.	97.5 ft.	55 ft.
B Changed	.0037	3,800	88 ft.	105 ft.	55 ft.
C	.0038	4,475	82 ft.	110 ft.	62 ft.
D Changed	.0047	2,400	80 ft.	90 ft.	67 ft.
E	.0033	2,750	72 ft.	92.5 ft.	60 ft.
F Changed	.0025	1,200	82 ft.	90 ft.	77 ft.
G	.0018	550	90 ft.	100 ft.	80 ft.
H Changed	.0040	775	85 ft.	92 ft.	75 ft.
I	.0024	425	67 ft.	85 ft.	45 ft.
J	-	9,920	75 ft.	110 ft.	40 ft.

No quantitative measurements on the substrate were made in the changed and unchanged areas. However, subjective catagorization of the substrate indicate that the substrate in the unchanged area was of the rubble-gravel complex (Cummins, 1962) and is considered fairly stable. The substrate in the changed area after construction contained excessive amounts of exposed dirt and small grained material and was considered

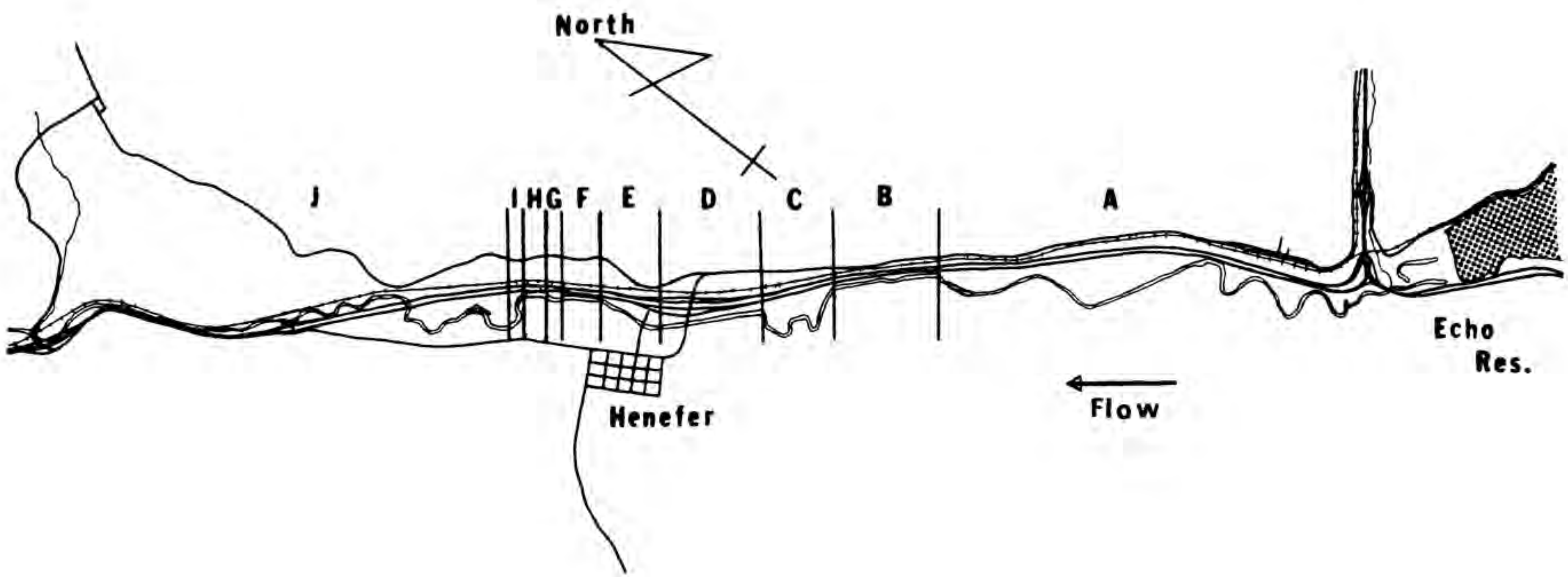

Fig. 2. Map of Weber River, Summit County, Utah showing study sections.

unstable. After a period of stream flow, the fine materials were eroded away, and a stable substrate was formed of the rubble-gravel complex, indistinguishable from the substrate in the unaltered areas.

No measurements were taken to evaluate the movement of sediments into or out of the area. From appearances of the channel, sediment was deposited mainly within the study area, especially behind certain structures. Observations downstream from the channeled sections showed no excessive silt accumulation in those areas.

Hydraulic Structures

Gabions or wire baskets filled with rocks were the major structures used to rehabilitate the channeled portions of the Weber River (Fig. 3A). The gabions were constructed of heavy wire fabric similar to the type used in chain link fences. The wire was formed into baskets which were then filled with rubble size rocks.

Three types of gabion structures were utilized:

1. Check dams; gabion structures placed completely across the stream perpendicular to the stream banks.
2. Wing deflectors; gabion structures placed at a 45 degree angle to the bank and extending out into the main flow of the channel to approximately the center of the channel.
3. Double deflector; two gabion structures at a 45 degree angle to the bank placed opposite each other with their ends extending towards the middle and separated by about 20 feet.

* Large rocks were also used to form wing deflectors, V-deflectors and check dams (Fig. 3B) and large rocks (1-4 ton) were used as random rocks placed periodically through the channel of the altered sections

(Fig. 3C). Figure 4 summarizes the types of structures and the patterns that were used for rehabilitation structures in the channelized portions of the Weber River.

The rechanneled sections of the Weber River were designed to accomodate 5400 cfs of flood water. A trapezoidal shaped channel was constructed with a bottom width of 70 feet and side slopes of 1:1. However, Section B was not rip-rapped until some time after the water was released into it and therefore the width of the channel was scoured out to about 100 feet in several places. Rip-rap on the sides was extended from the top of the bank to 4 feet below the channel bed on straight stretches and 8 feet below on curves.

Wing deflectors were approximately 100 feet apart in Sections D, F, and H. A total of 39 gabion deflectors and 6 gabion check dams were placed in the river. Five rock deflectors were placed in the channeled reach in Section A and 3 rock deflectors, 3 rock check dams and 2 deflectors were placed in Section B.

Numerous random rocks were spread throughout the channelized portions of the Weber River. Random rocks were also placed in the narrow channel formed by the continuing construction of I-80 in the Devil's Slide Area. This area contains rock check dams spaced at 600 foot intervals and the random rocks were placed no closer than 300 feet upstream from these structures in order to avoid the backwater effects of the dams.

A concrete check dam used for water diversion was installed in the middle of Section B.

A.

B.

C.

Fig. 3. Example of several kinds of structures placed in the channeled sections of the Weber River, Summit County, Utah.

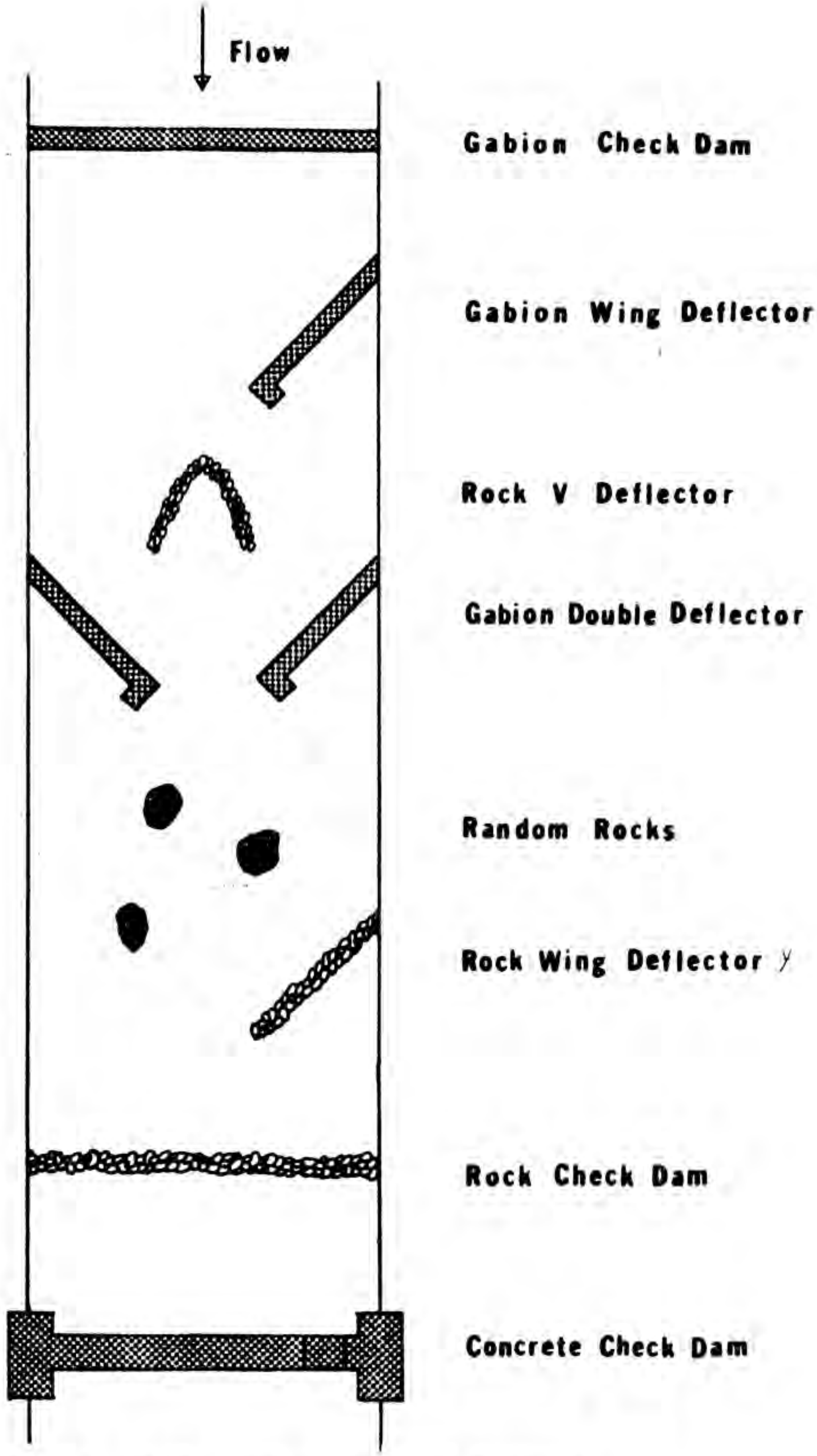

Fig. 4. Summary of the various types of instream structures utilized in the channeled portion of the Weber River, Summit County, Utah.

Description of the Study Sections

Section A

This section is considered a natural area except for a short channeled stretch (640 feet) about one mile below the Echo Reservoir. The total section is 9600 feet long. There were 15 random rocks and 5 rock deflectors placed in the altered portion of this section. No data other than invertebrate data were collected in this section due to access problems. This section ends immediately above the changed section entering the W-shaped bend.

Section B

Section B is a channelized section 3800 feet long. It contains the concrete check dam, two inverted rock V midstream deflectors, 3 rock deflectors, 3 rock check dams and about 30 random rocks (most of them below the concrete check dam). There were 4 stock watering areas placed in this section.

Section C

This section is an unchanged portion of the Weber River. It contains two meanders (forming a W-shaped bend) and abundant streamside vegetation. The portion immediately below Section B was rip-rapped before this project was initiated to prevent bank erosion, on the north bank.

Section D

Section D is a changed portion of the Weber River beginning immediately below the new concrete bridge east of Henefer, Utah and continuing upstream for 2,400 feet. The bend just above this changed section has been rip-rapped and several (10) random rocks were placed in the area. A riffle was formed at the upstream end by placing boulder sized rocks (about 60), 3 gabion check dams and 20 gabion deflectors, 4 of which (2 pair) were placed in the double deflector fashion. Three stock watering areas were constructed in this section.

Section E

Section E is an unaltered section starting below the Henefer Bridge (U.S. 30) downstream to the first changed section below Henefer. This portion of stream is 2700 feet long and fairly straight. A lot of trash has been thrown in the river and along its banks in this area.

Section F

This section is the first changed area north of Henefer. This section is 1200 feet long. During construction a large pile of gravel was left in the middle of the upstream end of this reach. When the water was released into this area, it eroded the pile of gravel and formed a large riffle area. Below this riffle, 9 random rocks, 10 gabion deflectors and 1 check dam were placed. Two stock watering holes were also constructed.

Section G

This unchanged section is a short (550 feet) stretch below the end of Section F and above the start of H. This portion is the bend part of an old meander. The sewage effluent from Henefer settling pond enters at its upstream end. This stretch is a wide shallow area.

Section H

This section is the last changed area below Henefer. It is 775 feet long with gabion check dams at the upstream and downstream ends. Nine gabion deflectors (4 in the double deflector pattern) and 25 random rocks were placed in this section.

Section I

This is an unchanged area with two large holes with undercut banks and two riffle areas. The length of this section was 725 feet. A large tree was broken off and covered most of the upstream hole.

Section J

This section is the unchanged area below Section I which continues downstream for 9920 feet. A short stretch of river at the downstream end of this stretch, at a roadside park, was used for fish and invertebrate sampling. This area has been subsequently changed by the additional construction of I-80.

Analysis of Structure Effectiveness

To give a visual representation of what has happened to the river in the changed areas as a result of the instream structures, contour maps at a one inch to twenty foot scale were made (see Appendix III). These maps were made with a plane table and alidade. Elevations were read to the nearest tenth of a foot. The contour lines on the map were drawn in foot intervals with dashed lines at the half foot intervals. The map is identified by map number, section, and condition of flow.

Structures will be referred to by map number and section number. Each structure has a number placed near its center to identify it. For example, 10A-H-F refers to map 10A, Section H, structure F. * Evaluation of the failure of a structure is based on either actual structural failure or failure to develop a hole or a riffle area.

Section B

In the changed channel at Section B, all of the structures installed were constructed of rip-rap except one structure which was a concrete diversion dam. In this area the rip-rap along the sides of the channel was placed after water had flowed in the new channel for several months. During this time, the sides had eroded and the channel width was over 100 feet in some places instead of the designed 70 feet. Above the concrete dam, a small island in the channel was protected by rip-rap placed in a V-shape on the front of the island (1B-B-Rock V, Appendix, page 170). This has produced a divided channel and some good gravel riffle areas in the stream. This is the only structure above the concrete dam and this section of the changed channel contains several holes, especially below the island.

Below the concrete diversion dam, there are about 30 large random rocks, three rip-rap check dams and three rip-rap deflector structures.* The random rocks were positioned in the fall of 1970 and were not included on the maps. The three check dams are about eighteen inches above the floor of the channel and are in a series of three with a distance of 200 feet between neighboring dams (3A-B check dam, Appendix, page 173). These structures have provided holes both above and below each structure as well as backing up the water forming pool type situations.

The three rip-rap deflector structures are also in a series on a 200 foot spacing (4A-B-A, B, C, Appendix, page 175). The structures * have created more of a meandering pattern in the stream than the gabion deflectors in the 70 foot wide channel. The riffle-pool series appears more pronounced here due to the three gravel bars formed below each structure. Holes have developed near the ends of the deflectors and downstream from them.

Of the 45 gabion structures placed in the stream channels, ten have failed to form holes and or riffles. The ineffectiveness was generally due to sedimentation. The following four conditions resulted in sediment deposition or general ineffectiveness of the structures.

1. The deflectors were placed too close upstream to a check dam structure and thus, they were affected by the backwater of the check dam. The slow flowing water in this area resulted in deposition of sediment thereby partially burying the deflector structure.
2. The deflector was placed on the inside of a bend where there normally is deposition. The result was burial or partial burial of the structure.
3. Cattle watering areas were located between some deflectors and random rocks were placed in a line between the deflectors. The random rocks slowed down the flow, and the structures and watering areas were covered with sediment.
4. Two structures were placed too low and not enough of the structures were projecting above the channel floor to cause a scouring action and were thus ineffective.

Section D

Most of the structures just above the new Henefer bridge are functioning reasonable well, except that structure 7B-D-D has failed (Appendix III, page 181). The wire fabric ruptured at one point and much of the contents of the basket spilled into the channel. The cause of this failure is unknown. Deep holes and channels were formed below the checkdam, 7B-D-A, B and between 7B-D-E, F. A large hole was formed below the checkdam, 6B-D check dam No. 2 (Appendix, page 188). Water was also backed up to some extent above this check dam. Structure 5B-D-R has been buried by the sediment load of the river. The upstream check dam did not form a large hole below it (Appendix, page 180).

Section F

In Section F, three structures 8B-F-H, I, J, were buried (Appendix III, page 184). They were located at the upper end of Section F. The large pile of gravel partially covering the deflectors has formed the largest riffle area in this changed section. Riffles are important to fish life and production as they provide feeding areas and egg laying areas for fish (Needham and Johnson, 1949). More research is needed to discover better ways to create these riffles in a changed area. A large hole was formed above 8B-F-J as a result of several random rocks being placed in a semicircle around a stock watering area. A deep hole was also formed between structures 10B-F-E, F a double deflector combination. Holes were formed around the ends of the deflectors but the water was backed up as a result of the downstream check dam and reduced the size of the holes that were formed.

Section H

In section H, gabion deflector 10A-H-F has failed (Appendix III, page 187). The end near the center of the channel has fallen. The channel bed in this area seems very unstable and has washed away from under the structure causing a foundation failure. The wire fabric has not ruptured yet but the wire has been twisted and bent. Structure 10A-H-G on the opposite shore from 10A-H-F and approximately 75 feet upstream, is partially buried. Holes were formed near the downstream ends of the deflectors, especially on the upstream end of this section. The effectiveness of the downstream deflectors near the check dam was probably hindered by the water being backed up from the check dam at the lower end of the section. Holes were scoured around the random rock.

Channel Profile

In December 1971 profile measurements were taken down the thalweg or main channel of the Weber River about 3.1 miles or 16,400 feet were measured. There was a drop in elevation in this length of stream of 66 feet or a 0.4% slope. Measurements were started about 1000 feet above Section B and continued downstream to 400 feet below Section H.

Sections of river not altered by this construction (Sections A, C, E, G, and I) are considered as comparative stations with those that were altered (Sections B, D, F, and H). As can be seen by Figures 5, 6, and 7 there are as many holes in the changed areas as the unchanged. The contour of the bottoms are very similar. The areas most dissimilar in appearances are those areas that were previously channeled and no

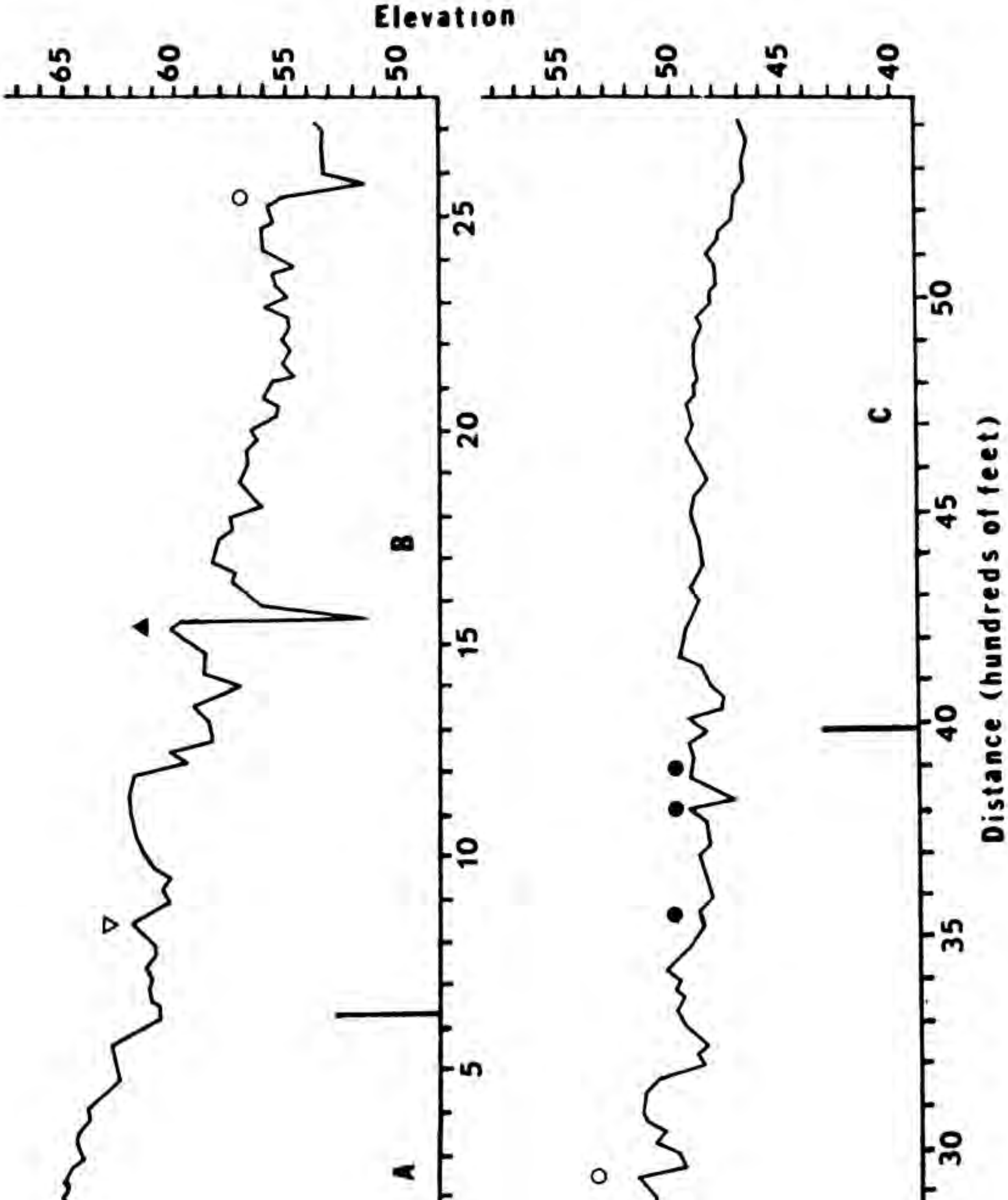

Fig. 5. Profile of the channel in Sections A, B, and C.

(▽ = Inverted "v"; ▲ = Concrete Diversion Dam; ○ = Rock Check Dam; ● = Rock Deflector)

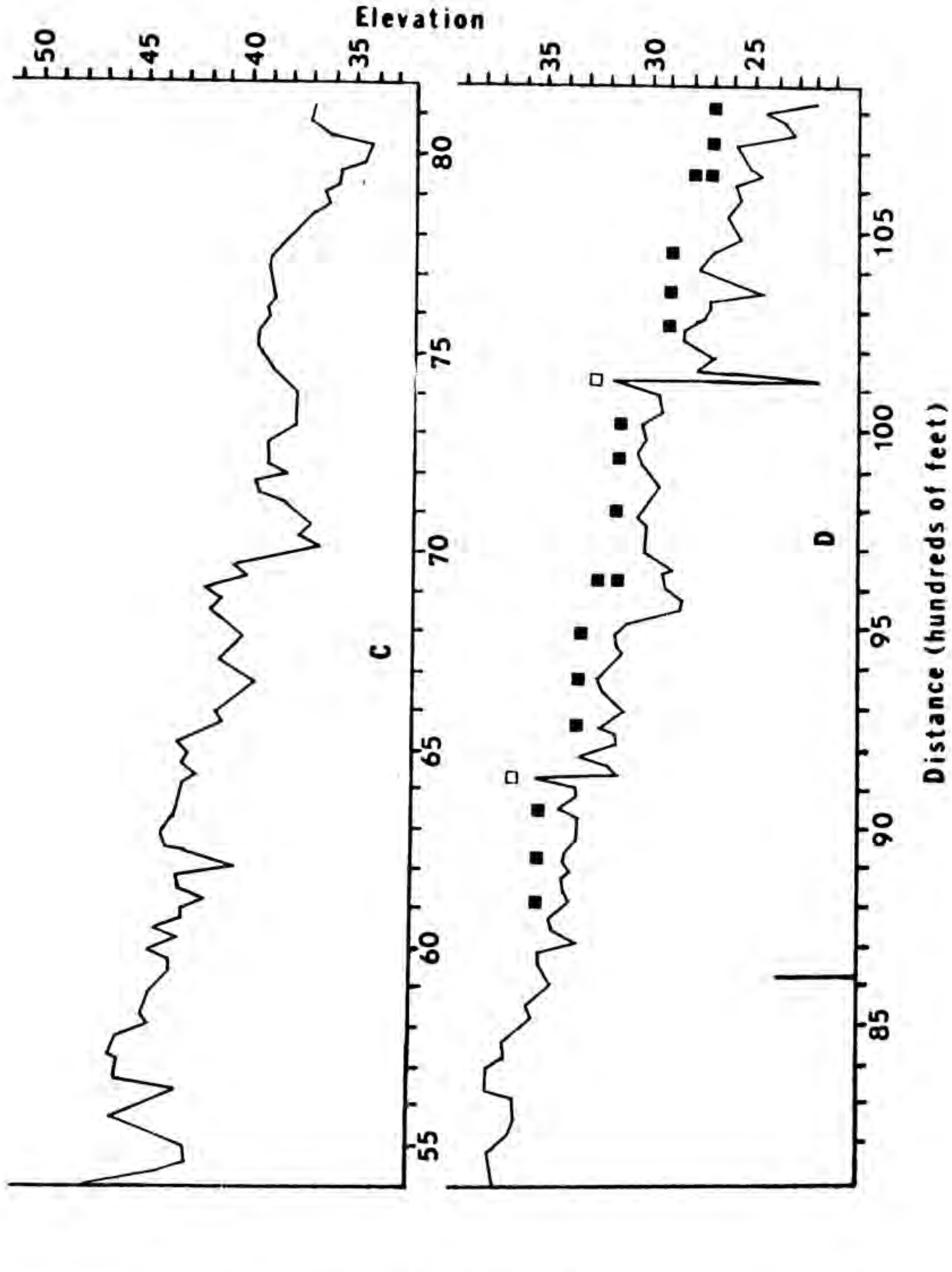

Fig. 6. Profile of the channel in Sections C and D.

(□ = Gabion Checkdam; ■ = Gabion Deflector)

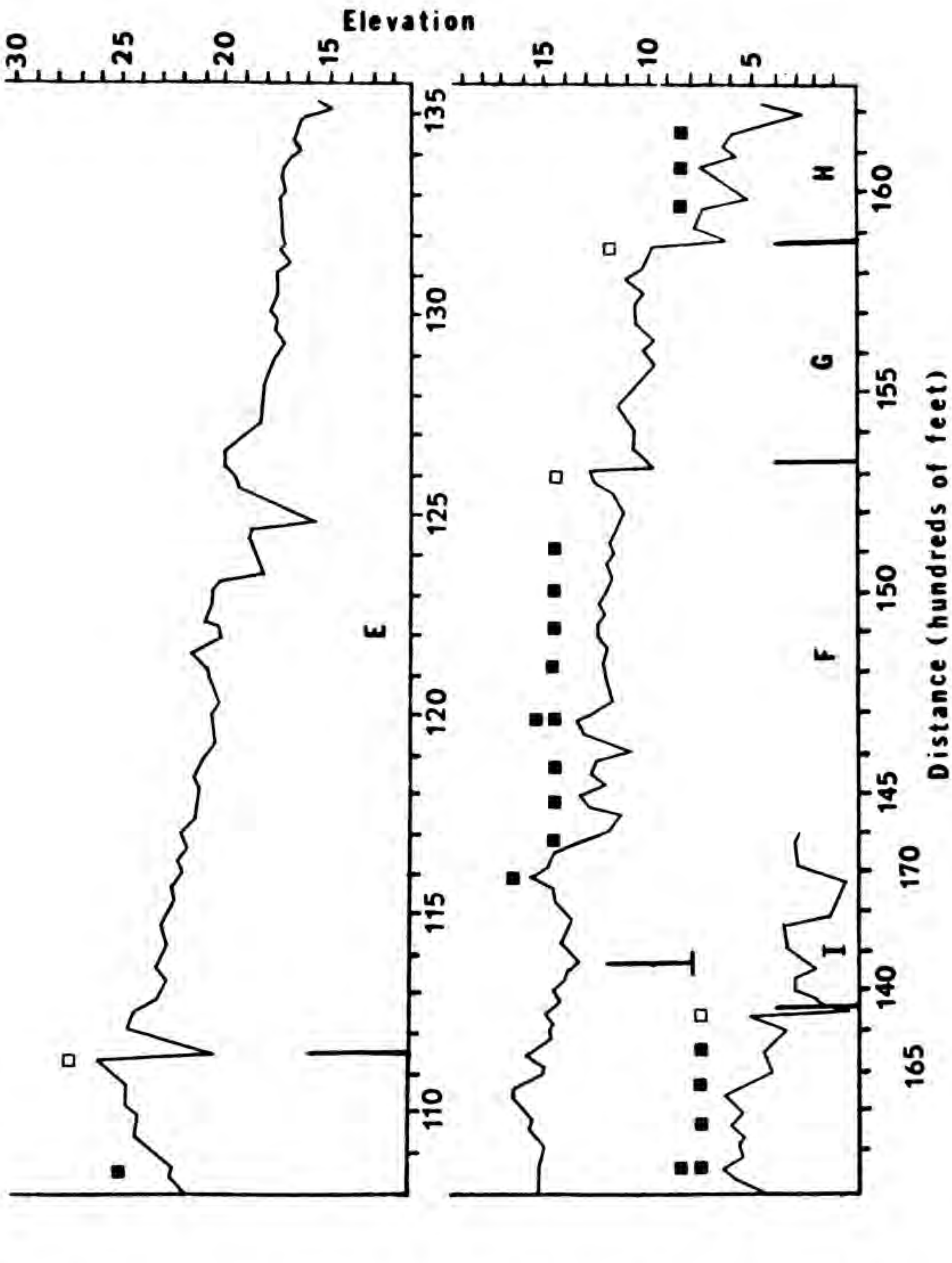

Fig. 7. Profile of the channel in Sections E, F, G, H, and I.

(□ = Gabion Checkdam; ■ = Gabion Deflector) diversity thereby providing limited holes and riffle areas and limited fish habitat.

The structured changed sections have holes formed mainly as a result of the structure placement. Large deep holes were formed immediately downstream from the check dams (See Sections B, D, F and H). The rock check dams also provided holes below them but were not nearly as deep (Section B). Gabion deflectors were effective in creating holes near their downstream ends. Rock deflectors caused holes to be formed but of a smaller scale. The holes in the structured changed areas appear to have holes somewhat more abrupt or extreme in their outline than the unchanged areas.

In Section F, it can be seen that the four structures upstream from the check dams have been relatively ineffective in forming holes. This is apparently from the backwater effect of the check dam.

Summary of the Structures Effectiveness

A total of 45 gabion structures were placed in the altered sections of the Weber River. Of this total number, 10 have been ineffective mainly because of improper placement resulting in their sedimentation. The deflector structures have been effective in creating holes near the downstream ends of the structures and riffles have formed in front of them. Check dams form holes below them and tend to pool the water upstream.

Rock deflectors which were spaced at a greater distance apart in the wider channel caused the river to have a more meandering condition providing holes around the ends of the rock structures and riffle and ground areas between them. There was substantial flow through the rock structures and there appeared to be less silt accumulation behind them than behind the gabion deflectors.

Rock check dams formed pools above them and holes immediately below them. There was flow through these structures and most deposition occurred above them.

Random rocks were effective in creating holes formed around them but no other measurements were taken on them. As a result of the in-stream structures in the altered areas, the profile indicates that the number of holes and riffle areas in the changed sections and in the unchanged sections are essentially the same.

AQUATIC INVERTEBRATE STUDIES

Aquatic invertebrates are important in the trophic relationships of an aquatic system as well as being important as good indicators of pollution (Gaufin and Tarzwell, 1956). For the most part, they are primary consumers feeding on the algae and detritus in the system. They are in turn fed upon by fish, birds, and other invertebrates.

Many aspects of the aquatic environment are important in maintaining invertebrate populations. Stream velocity, flow type, substrate size, temperature, turbidity, and chemical properties all influence and determine what organisms are present in the particular habitat (Cummins, et al., 1966; Reid, 1966; Slack, 1955).

Several studies in recent years have been concerned with the effects of channel alterations on the productivity of streams, especially with regard to fish populations. Little work has been done directly on the effect of rechanneling on invertebrate populations.

The main objectives of this project were to determine:

1. The effect of channelization on the macroinvertebrate populations in riffle areas of the Weber River.
2. The colonization rate by the macroinvertebrates into the newly formed riffles below the instream structures.
3. The difference in the invertebrate standing crop, species composition, and species diversity of the riffle areas in changed and unchanged sections.

4. Differences between the invertebrate populations around a rock deflector and a gabion deflector.

Weber River Literature

Relatively little biological research has been done on the Weber River, especially in the Summit County area. Several unpublished theses are the main literature source for the Weber River. Jones (1935) conducted research on the mollusca of the Weber River. The geology of the upper Weber River was investigated by Root (1952). Schick (1955) studied the geology of the Weber River area in Morgan and Summit Counties.

Smith (1959) worked on the organic pollution entering the upper section of the Weber River. A limnological survey of the Weber River in Summit County was conducted by Jorgenson (1961). Stephens (1969) analysed the environmental requirements of Trichoptera and their related distributions in the Weber River. Some physical and biological information concerning the Weber River is included in an inventory survey of selected drainages in Utah (Neuhold, 1955). A limnological analysis of the rivers in the northeastern portion of Utah included the Weber River (Gaufin, 1957, 1958).

Description of Study Area

Changed Areas

Stations 2, 3 and 4 (Section A) were not sampled after the first few months of the study due to access problems. Stations 5 (Section F), and 6 (Section H) were 0.4 kilometers (0.25 mile) northwest of Henefer, Utah, in areas channeled as a result of the highway construction. Station 5 was a section of river 65 meters (1200 ft) in length, and

Station 6 was 237 meters (775 ft.) in length. The width at both stations was 23 meters (77 ft.). The samples were collected on riffle areas downstream from gabion deflectors. The bottom substrate in these areas was gravel to rubble. After construction of the channel, the substrate in this area was very unstable, but as more scouring by the water occurred it became stable.

Unchanged Areas

Station number 1 (Section A) was located about 1 kilometer (0.6 mile) downstream from Echo Reservoir. This portion of the river is relatively unchanged and is covered on both sides by heavy vegetation consisting mainly of cottonwood (Populus angustifolia, willow (Salix sp.), hawthorne (Crataegus douglasii), and rose bushes (Rosa sp.) with a grassy ground cover. The rubble substrate was considered stable. The depth and width of the river as in all the stations below Echo Reservoir, were dependent upon the flow releases from Echo Dam. The width of the river in this section was about 26 meters (85 ft). A riffle area adjacent to the east shore of the river was used as the sampling area.

Station 7 (Section I) was also northwest of Henefer and was a 130 meter (425 ft.) section downstream from Station 6. This was a natural area with abundant streamside vegetation (similar to Station 1) along its banks and a stable rubble substrate. The riffle area on the north side of the stream below a large deep hole was used for the sample area. The channel width was 19 meters (62 ft.) in this area.

Station 8 (Section J) was 4.2 kilometers (2.6 miles) downstream from Henefer at a road side park by the river. This station was a natural area and the river at this point was braided. The riffle area in the southern channel was sampled. The channel was 6.5 meters (21 ft.) wide in this area. Streamside vegetation was abundant, and the substrate consisted of stable rubble. This station was completely destroyed by more recent construction of I-80.

Sampling

Invertebrate samples were collected monthly from August, 1968 to August 1970 at Stations 1, 5, 6, 7, and 8. Nearly all of the samples were collected in the next to the last week in each month. Since no prestudy was possible, changed areas were compared to unchanged areas.

Basket samples, bottom samples, drift samples and water samples were collected at each station.

Artificial Substrate Sampler

Basket samplers were constructed from one inch chicken wire formed into the shape of a one gallon can. Six rocks of uniform size and shape were placed inside of the basket. The baskets were anchored by a chain to a stake or solid object in the stream. They were retrieved by holding an aquatic net downstream from the basket and then lifting and placing the basket in the net. The dislodged organisms were collected in the net. The basket was then rinsed and agitated in a bucket of water for 30 seconds. The organisms from the net and those in the bucket were concentrated and placed into jars and preserved in 10% formalin solution until they could be analyzed in the laboratory. One sampler was left at each station for a month to allow adequate time for colonization by the invertebrate organisms. Unfortunately little information was gathered using basket samplers, because they were removed by people utilizing the area. For this reason, basket sampling was discontinued after seven months.

Bottom Samples

Bottom samples were collected using a circular one quarter meter (9.7 inches) squared (1/16 m^2) (0.67 ft^2) sampler similar to the bottom sampler described by Hess (1941) (Fig. 8). One sample per month from a riffle area was taken at each station. The sampler was forced into the substrate to a depth of about 2-4 cm (1 - 1.5 inches). The larger rocks were washed so that the organisms entered the collecting pouch. After all of the large rocks were removed the bottom sediments were stirred until all the organisms in the upper 4 cm (1.5 inches) of the substrate were dislodged and swept into the zippered downstream collecting pouch. When the water inside the sampler contained no organisms, the sampler was removed from the stream. The collecting pouch was removed and the organisms concentrated and placed into a jar and preserved with 10% formalin solution until they could be analyzed in the laboratory. After the organisms were sorted into taxonomic groups they were counted, weighed and measured. The numbers and weight of organisms from the bottom samples were converted to number or weight per meter squared.

If the samples were large, subsamples were taken using a subsampler similar to the one described by Waters (1969).

Gabion - Rock Deflector Analysis

In the fall of 1971 bottom samples were collected around a gabion (in altered section above Henefer) and a rock deflector (in a section

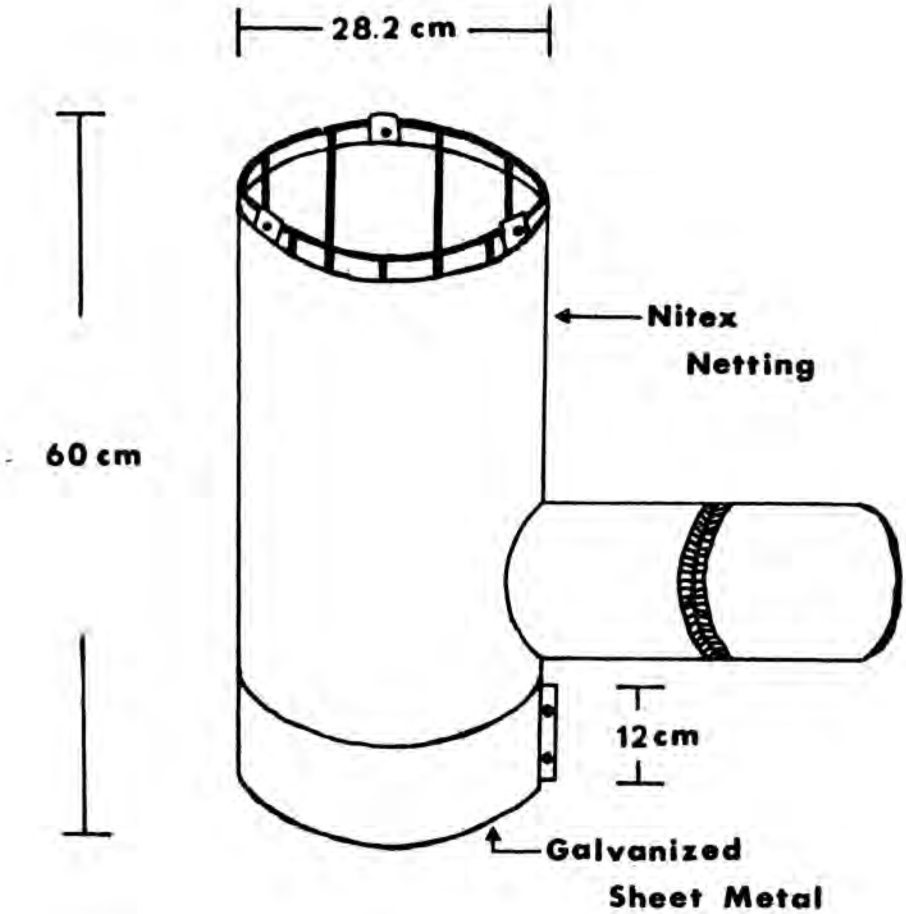

Fig. 8. Diagram of circular quarter meter squared ($1/16m^2$) bottom sampler.

below concrete checkdam) to determine if there existed any differences in the benthos as a result of the type of structure. Samples were collected using a 1/32 m^2 (.33 ft^2) circular bottom sampler (Fig. 9). This can be used in deeper water by using a face mask and snorkel or scuba equipment. Samples were collected in two transects behind the deflectors. The first transect was 150 cm (5 ft.) downstream from the structure and the second transect was one meter (3.2 ft.) downstream from the first transect. Samples were collected every meter from the shore out to the edge of the structure. Three samples were collected one meter in front of the structures, one at the shore, one in the middle and one near the midstream end of the structure.

Water depth and velocity were measured at each collection site and the type of substrate was subjectively categorized according to the size of the rocks (Cummins, 1962). Velocities were taken with the Ott C_1 current meter at 5 cm from the bottom. The data from this portion of the study was analyzed using an analysis of variance on a multiple regression computer program.

Drift Samples

Drift samples were collected monthly at each station. Drift nets were constructed of a 40 x 15 cm (15.7 x 5.8 inches) rectangular frame with a 90 cm (35.4 inches) net extending from it (Fig. 10). The frame had door hinges welded to it with adjustable sleeves attached to them. The nets could be attached at any depth to 2.5 cm (1 inch) rods that were driven into the bottom of the stream. The netting was made from Nitex netting with 273 micron mesh opening.

Behavioral drift of invertebrates was not analyzed since samples

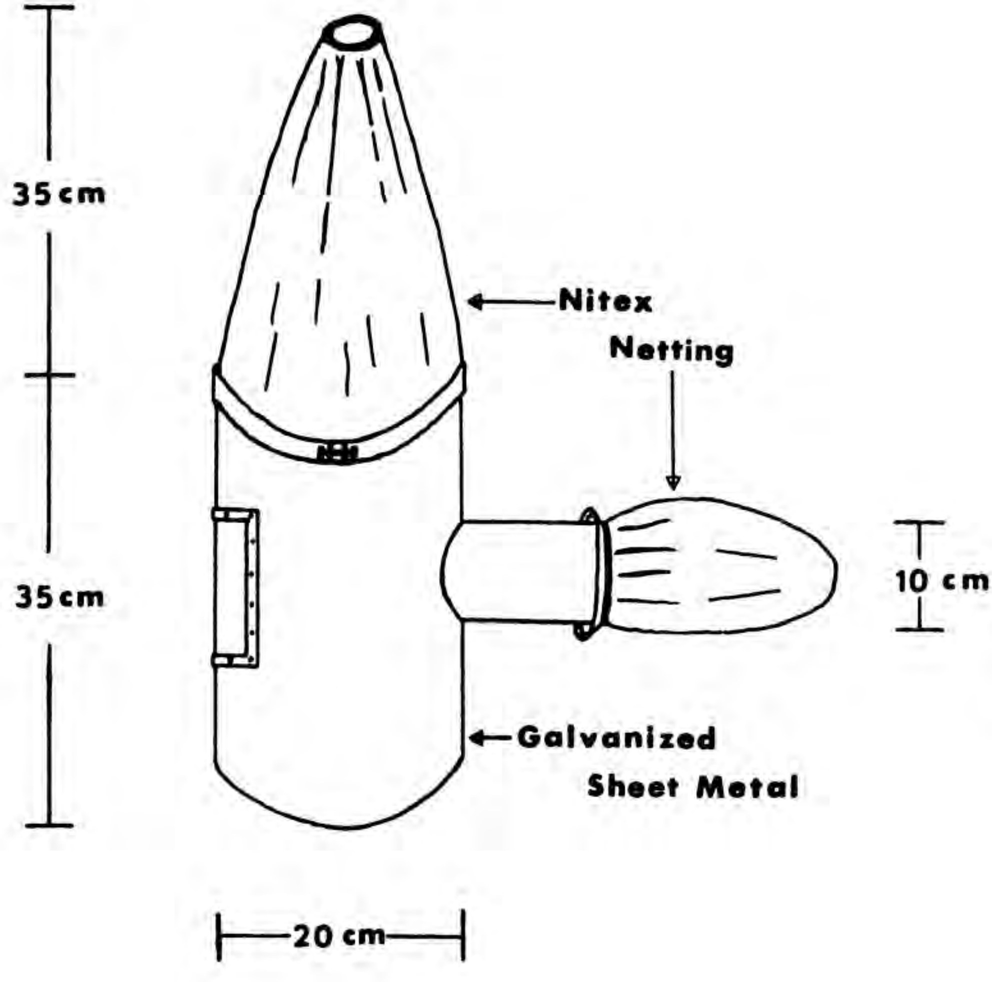

Fig. 9. Diagram of a circular bottom sampler (1/32m^2).

were always taken during the day. Drift samples were used to measure the amount of inorganic and organic material drifting in the free water phase of the stream at that time. The samplers were placed in the stream for a period of 10 minutes. The upper 20 cm (8 inches) of water were sampled. A 5 minute sample was taken if the quantity of material in the drift was large. Water velocities were measured in the mouth of the drift net using a current meter. Drift samples were removed from the net, concentrated and preserved in 10% formalin until they could be analyzed in the laboratory. These samples were dried for 24 hours in a drying oven at 110°C and then weighed. Next they were burned in a muffle furnace at 600°C for 3 hours and then weighed. The burned weight was considered to be the inorganic content of the sample and the difference between the burned weight and the dry weight was considered to be the organic content of the sample. This procedure is not completely accurate, but it should give the relative values that occurred at that time. This technique doesn't account for the ash residue left from burning the organic material causing an increase in the inorganic weight.

Water Chemistry

Water samples were collected monthly above and below the construction area (Stations 1 and 7). Water samples were analyzed for hardness, pH, alkalinity, phosphate, sulfate and turbidity using a Hach Chemical Kit.

Water temperatures were measured during the sampling period with a centigrade thermometer.

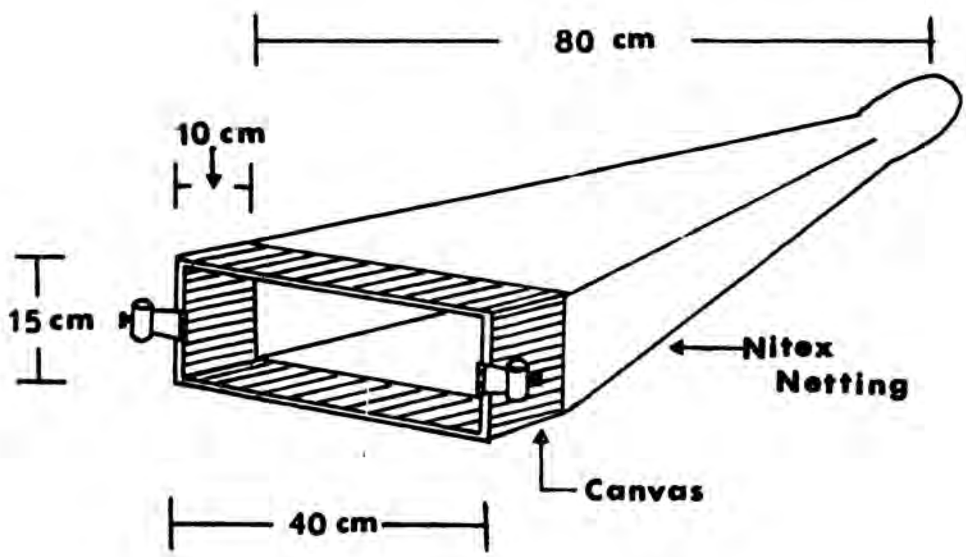

Fig. 10. Diagram of drift net.

Vegetation Analysis

Streamside vegetation analysis was conducted by determining the amount of ground cover which occurred in changed and unchanged areas. This was accomplished by using 1 square foot quadrat ($0.092m^2$) and collecting all vegetation within that area. The sample plots were collected every 15 meters along a transect on the river bank 10 meters (32.8 ft.) from the water's edge in both changed and unchanged areas in June, 1971. The samples were placed in paper bags and returned to the laboratory where they were dried and weighed. Tree and shrub vegetation was analyzed using the quarter method. Points were established every 30 meters (98 ft.) while walking in a straight line through the band of remaining riverside vegetation. Species composition, density and relative dominance were calculated.

Gut Analysis of Macroinvertebrates and Fish

Fish food analyses were conducted during July of 1969. Fish were electroshocked at stations 1, 5 and 7, and the guts were collected and preserved in 10% formalin. The guts were examined and the food organisms for the fish at that season of the year were tabulated. Fish gut analyses were conducted periodically throughout the rest of the study. Gut analysis of the macroinvertebrates was conducted periodically on the organisms collected in bottom samples.

Analysis of Data

Actual values for the data were plotted as well as the log of the number plus one on the bottom sample data. Statistical differences between the values obtained from that of one station with that of another were determined using the student T-test. The numbers were transformed to the logarithm of 1 plus the value since the populations were determined to follow a negative binomial distribution (Elliot, 1971b).

Species diversities were calculated for each of the stations using Fisher's index of diversity (Fisher, et al., 1943).

$$d = \frac{S - 1}{\log N}$$

Where d = species diversity
S = number of species
N = total number of organisms

Each distinguishable taxon was considered a separate species.

An ordination analysis was used on the values obtained from the bottom samples to compare each sampling station each month with each other. This is a technique similar to the one Bray and Curtis (1957) and Newsome and Dix (1968) used.

Importance values for each species, each month at each station were determined by adding the percent of weight and percent of numbers each species contributed to that sample. This gave a possible value of 200. These values were placed into the following formula to give similarity values:

$$C = \frac{2W}{a+b}$$

C = Index of similarity
a = total importance value of a
b = total importance value of b
W = Sum of lowest importance values for species in common to both locations

The dissimilarity values are found by subtracting the similarity value from 100. These values were then placed into a matrix showing the similarity and dissimilarity values. The values for each station were totaled and the one with the highest value was used for location A and the station that had the lowest value of similarity with location A was location B. These give the two end points on the X axis. The dissimilarity values from A and B were used in the formula:

$$X = \frac{L^2 + A^2 - B^2}{2L}$$

A = dissimilarity of location to be positioned with reference location A

B = dissimilarity of location to be positioned with reference location B

L = distance from A to B

X = point on the X axis

These values gave the location of each point along the X axis.

The values for the Y axis were found by determining the station with the highest e^2 value which was calculated by:

$$e^2 = X^2 - A^2$$

This gave point A for the Y axis. Point B was derived by finding the station with the least dissimilarity value of those stations within 10% of the value of Station A. The X and Y values were plotted to give a graphical representation of the relationship of one station with another. A computer program was written to construct the matrix containing similarity and dissimilarity values for this ordination study.

A summary flowchart of the methods used is shown in Figure 11.

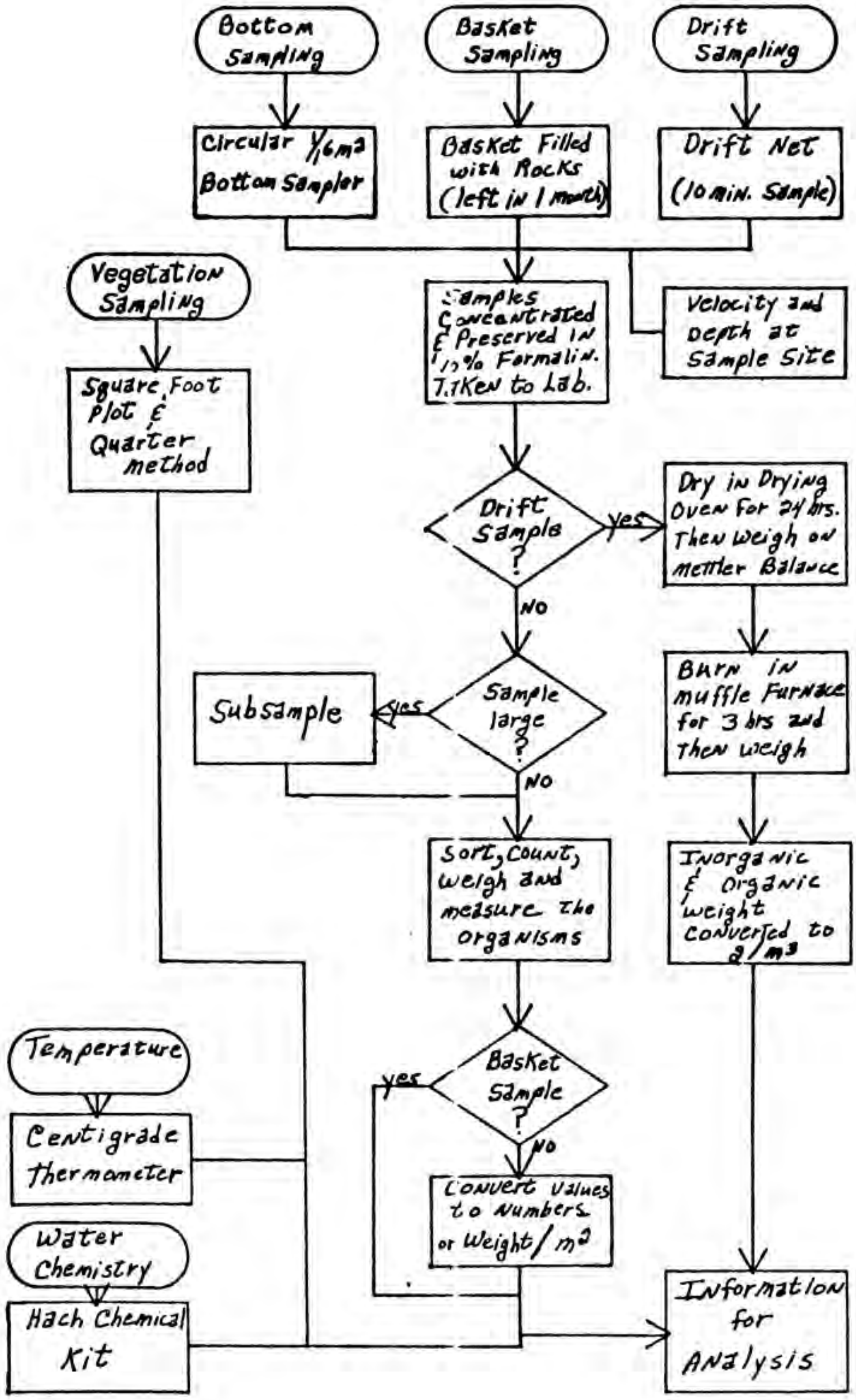

Fig. 11. Summary flow chart of materials and methods used in this study.

Water Chemistry

Hardness

The results indicated that the Weber River below Echo Reservoir was a hardwater river with values ranging from 130 ppm at Station 1 in the fall of 1969 to 290 ppm at both stations 1 and 7 in the fall of 1968 (Fig. 12). The mean total hardness during the study period was 205 ppm below Echo Reservoir.

Alkalinity

The alkalinity of the water in the Weber River followed similar patterns at both stations (Fig. 13). The range in alkalinity was from 160 ppm in the fall of 1969 at Station 1 to 340 ppm at Station 1 in the spring of 1970. The average alkalinities during the study period were 217.6 ppm at Station 1 and 214.7 pp at Station 7.

Phosphate

Phosphate concentration in the Weber River was similar except in the winter of 1969 at Station 7 and in the spring of 1970 at Station 1 when higher values were measured (Fig. 14). The phosphate concentration ranged from 0.04 ppm at Station 7 in the spring of 1969 to 1.78 ppm at Station 1 in the spring of 1970. The mean concentration during the study period at Station 1 and 7 was 0.21 ppm.

Sulfate

The seasonal patterns of the sulfate concentration were similar for both stations with peaks occurring in the spring and early summer

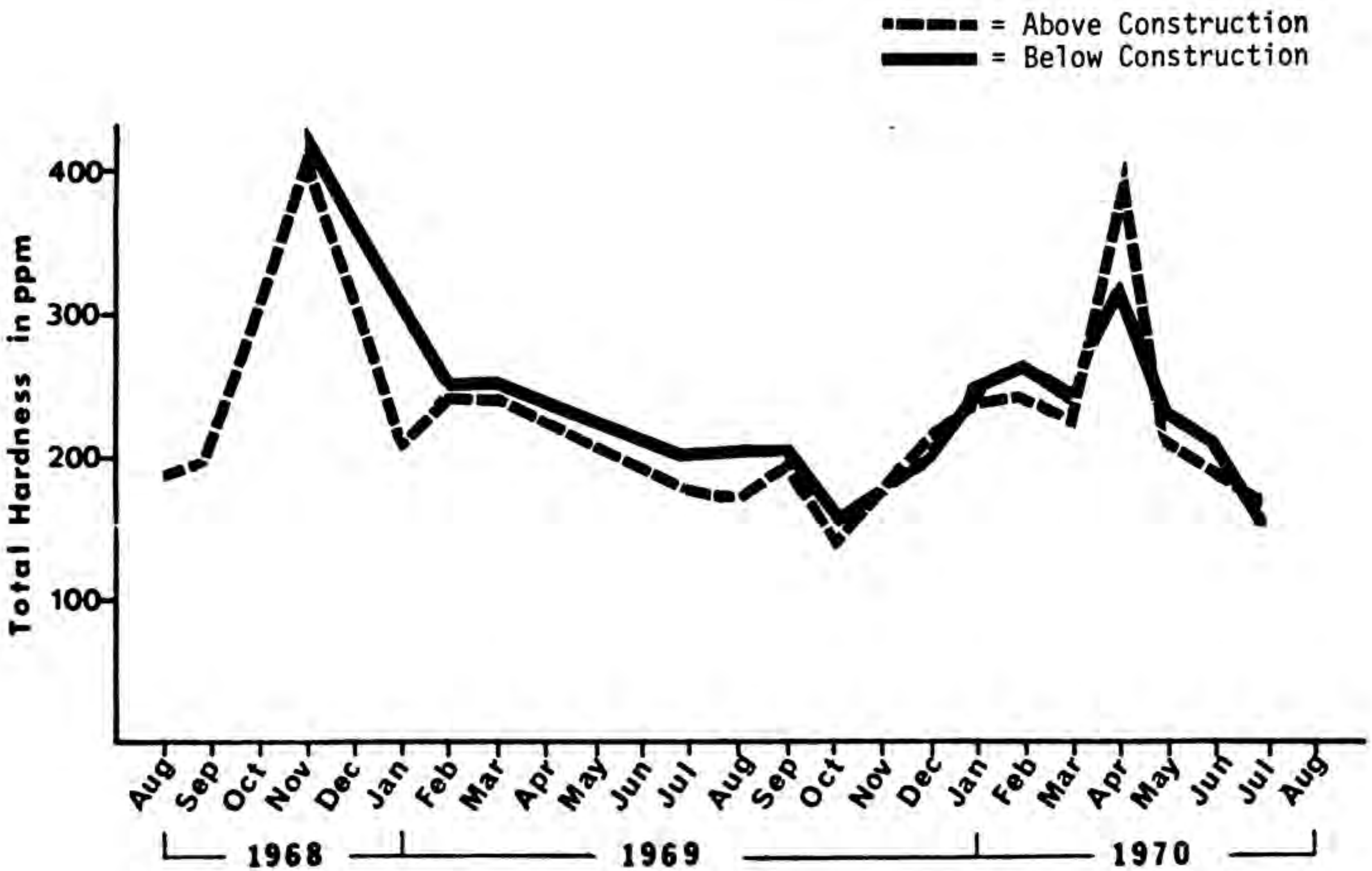

Fig. 12. Total water hardness concentration of the water collected above and below the construction area in the Weber River, Summit County, Utah.

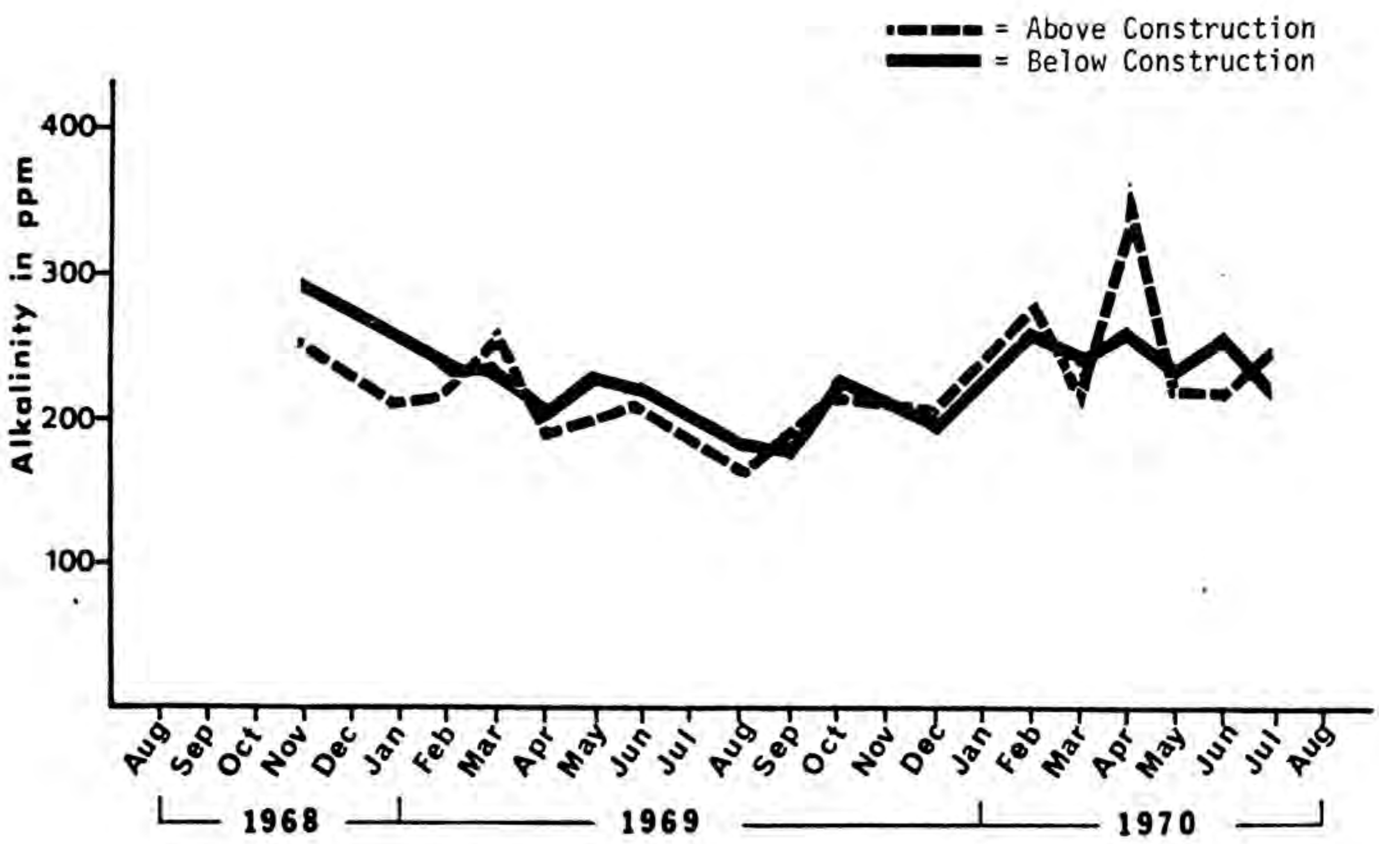

Fig. 13. Alkalinity concentrations of the water collected above and below the construction area in the Weber River, Summit County, Utah.

(Fig. 15). During December (1968) at Station 7 and at Station 1 in June, 1969, high values were measured (135 ppm at Station 7 and 105 ppm at Station 1). The range of sulfate concentration was 14 ppm at Station 7 in the spring of 1969 to 136 ppm at Station 1 in the fall of 1968. The mean concentration was 31 ppm for both stations.

pH

A uniform seasonal pattern was measured for the pH at both stations except for a drop from 8.5 in August of 1969 to 6.8 (Fig. 16). This drop may have resulted from faulty equipment or reagents. The average pH for both stations was 8.4.

Temperature

The temperature of the water in the Weber River followed a fairly uniform cycle with the maximum temperatures (19.5°C) occurring in August and September and the coolest temperatures occurring in January, February and March (0.5°C) (Fig. 7). The mean temperature was 9.2°C for the Weber River below Echo Reservoir.

Turbidity

Turbidity of the water (Fig. 18) was very high at Station 7 (310 JTU) in the fall of 1968 during construction but dropped off in the early spring. There was an increase in turbidity at Station 1 in the spring of 1970 (355 JTU). The average turbidity during the study at Station 1 was 46 JTU and at Station 7 it was 61 JTU.

Following the construction period in November of 1968, water was diverted into a new channel at Station 5. Turbidity measurements were

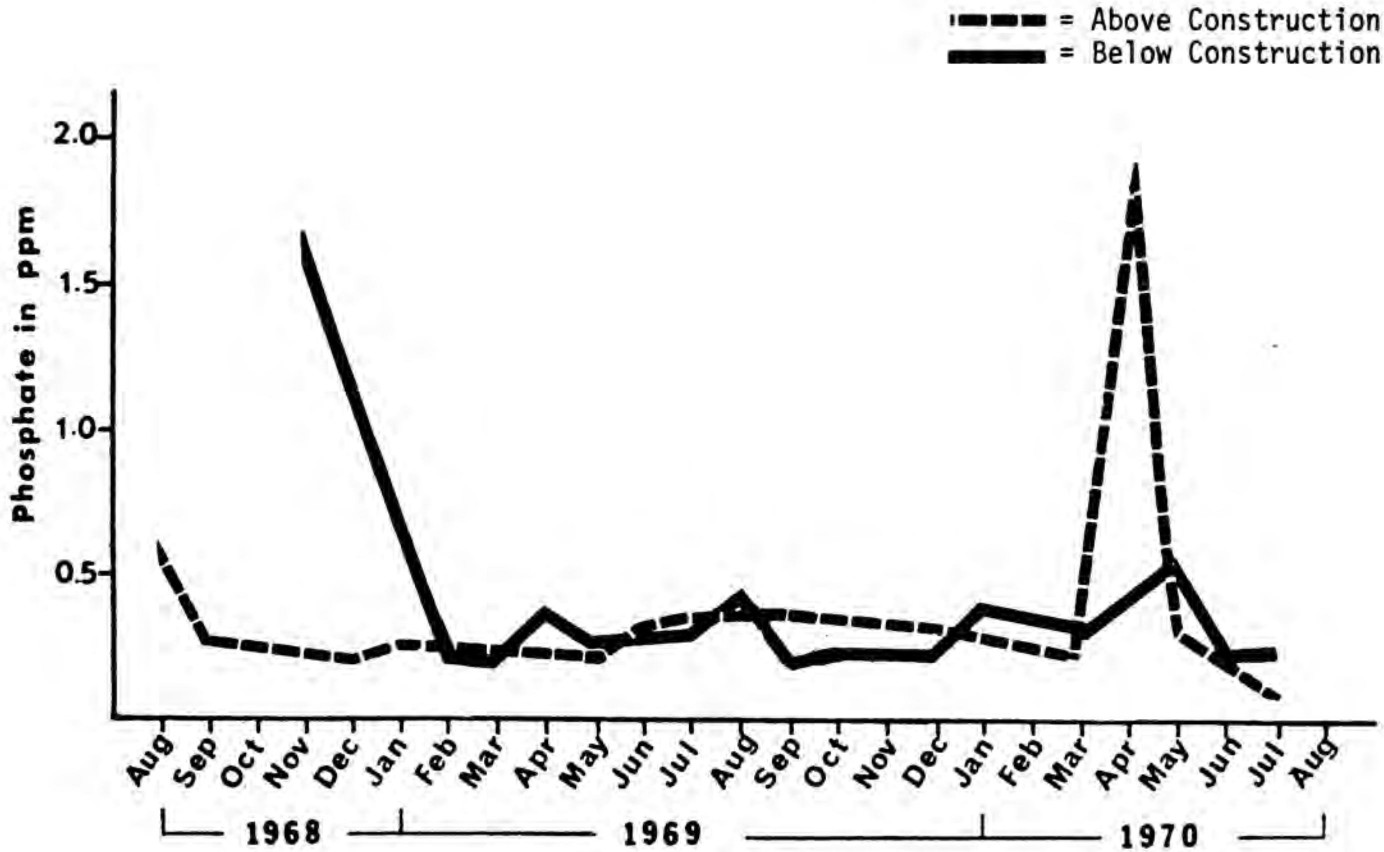

Fig. 14. Phosphate concentration of the water collected above and below the construction area in the Weber River, Summit County, Utah.

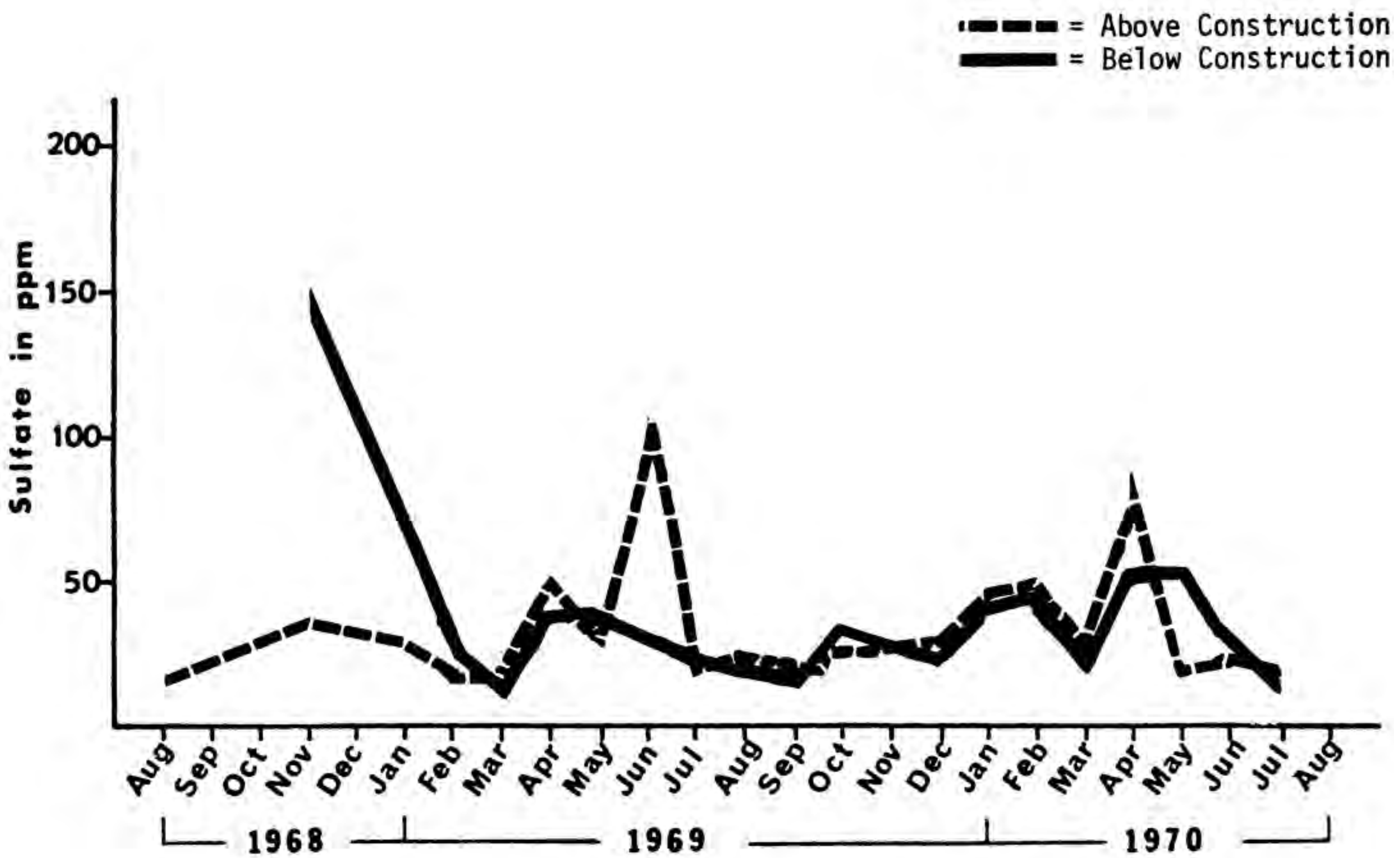

Fig. 15. Sulfate concentration of the water collected above and below the construction area in the Weber River, Summit County, Utah.

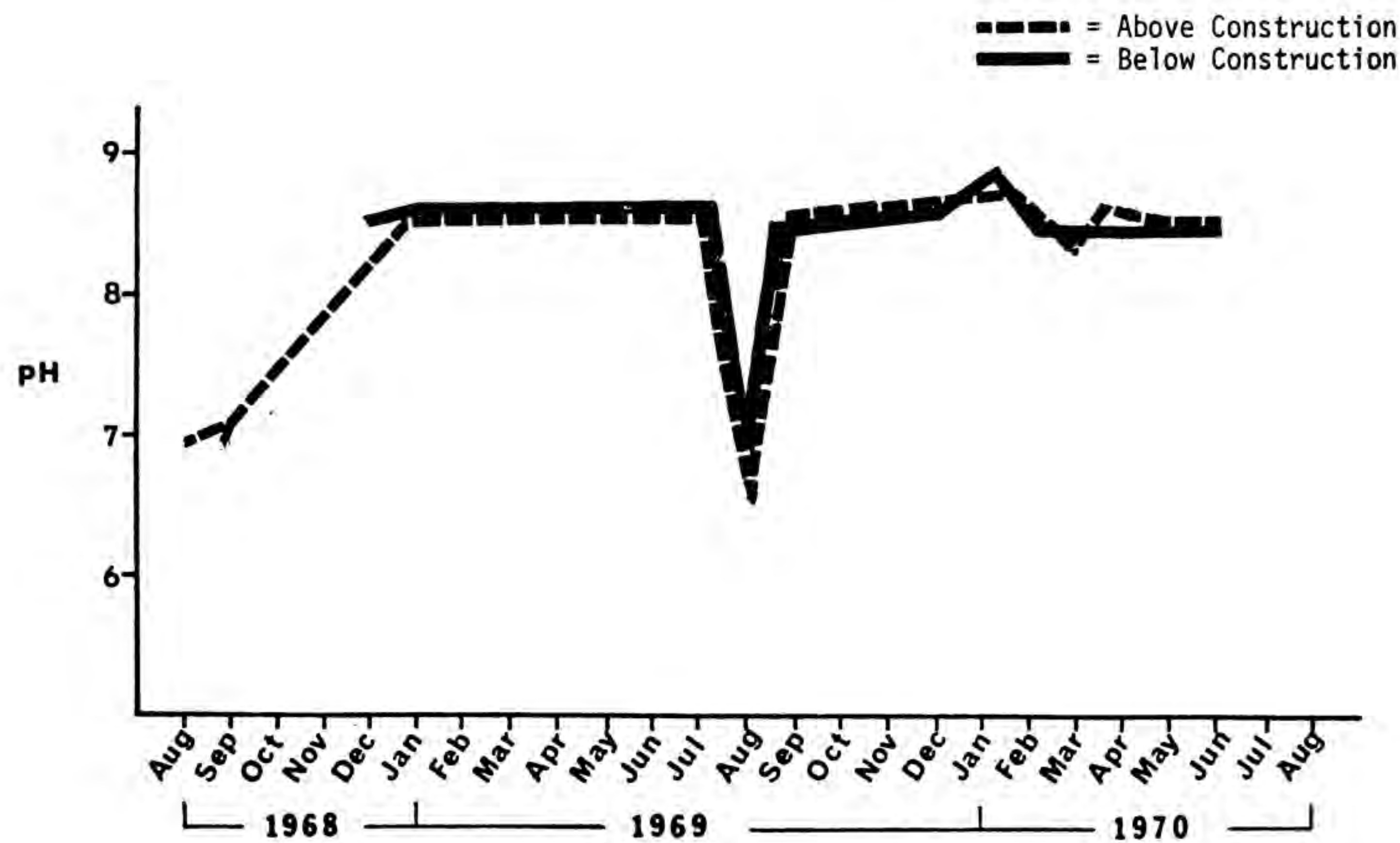

Fig. 16. The pH of the water collected above and below the construction area in the Weber River, Summit County, Utah.

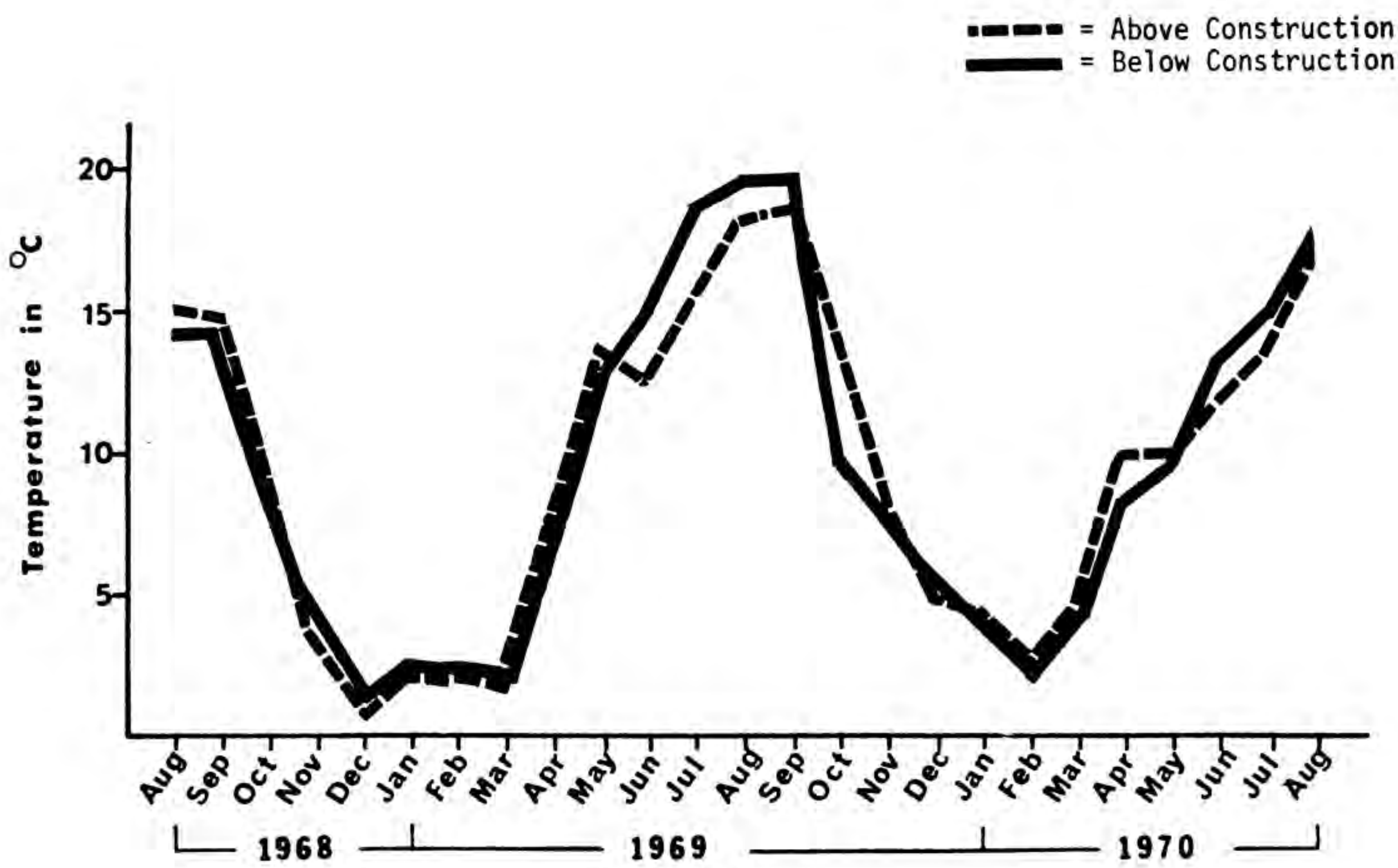

Fig. 17. Temperature of the water at the sampling stations above and below the construction areas in the Weber River, Summit County, Utah.

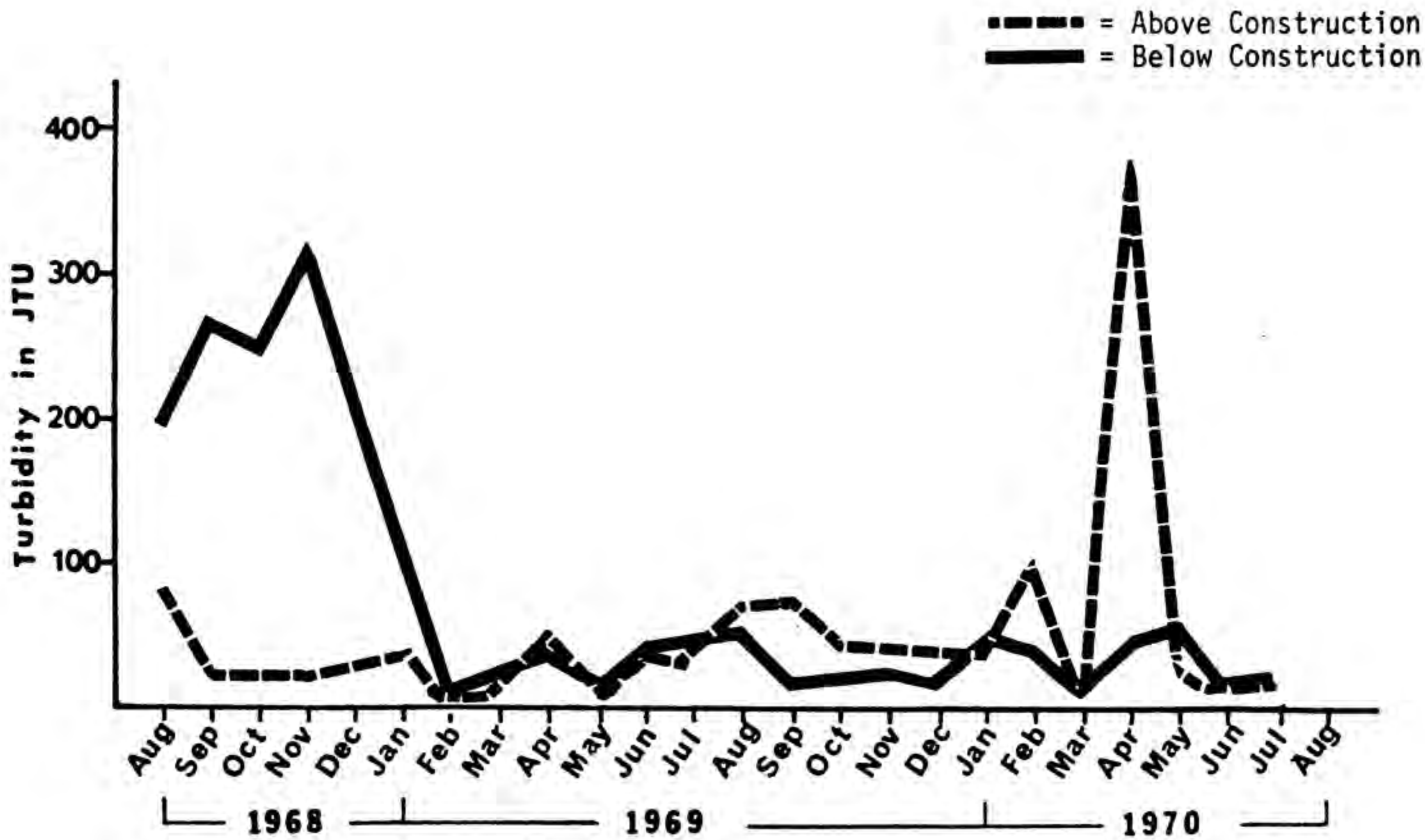

Fig. 18. Turbidity of the water above and below the construction area in the Weber River, Summit County, Utah.

taken above, at and below the channel alteration (Table 5). The turbidity values were low (0 JTU) above the new channel but were very high at it and below it (310 JTU). Below this area the turbidity dropped off rapidly and after 4.3 kilometers of river the turbidity values were very low again (0 JTU).

Table 5. Turbidity measurements (JTU) of water collected at all stations shortly after channelization at Station 6 (November 12, 1968).

Station		Turbidity
	1	0
	2	0
	3	1
	4	1
	5	3
(New Channel)	6	760
	7	310
	8	0

Discharge

Discharge (Fig. 19) of the water below Echo Reservoir fluctuated drastically throughout one month. The maximum and minimum (1180 to 0 cfs) can occur within a short period of time. There was a seasonal pattern of high flows during the summer months and low flows during the mid-winter months. During the study, the yearly discharge was 318 cfs.

Fish and Macroinvertebrate Gut Analysis

The majority of fish species in the Weber River utilize the aquatic insects as a major food source. The gut contents of most of the aquatic insects analyzed contained detritus, algae, and diatoms. Only Isoperla and Eropdella stagnalis were thought to be carnivorous, feeding on Chironomidae and Oligochaeta. The information gathered on food analysis is summarized in Table 6.

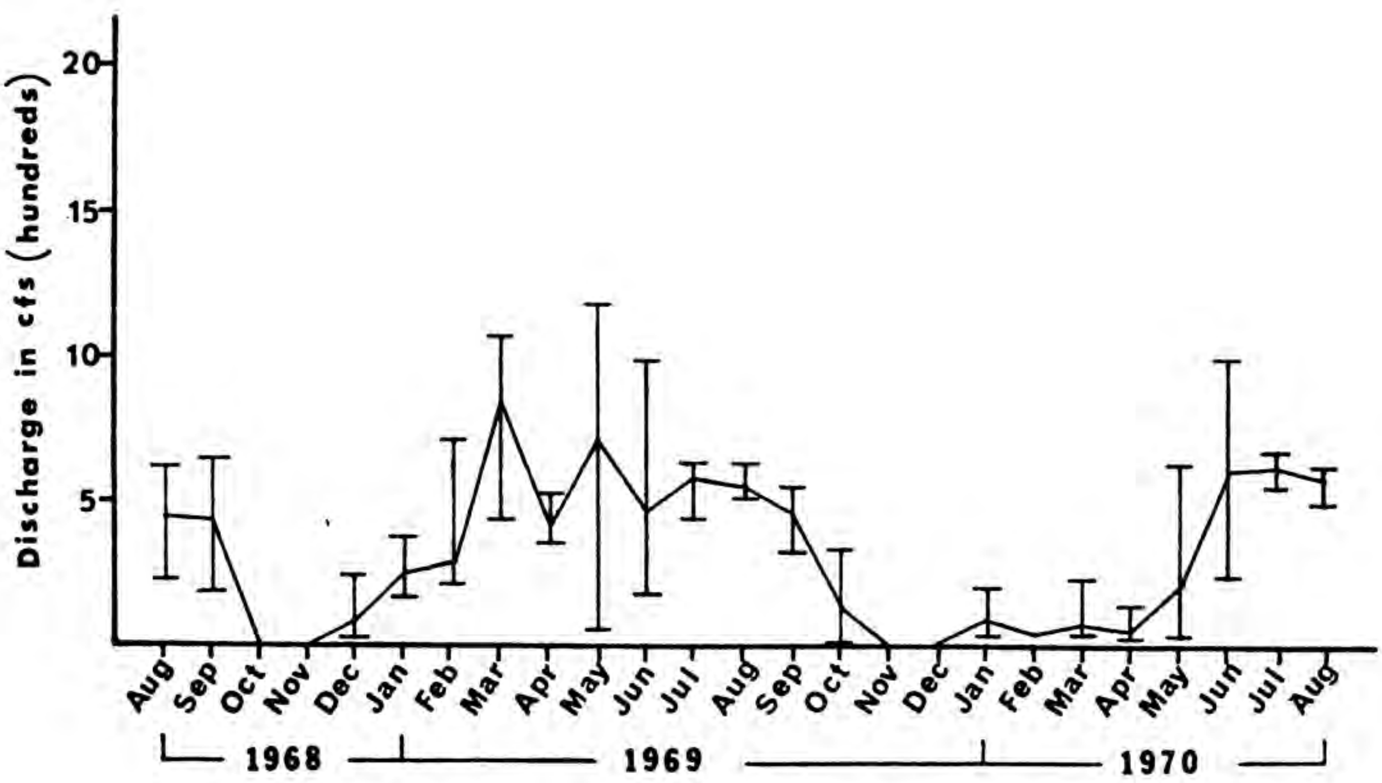

Fig. 19. Discharge of water from Echo Reservoir showing mean, maximum and minimum per month.

Table 6. Gut analyses of the macroinvertebrates and fish of the Weber River, Summit County, Utah.

	Detritus	Diatoms	Algae (Filamentous)	Crustacea	Oligochaeta	Ephemeroptera	Plecoptera	Trichoptera	Diptera (Chironomidae)	Terrestrial Insects	Fish
Ephemeroptera	X	X	X								
Plecoptera	X	X	X		*				*		
Trichoptera	X	X	X								
Diptera	X	X	X								
Oligochaeta	X										
Hirudinea					X	X			X		
Whitefish				X	X	X	X	X	X	X	
Bluehead Sucker	X	X	X								
Utah Sucker	X	X	X		X	X			X		
Carp	X	X	X		X	X	X	X	X	X	
Cutthroat trout						X	X	X	X	X	X
Rainbow trout			X			X	X	X	X	X	X
Brown trout						X	X	X	X	X	X
Redsided Shiner					X	X	X	X	X		
Utah Chub					X	X	X	X	X		
Long Nose Dace					X	X	X	X	X		
Speckled Dace					X	X	X	X	X		
Cottus					X	X	X	X	X		

*one species of Isoperla

Macroinvertebrates and Algae in the Weber River

Listed in Appendix 1 are the types and distribution of algae and diatoms found in a cursary examination of the bottom samples collected in the Weber River below Echo Reservoir and above Echo Reservoir and above Wanship Reservoir. An abundance of *Cladophora* sp. was found below Echo Reservoir especially from July through October, but relatively little was found above it. It was replaced by the gelatinous diatom *Gomphonema* sp. during the winter and spring months.

A checklist of the invertebrates collected in the Weber River and their distribution within the river above and below Echo Reservoir and above Wanship Reservoir area are shown in Appendix II. This list is not complete because only riffle areas were sampled regularly. However, some pool and back water species are included. Only the adults of some species were collected.

Organic and Inorganic Drift

Evaluation of the amount of inorganic and organic matter occurring in the drift showed that there was an increase in the amount of organic and inorganic matter in the river in the winter and spring of 1969 and 1970 at the stations below Echo Reservoir (Figs. 20 and 21). There was no increase downstream in the organic or inorganic drift load. In most instances more material was collected in the drift at Station 1 (above the channelization) than at Station 7 (below the channelization). The average amount of organic matter in the drift was 0.92 g/m^3 ($0.02/ft^3$) at Station 1 and 0.19 g/m^3 (0.005 g/ft^3) at Station 7. The maximum and minimum amount at Station 1 was 16.8 (0.475) to 0.004 g/m^3 (0.0001 g/ft^2) and 0.78 (0.02) to 0.005 g/m^3 at Station 7. The inorganic drift averaged 61.6 g/m^3 (1.75 g/ft^2) at Station 1 and 0.25 (0.007) at Station 7 with the maximum and minimum of 1381.8 (39.1) to 0.0006 g/m^3 (0.000 g/ft^2) for Station 1 and 1.15 (0.032) to 0.001 g/m^3 (0.000 g/ft^2) at Station 7.

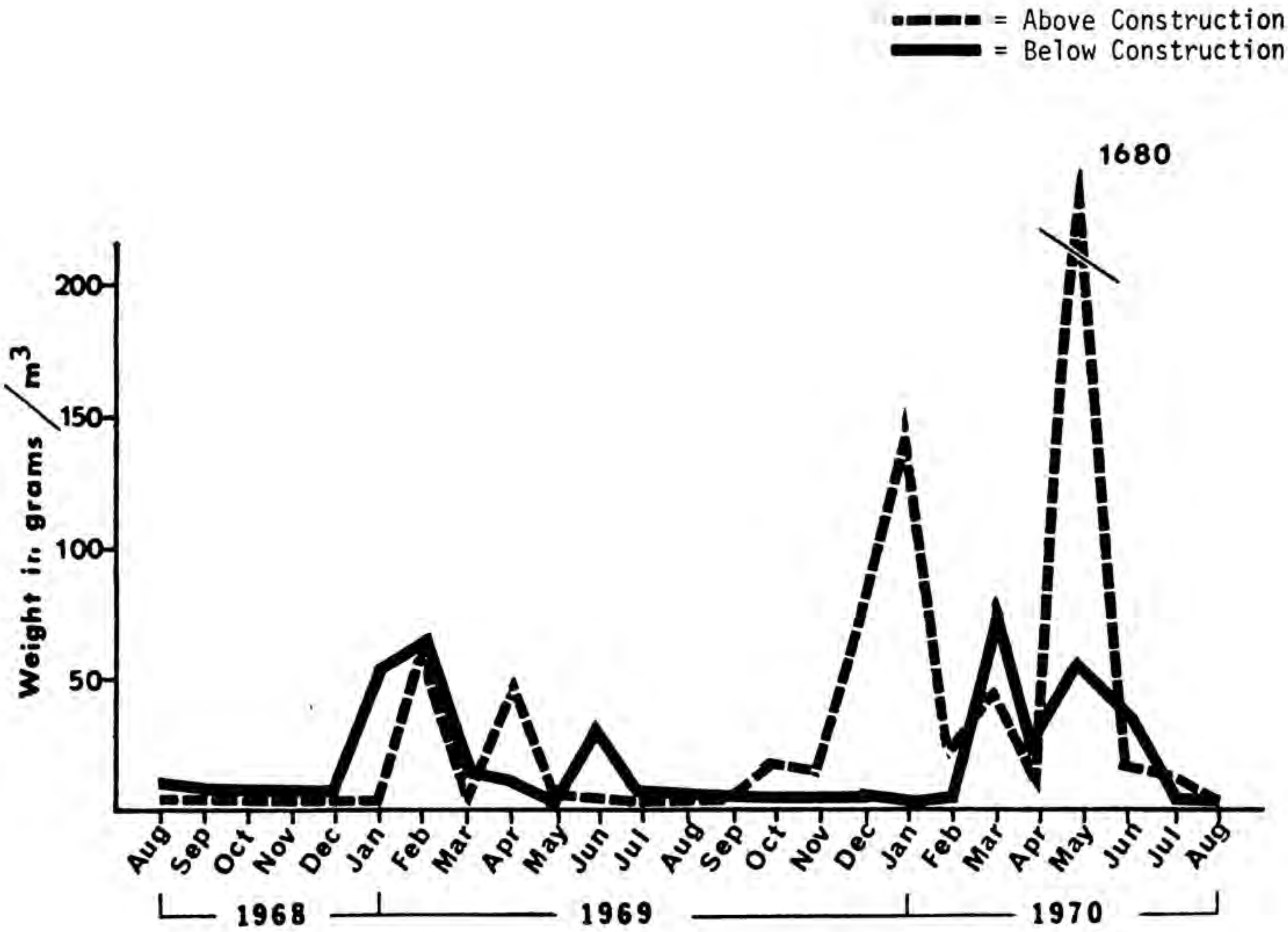

Fig. 20. Organic drift collected above and below construction areas in the Weber River, Summit County, Utah.

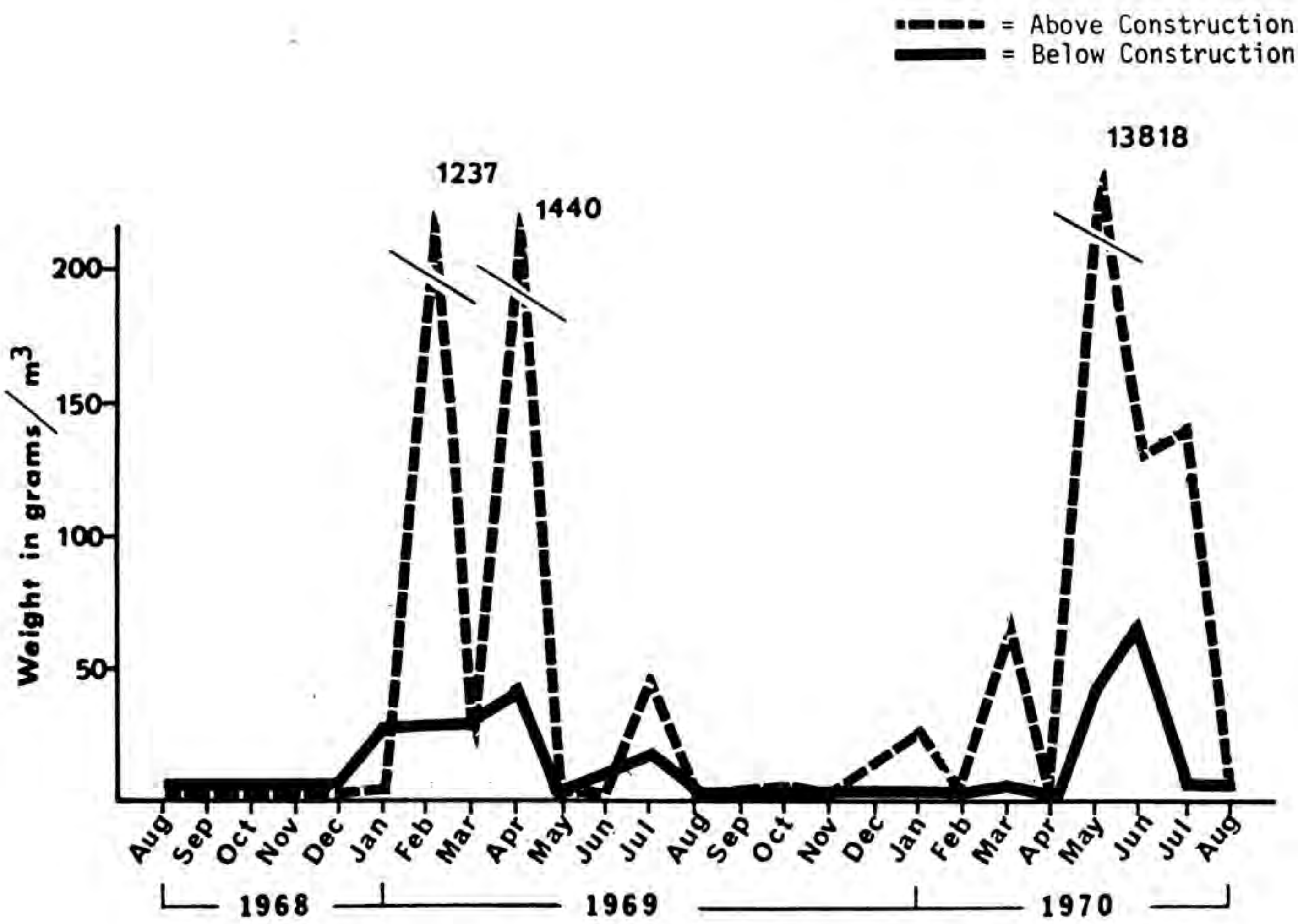

Fig. 21. Inorganic drift collected above and below construction areas in the Weber River, Summit County, Utah.

Vegetation

From the square foot (0.092 m^2) plot it was calculated that there were 215.8 g/m^2 (6.1 g/ft^2) of organic matter in changed areas and 614.3 g/m^2 (17.4 g/ft^2) in the unchanged areas (Table 7).

The quarter method used to analyze the remaining streamside vegetation showed (Table 7) that in those areas along the stream that were highly grazed there were 36.8 trees/hectare (14.9 trees/acre) with the narrow leaf poplar (Populus angustifolia) being the most dominant (90.4%) and then hawthorne (Crataegus douglasii) (7.6%). Narrow leaf poplar had an average basal area of 13.6 cm^2/tree (2.1 in^2/tree) and hawthorne had 6.5 cm^2/tree (1.0 in^2/tree). There were no shrubs or understory plants at all in the grazed areas. Unaltered areas that were not grazed had 41.3 (16.7) (Station 7) and 31.8 (12.8 trees/acre) (Station 8) trees per hectare. The narrow leaf poplar was the most dominant (97.2% and 97.6%) and the hawthorne next dominant (2.7% and 2.4%). The basal area was 28.9 (4.4) and 26.9 cm^2/tree (4.1 in^2/tree) for the narrow leaf poplar and 4.9 (0.7) and 3.3 cm^2/tree (0.5 in^2/tree) for the hawthorne. There was extensive shrubs and undergrowth in these areas with 74.5 (30.1) and 29.3 bushes/hectare (11.8 bushes/acre).

Macroinvertebrate Populations

Changed and Unchanged Areas

Samples taken in the newly channeled areas in October and November 1968, contained no organisms. Within two months the macroinvertebrates were beginning to establish themselves in the new channels. The establishment of the organisms corresponded to a period of increased

Table 7. Analyses of streamside vegetation at changed (Station 5 and 6) and unchanged (Stations 7 and 8) areas on the Weber River, Summit County, Utah.

	Station			
	5 & 6	7	8	Average
Quarter method				
Area samples (m^2)	36.8	40.7	52.9	43.4
Number trees/Hectare	45.8	41.3	31.8	39.7
Relative Dominance (%)				
Populus angustifolia	90.4	87.5	98.6	92.1
Crataegus douglasii	7.6	12.5	2.4	7.5
Basal Area (cm^2)				
Populus angustifolia	13.6	28.9	26.9	23.1
Crataegus douglasii	6.5	4.9	3.3	4.9
Shrubs				
Area samples (m^2)		22.6	57.1	39.8
Number/Hectare		74.5	29.3	51.9
Relative Dominance (%)				
Populus angustifolia		22.5	42.8	35.4
Crataegus douglasii		50	17.8	33.9
Lonicera involucrata		7.5		3.7
Amelanchier alnifolia		12.5		6.25
Salix ap.		2.5	7.1	4.8
Rosa woodsii			7.1	3.5
Ribes aureum			14.2	7.1
Rhus trilobata			7.1	3.5
Square foot plot (0.092 m^2) (g/m^2)	215.8	614.3		

discharge in January and February, 1969, (Fig. 19) and to a corresponding increase in the stability of the substrate. Within six months the macroinvertebrates were established in numbers and weight similar to those of the unchanged areas (Figs. 22 and 23). From April, 1969, the populations in the changed and unchanged sections followed the same seasonal pattern. The weight of the organisms was higher however, in December of 1969 and April of 1970 in the unchanged areas. The log of the number gives a more concise picture of the establishment of organisms in the changed areas and the subsequent similarity in seasonal patterns shown between the changed and unchanged sections (Fig. 24).

The establishment of organisms on artificial substrate in the changed areas occurred faster than it did on the unstable substrate of the new stream channel. The number of organisms collected in the baskets was higher than the number of organisms on the regular substrate following channelization (Table 8). After three months, the numbers of organisms in the bottom samples increased to 384/m^2 (35.6/ft^2) and then declined for the next two months while the number of organisms collected in the basket samples remained relatively constant.

Table 8. Number of organisms collected in basket samples and bottom samples at Station 5 before, during and after channelization.

	Bottom Samples (no./m^2)	Basket Samples
August 1968	7585	625
September 1968	6576	923
October 1968 (Channelization)	0	---
November 1968	32	618
December 1968	384	842
January 1969	240	704
February 1969	128	680

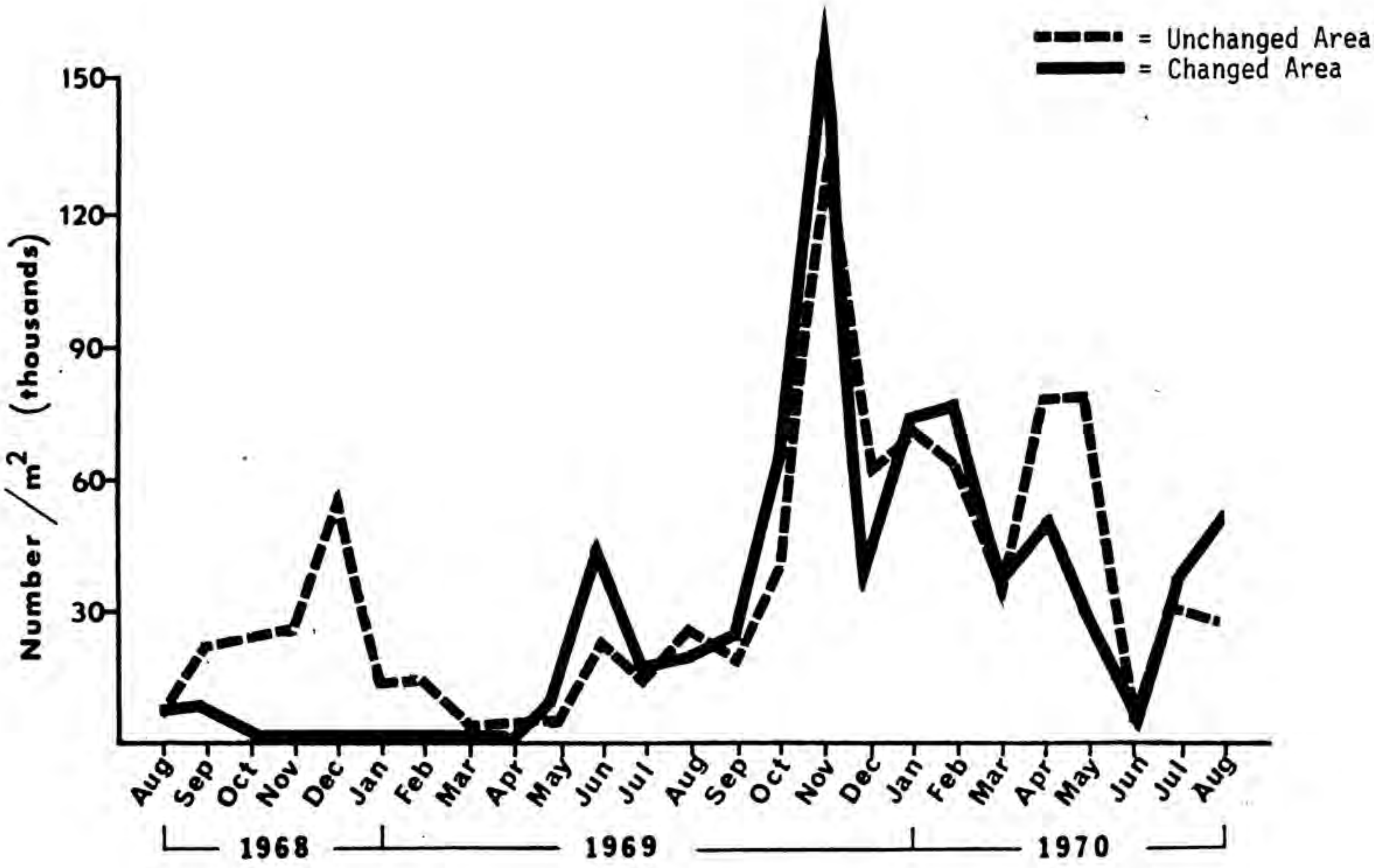

Fig. 22. Numbers of organisms per meter squared in changed and unchanged areas of the Weber River, Summit County, Utah.

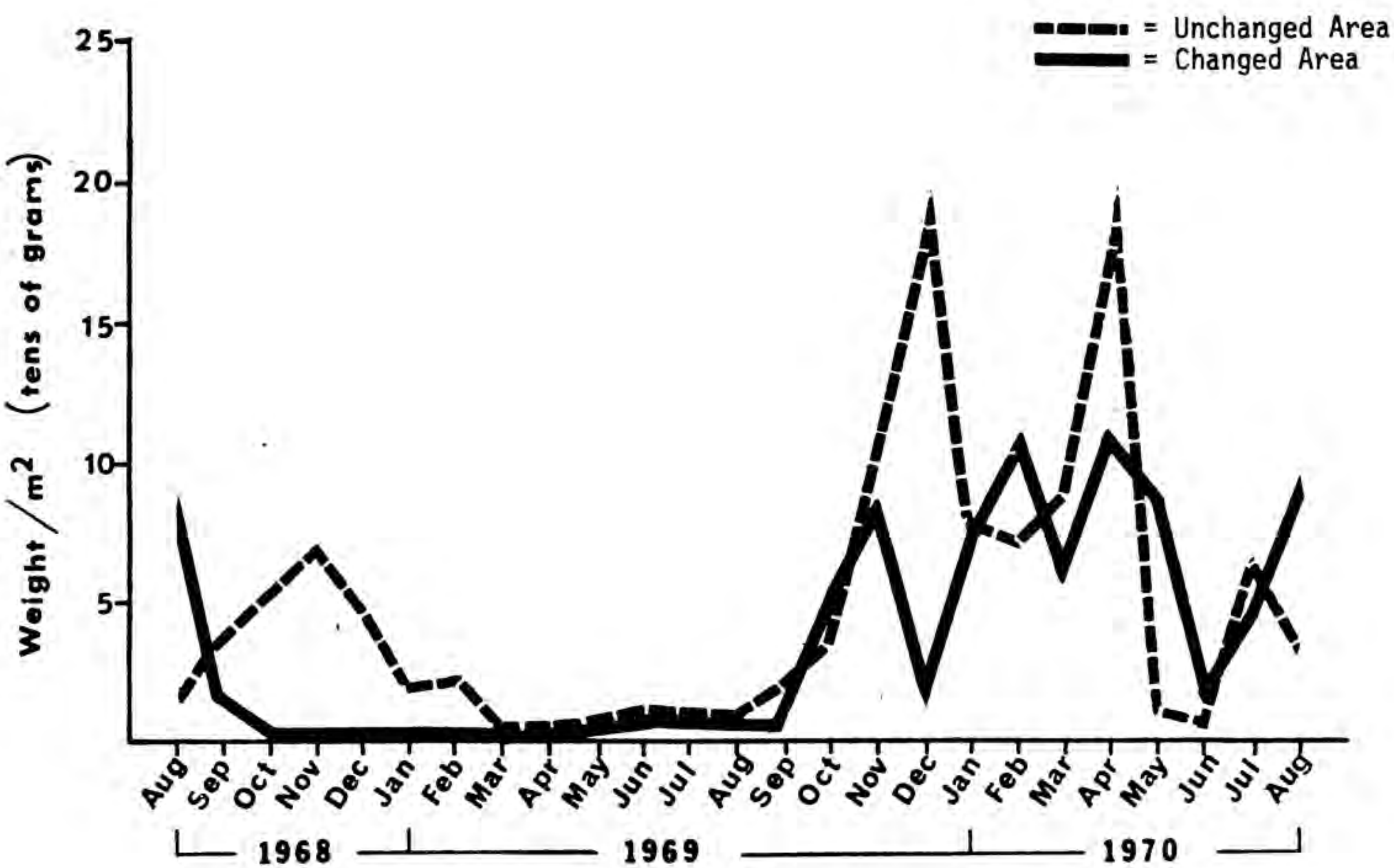

Fig. 23. Weight of organisms per meter squared in changed and unchanged areas of the Weber River, Summit County, Utah.

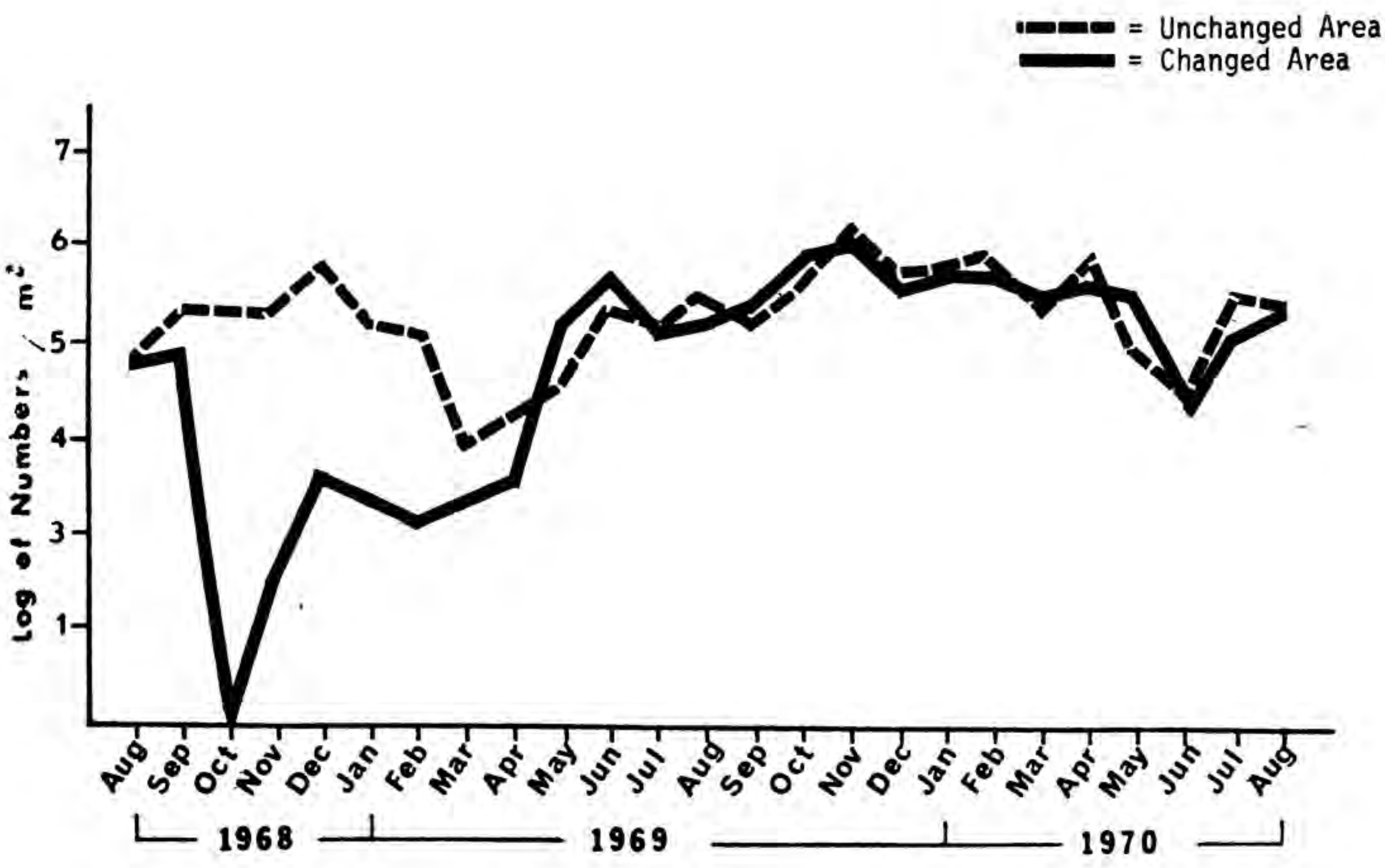

Fig. 24. Log of the numbers of organisms per meter squared in changed and unchanged areas of the Weber River, Summit County, Utah.

In the changed and unchanged section there was no significant difference in the number of organisms in each taxonomic group except during and immediately after construction of the new channel (Fig. 25). A comparison of the taxa present showed that Hydropsyche sp. and Chironomidae were the first to invade the new channels. Other organisms (snails and water mites) and miscellaneous Diptera (Rhagionidae, Tipulidae and Empidae) were in relatively lower numbers and took a longer period to establish themselves in the changed areas.

The standing crop of macroinvertebrates at Station 8 (unchanged) was very similar to that in the changed and unchanged sections (Fig. 26). The same organisms occurred there and showed the same seasonal variations as those found in the changed and unchanged sections.

After colonization of the changed area, the species composition was found to be similar to that in the unchanged areas. Figure 27 shows the percent of the samples which contained each of the dominant taxa in the changed and unchanged areas. With the exception of three taxa (Heptegania sp., Paraleptophlebia sp., and Tricorythodes minutus) all organisms were collected with a higher frequency in the unchanged areas.

The macroinvertebrate population of the changed section had a low species diversity (0.6) at construction (October, 1968) but increased rapidly in November and December of 1968 and was similar to the species diversity of the unchanged area throughout the rest of the study although it did show a more erratic pattern during the first year after construction (Fig. 28). The average species diversity during the study for the changed areas was 1.92 and that for the unchanged areas was 2.06.

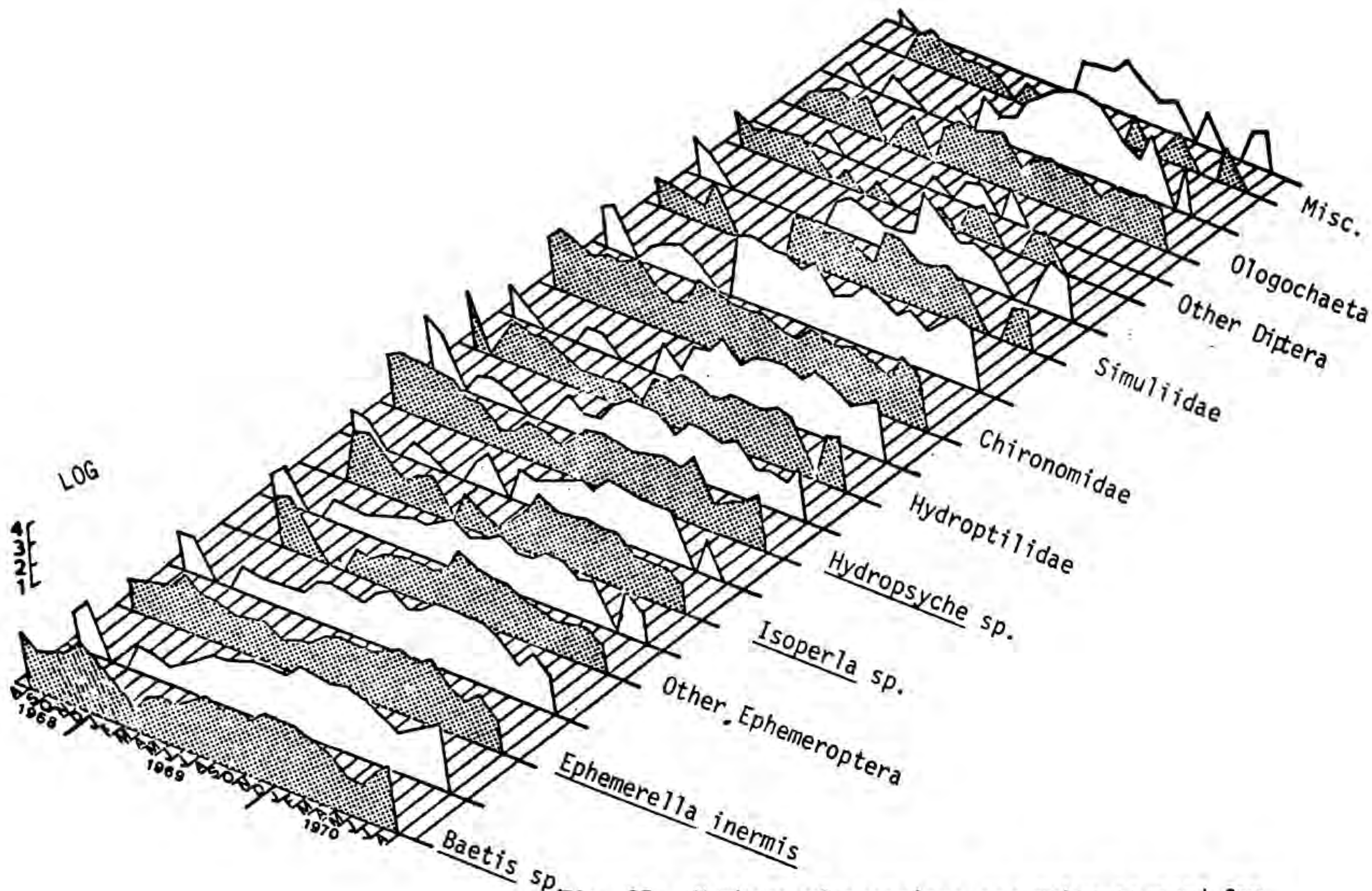

Fig. 25. Numbers of organisms per meter squared for each taxon collected in changed and unchanged areas of the Weber River, Summit County, Utah.

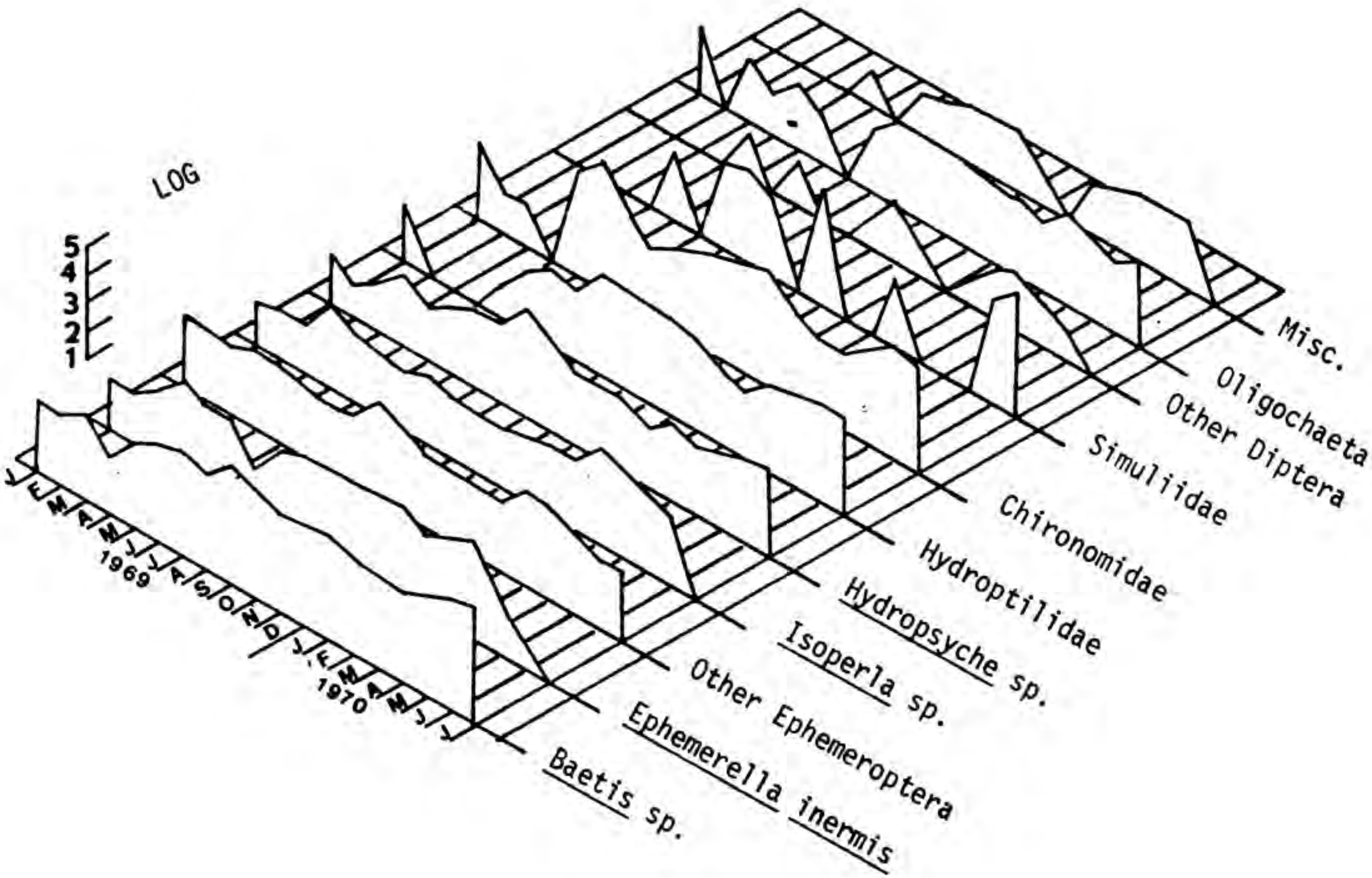

Fig. 26. Numbers of organisms per meter squared for each taxon collected at Atation 8, Weber River, Summit County, Utah.

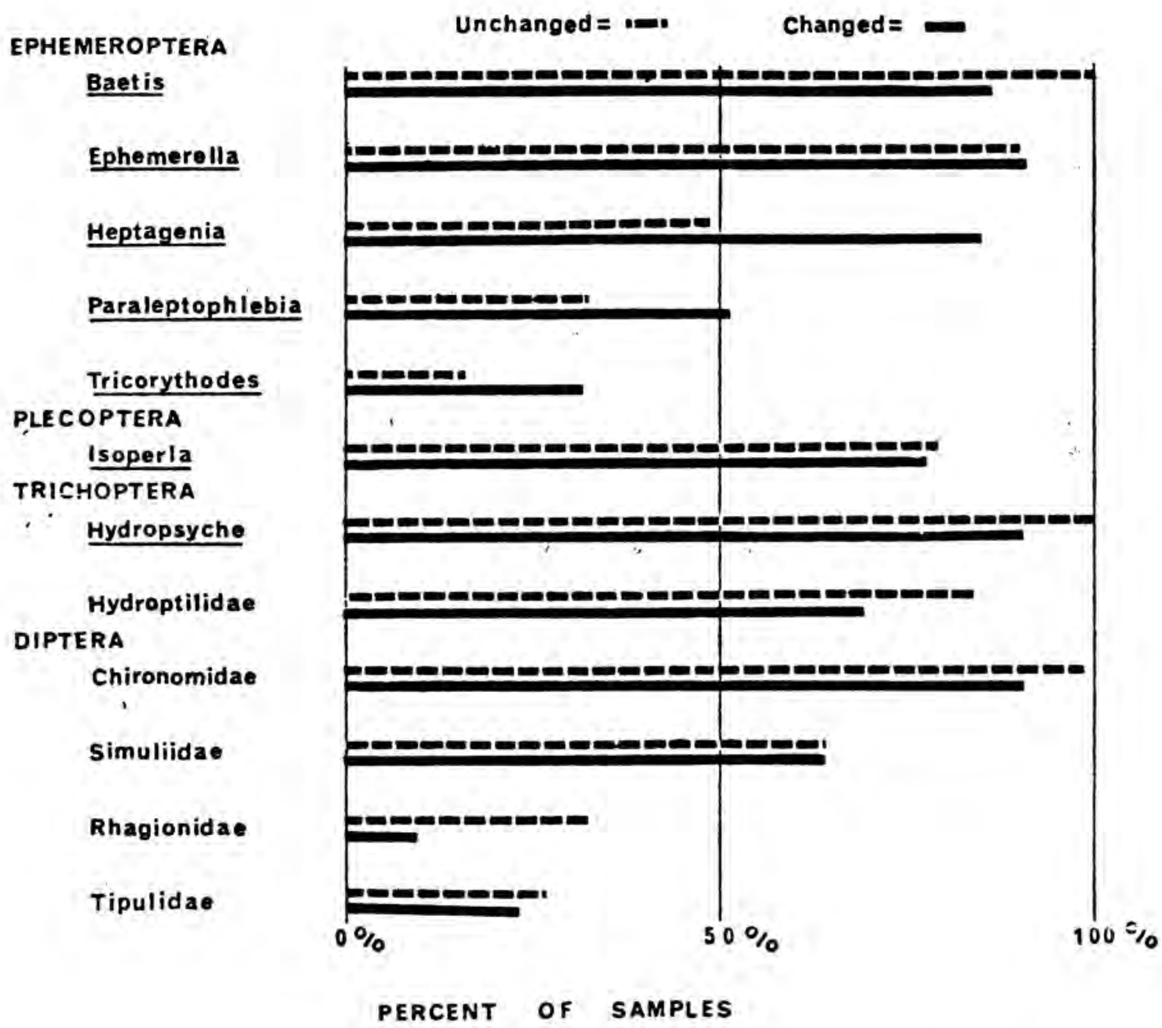

Fig. 27. Species composition of the invertebrates collected in bottom samples in changed and unchanged areas of the Weber River, Summit County, Utah.

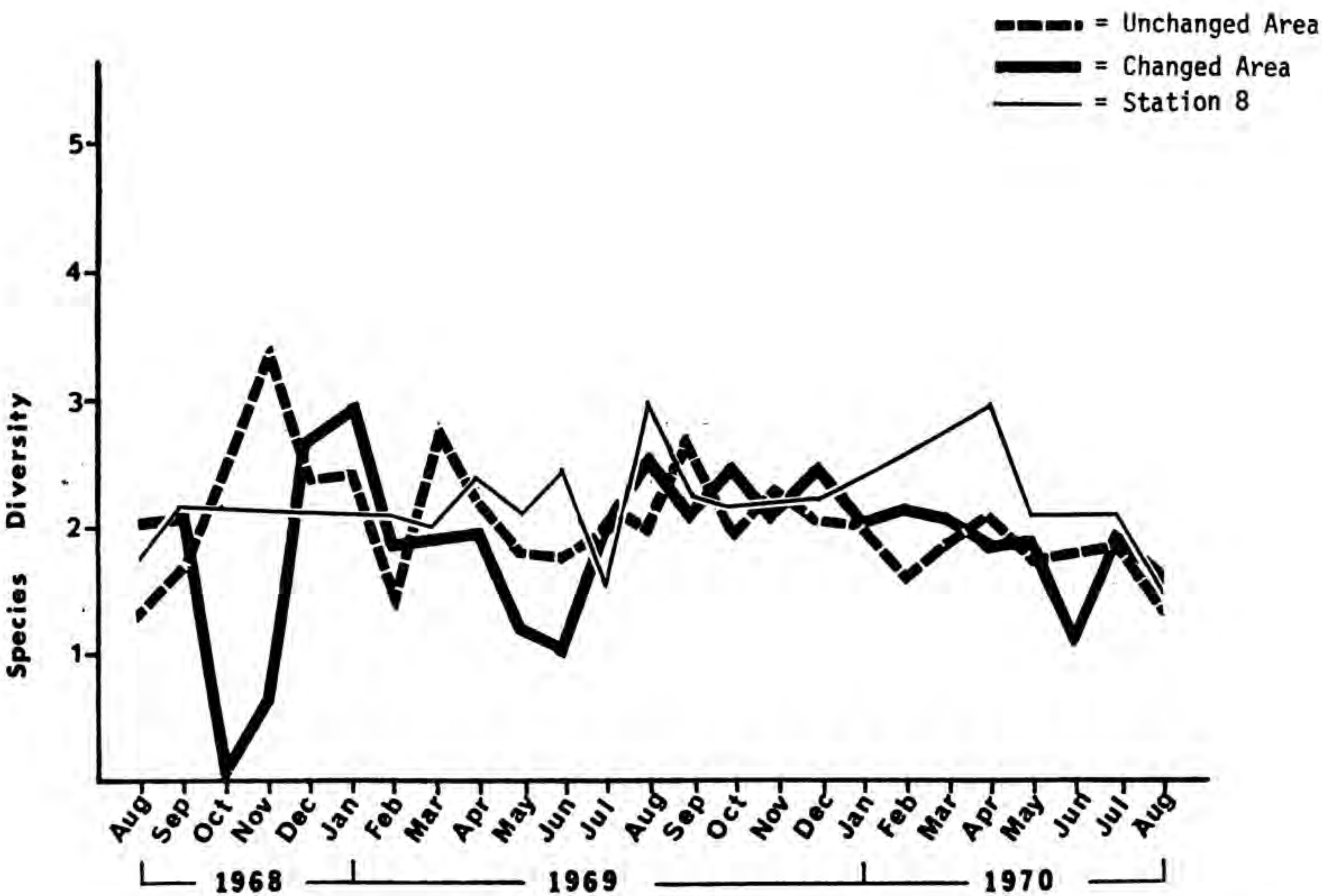

Fig. 28. Species diversity of the invertebrate populations collected in changed and unchanged sections of the Weber River, Summit County, Utah.

Ordination analysis (Fig. 29) indicates that there was no difference between the macroinvertebrate populations of the changed and unchanged sections of the Weber River. It shows the samples collected at Station 8 and in the changed and unchanged sections group together.

Gabion-Rock Deflector

The diagram of the rock and gabion deflectors shows the sample sites around the structures and the number of organisms per meter squared collected at each site (Fig. 30). The data indicate that the gabion has a few more organisms around it than the rock structure. There were more organisms in the first transect behind the gabion than in transect two, especially near the middle of the structure. Computer analysis showed that the gabion deflector had higher standing crop than the rock deflector (Table 9). Rubble had a higher standing crop than gravel or sand for most organisms and for the total numbers of organisms. Gravel supported higher numbers than sand. Organisms were more numerous in the transect immediately behind the structures for the total numbers of organisms but for several species and two orders of insects, more organisms were found in front of the structures. There were more organisms found near the end of the structures. Simulium sp. and Hydropsyche sp. were more numerous near the bank.

A summary of the mean, maximum and minimum values obtained for each of the parameters measured for each of the stations is shown in Table 10.

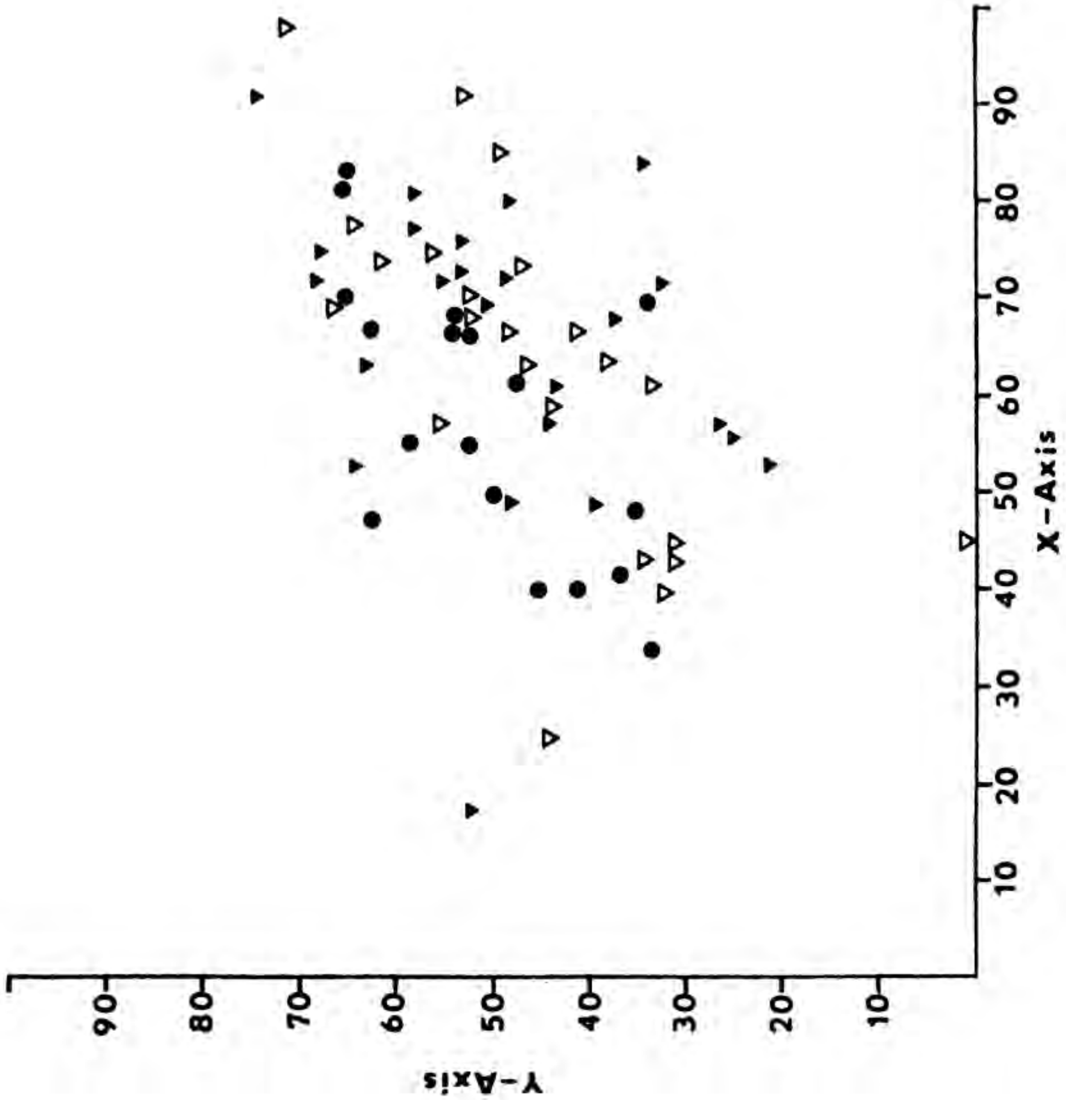

Fig. 29. Ordination analysis showing graphical representation of macroinvertebrate population relationships between all stations.

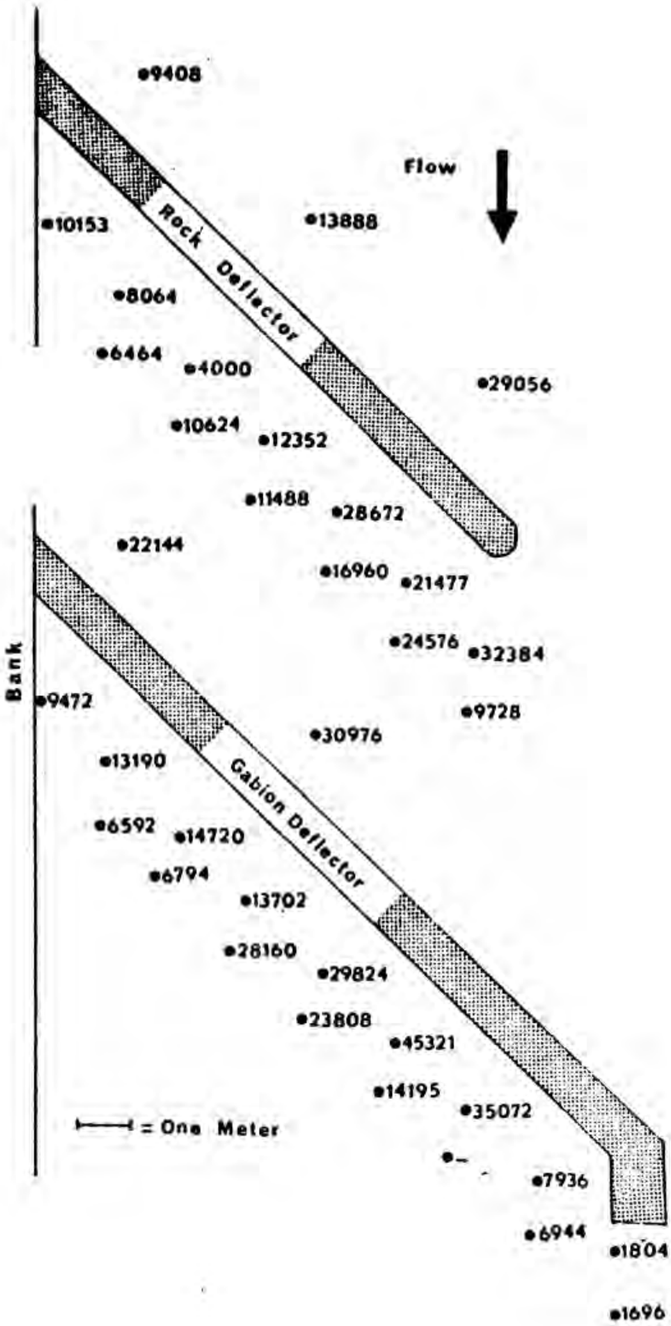

Fig. 30. Diagram of the gabion and rock deflectors showing sampling sites and numbers of organisms collected at each site.

Table 9. Evaluation of significance each variable contributes to the distribution of the macroinvertebrate populations around a gabion deflector and rock deflector placed in the Weber River, Summit County, Utah. (- = 1%; * = 5%; ** = 10%)

	Location	Transect	Substrate	Deflector	Significance (Percent)
Baetis		Front			*
Ephemerella	End	Near	Rubble		-/**/**
Tricorythodes	End	Near		Rock	-/*/-
Paraleptophlebia					
Rhithrogenia		Front		Rock	*/-
Isoperla		Front			**
Hydropsyche	Bank/End				-/*
Hydroptilidae		Front	Rubble	Gabion	*/**/**
Chironomidae	End/ Middle			Gabion	*/-/*
Tipulidae			Rubble	Gabion	*/*
Rhagionidae				Rock	**
Simuliidae	Bank	Far		Gabion	*/-/-
Oligochaeta			Rubble/ gravel		**/**
Physa			Rubble/ gravel		-/*
Mayflies	End	Front/ near	Rubble		-/*/**/**
Stoneflies		Front			**
Caddisflies		Front	Rubble	Gabion	*/**/-
Diptera					
Other			Rubble/ gravel		**/**
TOTAL	End/ Middle	Near	Rubble/ gravel	Gabion	-/-/-/**/-/-

Table 10. Summary table of mean, maximum, and minimum values measured for chemistry, standing crop and drift in the Weber River

	Station	Mean	Maximum	Minimum
Temperature (°C)	1	9.1°C	18°C	1°C
	7	9.3°C	19.5°C	1°C
Discharge (cfs)	Echo	318.5 cfs	1180 cfs	0 cfs
Turbidity (JTU)	1	46.47 JTU	355 JTU	0 JTU
	7	61.94 JTU	600 JTU	0 JTU
Hardness (ppm)	1	207.5 ppm	290 ppm	130 ppm
	7	203.4 ppm	290 ppm	135 ppm
Alkalinity (ppm)	1	217.5 ppm	340 ppm	160 ppm
	7	214.7 ppm	280 ppm	170 ppm
pH	1	8.4	8.75	6.7
	7	8.3	8.7	6.8
Phosphate (ppm)	1	0.21 ppm	1.78ppm	.05 ppm
	7	0.21 ppm	1.6 ppm	.04 ppm
Sulfate (ppm)	1	31.15 ppm	105 ppm	16 ppm
	7	31.11 ppm	135 ppm	14 ppm
Organic Drift (g/m^3)	1	0.925 g/m^3	16.8 g/m^3	.004 g/m^3
	7	0.191 g/m^3	0.784 g/m^3	.005 g/m^3
Inorganic Drift (g/m^3)	1	61.69 g/m^3	1381.8 g/m^3	.0006 g/m^3
	7	0.252 g/m^3	1.151 g/m^3	.001 g/m^3
Standing Crop (Number and Weight)	Unchanged	31474 51.9	132848 239.1	896 42
	Changed	30431 40.52	76832 163	0 0

Discussion

Bottom Sampling

The evaluation of stream conditions can be related to the richness of the standing crop of the benthos. This procedure is basic to any ecological study of the aquatic environment. However, a problem that studies of benthos have failed to resolve is, what is an adequate number of samples to collect in order to make the results statistically significant and to adequately represent the environment Leonard (1939) arbitrarily took 5 samples in his studies. Hess and Swartz (1941) took sufficient samples to keep the standard error within 10% of the mean. Needham and Usinger (1956) determined that it would take 194 samples to get statistically significant (95%) results for weight and 73 for numbers of organisms from a riffle community. Chutter (1972) found these estimates to be optimistic and showed that it would actually take 448 samples to be 95% confident that the sample mean would be within 5% of the population mean. Hales (1962) found using a formula at different confidence limits, values from 2413 to 2 samples would be adequate. He concluded that in a typical Utah stream, bottom sampling is an inadequate means of quantitatively measuring the bottom fauna. Elliott (1961) discusses a formula for deciding how many samples are needed and they vary with the type of distribution the population has and the mean of the population. Chutter and Noble (1966) found that 3 samples would be adequate for making a general survey of streams. Thus the sampling problem is one which requires a choice to be made as to what the needs and objectives of the study are. A compromise must be made between statistical validation and reasonable operating time.

For this reason one sample was collected at each station for each month in this study. It was felt that any more samples would be too burdensome and there would not be enough time to anlayze them. It was also felt that the actual values in stream benthos sampling is not the important principle but that the changes in magnitudes are the important thing. A single sample should give a reasonable idea of the magnitude of numbers and weight occurring at that time in a riffle community. This seems justified as the values of organisms/m^2 obtained each month from the changed areas (Stations 5 and 6) and unchanged (Stations 1 and 7) were very similar (Fig. 25). The data from the changed stations were averaged together as were the data from the unchanged stations. This was then considered to be similar as taking two samples in one area of changed or unchanged. The close relationship of the measured values from Station 8 to those of the changed and unchanged areas indicate that this sampling procedures gave adequate information.

The statistical significance of the results from this sampling procedure may be subject to criticism but then even if anything less than 194 or 73 (Needham and Usinger, 1956) or more accurately 448 (Chutter, 1972) samples were taken at each riffle each month it would also be subject to such criticism.

Changed and Unchanged Areas

The structures in the channeled portions of the Weber River increased the riffle-pool complex. In comparing the structured sections of stream with the other sections, it was found that there were just as many holes and riffles in the changed areas as the unchanged.

The profile of the structured stream channel was very similar to that of the unaltered area (Fig. 5, 6 and 7). The altered unstructured portion of river has a smooth bottom and few holes. The structures in the Weber River have caused the water to cut holes and form riffles which allows a diversity of habitats to develop and affords a variety of microhabitats for flora and fauna.

This study suggests that structured, altered areas are capable of supporting a fish and invertebrate population comparable to that in the unaltered sections. Channels which are dug and left in straight, canal-like form have a reduced abundance and variety of organisms (Gaufin, 1959; Etnier, 1972). Generally there is an increase in invertebrate standing crop due to improvement structures (Jester and McKirdy, 1966; Morofsky, 1936; Tarzwell, 1932, 1937). The invertebrates may have been there even without the structures, but with the structures a more stable, rapidly established riffle, pool complex was formed.

A comparison of the invertebrate populations around the rock deflector and the gabion deflector indicates that the gabion had a slightly larger invertebrate population. However, it would be impossible from this one study to determine which type of structure is the most effective. It does indicate that the invertebrate populations were there and in somewhat similar distribution and numbers around both types of deflectors.

The number of organisms per meter squared in the changed and unchanged areas was very similar. The weight of organisms per meter squared was higher in December of 1969 and April of 1970 in the unchanged areas. A great number of large organisms were found in the unchanged areas during this time which accounts for the higher weight values. In the summary table (Table 10) the mean weight and numbers of the organisms per meter squared was substantially lower in the changed than in the unchanged areas. The mean values includes those periods of channelization and colonization when few or no organisms were collected thus resulting in the low values.

There were probably several reasons why the invertebrate organisms established themselves so rapidly and completely in the rechanneled areas of the Weber River. One reason was that only short stretches of the river were channeled in one place and this left ample areas for a refugium both above and below from which organisms could move into the rechanneled sections. Cairns, et al. (1971) found that areas not damaged could act as a source for recolonizing organisms and rapid recovery can be expected from these.

Both movement upstream and downstream would have allowed enough organisms to colonize the channeled area. This is especially true of the drift or organisms downstream. Drift appears to be the main source of organisms for colonizing denuded areas (Crisp and Gledhill, 1970; Hansen and Muncy, 1971; Waters, 1964). Drift is a common occurrence in all streams and rivers and the number of organisms moving over a fixed area in the stream is many times the standing crop in that area. Crisp and Gledhill (1970) estimated 20,000,000 organisms (14kg) passing a point in a stream in England in one year.

Some colonization may occur from downstream which would involve a swimming or crawling movement upstream (Bishop and Hynes, 1969; Elliott, 1971a). This is probably not nearly as important as the downstream drift in colonizing a denuded area, but still should be considered.

Another factor influencing the rapid colonization of the new stream bed was the rapidity with which the substrate was stabilized in the

Weber River. Patrick, (1959) points out that the stream bed must undergo changes and become stabliized before it is inhabitable. The type and stability of the substrate determines the number and kinds of organisms occupying it (Ballinger and McKee, 1971; Elder, 1969; Morgans, 1956; Cummins and Lauff, 1969). Rubble-gravel substrates are the most stable and support the largest standing crops. During the early spring of 1969, large volumes of water were discharged from the Echo Reservoir. These large volumes of water rapidly eroded the stream bottom and a stable substrate was formed in the channeled areas. Leopold, et al. (1964) points out that the greatest amount of sediment is moved during high flows and that subsequent reduced flows do not disturb the bottom material. Although the stability of the substrate was not quantitatively measured in this study the subjective description does give some indication of the conditions occurring there. A substrate of uniform size supports few organism and a good stable substrate requires a heterogenous collection of substrate sizes (Uresk, 1967). Stable substrates are of the rubble-gravel size (Leopold, et al. 1964). There are more invertebrates established on rubble substrates than the other types (Percival and Whitehead, 1929; Tarzwell, 1938; King and Ball, 1964; Uresk, 1967; Wene and Wickliff, 1940).

The early colonization of the "stable" artificial substrate in the baskets used in this study also indicates that the colonization was related to the stability of the substrate. The rocks in the basket were held in a stable position by the basket. This offered a place of attachment more stable than the eroding stream bottom. After a substantial stream flow and the substrate was eroded into a more stable condition the organisms inhabited the river bottom in increasing numbers. Hansen and Muncy (1971 also suggested that the rapid colonization of artificial substrate samplers in channeled areas indicated that there may be a lack of places for suitable attachment in the channeled bottom and thus attached in greater numbers to the stable artificial bottom samplers.

The rapid establishment of organisms in an area is not a new or uncommon occurrence. Several investigators have found that the invertebrates can establish themselves rapidly in denuded or newly exposed areas. Kennedy (1955) reported that a bulldozed stream channel recovered completely and a community similar to the one occupying the area previously, developed within 3 months. Warner and Porter (1960) also found recolonization by the invertebrates after a stream bottom was bulldozed. Larimore, et al. (1959) determined that recolonization of a denuded area began as soon as the water flow was resumed in a stream that was cut off from water during a drought. They point out that the invertebrates were there early enough to serve as food for the ingressing fish. Meeham (1971) found that in a stream where a "riffle sifter" (a device used to clean spawning gravel) was used, the invertebrate populations were virtually destroyed but that recolonization and establishment of the invertebrate organisms was complete within 3 months. Areas decimated by floods also recovered quickly (Moffett, 1936). Bachman (1958) found that a rechanneled portion of stream was colonized by invertebrates within one winter. This study on the Weber River showed that the macroinvertebrates were established within 6 months following channelization.

The establishment of former species composition and species diversity is also rapid in some streams and several investigators have found that the establishment of invertebrates is complete shortly after the conditions of "stress" are removed (Bachman, 1958; Warner and Porter, 1960; Morris, et al, 1968; Meeham, 1971; Kennedy (1955). A steady increase in species diversity continues until the community reaches natural conditions (Crisp and Gledhill, 1970).

The species composition in the changed and unchanged area on the Weber River showed minor differences (Figs. 25 and 27) which could be explained on the basis of colonization rates of the organisms and the fact that few or no organisms were collected at and immediately following channelization in the changed area. The single grouping of all the points in the ordination analysis further confirms that there was no detectable difference in the invertebrate populations in the changed and unchanged areas. If a difference existed, there would be a splitting or distinct group set apart from the rest of the points. This is not shown, thereby indicating the similarity of the populations in changed and unchanged areas.

The loss of vegetation along the stream reduced the amount of streamside ground cover which may have contributed to some erosion. Streamside vegetation acts as a buffer zone for streams by absorbing water and waste materials (Baily and Copeland, 1961). There has also been a reduction in the aesthetic value of the area due to vegetation loss.

The overall average values for number of trees/hectare was 39.7 and 51.9 shrubs/hectare. With the loss of about 20.8 hectares of vegetation as a result of this construction, the calculated loss was about 825 trees and 1079 shrubs or understory plants. This amounts to a substantial loss of production biomass along the Weber River. Vegetation removal as a result of this construction allowed 4 kilometers of river to be exposed more directly to sunlight than before its removal. This may have effected the temperature of the Weber River. Some streams which have had a loss in streamside vegetation showed an increase in stream temperature (Crisp and LeCren, 1970; Gray and Edington, 1969; Swift and Messer, 1971). There is a slight increase in temperature from below Echo reservoir to Station 8 but this may have occurred before the vegetation loss.

It appears that a river the size of the Weber River and the amount of discharge received from Echo Reservoir, that the temperature of the water could be controlled mainly by the releases from the dam. Brown (1969, 1970) states that large rivers have more capacity for heat storage than small ones. He points out that water temperature is directly proportional to the surface area and heat load and inversely proportional to the flow. The highest flows on the Weber River occur during the summer months when air temperatures are high. The low flows occur during the colder fall and winter months when temperature is not as critical. It would take a very shallow, slow flowing river the size of the Weber River a long time to heat up to values above its normal range.

To help alleviate the effects of the vegetation loss along the stream banks, broad leaf cottonwood (Populus sp.) and Russian Olive trees (Elaeagnus angustifola) were planted. It will be a long time before any benefit from these tree plantings will be felt, since many of the cottonwood trees have died and the Russian Olive trees are growing slowly in the infertile gravel left as stream banks. Natural revegetation is occurring in some areas along the rip-rapped banks near the water's edge. This vegetation is mostly willow (Salix spp.) and some grasses (Grammaceae).

The water chemistry below the construction area was little different from that occuring above the construction. The small differences that did occur may have been due to organic enrichment entering the river from the Henefer and Echo sewage outfalls. This may explain the high sulfate and phosphate concentrations downstream in the fall of 1968. This also corresponded to a period of low discharge which would not dilute the imput of organic enrichment. However, the increase downstream of phosphate and sulfate could have been the result of increased leaching from freshly exposed soils due to rechanneling.

The inorganic and organic drift is fairly uniform between, above and below construction and in most cases the drift is higher below the Echo Reservoir than the downstream station. The reservoir is either contributing material or is causing a lot of erosion below it.

Siltation and sedimentation reduce a streams productivity and the numbers and kinds of organisms are reduced (Peters, 1965, 1967; Gammon, 1970; Kelley, 1962; Saunders and Smith, 1965; Tebo, 1955; and Eustis and Hillen, 1959). The occurrence of increased amounts of siltation and sedimentation may have profound effects on the biota of a stream, especially if it persists for long periods of time (Brown, 1991). Croft and Baily (1964) believe there is more erosion now than in the past and that it is due to the disturbance of man. The occurrence of silt in some streams has caused the elimination of some mayflies and stoneflies (Agnew, 1962; Hamilton, 1961). Allen (1960, 1961) also believes that siltation has caused drastic changes in the faunas of New Zealand and may have even caused the extinction of the New Zealand grayling. Erosion silt screens out light, changes the heat radiation of streams, blankets the stream bottom and is very harmful to some organisms (Ellis, 1936).

Because of the shortness of duration in the turbidity downstream from the construction area, it appears that little damage or long-lasting effect occurred to the invertebrate populations of the Weber River. It generally takes high values for extended periods to be lethal in nature (Wallen, 1951). Recovery from increased silt loads is very rapid by invertebrate organisms (Gammon, 1970).

Most reservoirs release water of a less turbid quality than the water entering it (Chutter, 1963; Hokpins and Popalisky, 1970; Irving and Culpin, 1956; Johnson, et al., 1969; Morris, et al., 1968; Neel, 1963; Pearson, 1967; Pearson and Franklin, 1968; Spence and Hynes, 1971a and 1971b; Stober, 1963; Symons, et al., 1964). It appears, however, that Echo Reservoir does not conform to this characteristic. The water below Echo Reservoir usually had a higher turbidity value than did the Weber River entering it. A major tributary to Echo Reservoir is Chalk Creek which drains a heavily grazed area east of Coalville, Utah. This stream is highly turbid in the spring during run-off and after rainstorms. This may contribute to the reason for the higher turbidity below Echo Reservoir. Also the small Echo Creek dumps a high level of silt directly into the Weber River below Echo Reservoir during spring run-off and after rainstorms.

The high values of turbidity that occurred in the downstream areas in the fall of 1968 and early spring of 1969 were the result of the water being released down the newly constructed stream channels which caused an excessive amount of erosion at that time. Sedimentation and siltation are usually greatest during construction (Burns, 1970). The high turbidity values in the Weber River were or relatively short duration and apparently had little effect on the invertebrate organisms within the study area. Kopperdahl, et al. (1971) also found high turbidity values during and shortly after construction and it was also short-lived.

Probably the most serious loss resulting from channelization has been the reduction in stream length (Peters and Alvord, 1964). The rechanneling on the Weber River resulted in a loss of about 0.64 km (0.6 mile) which is roughly 1.62 hectares (4 acres) of stream habitat. Using the average standing crop for the area (50 g/m^2) it was calculated that there was a loss of about 907 kg (1955 lbs.) of fish food organisms as a result in the loss of river length.

It is apparent from the food analysis that the invertebrate organisms are dependent upon the detritus and algal constituent of the stream. This was also found by Chapman and Demory (1963) and MacKay (1969). The fish in the Weber River rely to a great extent upon the aquatic macroinvertebrate organisms as a food source. Other investigators have reported the importance of macroinvertebrates as a food source for fish (Allen, 1951, 1952, 1969; Greene, 1950; Kennedy, 1967; Metzelaar, 1929; Needham and Johnson, 1949; Tebo, 1955).

There are about 90 species of macroinvertebrates in the study section of the Weber River. The stream is a very productive river at least as far as the invertebrate organisms are concerned with an average standing crop of 30,000 organisms/m^2 (2788/ft^2) and an average weight of 45.00 gram/m^2 (4.18 g/ft^2). These values are higher than those reported by Hazaard (1934) as being the range in Utah streams (434-5266/m^2 or 12-150/ft^2 and 18.1 g/m^2 or 0.5 g/ft^2). The classification Hazzard (1934) used in determining richness of an aquatic system states that rich streams (Grade I) have an excess of 22 g/m^2 (2.1 g/ft^2) of invertebrate organisms. Grade II streams contain 11-22 g/m^2 (1.2-2.1 g/ft^2) and Grade III or poor streams have less than 11 g/m^2 (1.2 g/ft^2). According to this rating system the Weber River would fluctuate from a Grade I river to a Grade II with it being mostly in the Grade I category.

Summary and Conclusions

The placement of structures in the altered river channels allowed holes and riffles to be formed similar to those found in the unchanged areas, and has been successful in creating a more natural environment than would have existed if no structures were utilized. Both gabion and rock deflectors had rich standing crops around them, but the gabion structure had a larger standing crop of invertebrates.

The establishment of the invertebrate organisms in the riffle areas formed by the structures occurred within a relatively short period of time. Numbers, weight, species diversity and composition were the same in the changed and unchanged sections within six months after channelization. The colonization of the river bed was dependent upon the stability of the substrate which was controlled mainly by the amount of water flow. The substrate was considered stable within 6 months after channeling following a period of high discharges from Echo Reservoir.

The water chemistry was similar above and below the channeled area except for sulfate and phosphate which had high values in the fall of 1968 below the construction area. High turbidity of the water below the channeled areas occurred at and immediately following channelization but normal levels were achieved in a short time. Inorganic and organic drift showed the same seasonal pattern and no increase in the inorganic drift downstream from the altered areas was measured. Since the sedimentation and turbidity were of such short duration in the study area, little damage was done to the invertebrate populations.

Streamside vegetation loss resulted in a reduction in the aesthetic value of the area. The removal of the vegetation represents a loss in the buffer zone to the river which may prove harmful to the Weber River in the future. However, the loss of organic material to the river did not seem to effect the invertebrate populations studied. The temperature of the water may have been influenced to some degree by the loss of vegetation, but the temperature regulation of the water is controlled mainly by the water releases from Echo Reservoir.

The most serious effect of channelization on the macroinvertebrates has been the loss of river length with resultant loss of potential living space.

The Weber River has a productive fish food fauna, with high numbers and weights of organisms occurring throughout the year even in the ecologically disturbed areas.

FISHERY INVESTIGATIONS

Because of their recreational value, protection of sportfish populations should be one of the foremost considerations in any proposed channel modification. Numerous studies, in widely different ecological situations have described the detrimental effects of channelization. The fact that the effects of channelization do not readily mend themselves even with considerable time, as has been shown especially by studies in North Carolina (Bayless and Smith, 1964) makes it imperative that measures be taken to restore these scarred waterways and to protect others from unnecessary damage.

It has been the objective of this study to evaluate the influence of channelization and subsequent channel improvement on the fish populations in the Weber River between Echo Reservoir and Devil's Slide, Utah.

Larkin and graduate students (1959) reviewed some of the more important effects of man's activities on the streams of British Columbia. Other general articles covering a wide gamut of man's acticities include Mills, Starrett and Bellrose (1966) and Green (1950).

Modification of channels and their direct effects on the fisheries of streams have been discussed by Beland (1953), Spindler (1955), Stuart (1969), Alvord and Peters (1963), Peters and Alvord (1964), Burkhard (1967), Elser (1968) and others. More specifically, channel alterations due to highway construction have been discussed by Whitney and Bailey (1959), Sport Fishing Institute (1962), Utah State University (1961) and Swedberg and Nevala (1964).

On the other hand, there has been considerable work done to improve the habitat of streams by installation of artificial devices to improve the depth of streams along with fish cover and food. A few of the many references on this subject and its effectiveness are: Greeley and Tarzwell (1932), Hubbs, Greely and Tarzwell (1932), Burghduff (1934), Smith and Swingle (1950), Westerman (1953), Wilkins (1958), Cormack (1961), Saunders and Smith (1962), Calhoun (1966), Taube (1967), White and Brynildson (1967), Hale (1969) and Hunt (1971).

Gaufin (1958) and Smith (1959) discussed the Weber River with regard to limnology and pollution respectively. Neuhold (1955) inventoried the Weber River to evaluate its fishery. His evaluation was that the Weber River in the Henefer area has acceptable trout habitat, but fishing pressure was such that it exceeded the ability of the stream to produce fishable populations.

Fish Sampling

Throughout the study fish were collected by means of a Sears 115 volt, 110 watt alternating current generator. The current from the generator was rectified to give a pulsating direct current which would attract the fish to the positive electrode. The direct current was used almost exclusively while sampling, whether wading or from the boat. The fish handled were weighed (pounds - ounces) and measured (cm). All fish were then marked, either by fin clipping, (fish less than 20 cm) or by tagging with Floy FD - 67 tags and returned to the river. Over 5,000 numbered tags and more than 10,000 color coded tags were used to mark fish captured during the study. Precise information on the location of release of numbered and colored tags enabled the study of fish movements.

Populations estimates were computed using appropriate formulae from Ricker (1958). Quantitative estimates of populations were made for whitefish (Prosopium williamsoni), cutthroat trout (Salmo clarki), rainbow trout (Salmo gairdneri), Utah sucker (Castostomus ardens), and bluehead sucker (Castostomus discobolus). Subjective estimates of abundance were made for sculpins and minnow species. These species were not captured regularly or effectively enough to make quantitative estimates of their abundance possible.

1968

During the fall of 1968 the fisheries studies on the Weber River were initiated. Areas of the river corresponding to the study reaches where physical and invertebrate data were collected, were electrofished by wading. At the same time that fish sampling operations were continuing the water flows were held very low to facilitate construction of the new channels. This permitted the wading of most of the river channel, but there were still areas at every study reach except station 5 (Section F) that were inaccessable because of water depth. The initial sampling took place on October 5 and 6, 1968. On October 5, Reaches 8 (Section J), 7 (Section I), 6 (Section H), 5 (Section G) and 4 (Section B) were sampled, and on October 6, Reaches 3, 2 and 1 (Section A) were sampled (Fig. 2). Within a week after the initial sampling, construction of new channels either obliterated or made inaccessable reaches 5, 6 and 7 so no further information was obtained from these areas during the fall of 1968. Reaches 1, 2, 3, 4 and 8 were reshocked from November 16 to December 14, 1968.

1969

During 1969, as in 1968, shocking was confined to specific reaches of the river. The construction had already eliminated the original Reaches 4, 5 and 6 so the new channels that replaced these areas were designated accordingly. Most of the shocking for 1969 was concentrated in the new channels near the original Reaches of 4, 5 and 6.

Early in the summer of 1969, discharges from Echo Reservoir prevented shocking while wading. It became apparent that if progress towards evaluation of the fish populations was going to be made, a technique needed to be devised to sample fish while flows were high. The equipment used consisted of a twelve foot aluminum pram with an electrode attached to the bow (Fig. 31). The probe was the anode and the boat the cathode. One or more netters stood in the boat which was controlled by a pair of 100 foot nylon ropes pulled by workers on the shore. Shocking generally proceeded from downstream to upstream. The boat was worked back and forth across the river to insure total coverage of all areas. In areas of very swift water the boat was pulled upstream in an area of slower current and drifted down through the faster portions of the river.

1970-71

After the experiences of 1968-1969 it was decided that sampling short stretches of the Weber River was not yielding results that pro-

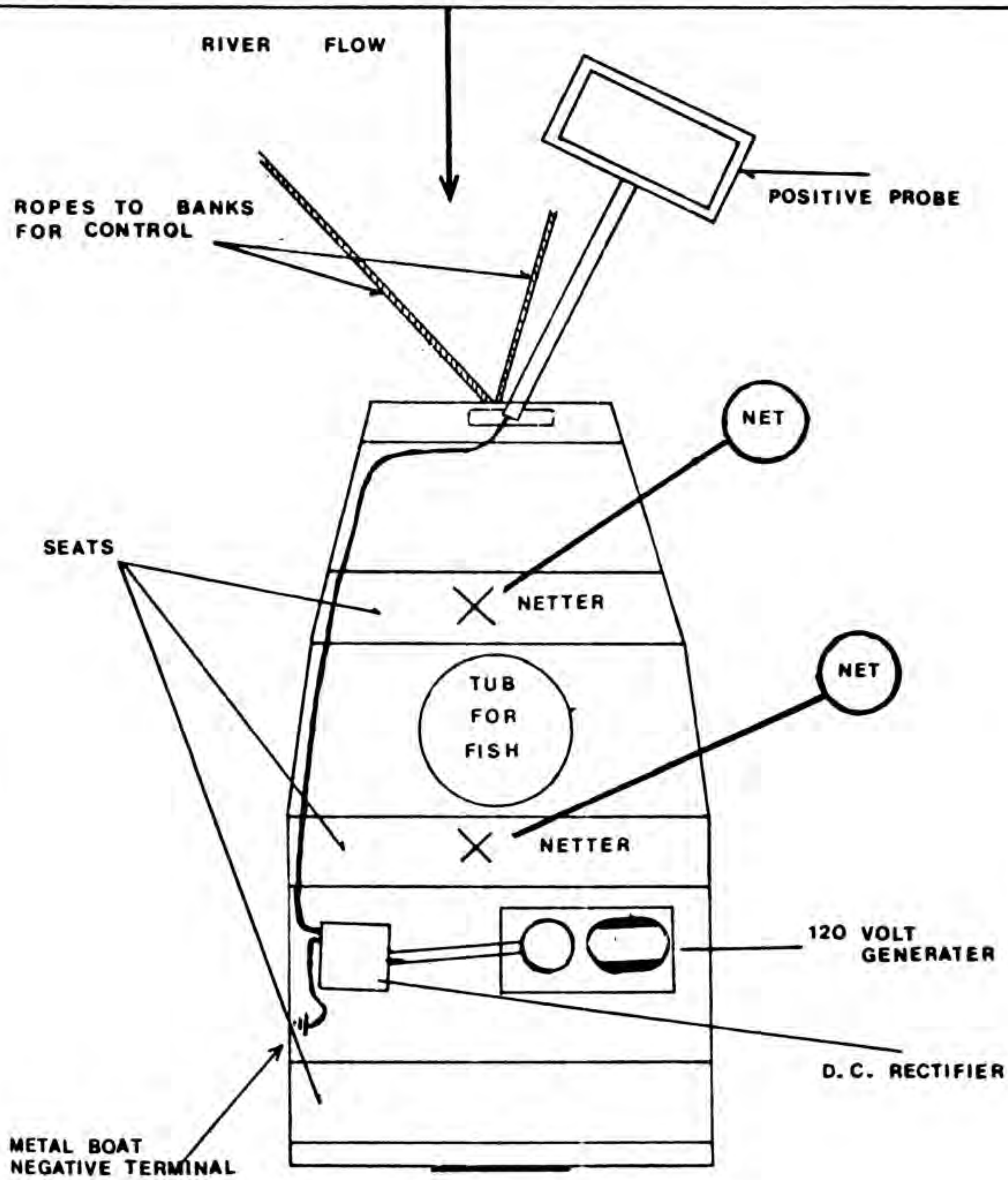

Fig. 31. Diagram of boat and equipment used in electrofishing in the Weber River, Summit County, Utah.

vided adequate information to evaluate the status of fish populations in specific areas of the Weber River.

First the river was mapped on a scale of 1 inch to 40 feet. The mapped section of the river began at Reach 8 (Section J) and extended upstream for a distance of about 6 miles, as measured along the center line of the river channel to about 1.6 miles in section A. It was hoped that the study area would extend up to Echo Dam, but access problems made this impossible.

In most cases the area to be shocked was fished from downstream up, but in areas where there was extensive fast water, shocking was down from upstream down. As the fish were shocked, the position in the river where they surfaced was plotted on the detailed map of the river. Netters in the boat called out identifications and numbers of each species to assist the mapper in marking proper information on the maps. Locations of small (age 0) fish were noted as were pertinent notes dealing with vegetation, substrate composition and location of points where weighing, measuring and tagging were done. Each tagging area was given a number which described its position along the length of the study section. These positions were expressed as distances in hundreds of feet from the most downstream part of the study section. This enabled a more precise quantification of fish movements and comparison of fish abundance from shocking to shocking and year to year.

The shocking efficiency was considered low, especially during moderate to high flows. It was more efficient at low flows which occurred in the fall months when the water from Echo Reservoir was reduced or shut off (See Fig. 19).

It was assumed that there was no difference in shocking efficiency between changed and unchanged areas since the number of fish and number of recaptures were similar in both areas. Since it was assumed that the efficiency was the same in changed and unchanged areas, it was possible to compare the number of fish collected in changed areas with those collected in the unchanged areas.

Due to high flows and the mobility of the fish populations, relatively few tagged fish were recaptured. For this reason, population estimates within reasonable confidence limits were not obtained with any regularity. It was therefore decided that the actual number of fish collected in each of the areas would have to be used to compare changed areas with the unchanged areas.

Since the length of the study section, 4 miles, was too great to shock during a single day, individual days of shocking were terminated at a natural or man made obstruction which would serve as a deterent to mixing between daily shockings. The shocking was accomplished in as short a time as possible under existing manpower limitations. Two complete shockings of the study areas were done in 1970 (summer and fall). The same area was shocked during the summer of 1971, but only about one half of the study area was shocked during the fall of 1971 due to high water and inclement weather conditions.

1972

The information gained from the shocking from 1968 to 1971 gave inadequate data, allowing few population estimates, thereby reducing the amount of information needed to compare changed areas with unchanged areas. Because of this, different techniques were employed in 1972 in an attempt to secure population estimates that could be used for comparative purposes.

A fenced off portion below the concrete checkdam (Section B) was used to make a tag--recapture population estimate in June of 1972. This gave a fairly good estimate of the species in the area but highwater releases occurred and no further shocking using a closed system was possible. In November of 1972 DeLury (1947) population estimates were made in two changed sections and two unchanged sections. These estimates provided valuable information in comparing changed areas with unchanged.

Ordination

A comparison of the fish populations in specific areas of the river in 1970 (tagging stations) was made by using ordination. This technique is described in the macroinvertebrate section (Page).

This ordination method compares fish populations from each shocking location with all other shocking locations at that time of the year. It allows a graphical representation of the similarities between these populations and theoretically should show groupings of populations with similar physical habitat characteristics. From this ordination graph it should be possible to describe the groupings in physical parameters characteristic for that group. This is a relatively new technique, especially in fisheries, but should prove very beneficial in the comparison of fish populations.

Results and Discussion

1968

The results of the shocking from the fall of 1968 are presented in Table 11. The small number of recaptures precludes any attempt to cal-

Table 11. *Number of fish in each species collected in the study sections in the Weber River, Summit County, Utah.* (October 5 - December 14, 1968.)

Initial shocking (number of fish marked and returned in each reach).

Reach	1 (Oct. 6)	2 (Oct. 6)	3 (Oct. 6)	4 (Oct. 5)	5 (Oct. 5)	6 (Oct. 5)	7 (Oct. 5)	8 (Oct. 5)
Species								
Whitefish	18	53	22	40	82	129	26	19
Cutthroat Trout	3	5	3	1		8	4	
Rainbow Trout	29	7	3	3			3	3
Brown Trout								5
Utah Sucker				1		1		23
Mt. Sucker			10	4		1		1
Carp						2		

Second shocking (number of fish marked and returned in each reach; number of recaptures in parenthesis)

Reach	1 (Dec. 14)	2 (Nov. 23)	3 (Nov. 23)	4 (Nov. 16)	5 Not Samp.	6 Not Samp.	7 Not Samp.	8 (Nov. 16)
Species								
Whitefish	32	134(3)	57	46				36
Cutthroat Trout	2(1)	4	1	5				9
Rainbow Trout	14(1)	1		1				
Brown Trout								
Utah Sucker		14						
Mt. Sucker		2	12	2				
Carp		3						

culate a meaningful population estimate. The data indicate a preponderance of whitefish in the collections made.

1969

High water flows prevented shocking during the early part of the summer during 1969. By August the flows were reduced enough so that shocking from the boat could begin. Shocking was conducted on several sections of stream, both changed and unchanged, but emphasis was concentrated on the changed areas at Reaches 4 (Section B), 5, (Section F) and 6 (Section H). Reach 4 was shocked twice on September 9, 1969. The only species with sufficient recaptures for a calculation of a 95% confidence interval was the whitefish with a population estimate of 355 ± 185. Reach 5 was shocked five times between August 13 and August 27, 1969. Again, the only species which was recaptured with sufficient regularity to warrent a meaningful estimate was the whitefish. The population estimate calculated by Schnables' (1938) method was 312 ± 48. The other species captured yielded only two recaptures in the four reshockings out of the 73 tagged fish. Reach 6 was shocked twice on August 27, 1969 and as before the whitefish was the only species recaptured regularly enough to attempt a population estimate, which was 186 ± 100. On November 1, 1969 Reaches 5 and 6 were shocked again (Table 12). Only two recaptures (rainbow) were recovered. The water was low and clear making shocking conditions optimal. No untagged fish were encountered in a visual check of several holes one half hour after tagging. This indicates that shocking during this period was efficient.

Table 12. Summary of Fish Shocking in Reaches 5 and 6 November 1, 1969. (Numbers in parentheses indicate number of recaptures).

Species	Reach 5	Reach 6
Whitefish	87	193
Cutthroat Trout	17	12
Rainbow Trout	11 (1)	4 (1)

As indicated in Table 12, only two fish were recaptured from an area where 260 fish had been tagged only two months before. Possible reasons for this are:

1. All the fish died and the tags were removed from the population.
2. The population is so large that the number of fish tagged was insignificant.
3. The tagged fish moved from the area sampled.

Subsequent evidence indicates that the last is probably the most accurate reason for the small number of tag returns.

1970

The ideal situation of having a closed system where no additions or subtractions from the population sampled was unrealistic on the Weber River because of the volume of flow which is present in the river during most of the year. Block netting a river the size of the Weber River is just not feasible except at low flows and this represents only one hydrologic condition in the whole regime to which the fish are subjected. Shocking short reaches (600-1800 feet long) was not giving the adequate information about the fish populations since few recaptures were taken.

Shocking of short lengths of the river yielded little information on the actual population of fish in the study sections. Since it was felt that fencing off a section of the river was not feasible during high flows it was decided to shock a long stretch of river. It was assumed that by increasing the size of the area sampled, movement in and out of the tagged population would be reduced. During the summer of 1970 nearly 5.2 consecutive miles of stream were shocked beginning at the I-80 bridge in Section J up to the diversion dam in Section A. This shocking took place in early September when the discharges from Echo Reservoir were quite stable at about 300 cfs. Access difficulties prevented the shocking of about 1.3 miles of the river during the fall of 1970 so the length of stream shocked was reduced to about 3.8 consecutive miles of stream. The fall shocking commenced on November 6 after discharges from Echo Reservoir were less than 500 crs, reducing one variable that would influence the efficiency of the shocking operation. The long time interval between the two shockings was of definite concern because of the mortality due to natural causes and angling pressure that may have taken place during this period. However, contact with local residents and personal observation indicated that fishing pressure especially on whitefish on this section of the Weber River was minimal after Labor Day.

Thirteen species of fish were collected in the Weber River (Table 13) but only five species were captured regularly and effectively enough to be considered as indicator species. These were the whitefish, cutthroat trout, rainbow trout, Utah sucker and the bluehead sucker. Brown trout and carp were collected occasionally. Sculpins were very common, but their small size and their not showing the galvanotactic response

Table 13. A list of the species of fish found in the Weber River between Echo Dam and Devil's Slide, Utah, (1967-1971) (*Bailey, et al. 1960) (**Smith, 1966).

Scientific Name	Common Name
Salmonidae:	
Prosopium williamsoni (Girard)	Mountain Whitefish
Salmo clarki Richardson	Cutthroat trout
Salmo gairdneri Richardson	Rainbow trout
Salmo trutta Linnaeus	Brown trout
Cyprinidae:	
Cyprinus carpio Linnaeus	Carp
Gila atraria (Girard)	Utah Chub
Rhinichthys cataracta (Valenciennes)	Longnose dace
Rhinichthys osculus (Girard)	Speckled dace
Richardsonius balteatus (Richardson)	Redside shiner
Catostomidae:	
Catostomus ardens Jordan and Gilbert	Utah sucker
Catostomus discobolus Cope**	Bluehead sucker
Catostomus platyrhynchus (Cope)**	Mountain sucker
Cottidae:	
Cottus bairdi (Girard)	Mottled sculpin

shown by the other fish species resulted in few being collected. This species was, however, very abundant in all shocking areas on the Weber River especially in the riffles, near shore and in the shallow areas. The other five species of fish were not collected regularly because they are small and their habitat was usually in the very shallow areas next to the banks and in the vegetation.

Using the shocking data from the summer of 1970, it was possible to determine the percent each species contributed to the total number and weight of fish captured (Fig. 32). This may give a somewhat misleading picture, since whitefish are shocked with more efficiency than the other species. Nevertheless, from tag and recapture data, it was concluded that the whitefish do form a significantly high percentage of the population of fish in the Weber River in this area. The whitefish were 67.7%, cutthroat trout were 9.1%, rainbow trout 9.1%, and the brown trout 0.2% of the game fish species. The Utah sucker (3.9%) and the bluehead sucker (8.3%) form the highest percent of non-game fish species. Carp were 1.1% of the total fish in the area. The percent composition of rainbow trout seems to fluctuate the most since fish plantings cause drastic increases in the rainbow populations. After stocking with rainbow trout, many were collected while shocking, but following a period of fishing pressure the capture percentage of rainbow decreased markedly.

The average weight and number per acre of each species of fish was calculated from the fall 1970 data for the whole study reach (Table 14). There were 239 whitefish per acre weighing 206.5 lb. About equal amounts of cutthroat and rainbow were found with the cutthroat numbering 32 per acre with a weight of 24.9 lb. and the rainbow having 33 per

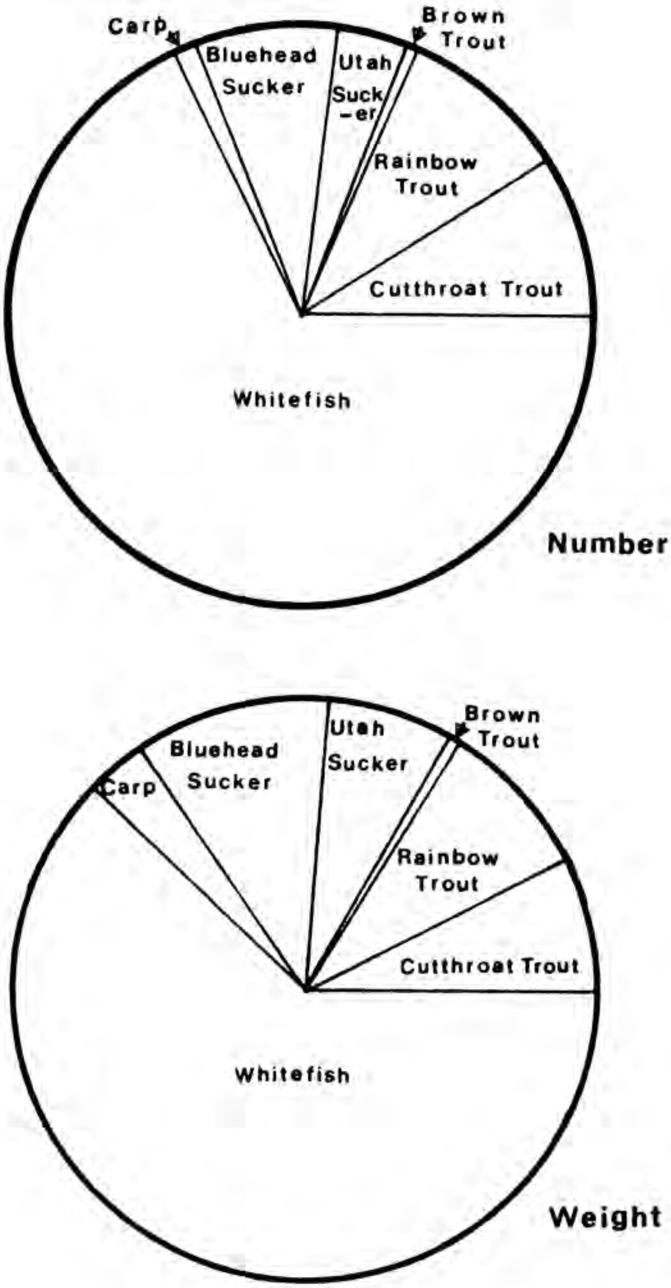

Fig. 32. Percent composition of weight and numbers each species contributes to the fish population in the fall 1970.

acre at a weight of 28.3 lb. Less than 1 brown trout weighing 0.6 lb. per acre was collected. There were 14 Utah suckers per acre at 23.1 lb. whereas the bluehead suckers were more abundant with 29 per acre and weighing 26.4 lb. There were 4 carp per acre weighing 12.7 lb. This gives a total of 352 fish per acre with a weight of 332.5 lb.

Table 14. Number and weight of each fish species per acre in the Weber River, Utah, fall 1970.

Species	Number of Fish Per Acre	Weight of Fish Per Acre (Pounds)
Mountain whitefish	239.00	206.05
Cutthroat trout	32.00	24.90
Rainbow trout	33.00	28.30
Brown trout	1.00	00.60
Utah sucker	14.00	23.10
Bluehead sucker	29.00	36.40
Carp	4.00	12.70
TOTAL	352.00	332.5

During the summer of 1970, 9,000 tagged rainbow trout were planted in the study section of the Weber River. Three planting periods were used with a planting of 3,000 fish each time. The date of plantings were May 22, 1970, July 20, 1970, and September 4, 1970. The fish were distributed throughout the study area and different colored tags were used for each location. Creel census data (personal contact and creel census cards left in creel census boxes along the stream) collected showed a total of 283 fishermen censused. This number is probably low compared to the actual number of fishermen actually utilizing the river in this area. Some local people and people owning the land adjacent to the river were generally not cooperative with their fishing information and the public was not allowed to fish in most of the river in this area. Also, creel census cards left in boxes are not a very efficient means of examining fishing success. Cards and pencils were usually taken and most fishermen would not take the time to fill the cards out. On the scene creel census was periodic and did not follow a uniform pattern and was most intensive the opening weekend of fishing.

Since access to the river was generally limited to the changed areas, more fishing pressure occurred in the changed areas. There were 67 fishermen censused in unchanged areas compared to 216 in the changed areas. Again this doesn't account for those local people fishing from the other side of the river closed to the general public.

From the creel census data, it was found that 91% of the fish caught were planted rainbows (Table 15). This is from a total of 608 fish caught. The next most catchable fish was the cutthroat which made up 6% of the catch. Brown trout, whitefish, and suckers made up the other 3% of the reported catch.

Most fishermen interviewed were pleased with their fishing success and had complimentary comments concerning the fishing in the changed areas.

The changed areas were utilized more than the unchanged areas. This was due to several factors. The main one being that most of the unchanged sections of the Weber River were restricted and allowed no trespassing. Another reason was the easy access to the changed areas, each of them being adjacent to the access road. These areas would be even more accessable if steps were placed over the wire fence running along the shore, allowing easier passage over the fence.

Table 15. Percent of total catch each species contributed from creel census data on the Weber River, Utah, 1970.

Species	Number	Per Cent
Rainbow	553	91
Cutthroat	37	6
Brown	4	1
Whitefish	9	1
Suckers	5	1
TOTAL	608	100

Since most of the fishing pressure appeared to occur in the changed section, it would seem that there would be more tagged rainbow in the unchanged areas. During shocking of the Weber River in the summer of 1970, it was found that only 52 tagged rainbows were recovered in the changed areas and 174 tagged rainbows were recovered in the unchanged areas.

Shocking also showed that out of 9000 fish planted only 665 were recovered while shocking. This is a low percentage (7.3%) of the total fish planted. During shocking in the summer of 1971 only one tagged rainbow was recovered indicating that few of the planted rainbows survive the winter in this area, or they are caught, or they move from the area.

The recovery of tagged fish during shocking periods from the first planting resulted in only 350 of the 3000 fish (11.6%) being recovered on shocking. Only 244 were recovered from the second planting (8.1%) and 71 from the last 3,000 group of trout planted (2.4%). This would indicate that the fish remain in the planted section longer or better in the spring of the year than during the fall of the year. It might also mean that in the late summer and fall during lower water that the fishing efficiency is greater. The movement of the rainbow trout after planting indicates that they move both upstream and downstream, but they tend to remain near the planting areas.

Very little fishing is done for the whitefish. A few are caught by fishermen, but not in any great numbers. This could be a valuable fisheries if it were exploited.

The fish populations were calculated for the changed and unchanged areas from the data collected in the summer and fall of 1970 (Table 16). In comparing the populations in the changed and unchanged sections of the river during 1970, it was found that the populations in the two areas were similar in both weight and numbers. The whitefish and cutthroat were found to be slightly more abundant in the changed areas than in the unchanged. Rainbow trout, brown trout, both species of sucker and carp were more abundant in the unchanged areas. The total number of fish for the changed and unchanged areas was 379 per acre and 330 per acre respectively. Both changed and unchanged areas had 334 lbs./acre standing crop. There were 72 trout weighting 59 lbs. per acre in the changed section and 61 trout weighing 50 lbs. per acre in the unchanged areas.

Elser (1968) reported 40-226 lbs. of trout per acre in Montana and McFadden and Cooper (1962) in Pennsylvania reported 60-137 lbs. of trout per acre. Wipperman (1963) found from 67-34 lbs. per acre in Montana and Nicholls (1958) gave values of 3-196 lbs. per acre. Gunderson (1968) also in Montana reported 121 lbs. of trout per acre in undistributed sections. Whitefish populations in Montana were from 2-52 lbs. per acre (Elser, 1968).

From these comparisons, it can be seen that the Weber River in the study area does not support an excellent trout population. It does, however, fall within the range of those already reported. The cutthroat trout population in the Weber River is self-propogating since no cutthroat have been planted in the area for several years. Rainbow trout populations were low especially after fishing season when planting was discontinued. The whitefish, on the other hand, show an extraordinarily high standing crop in the Weber River. Whitefish are considered game species as are trout. Considering this, the Weber River supports a higher than average standing crop of game fish.

The shocking during 1970 included 1.96 miles of unchanged areas and 1.94 miles of changed areas. During this shocking, 54.5% of the fish handled were from changed areas and 45.6% were handled from the unchanged areas. Game fish populations (whitefish and trout) formed 83% of the standing crop in the changed areas and 73% of standing crop in the unchanged areas.

In comparing fish populations in changed areas with structures, changed areas with no structures (upper portion of Section B, upper portion of Section C) and unchanged areas, it was found that the areas

Table 16. Percent of numbers, estimates of populations, percent of weight and estimates of standing crops by species for changed and unchanged areas of the Weber River Study Area, fall 1970.

Changed Areas

Species	Percent of Population	Population Estimate	Percent of Total Weight	Standing Crop (pounds/acre)
Whitefish	69.3	261	65.4	218
Cutthroat trout	10.0	38	8.5	29
Rainbow trout	8.7	33	8.5	29
Brown trout	0.2	1	0.1	1
Utah sucker	3.0	12	5.8	18
Blueheaded sucker	8.4	32	10.8	36
Blueheaded Carp	0.4	2	0.9	3
TOTAL	100.0	379	100.0	334

Unchanged Areas

Species	Percent of Population	Population Estimate	Percent of Total Weight	Standing Crop (pounds/acre)
Whitefish	66.2	218	57.8	193
Cutthroat trout	8.0	26	6.2	21
Rainbow trout	10.3	34	8.4	28
Brown trout	0.2	1	0.3	1
Utah sucker	5.1	17	9.0	30
Blueheaded sucker	8.1	27	10.9	36
Carp	2.1	7	7.4	25
TOTAL	100.0	330	100.0	334

that were previously channeled and no rehabilitation structures installed supported fish populations of 150 fish per acre or about half of that found in those of the changed areas with structures and the unchanged areas. When the number of fish handled for each section was converted to numbers of fish per acre, it was found that no distinction could be made between changed and unchanged areas (Fig. 33). In the summer of 1970, more fish were collected in Section I than in the other sections which were more uniform. Flows were somewhat lower during the period that Section J was shocked, thereby increasing the efficiency of shocking and thus more fish were collected. Fall shocking gave more diversity in the results. It can be seen, however, that more fish were collected in the fall shocking than during the summer shocking indicating a greater shocking efficiency during the low flow periods in the fall. No statistical differences (Student-t test) were found between the numbers of fish collected in the changed sections and the unchanged sections. A statistical difference was found in two instances, however. These were the cutthroat trout in August of 1970 and the sucker population in December of 1970, where in both cases more of the respective fish species were found in the changed sections, than in the unchanged sections.

Since these values represent just the number of fish collected in the area, they are lower than the actual populations. This comparison procedure is then based on the assumption that the shocking efficiency was the same in changed and unchanged areas. Since this is difficult to prove, the only means available to lend some support to this assumption is by comparing the percent of recaptures collected in both changed and unchanged areas. From Table 17 it can be seen that the percent of recaptures is similar in both changed and unchanged areas with the higher percent of recaptures being collected in the unchanged area.

Table 17. Percent of recaptures in changed and unchanged areas of the Weber River, Summit County, Utah, summer and fall 1970.

	Changed	Unchanged
Summer	5.3%	12%
Fall	12.0%	15%

From the information gathered on fish in the summer and fall of 1970, it was possible to calculate the fish populations. The data from the 3.9 miles of river were used and then population estimates were extrapolated to the number of fish per acre. This information is summarized in Table 18.

Table 18. Fish population estimates in the Weber River, Utah during the summer of 1970.

Species	No./acre
Whitefish	200 ± 24
Cutthroat	24 ± 6
Utah Sucker	46 ± 22
Bluehead Sucker	188 ± 101
Carp	5 ± 4
TOTAL	463 ± 39

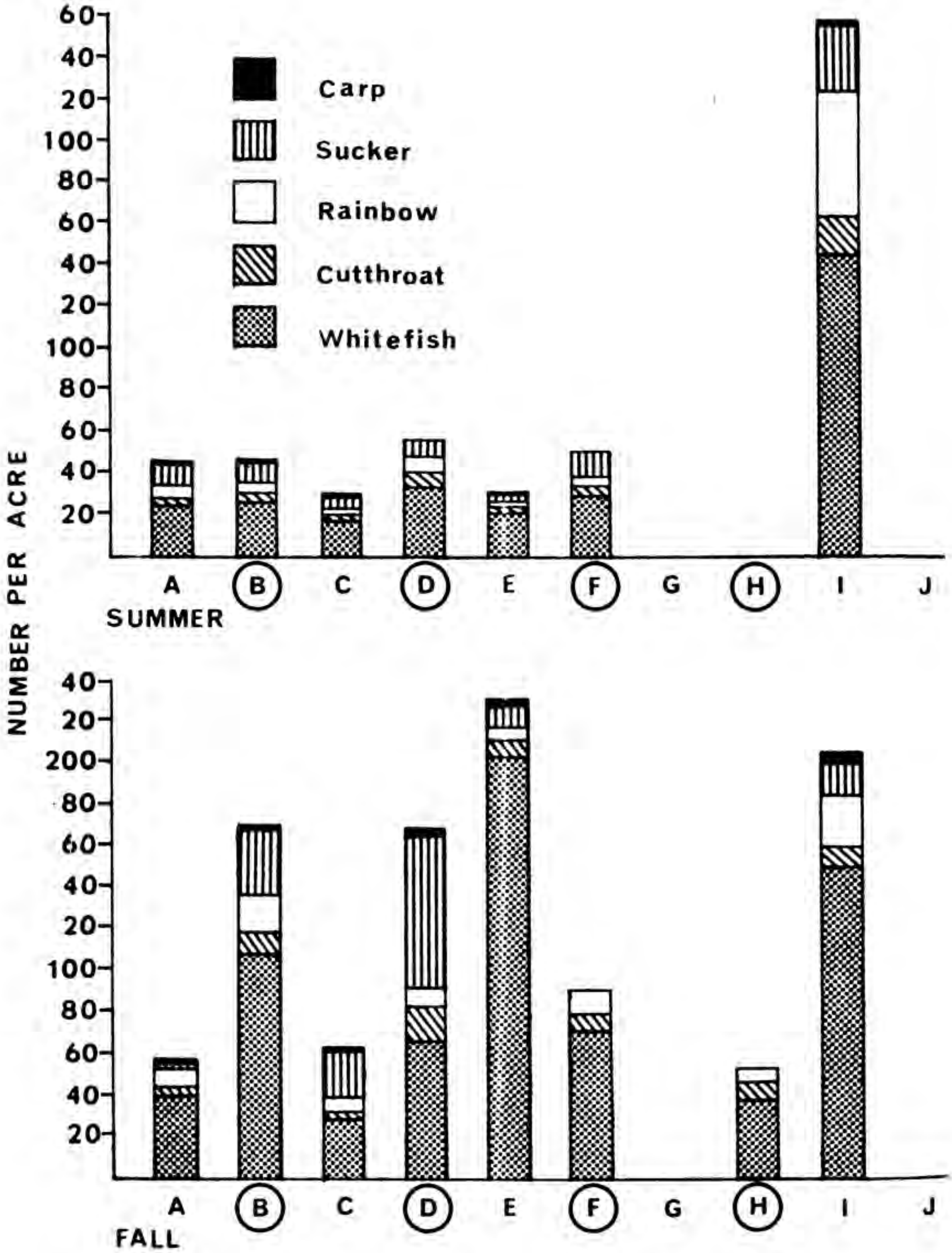

Fig. 33. Actual numbers of fish per acre collected during the summer and fall shocking of the Weber River, Summit County, Utah, 1970. (◯ = changed areas)

From these estimates, whitefish appear to be the most abundant. The cutthroat trout are relatively few. The bluehead sucker are quite abundant.

Not enough recaptures were obtained to give individual population estimates for individual changed and unchanged sections.

Ordination analysis of the fish populations in the Weber River in 1970 is summarized in Figure 34. The similarity of populations are shown graphically in this figure. Populations of less than 50% game fish are shown on the left of 5 on the X axis, and those with game fish over 50% of the population are on the right of 5 on the X axis. Those areas left of the 5 appear to be better suited to the non-game species. Conditions in these areas were typified by large, deep holes with slow flowing water. Those areas to the right contained conditions which were more conducive to game fish and these appeared to be the more moderate holes with substantial flow through them. This also indicates that both changed and unchanged areas contained areas that supported more non-game fish species than game fish. The large number of changed area points on the right indicate the presence of adequate game fish habitat in those areas.

Table 19 gives the location or place of fish release whether it was a changed or unchanged area, the X and Y coordinated and the estimated standing crop (pounds per acre) for that particular area. Shocking proceeded from downstream to upstream. Fish were collected and placed in a tub in the boat until it was full and then the fish were tagged, measured, weighed, and released at that point. The release points were characterized as distances upstream (in hundreds of feet) from the lower end of the shocking stations (I-80 bridge)

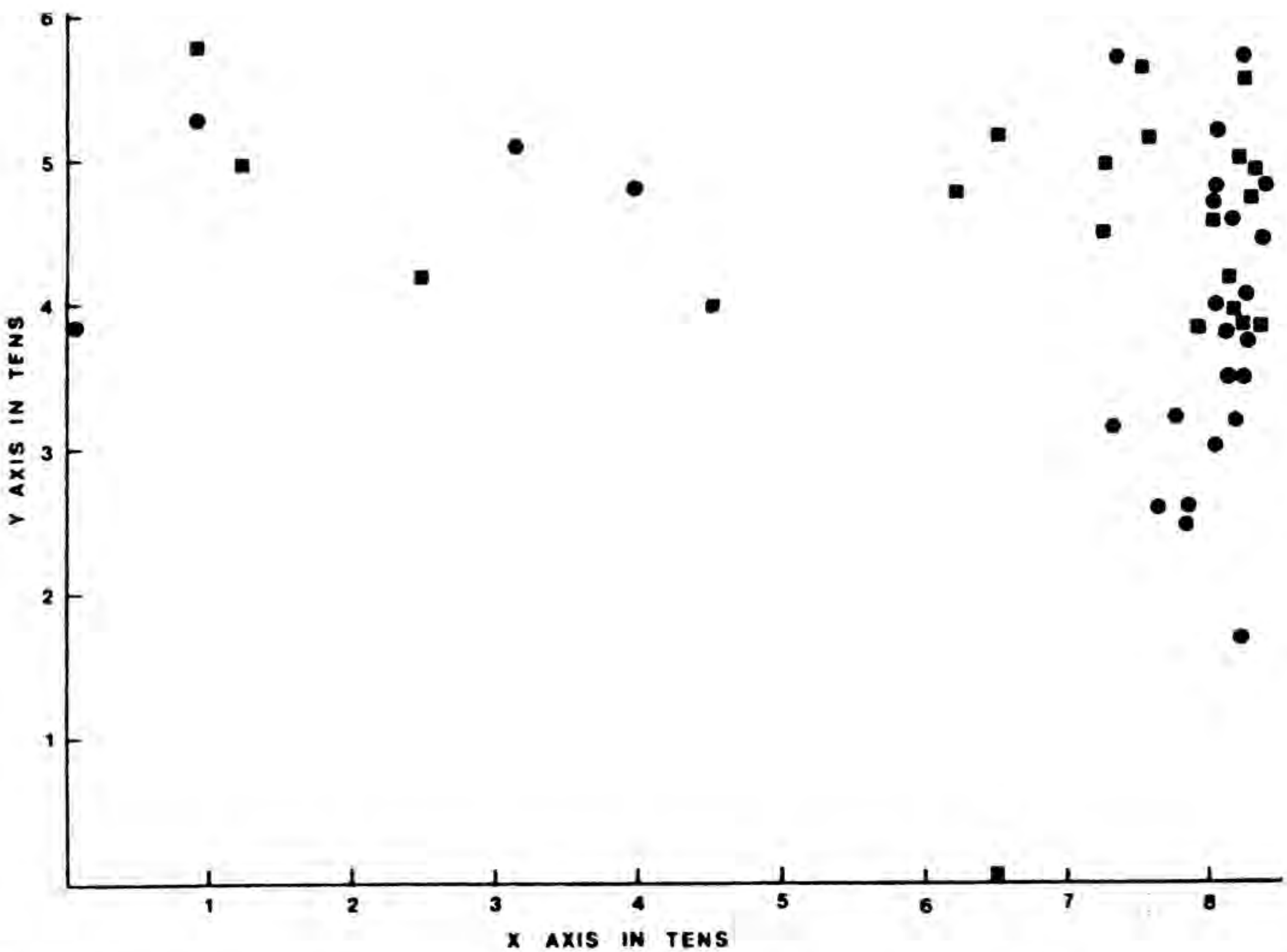

Fig. 34. Ordination of fish tagging locations on the Weber River, Summit County, Utah, fall of 1970.

Table 19. Ordination coordinates (X and Y) and estimated standing crops in pounds per acre for each tag and release location on the Weber River, Utah, fall 1970 (*C = changed, U = unchanged; ** indicates best station in this section of river).

Location	Type of Area*	Axis X Value	Axis Y Value	Estimated Standing Crop/Acre**
283	C	83.09	48.05	86
285.5	C	76.14	25.86	424
290	C	80.50	30.25	292
206.5	C	81.97	38.09	120
314	C	81.87	35.50	176
324	C	83.66	39.25	123
332	C	80.98	37.64	198
338	C	81.63	34.22	469
343	C	79.94	51.73	1051
350	U	75.25	57.58	695
368	U	82.50	49.35	310
375	U	83.61	47.97	813
377.5	U	75.44	52.60	1884
386.5	U	72.09	45.01	106
389	U	82.80	56.18	1202
406	U	81.70	38.67	123
409	U	83.13	49.01	609
414	C	73.13	57.78	683
415	C	39.74	48.08	2826
416	C	9.69	53.30	4311
419.5	C	0.00	44.51	3033
428	C	31.05	51.61	619
433	C	78.10	25.16	166
439	C	78.49	25.80	2527
452	C	77.81	24.40	67
458	C	73.28	31.66	130
466.5	C	80.29	47.40	79
483	C	80.53	39.66	157
497	U	81.82	42.64	100
504	U	9.50	58.74	854
512	U	64.75	52.12	740
523.5	U	62.33	48.23	456
539	U	45.35	40.54	284
549	U	12.08	49.99	897
587	U	24.31	42.26	162
605	C	82.08	35.45	125
620	C	82.28	38.05	56
627	C	11.22	70.90	1215
642	C	82.10	17.45	107
655	C	80.93	48.74	162
667	C	82.02	57.31	228

Table 19. (Continued)

Location	Type of Area*	Axis X Value	Axis Y Value	Estimated Standing Crop/Acre**
696	C	81.45	46.62	77
700	U	65.37	0.00	119
715	U	80.68	48.60	192
742	U	73.76	50.40	216
775	U	78.88	38.57	84
786	U	82.78	38.97	134
792	U	83.37	38.97	448
802	U	59.98	64.92	1299

below Reach 7 (Section J). Approximately equal amounts of changed and unchanged areas were shocked. A total of 3.9 miles were shocked and included in this ordination analysis. At release station 416 which was in Section D upstream from the Henefer Highway Bridge there was an estimated standing crop of 4311 lbs. per acre. This is a very high standing crop, but is not the most ideal fish population since better than half of this 4311 lbs. was made up of suckers.

The release station just upstream from this area also had a high standing crop made up mostly of suckers. Release station 439 (also in Section D) had the best fish populations as far as game fish and non-game fish ratios are concerned. This area had an estimated 2527 lbs. of fish per acre which was composed of 67% whitefish, 27% cutthroat, and 6% rainbow.

By correlating the types of fish populations in each of the areas with the type of physical conditions present (depth, velocity, substrate, etc.) it is possible to decide which type of conditions are the most conducive to the desired fish populations. It is evident from this ordination that those areas with very deep holes like the ones formed by the gabion structures just above the Henefer Highway Bridge (Section D) are areas inhabited by suckers. Those areas of moderate holes with substantial flow through them are best for game fish species. The placement of structures should be along these lines to emulate the conditions that provide the best holes for fish.

1971

In 1971, the river was shocked again in both summer and fall. The summer shocking covered about the same stretch of river as that shocked in the summer and fall of 1970 except that Section I and J were not shocked in the summer and the fall shockings did not include Sections A, C, and J.

The results from the 1971 shocking are summarized in Figure 35. The number of fish per acre collected in changed and unchanged areas are so similar that no distinction can be made between them. It is evident that more fish were collected in the fall shocking than in the summer shocking. This is undoubtedly due to the lower discharges in the fall. It appears that there are more fish in the lower sections of the study area than in those further upstream. This increase is due mainly to the whitefish population.

It is evident that the whitefish comprise the dominant percent composition of the population (Fig. 36). The whitefish form 82%, the cutthroat contribute 10%, rainbow trout 3%, and the brown trout contribute 1% of the population. The bluehead sucker and the Utah sucker each contribute 1% and the carp represent 0.2% of the population.

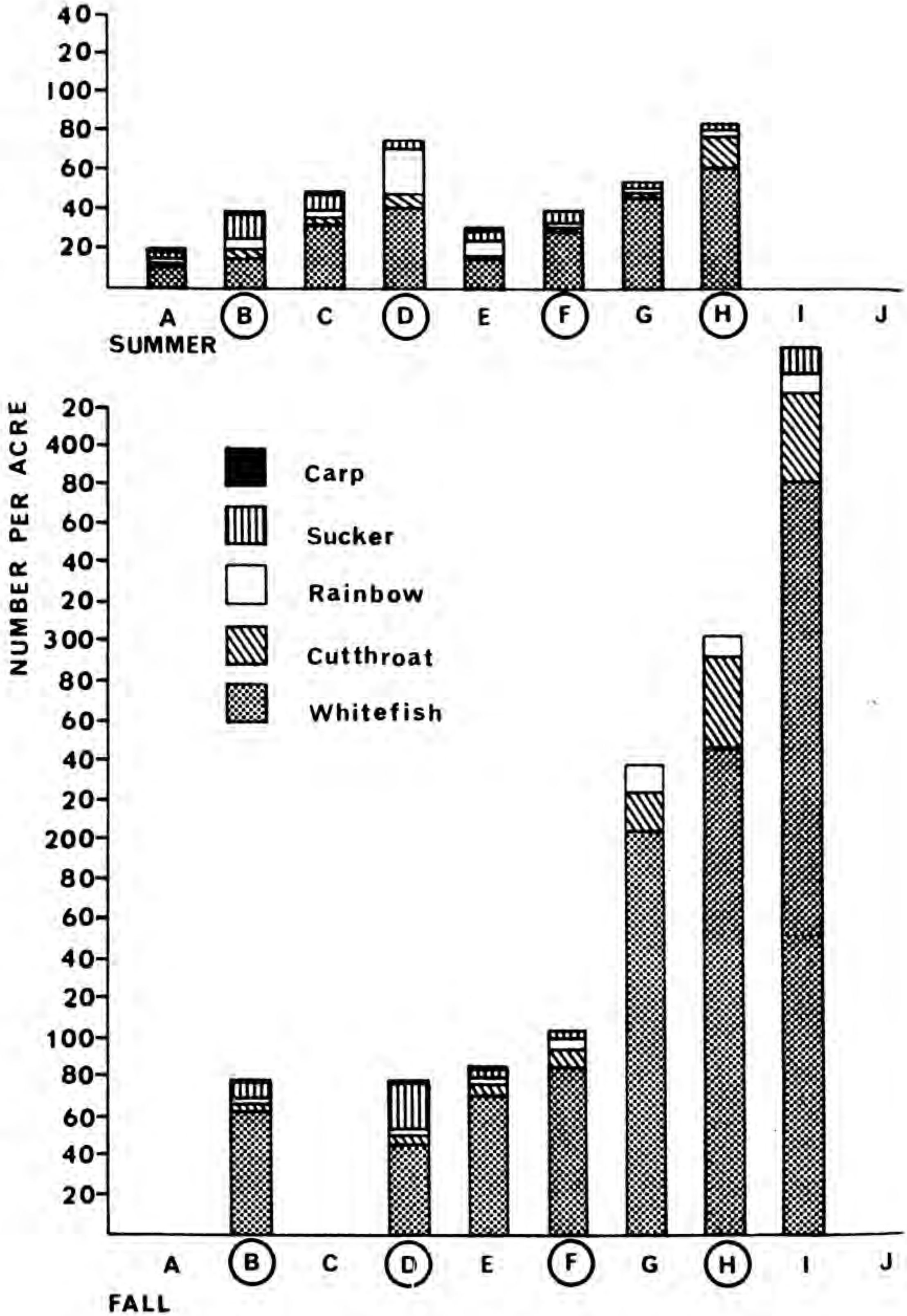

Fig. 35. Actual numbers of fish per acre collected during the summer and fall shocking of the Weber River, Summit County, Utah in 1971.
(◯ = changed areas)

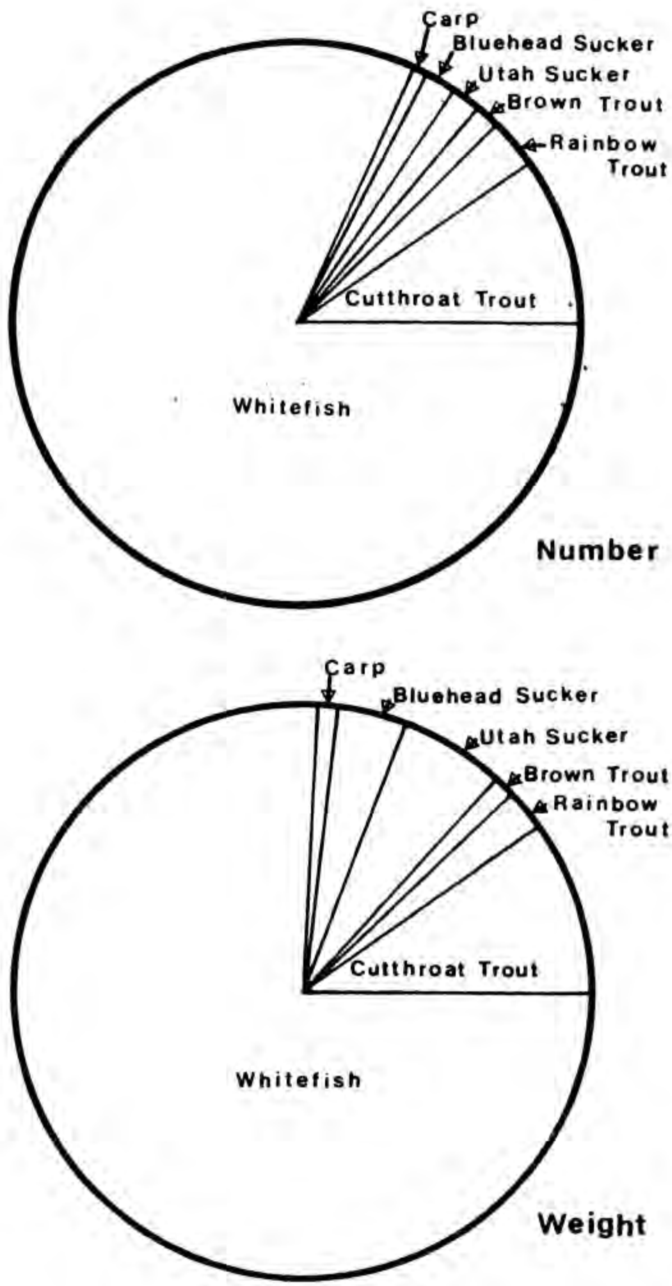

Fig. 36. Percent composition of weight and number each species contributes to the fish population in the fall of 1971.

1972

Because of the scarcity of recaptures during shocking operations, population estimates were not always possible and when enough recaptures were collected, the confidence limits were often high. In an attempt to obtain sufficient recaptures to estimate population size for all the species, an 800 foot stretch of river immediately below the concrete check dam (Section B) was fenced off at the downstream end. This stretch was shocked in the morning with all the fish collected being tagged and returned, and then a second shocking in the afternoon was carried out. These data indicate the most abundant fish was the rainbow trout at 436 per acre (Table 20). This shocking took place just prior to the opening of fishing season in June and this particular area is planted fairly heavily due to its accessability, thus accounting for such high numbers of rainbow trout being collected.

There were 129 whitefish per acre and 43 Utah sucker and 46 blueheaded sucker per acre. No cutthroat trout were found in this area during this shocking.

Table 20. Fish population estimates (numbers/acres) in an altered portion (Section B) on the Weber River, Utah, June 5, 1972.

Species	Number/Acre
Whitefish	129
Rainbow	436
Utah Sucker	43
Blueheaded Sucker	46
TOTAL	654

The effectiveness of using the tag and recapture method for estimating fish populations in the Weber River has been questioned, since it was not possible to make population estimates all of the time because the number of recaptures were so low. Also the degree of efficiency of shocking in the two areas (changed vs. unchanged) was not known but assumed to be the same.

For these reasons, an attempt was made in the fall of 1972 to make population estimates that would absolve some of the previous problems. The DeLury (1947) type population estimate procedure was decided upon which utilizes catch per unit effort information. This procedure requires that there be no movement into or out of the area. In order to meet this requirement, an electrified fence constructed of one inch chicken wire was placed on both the upstream and downstream boundaries of the section to be shocked. The fish were then shocked using the same shocking procedure as before only the fish were counted, weighed, measured and removed from the area. A minimum of 4 passes (Section F had only 3) through each section (varying in length from 1000 ft. to 1500 ft.) was completed. From this data, it was possible to make population estimates of changed and unchanged sections.

The estimates derived from these shockings indicate that the fish populations in the changed areas are similar in numbers, weight, and composition with those of the unchanged areas (Fig. 37). The lowest estimate was found in Section F (Station 5). This portion of stream was drastically altered during the high spring flows and contains no holes except at its upstream and downstream ends, thereby reducing the fish habitat that was there in the previous years. During the first two weeks of June, flow releases from Echo Reservoir down the river

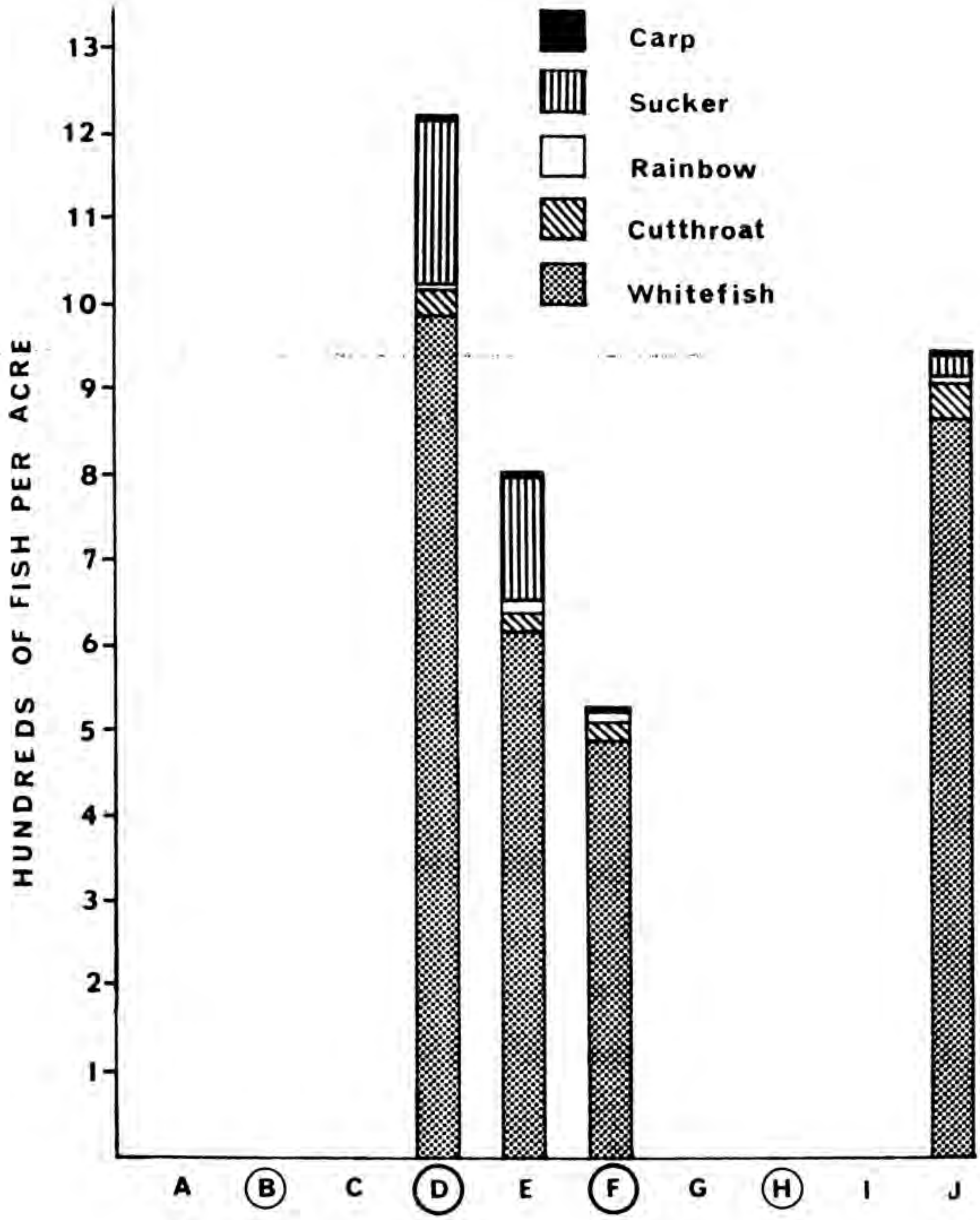

Fig. 37. Numbers of fish per acre estimated by the DeLury method on Weber River, Summit County, Utah in the fall of 1972.
(◯ = changed areas)

averaged 1300 cfs with maximum values of 1750 cfs occurring.

The highest population of fish was found in the changed Section D. This section had 195 suckers, 35 trout, and 987 whitefish. The section with the largest number of cutthroat and brown trout was an unchanged portion of Section J which had numerous holes and extensive cover provided mainly by deadfall trees covering or laying in many of the holes.

Both of the unchanged sections had about the same total number of fish but Section J had a much higher percent of whitefish.

From these population estimate data it appears that the shocking efficiency was essentially the same in both changed and unchanged areas when holes were present (Table 21). However, it does appear that the efficiency of shocking in changed sections where holes were not found was higher than that in areas where there were holes present. This may also be true for unchanged areas without holes.

These population estimates indicate that the fish population in the changed sections that have rehabilitation structures installed which have maintained holes, support fish populations similar to the unchanged areas. Changed areas, in which the rehabilitation structures have been covered by sediment rendering them ineffective and causing the holes to be filled in, support a total fish population that is lower than that in the changed areas where the structures are still functioning.

The population estimates obtained during the fall shocking of 1972 averaged 890 fish per acre. This estimate was generally higher than estimates of the population made previous to that time except at Reach 5 (Section F) in November of 1971 where the estimates were substantially

Table 21. Number of fish collected during each trial for DeLury fish population estimates on the Weber River, Utah, 1972

Section J Unchanged	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Population Estimate per/area	Number per/acre
Whitefish	584	308	59	71		1060	922
Cutthroat trout	25	12	5	2		16	40
Rainbow trout	5	2	1			8	7
Brown trout	3	1	1			5	4
Utah sucker	4	2	6	1		21	18
Bluehead sucker							
Carp	4						
TOTAL						1144	994
Section E Unchanged							
Whitefish	229	147	172	86	66	931	621
Cutthroat trout	14	10	4	3	1	35	23
Rainbow trout	7	4	5	1	1	20	13
Brown trout	1						
Utah sucker	7	9	6	4		33	22
Bluehead sucker	5	11	19	11	4	186	124
Carp			1	1	3	6	4
TOTAL						1211	807
Section F Changed							
Whitefish	598	72	25			697	497
Cutthroat trout	25	2	1			28	20
Rainbow trout	8	3	2			14	10
Brown trout							
Utah sucker		1				1	1
Bluehead sucker							
Carp							
TOTAL						740	528
Section D Changed							
Whitefish	696	405	131	75		1382	987
Cutthroat trout	25	7	2	8		40	29
Rainbow trout	3	2	2			8	6
Brown trout							
Utah sucker	14	10	6	9		58	41
Bluehead sucker	14	8	18	15		215	154
Carp	2	2	5			14	10
TOTAL						1717	1227

higher than the other tag-recapture estimates (Table 22).

Table 22. Comparison of DeLury fish population estimates in 1972 with tag-recapture population estimates made prior to that time in the Weber River, Utah. (* = changed areas).

Study Section	Time Period	Population Estimates (Number/Acre)						
		White-fish	Cut-throat	Rainbow	Utah Sucker	Bluehead Sucker	Carp	Total
H *	1969	186	4	3	8	2	1	204
H *	1969	204	4	3	10	2	1	266
F *	1969	144	3	6	132	51	0	336
Whole River	1970	200	24	46	46	188	5	463
F *	1971	960	31	20	--	--	-	962
B *	1972	129	436		43	46		654
J	1972	922	40	7	18	--	3	991
F *	1972	497	20	10	1			528
E	1972	621	23	13	22	124	4	807
D *	1972	987	29	6	41	154	10	1227

The data for the population estimates made at Section F in 1971 were collected on November 6, and November 20. The water was very low at this time and a substantial number of fish were tagged on the first day and a sufficient number of recapture were obtained on the second day to give an estimate that was closer to those collected in 1972.

It appears that on the Weber River the DeLury method gives a more realistic fish population estimate as compared to the tag-recapture method.

Fish Movement

One of the biggest problems encountered in the shocking, was the recovery of tagged fish. It is believed that the fish populations in the Weber River study area, especially the whitefish, are highly mobile and do not remain in any specific area very long.

On several shocking days, a stretch was shocked and the fish tagged and replaced in the morning; and then a second shocking the same afternoon would give a large number of fish, but very few recaptures.

The movement of these fish indicates that they have no specific territory and move vagrantly throughout the stream. Since many of the fish were tagged with numbered tags and the location of release was known, it is possible to say something about the movement of these fish (Table 23).

The average movement of whitefish from the summer of 1970 to the fall of 1970 was 3125 feet either upstream or downstream. Upstream movement averaged 3682 feet and downstream movement averaged 2202 feet. Movement immediately after shocking was quite extreme. The average movement of whitefish immediately after shocking (within two or three days) was 1550 feet from the place of capture. Better than 50% of the whitefish recaptured moved upstream 2700 feet or more, and 50% of those moving downstream moved 1900 feet. This information is from data on 53 whitefish recaptured during the summer of 1970.

Cutthroat trout moved an average distance of 3329 feet. The average movement upstream was 2442 feet and the average movement downstream was 5220 feet. Fifty percent of cutthroat moving upstream traveled at least 750 feet, and fifty percent of those moving downstream went 550 feet. This information is from 32 cutthroat recaptured during the summer of 1970.

Table 23. Movement of fish as recorded from recapture information in the Weber River, Utah.

Species	Time	No. Recap Fish	Average Movement	Average Upstream	Average Downstream
Whitefish	long	53	3125 ft.	3682 ft.	2202 ft.
	short	24	1550 ft.	1498 ft.*	
Cutthroat	long	31	3329 ft.	2442 ft.	5220 ft.
Suckers	long	18	5793 ft.	6670 ft.	5870 ft.
Carp	long	3	930 ft.	1100 ft.	600 ft.

*Since shocking occurred mostly from downstream upstream, only those fish moving upstream would be detected.

Concentration of Fish in Altered Areas

While shocking in 1970 and 1971 maps were used to locate the point of capture of the fish. Information from the 1970 shocking is shown in Appendix III. The capture location was marked on the map so as to indicate the position in the stream in relation to structures and type of fish collected. The only maps included are those from changed areas, however, similar maps were made for unchanged sections. The maps show the fish locations of both high and low flows.

In general, the whitefish and trout populations were found in the holes near the deflector structures and some whitefish were very numerous above several of the check dams. Suckers were found generally in the deep holes, especially in the lower portion of Section D. It was noted that the Utah sucker was collected in the portions of the stream that contained slower and deeper water. The bluehead sucker was found more often in the shallower swifter waters.

Summary and Conclusions

Comparisons of changed and unchanged areas using fish data presented several problems. The main problem was that relatively few fish were recaptured thereby minimizing population estimates on the fish. The small number of recaptures were due to several reasons: 1. Because of high river discharges, the shocking was not efficient enough to collect a high enough proportion of the population for the tag-recapture population methods. 2. The fish populations were so mobile that tagged fish moved from the immediate area thereby reducing recapture data or 3. High mortality of tagged fish.

Since population extimates from the tag-recapture method were not feasible to use as a comparative parameter on the Weber River, actual number of fish collected in each of the sections in 1970 - 1971 were used for comparative purposes. The numbers of fish collected were reduced to numbers per acre to facilitate the comparison of changed and unchanged areas. This comparison procedure is then based on the assumption that shocking efficiency was the same in changed and unchanged areas.

The total number of whitefish, cutthroat, and suckers per acre show no detectable difference between changed and unchanged areas. Statistical analysis (Student-t test) confirmed that these data showed no difference (95% significance) between changed and unchanged areas except for the cutthroat trout population in August of 1970, and the sucker population in December of 1970, where in both cases more of the respective fish species were found in the changed section.

From these data it can be concluded that no essential difference existed in 1970 or 1971 in the fish populations in the changed and unchanged areas of the Weber River study area.

Since it was not possible to make accurate population estimates using tag and recapture methods, thereby contributing to the information on shocking efficiency in the changed and unchanged areas, population estimates were made in the fall of 1972 using the DeLury population estimate procedure. From these data it was possible to make some evaluation of the effectiveness of the shocking procedure in changed and unchanged areas as well as giving reliable estimates of the population in the changed and unchanged areas. The populations were similar in both changed and unchanged areas where holes were present, whether produced artifically by instream rehabilitation structures or naturally produced. A changed area in which the structures were rendered ineffective due to being covered by sediment contained significantly fewer fish. DeLury population estimates were two to four times higher than those obtained from the tag-recapture method. The seasonal distribution and yearly variation may account for some of these differences, but probably not enough to change the estimates to such a magnitude. The DeLury method appears to be the most useful in making fish population estimates on the Weber River.

From the foregoing results, it is concluded that the fish populations in the changed structured areas (where structures are functioning) are similar to those in the unchanged areas. This is due to the structures that have been placed in these areas. Holes and riffles were formed which are similar to those in the unchanged areas as a result of the structures (Fig. 5, 6, and 7). Fish populations in the

Weber River, though highly mobile, do occupy the altered areas, especially around and near the structures which have formed the holes.

No differences in fish numbers or weight could be found between changed and unchanged areas in 1970 and 1971. This is exemplified by the ordination analysis which shows no difference or clumping of the fish populations stations from the changed or unchanged areas in 1970. Also, 1972 population estimates confirmed earlier data, that the fish are found in changed rehabilitated areas in numbers similar to those in unchanged areas.

This seems contradictory to most of the literature pertaining to channelization and fish population, but this is not necessarily so. Most of the papers dealing with the loss in fish and fish habitat refer to channeled areas where no rehabilitation measures were taken and no structures or rehabilitation measures were considered (Alvord and Peters, 1963; Bayless and Smith, 1964; Beland, 1953; Berryman, et al, 1962; Buntz, 1969; Burns, 1972; Einsele, 1957; Elser, 1968; Etnier, 1972; Hales, 1960; Irizarry, 1969; Langlois, 1941; Laser, et al, 1969; Peters and Alvord, 1964; Richards, 1963; Smith 1968; Stuart, 1959; Swedberg and Nevale, 1964; Trautman, 1939; Welker, 1967; Whitney and Bailey, 1959).

There have been several studies, however, that substantiate that if rehabilitation measures are taken, such as installation of instream structures, game fish populations recover and show improvements over previous conditions or unrehabilitated areas (Baker, 1970; Burghduff, 1934; Clark, 1945; Davis, 1941; Gard, 1961; Hale, 1969; Harrison, 1964; Hubbs, 1932; Hunt, 1968, 1971; Jester and Mckirdy, 1966; Johnson, 1967; Kanaly, 1971; Larimore, et al, 1959; Little, 1965; Mueller, 1954;

Robinson and Menendez, 1964; Saunders and Smith, 1962; Schuyler, 1971; Shetter, et al, 1946; Tarzwell, 1932, 1937, 1938, 1939; Warner and Porter, 1960; White and Brynildson, 1967; Wilkins, 1960).

Creel census data in 1970 indicates that the majority of fishing pressure in this portion of the Weber River occurs in the changed portion of the river. This is due to accessability and also that most of the private land is not open to the public. The greatest percent of the fish caught were rainbow trout and then the next catchable group were the cutthroat trout.

CONCLUSIONS

The review of literature lists many studies which show that channelization has been destructive to the environment of many streams. Many studies also indicate that when rehabilitation measures are taken that the detrimental effects of channelization can be decreased. Since it is difficult to eliminate all of the detrimental effects of channelization of a stream, it is wise to avoid channelization whenever possible. However, there are probably times when channelization is necessary and so continued effort should be made to find satisfactory solutions for all of the problems connected with channelization. Although part of the data for this study on the Weber River had some limitations as outlined in the report, the research indicates the following conclusions:

1. Fish populations in the study area on the Weber River are similar in changed and unchanged areas as a result of rehabilitation structures which were placed in the stream.
2. Much is yet to be learned on the correct placement and the type of structures required for desirable fish habitat. — *
3. The composition of fish populations varied in both changed and unchanged areas from high game fish percentages to low game fish percentages.
4. Fish are found in the changed sections of the Weber River and seem to be concentrated near the rehabilitation structures and in the holes formed by them.

5. Data from tagged recaptures indicate that the fish are quite mobile in the study area.
6. Game fish population estimates in the Weber River are not particularly high; nevertheless, they fall within the common ranges reported for populations of game fish in the western United States.
7. Planted rainbow trout move to some extent, but most are apparently caught near their stocking point especially in the altered areas. Few planted rainbow trout over-wintered in the study area.
8. Macroinvertebrate populations in changed areas were similar to those of the unchanged areas within six months after channelization. Benthic colonization was related to substrate stability.
9. No differences in numbers, weight, or species diversity of macroinvertebrate populations was found between the changed and unchanged areas after colonization occurred.
10. The water chemistry measured in the study areas showed no change that could be attributed to the channelization.
11. Water turbidity below the changed areas was greatly increased during construction but was of short duration.
12. Increased areas of sedimentation were not found immediately below the channelized sections. The fine sediment seemed to be moved out of the area by the high flows in the spring of 1969. The heavier material often deposited near the instream structures in the altered areas.

13. Channelization resulted in the loss of 0.4 mile of the Weber, eliminating this area as a potential fishery.
14. The channelization resulted in a loss of streamside vegetation thereby reducing the amount of overall production in the area as well as reducing the aesthetic beauty of this portion of the river. As of the summer of 1972, the planted vegetation had not been effective in producing much vegetative cover in the changed sections.
15. The water temperature regime in the Weber River was not altered by this channelization and appears to be controlled mainly by flow releases from Echo Reservoir.
16. Instream structures caused holes and riffles to be formed in the altered sections of the Weber River resulting in as many holes and riffles in changed areas as in unchanged areas. *
17. Most structures were effective in forming holes and riffles. However, some were ineffective, due mainly to improper placement.
18. This study indicates that if channelization is necessary, installation of rehabilitation structures will improve conditions over that which would exist if no structures were installed.

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APPENDIX I

APPENDIX I

List of the Algae Collected in the Weber River and Its General Distribution Within the Study Area. (1 = Below Echo Reservoir; 2 = Above Echo Reservoir; 3 = Above Wanship Reservoir)

	Location
Cyanophyta	
Hormogonales	
Nostocaceae	
<u>Nostoc</u> sp.	3
Chlorophyta	
Zygnematales	
Zygnemataceae	
<u>Spirogyra</u> sp.	2
Cladophorales	
Cladophoraceae	
<u>Cladophora</u> sp.	1, 2
Ulotrichales	
Chaetophoraceae	
<u>Stigeoclonium</u> sp.	2
<u>Microthamnion</u> sp.	1, 2, 3
Ulotrichaceae	
<u>Ulothrix</u> sp.	1, 2

	Location
Chrysophyta	
Heterosiphonales	
Vaucheriaceae	
Vaucheria sp.	2
Chrysocapsales	
Hydruraceae	
Hydrurus sp.	3
Pennales	
Tabellariaceae	
Diatomella sp.	3
Tabellaria sp.	3
Diatomaceae	
Diatoma sp.	2, 3
Fragilariaceae	
Fragilaria sp.	1, 2
Achnanthaceae	
Achnanthes sp.	2
Cocconeis sp.	2
Naviculaceae	
Navicula sp.	3
Gomphonemataceae	
Gomphonema sp.	1, 2, 3

APPENDIX II

APPENDIX II

Checklist and Distribution Within the Study Area of the Macroinvertebrates in the Weber River, Summit County, Utah. (1 = Below Echo Reservoir; 2 = Above Echo Reservoir; 3 = Above Wanship Reservoir).

	Location
Arthropoda	
Insecta	
Ephemeroptera	
Baetidae	
Baetis bicaudatus	1, 2, 3
intermedius	1, 2, 3
parvus	3
tricaudatus	3
vagans	1, 2, 3
Callibaetis montanus	3
Heptageniidae	
Epeorus (Iron) albertae	3
Heptagenia criddlei	3
flavescens	1, 2, 3
simpliciodes	3
solitaria	1

	Location
umbratica	2
Rhithrogenia decora	2
undulata	1
Leptophlebiidae	
Paraleptophlebia memorialis	1, 2, 3
packi	3
Ephemerellidae	
Ephemerella doddsi	3
excrucians	2
grandis	3
hecuba	3
inermis	1, 2, 3
margarita	3
Siphlonuridae	
Ameletus sparsatus	3
Tricorythidae	
Tricorythodes minutus	1, 2
Plecoptera	
Chloroperlidae	
Alloperla signata	2
Nemouridae	
Brachyptera pacifica	3
Capnia confusa	3
lemoniana	3
Perlidae	
Claassenia sabulosa	1, 2, 3

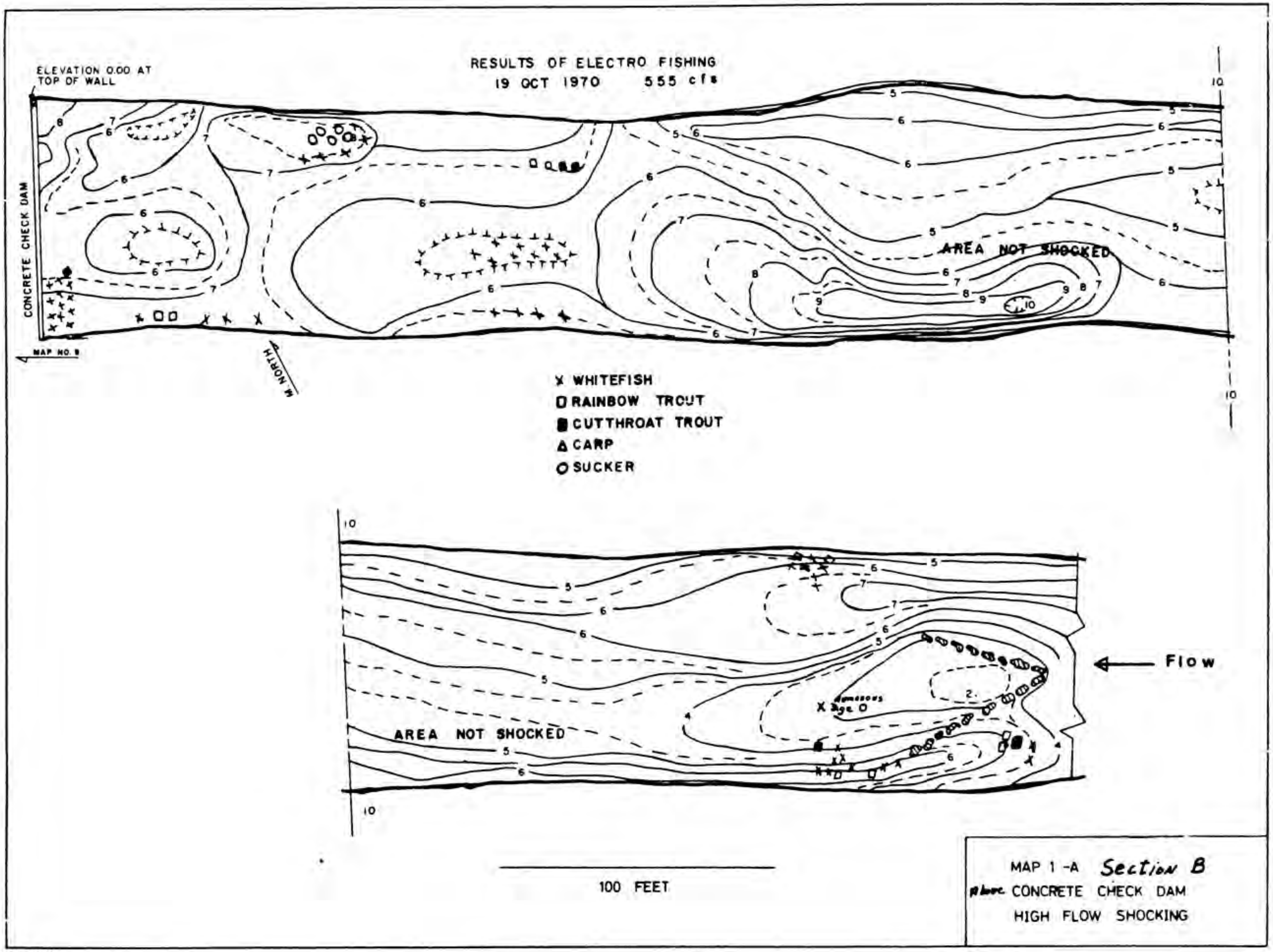
	Location
Perlodidae	
Arcynopteryx parallela	3
Isogenus aestivalis	1, 2, 3
expansus	2, 3
Isoperla fulva	2, 3
mormona	1, 2, 3
Trichoptera	
Brachycentridae	
Brachyentrus americanus	2, 3
Helicopsychidae	
Helicopsyche borealis	2, 3
Hydropsychidae	
Cheumatopsyche avalis	2
Diplectrona sp.	3
Hydropsyche placada	2, 3
recurvata	1, 2
slossonae	3
Hydroptilidae	
Dibusa sp.	1, 2
Hydroptila consimilis	1
Ochrotrichia arva	1, 2
Orthotrichia americanus	1
Leptoceridae	
Oecetis avara	2, 3
Limnephilidae	
Dicosmoccus sp.	3

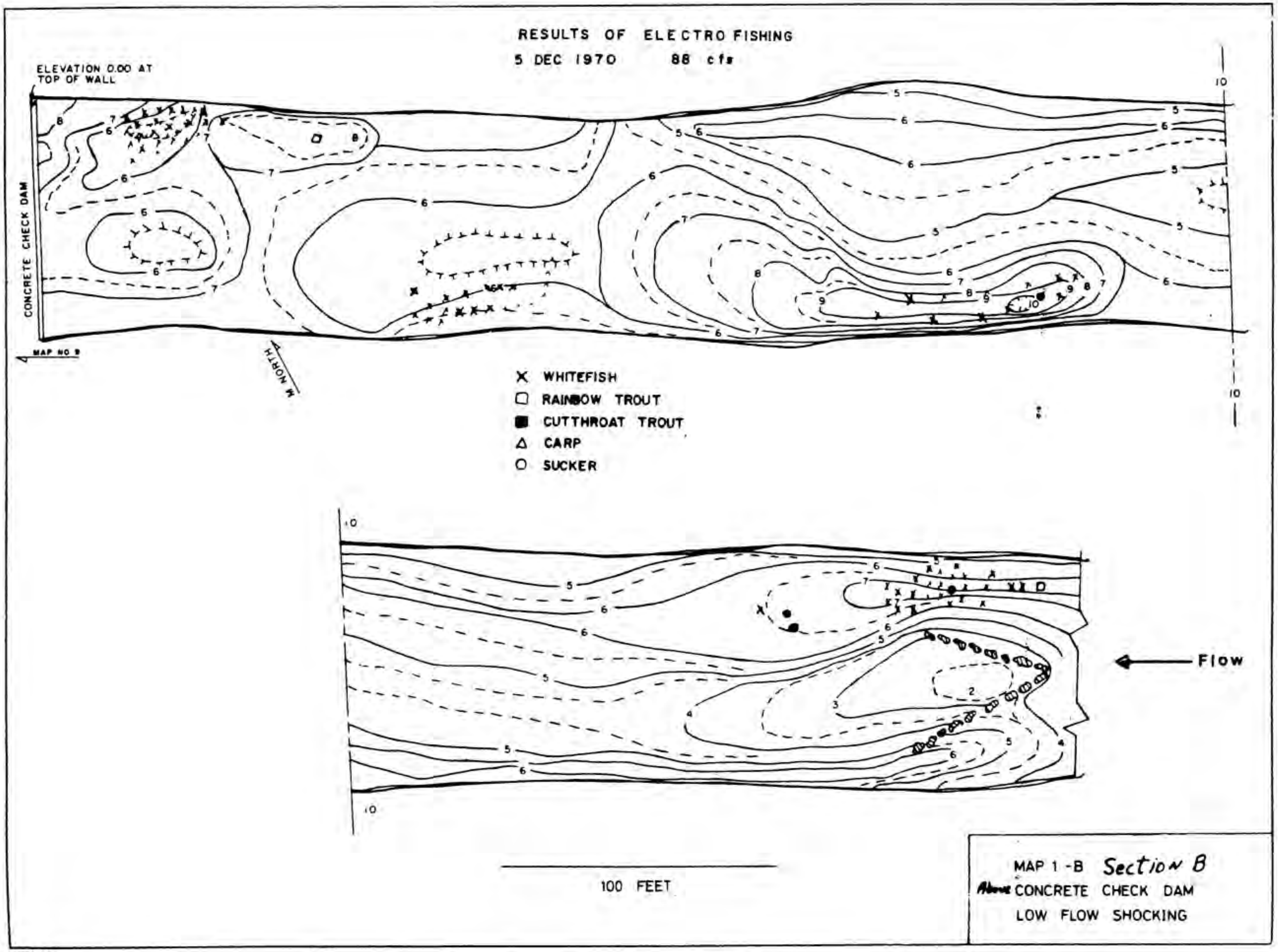
	Location
Hesperophylax incisus	2, 3
Limnephilus submonilifer	3
Neothremma sp.	3
Phryganeidae	
Ptilostomis semifasciata	2, 3
Psychomyiidae	
Lype diversa	2, 3
Polycentropus cincereus	2
Psychomyia flavida	2
Philopotamidae	
Dolophilus moestus	3
Rhyacophilidae	
Glossosoma sp.	2, 3
Rhyacophila fuscula	3
Diptera	
Anthomyiidae	3
Chironomidae	1, 2, 3
Empidae	1, 2, 3
Psychodidae	3
Simuliidae	
Simulium sp.	1, 2, 3
Rhagionidae	
Atherix sp.	1, 2, 3
Tabanidae	2, 3
Tipulidae	
Antocha sp.	3

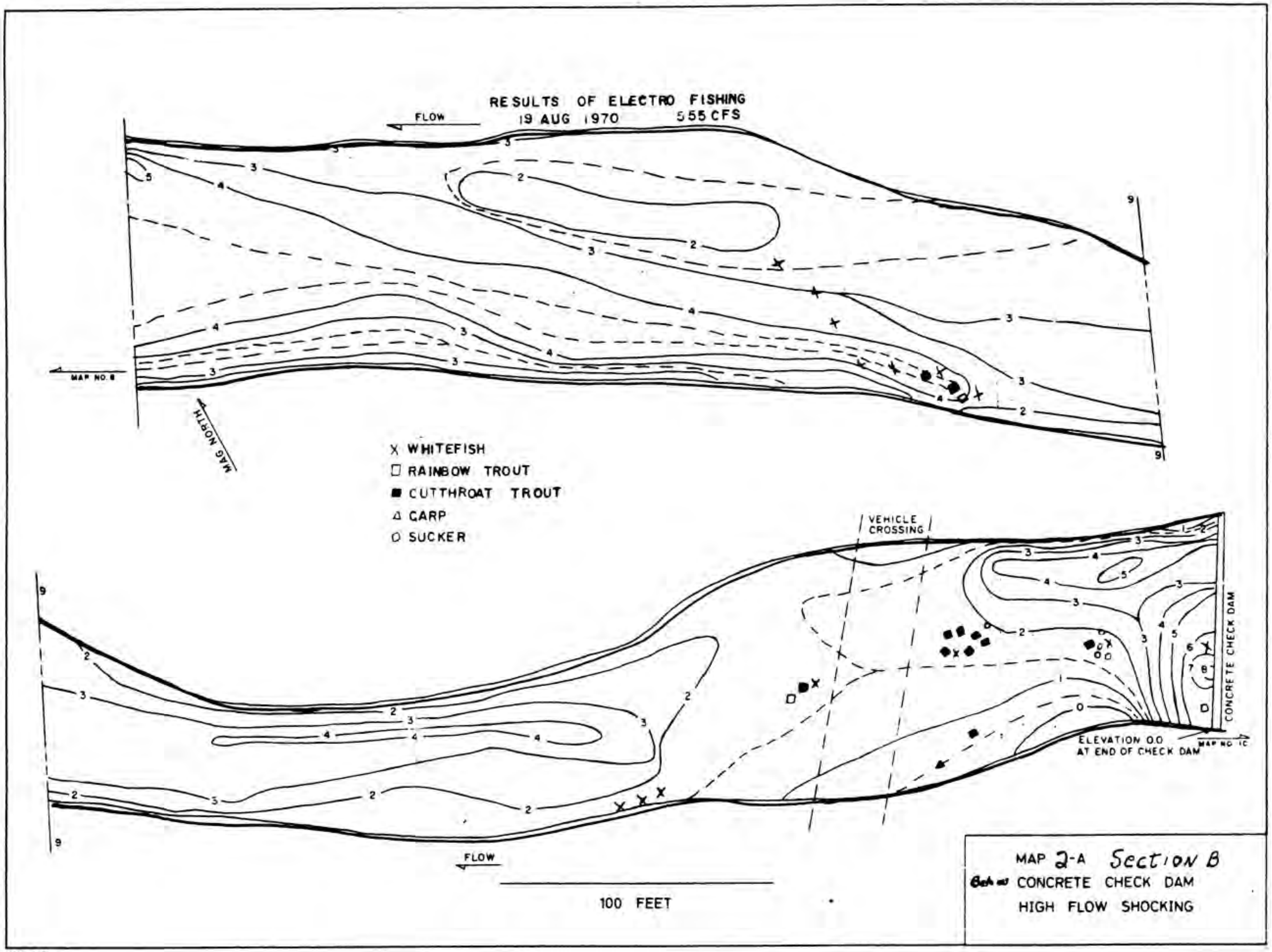
	Location
Hexatoma sp.	1, 2, 3
Limnophila sp.	1, 2, 3
Tipula sp.	1, 2, 3
Coleoptera	
Amphizoidae	2, 3
Dryopidae	2, 3
Dytiscidae	2, 3
Elmidae	1, 2, 3
Haliplidae	2, 3
Hemiptera	
Gerridae	1, 2, 3
Corrixidae	1, 2, 3
Odonata	
Aeschnidae	1, 2, 3
Crustacea	
Cladocera	1
Copepoda	1
Amphipoda	
Talitridae	
Hyallela azteca	1
Decapoda	
Astacidae	
Pacifastacus gambelii	1
Arachnida	
Hydracarina	

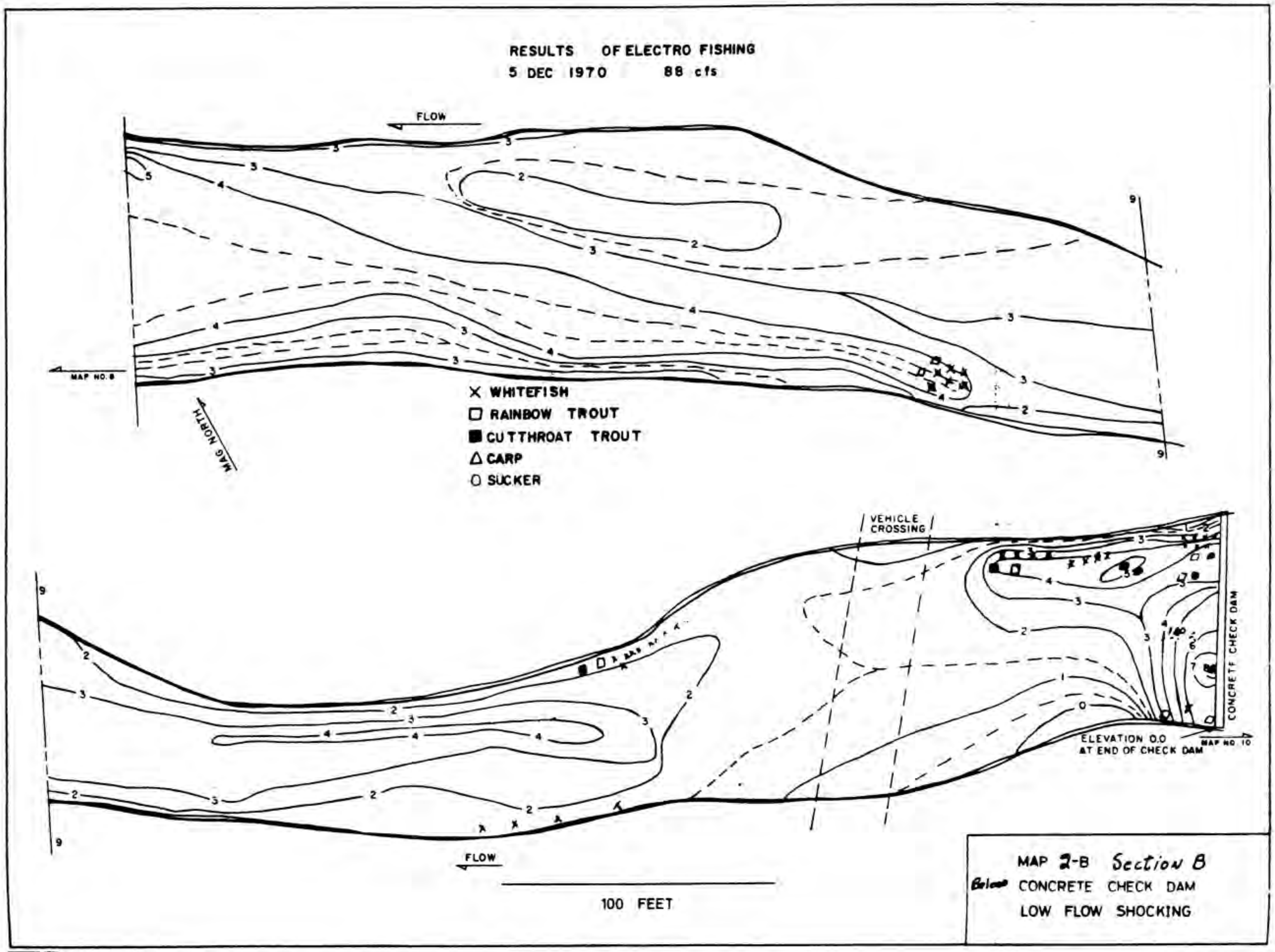
	Location
Lebertiidae	
<u>Lebertia</u> sp.	
Molluska	
Gastropoda	
Pulmonata	
Amnicolidae	
<u>Amnicola</u> sp.	2, 3
Ancylidae	
<u>Ferrissia</u> sp.	2
Lymnaeidae	
<u>Lymnaea</u> <u>stagnalis</u>	1, 2, 3
Physidae	
<u>Physa</u> sp.	1, 2, 3
Pelecypoda	
Sphaeriidae	
<u>Pisisium</u> sp.	1, 2
Annelida	
Hirudinea	
Arhynchobdellida	
Erpobdellidae	
<u>Erpobdella</u> <u>punctata</u>	1, 2
Oligochaeta	
Plesiopora	
Tubificidae	1, 2, 3

APPENDIX III

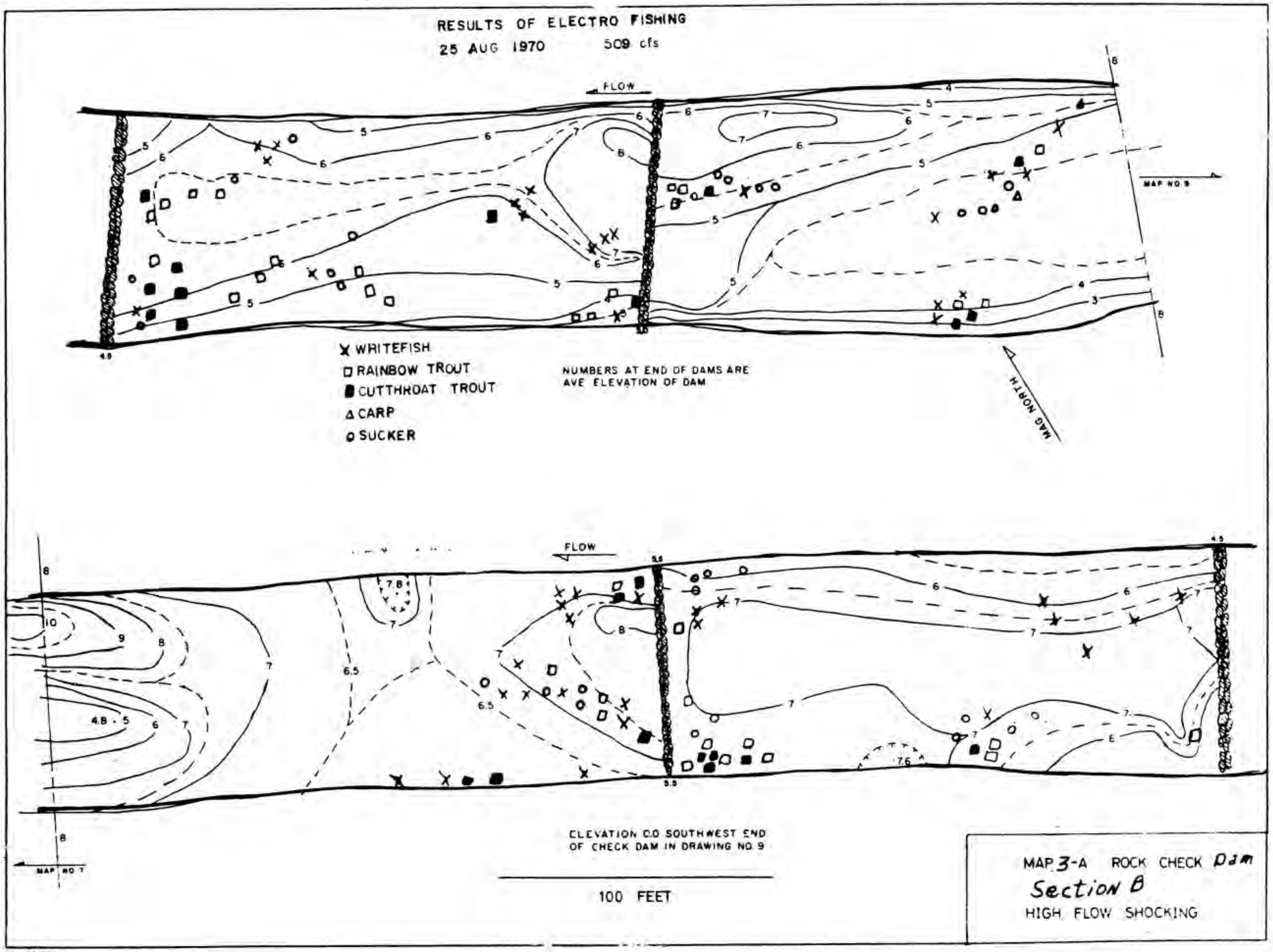

RESULTS OF ELECTRO FISHING
19 OCT 1970 555 cfs
ELEVATION 0.00 AT TOP OF WALL
CONCRETE CHECK DAM
MAP NO. 8
NORTH
AREA NOT SHOCKED
X WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
SUCKER
Flow
AREA NOT SHOCKED
100 FEET
MAP 1 -A Section B
Above CONCRETE CHECK DAM
HIGH FLOW SHOCKING

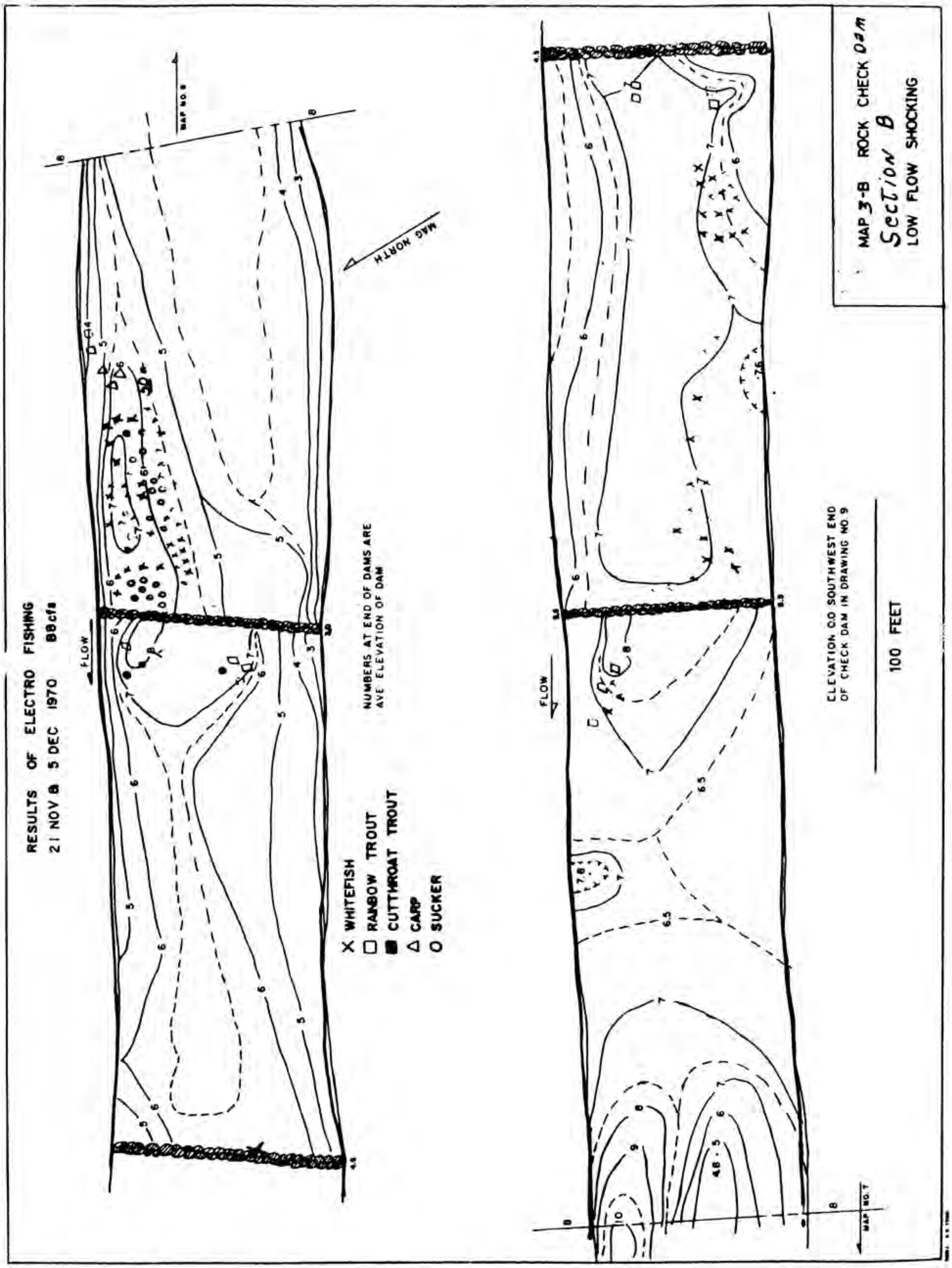

RESULTS OF ELECTRO FISHING
5 DEC 1970 88 cfs
ELEVATION 0.00 AT TOP OF WALL
CONCRETE CHECK DAM
MAP NO 9
M NORTH
X WHITEFISH
▢ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
Flow
100 FEET
MAP 1 -B Section B
Above CONCRETE CHECK DAM
LOW FLOW SHOCKING

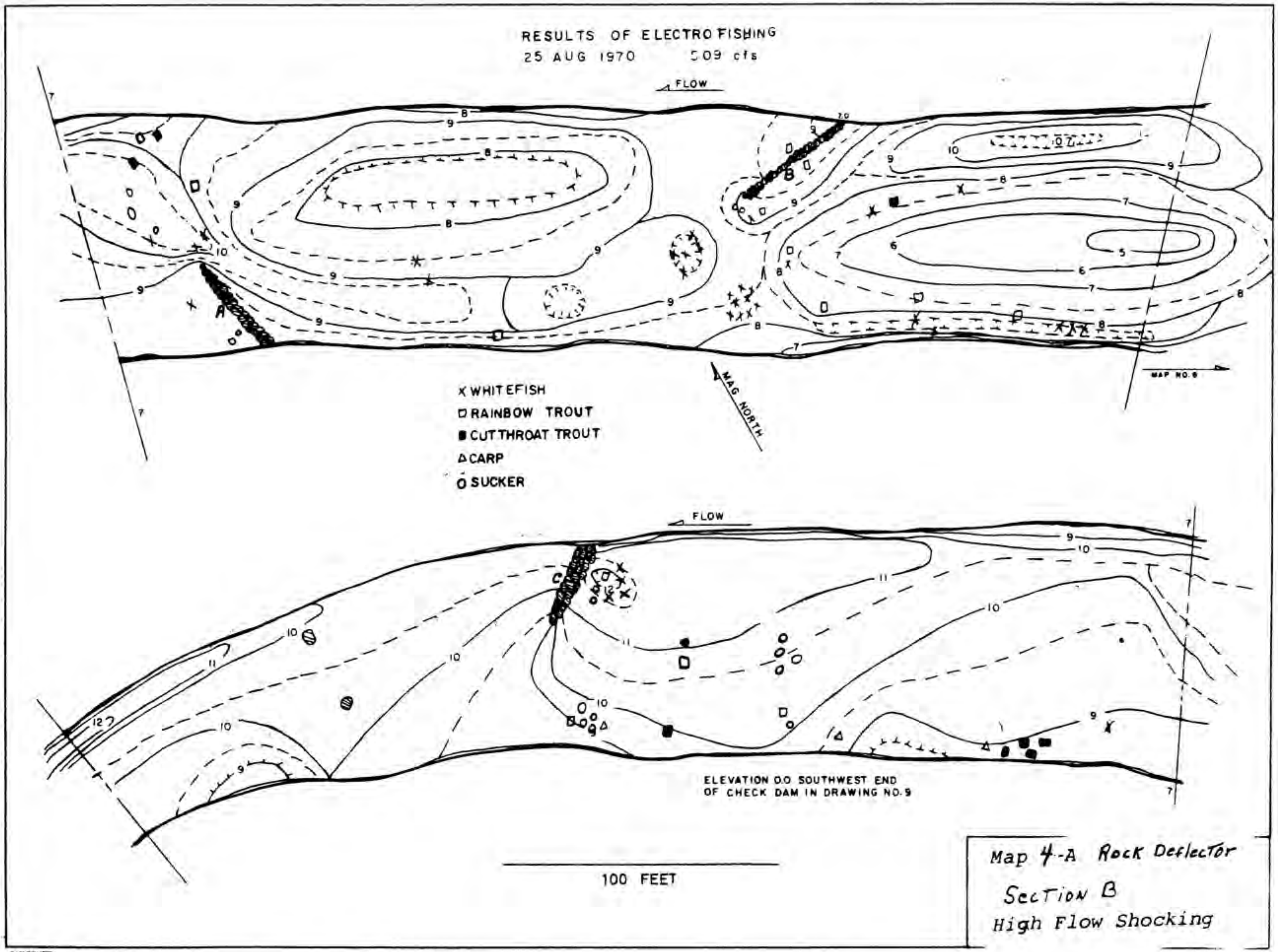

RESULTS OF ELECTRO FISHING
19 AUG 1970 555 CFS
FLOW
MAP NO. 8
MAG NORTH
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
VEHICLE CROSSING
CONCRETE CHECK DAM
ELEVATION 0.0 AT END OF CHECK DAM
MAP NO. 1C
FLOW
100 FEET
MAP 2-A Section B
CONCRETE CHECK DAM
HIGH FLOW SHOCKING



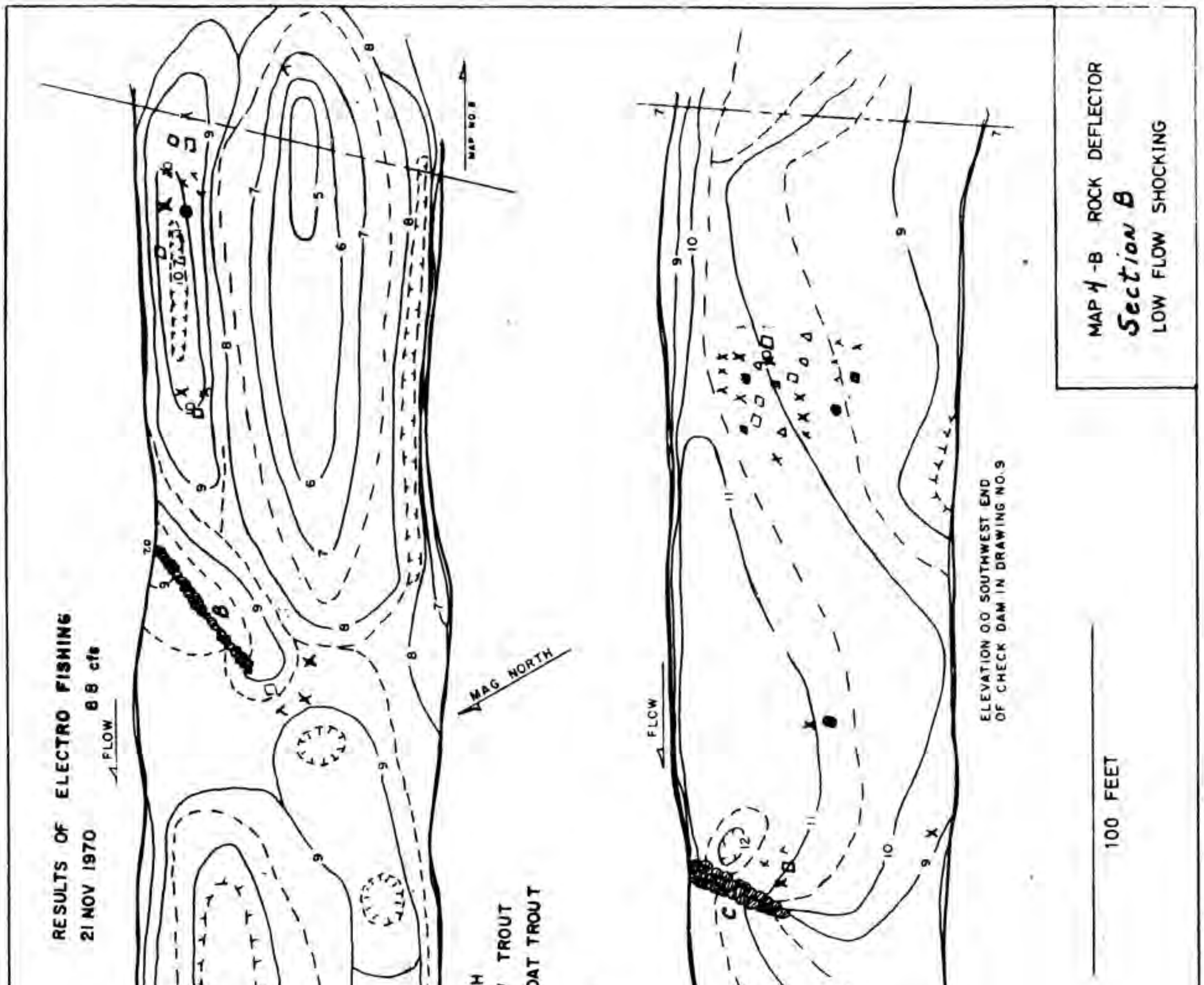
MAP 2-B *Section B*
Below CONCRETE CHECK DAM
LOW FLOW SHOCKING

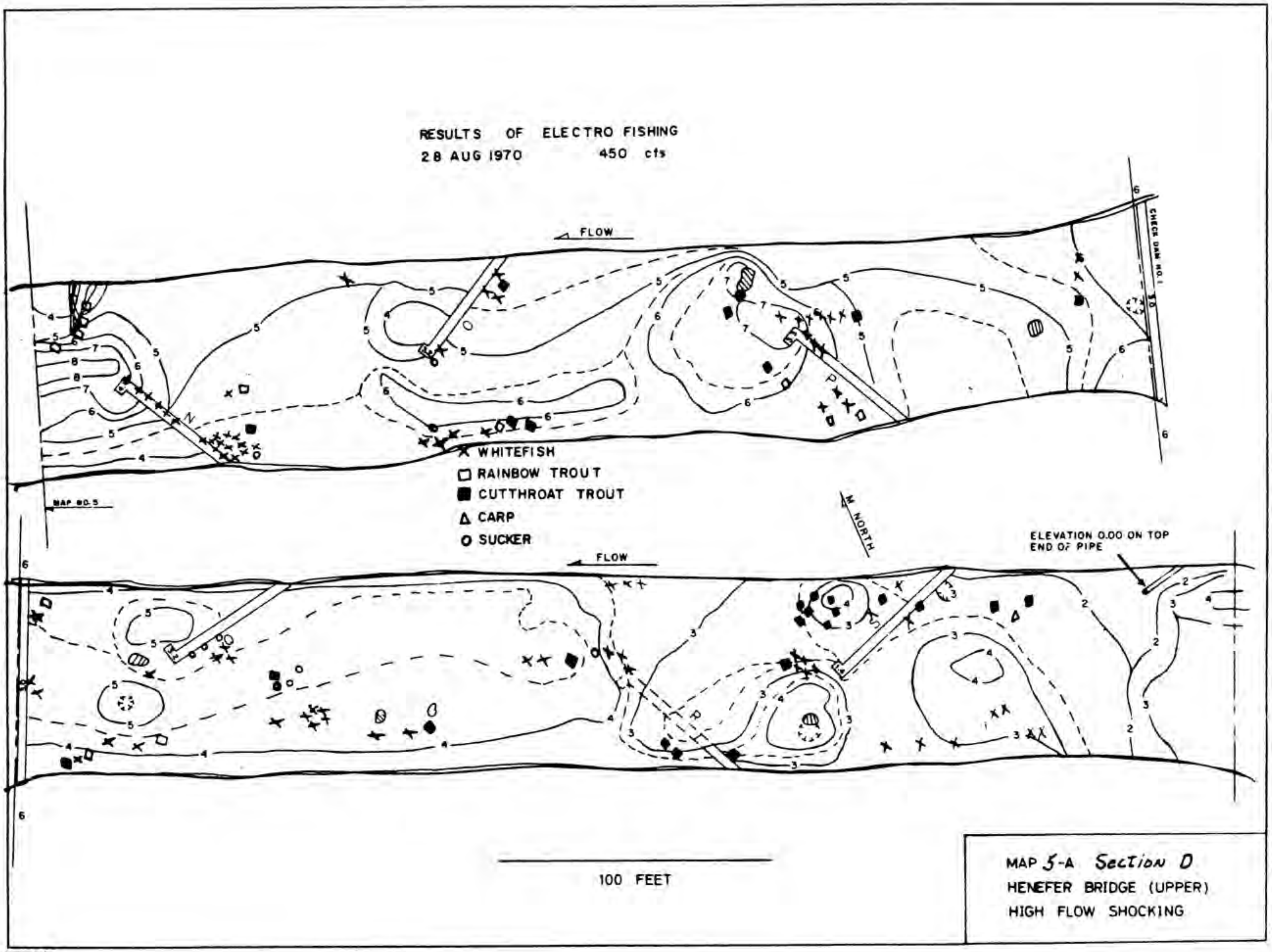

RESULTS OF ELECTRO FISHING
25 AUG 1970 509 cfs
FLOW
MAP NO 9
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
o SUCKER
NUMBERS AT END OF DAMS ARE
AVE ELEVATION OF DAM
MAG NORTH
FLOW
ELEVATION 0.0 SOUTHWEST END
OF CHECK DAM IN DRAWING NO 9
100 FEET
MAP NO 7
MAP 3-A ROCK CHECK Dam
Section B
HIGH FLOW SHOCKING

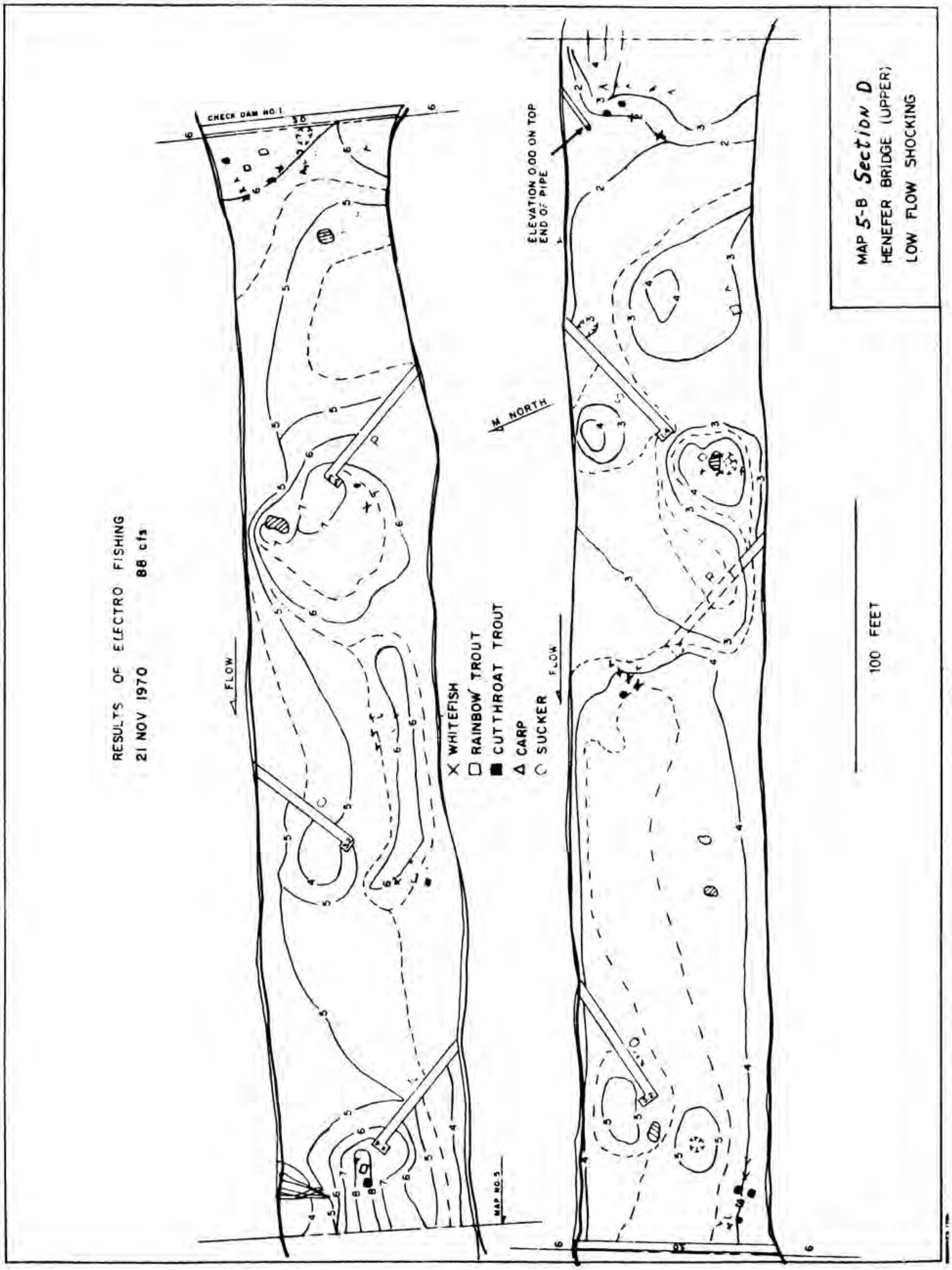

RESULTS OF ELECTRO FISHING
21 NOV & 5 DEC 1970 88cfs
FLOW
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
NUMBERS AT END OF DAMS ARE AVE ELEVATION OF DAM
MAG NORTH
ELEVATION OF SOUTHWEST END OF CHECK DAM IN DRAWING NO. 9
100 FEET
MAP 3-B ROCK CHECK Dam
Section B
LOW FLOW SHOCKING



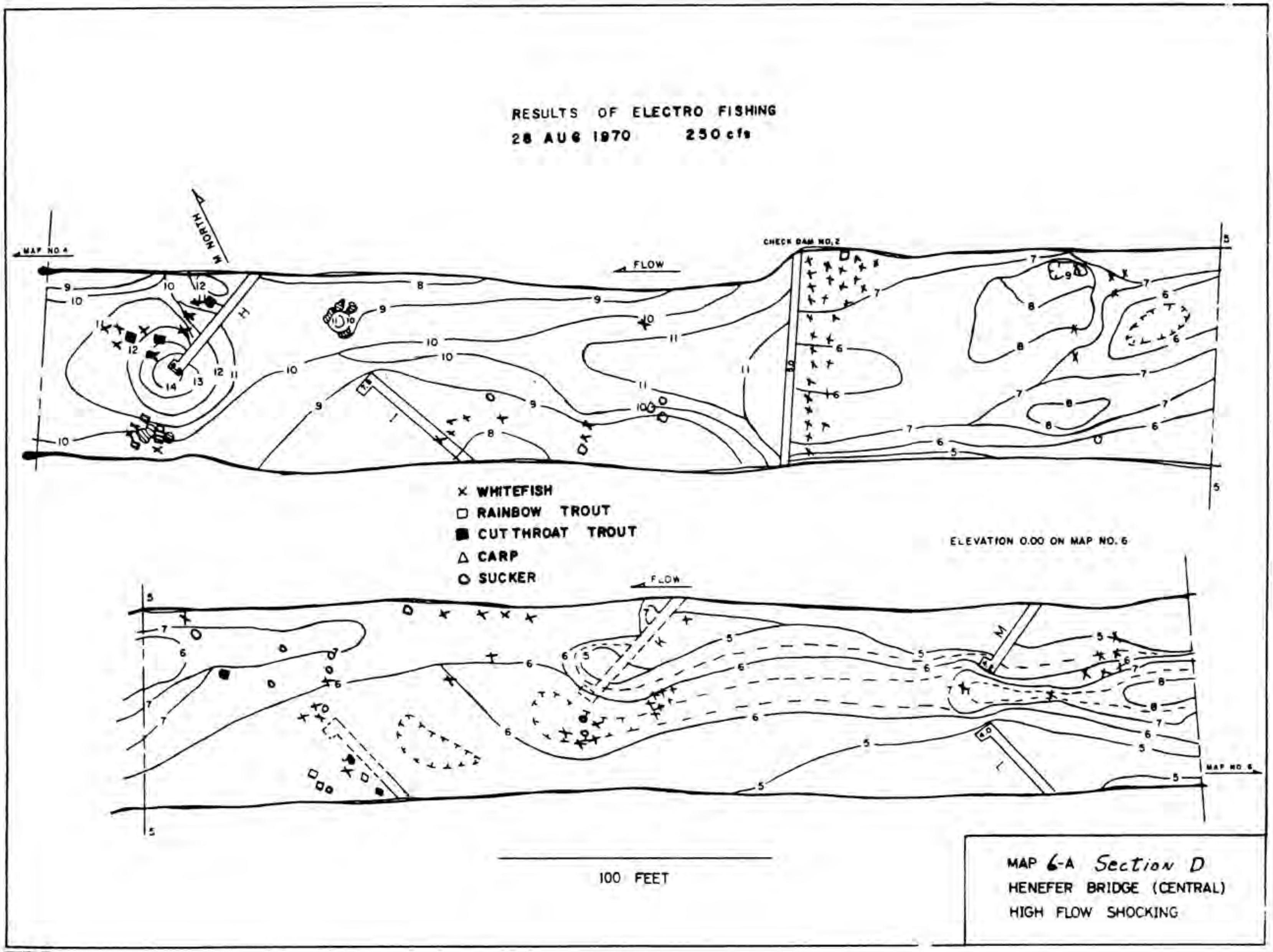
Map 4-A Rock Deflector
Section B
High Flow Shocking

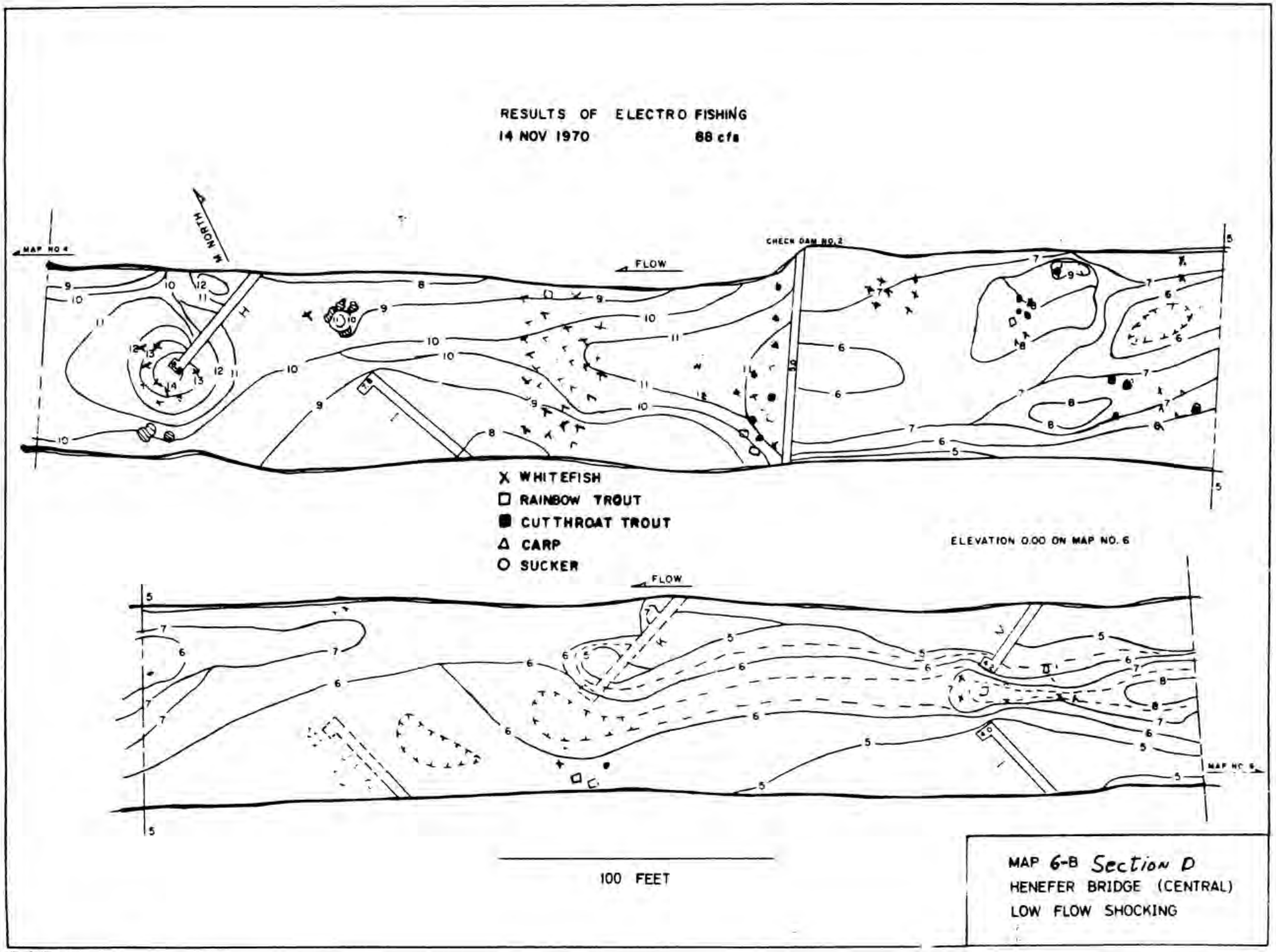

RESULTS OF ELECTRO FISHING
21 NOV 1970
88 cfs
FLOW
MAG NORTH
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
FLOW
ELEVATION OO SOUTHWEST END
OF CHECK DAM IN DRAWING NO.9
100 FEET
MAP 4-B ROCK DEFLECTOR
Section B
LOW FLOW SHOCKING

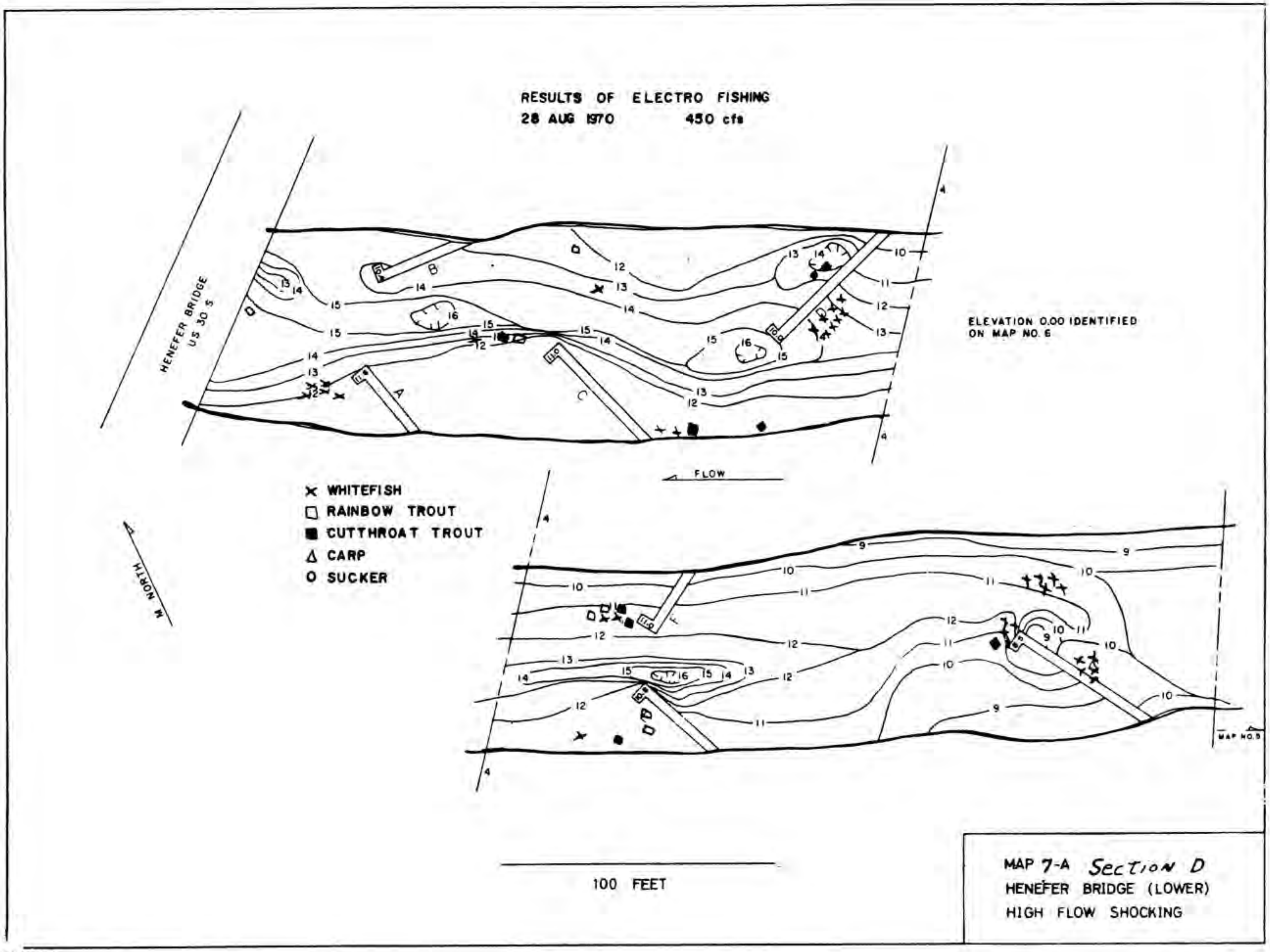

RESULTS OF ELECTRO FISHING
28 AUG 1970 450 cfs
FLOW
CHECK DAM NO. 1
WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
SUCKER
MAP NO. 5
NORTH
ELEVATION 0.00 ON TOP END OF PIPE
FLOW
100 FEET
MAP 5-A Section D
HENEFER BRIDGE (UPPER)
HIGH FLOW SHOCKING

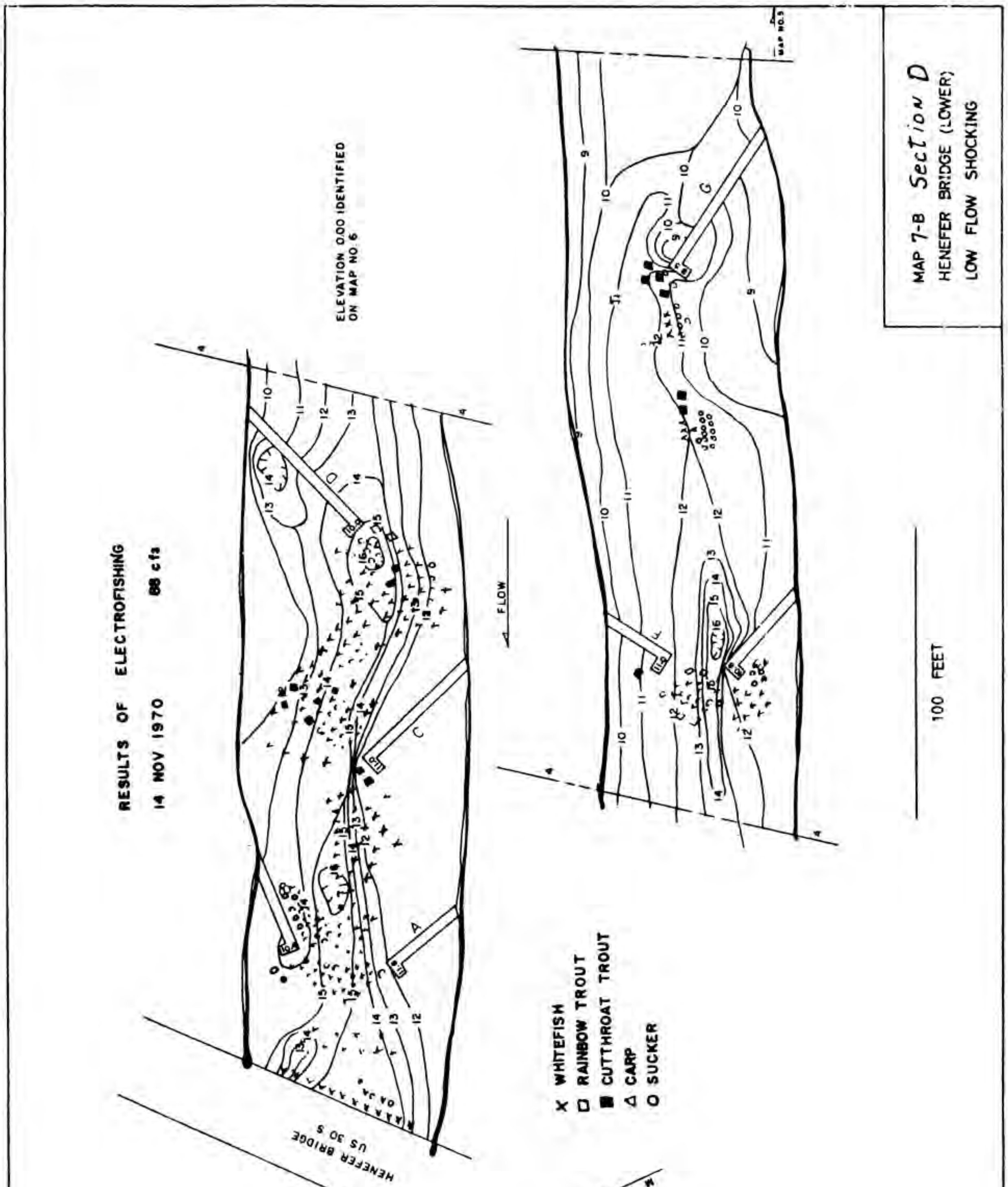


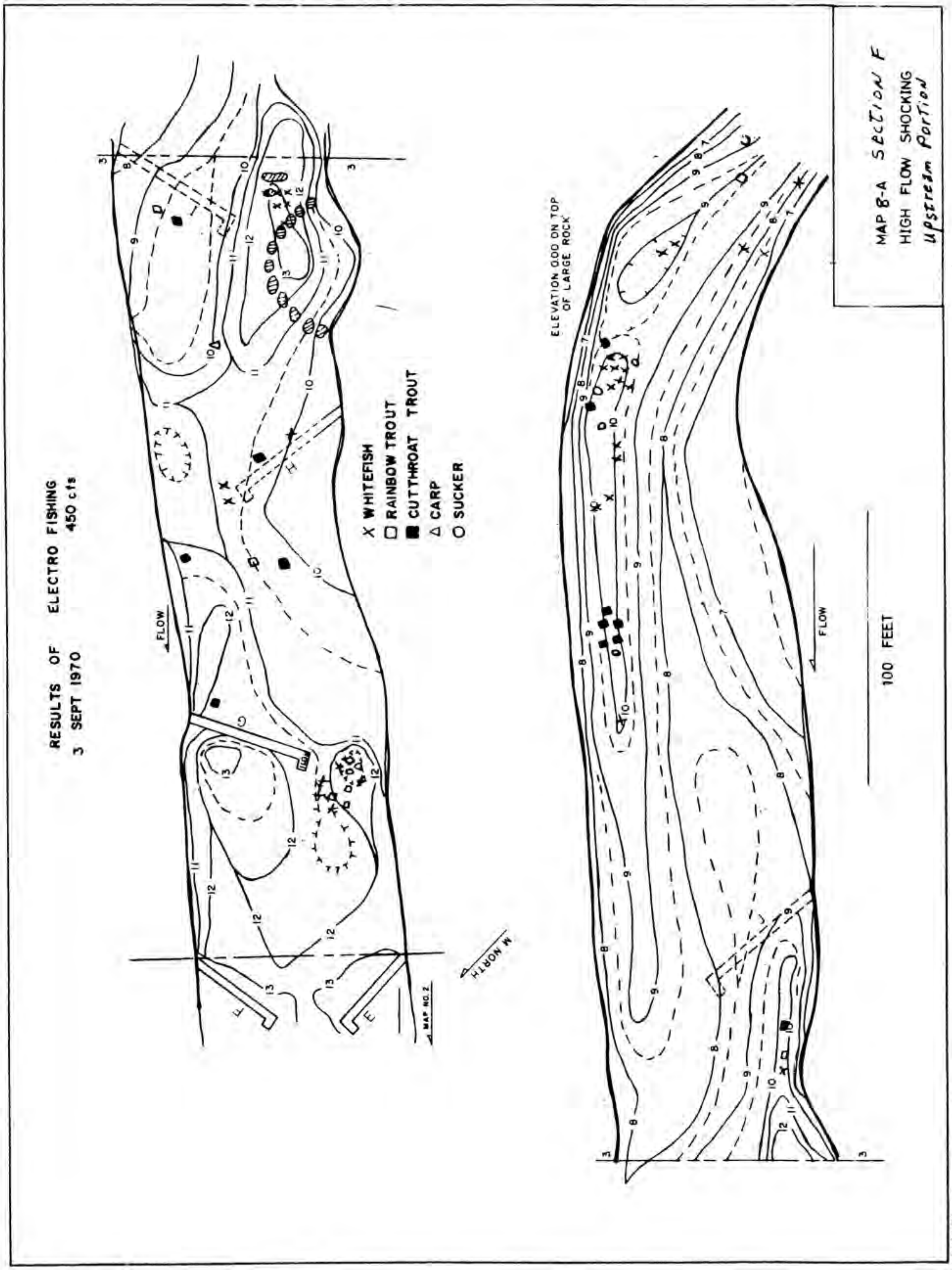
MAP 5-B Section D
HENEFER BRIDGE (UPPER)
LOW FLOW SHOCKING
RESULTS OF ELECTRO FISHING
21 NOV 1970
88 cfs
X WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
SUCKER
FLOW
NORTH
100 FEET
CHECK DAM NO. 1
ELEVATION 0.00 ON TOP END OF PIPE
MAP NO. 5


RESULTS OF ELECTRO FISHING
28 AUG 1970 250 cfs
MAP NO. 4
NORTH
FLOW
CHECK DAM NO. 2
× WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
△ CARP
○ SUCKER
ELEVATION 0.00 ON MAP NO. 6
FLOW
MAP NO. 6
100 FEET
MAP 6-A Section D
HENEFER BRIDGE (CENTRAL)
HIGH FLOW SHOCKING

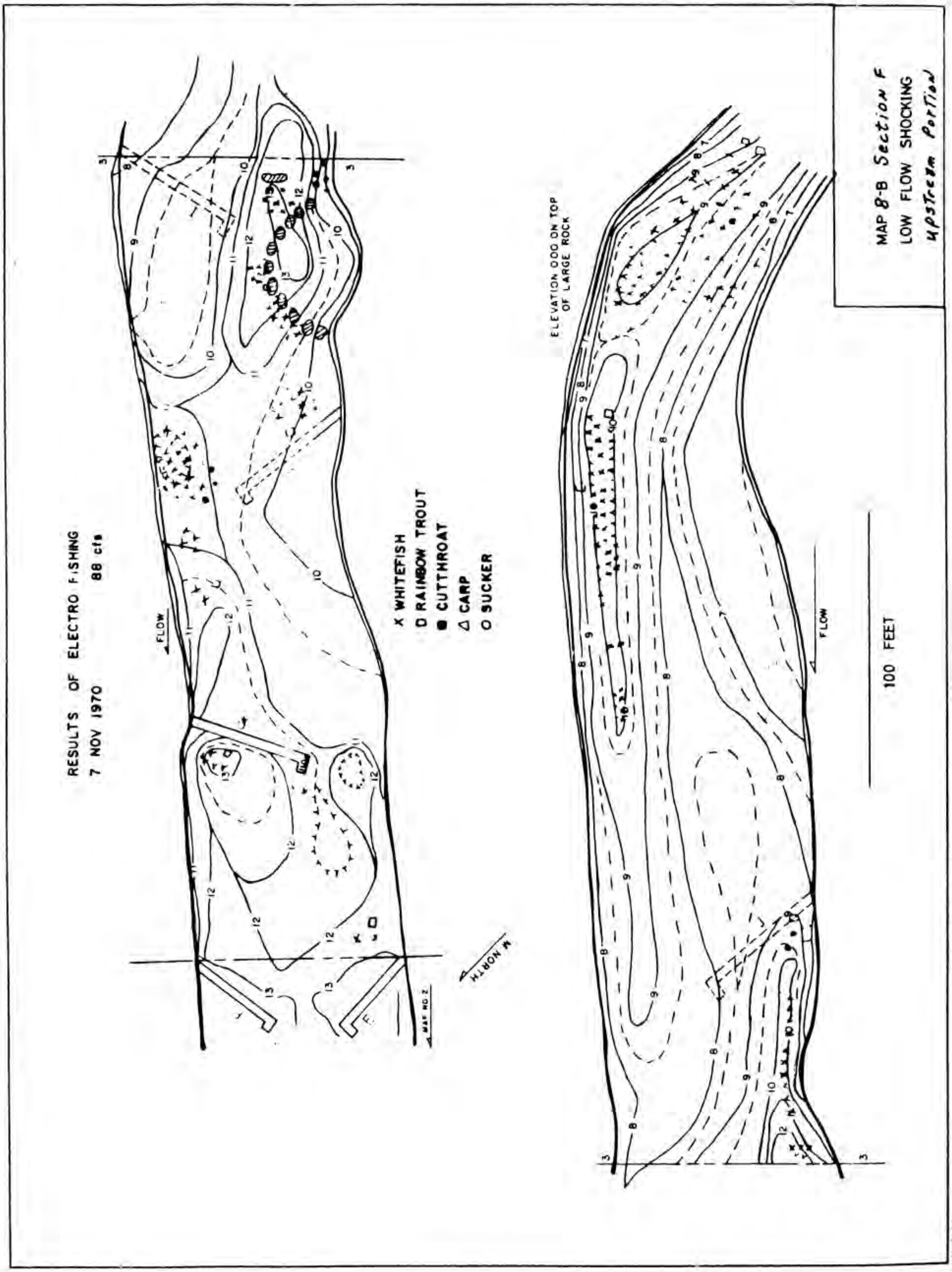

RESULTS OF ELECTRO FISHING
14 NOV 1970 88 cfs
NORTH
MAP NO 4
FLOW
CHECK DAM NO.2
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
ELEVATION 0.00 ON MAP NO. 6
100 FEET
MAP 6-B Section D
HENEFER BRIDGE (CENTRAL)
LOW FLOW SHOCKING

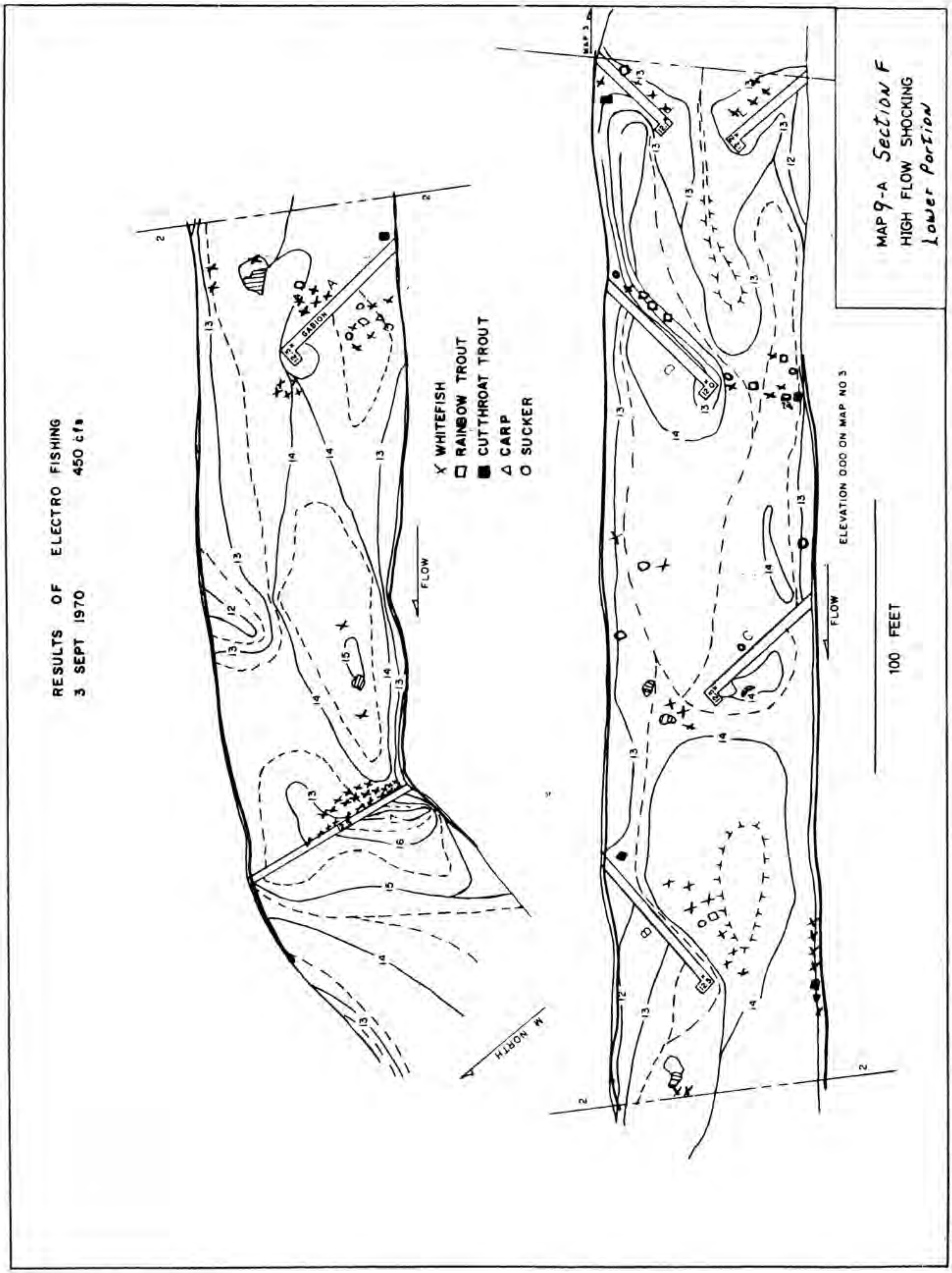

RESULTS OF ELECTRO FISHING
28 AUG 1970 450 cfs
ELEVATION 0.00 IDENTIFIED ON MAP NO. 6
HENEFER BRIDGE US 30 S
FLOW
NORTH
WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
SUCKER
100 FEET
MAP 7-A Section D
HENEFER BRIDGE (LOWER)
HIGH FLOW SHOCKING


RESULTS OF ELECTROFISHING
14 NOV 1970
88 cfs
ELEVATION 0.00 IDENTIFIED ON MAP NO. 6
FLOW
X WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
O SUCKER
HENEFER BRIDGE
US 30 S
M NORTH
100 FEET
MAP 7-B Section D
HENEFER BRIDGE (LOWER)
LOW FLOW SHOCKING

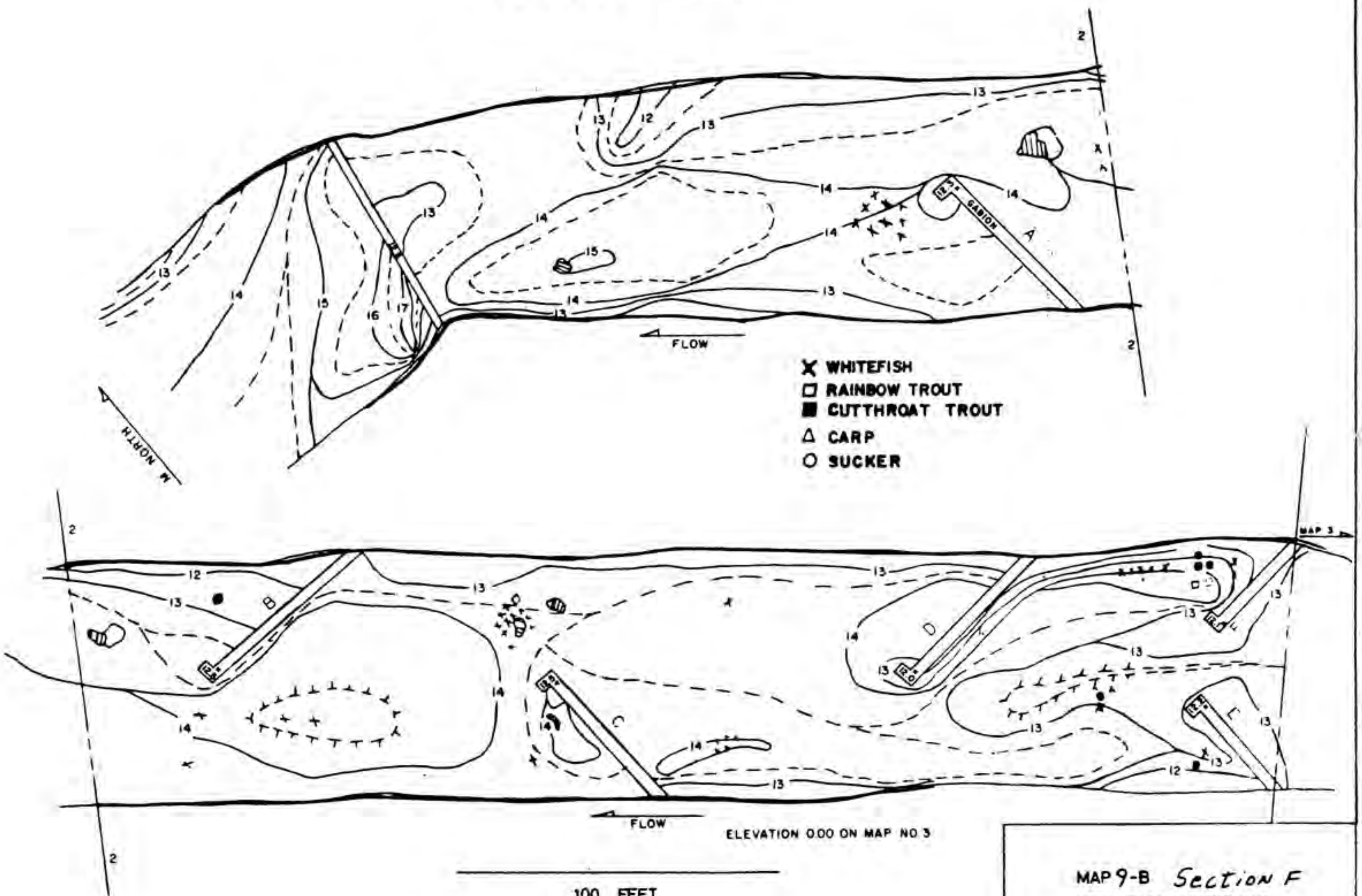


RESULTS OF ELECTRO FISHING
3 SEPT 1970 450 cfs
X WHITEFISH
☐ RAINBOW TROUT
■ CUTTHROAT TROUT
△ CARP
O SUCKER
FLOW
MAP NO. 2
M NORTH
ELEVATION 000 ON TOP OF LARGE ROCK
100 FEET
MAP 8-A SECTION F
HIGH FLOW SHOCKING
Upstream Portion


RESULTS OF ELECTRO FISHING
7 NOV 1970
88 cfs
X WHITEFISH
D RAINBOW TROUT
● CUTTHROAT
Δ CARP
O SUCKER
FLOW
NORTH
ELEVATION 000 ON TOP OF LARGE ROCK
FLOW
100 FEET
MAP 8-B Section F
LOW FLOW SHOCKING
upstream Portion

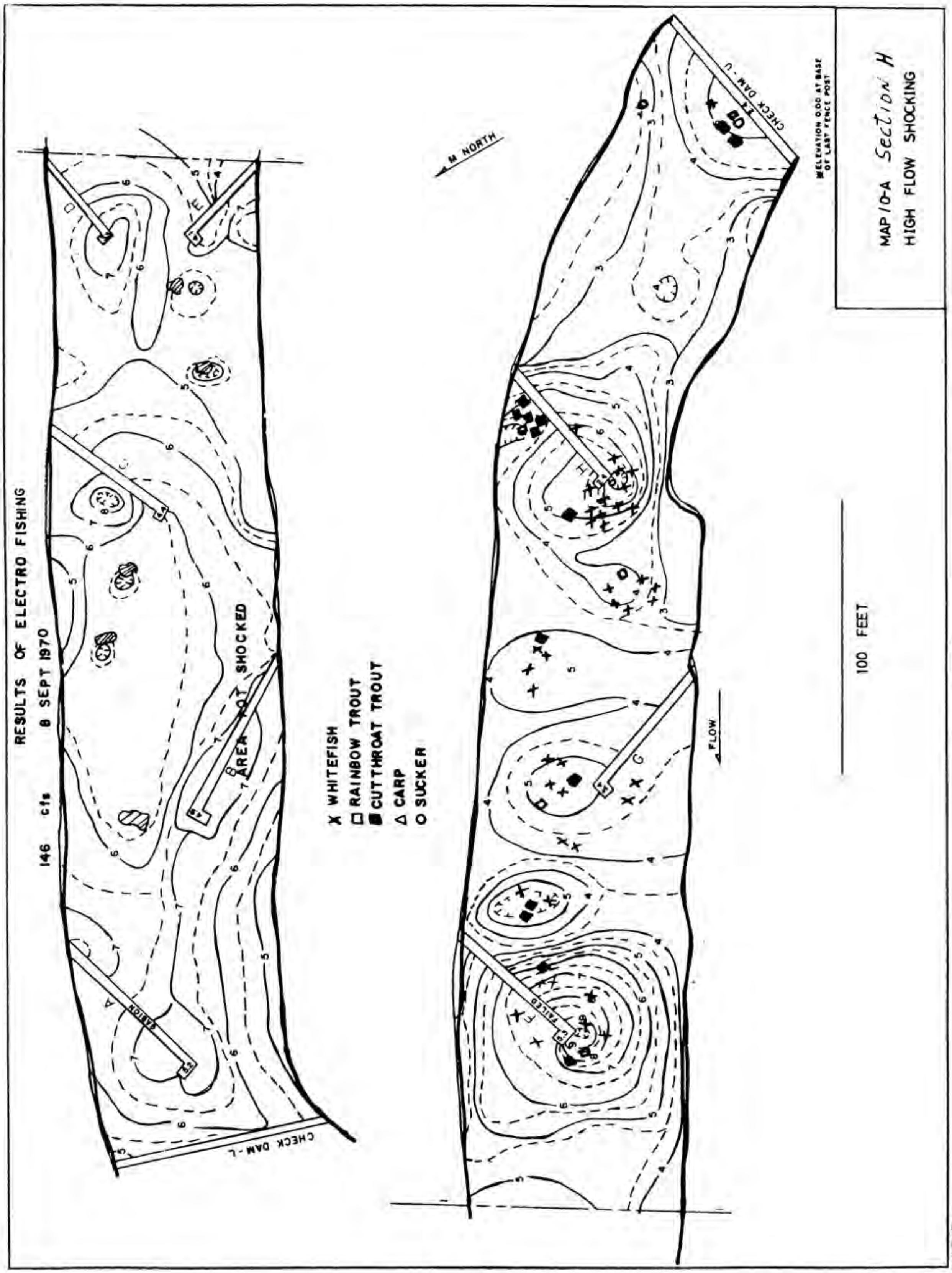

RESULTS OF ELECTRO FISHING
3 SEPT 1970 450 cfs
WHITEFISH
RAINBOW TROUT
CUTTHROAT TROUT
CARP
SUCKER
GABION
FLOW
M NORTH
ELEVATION 000 ON MAP NO 3
100 FEET
MAP 9-A Section F
HIGH FLOW SHOCKING
Lower Portion

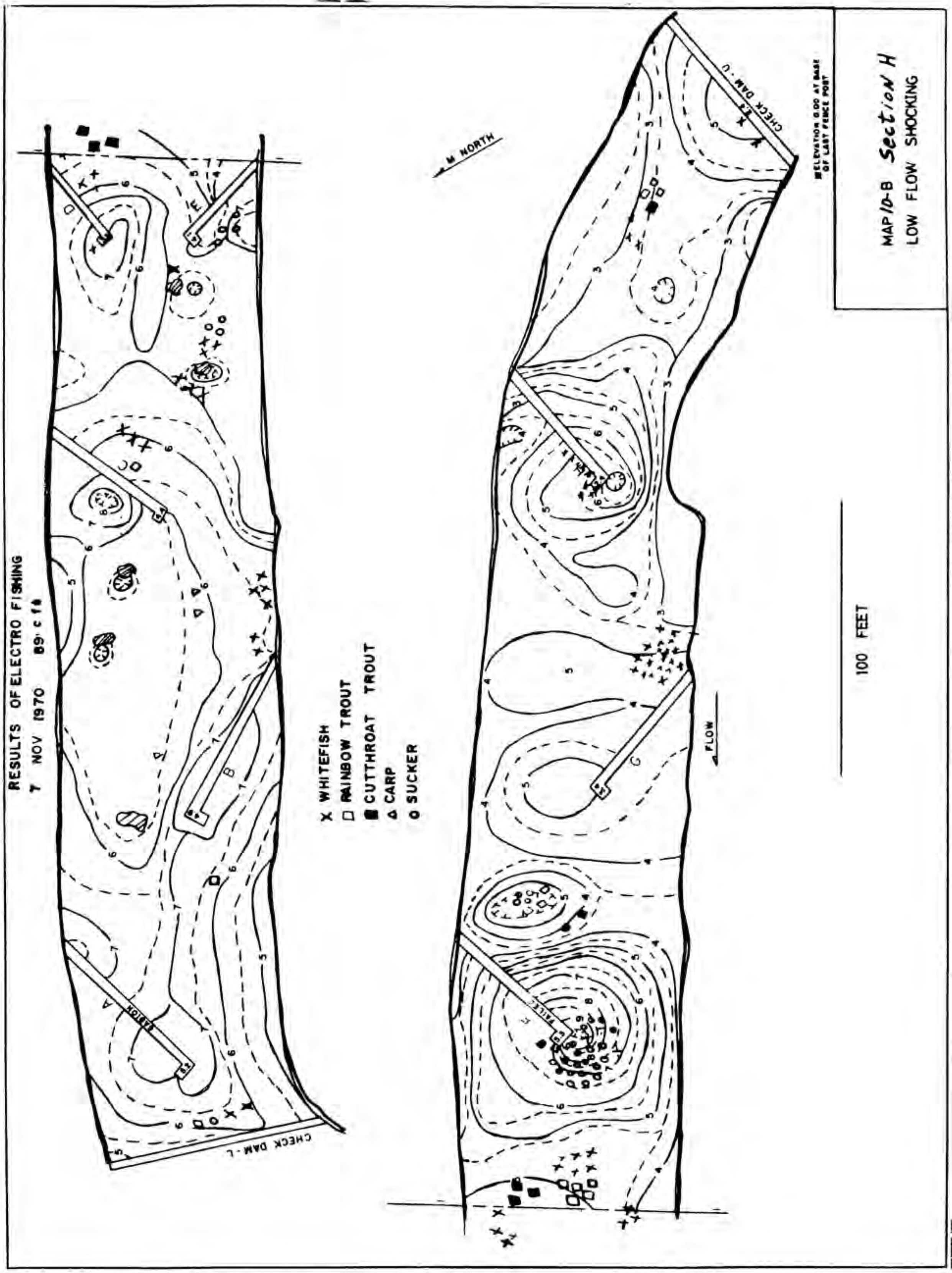
RESULTS OF ELECTRO FISHING
7 NOV 1970 ≃ 68 c.f.s.



100 FEET

MAP 9-B Section F
LOW FLOW SHOCKING
Lower Portion


RESULTS OF ELECTRO FISHING
146 cfs 8 SEPT 1970
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
AREA NOT SHOCKED
GABION
CHECK DAM-L
CHECK DAM-U
M NORTH
FLOW
FAILED
100 FEET
ELEVATION 0.00 AT BASE OF LAST FENCE POST
MAP 10-A Section H
HIGH FLOW SHOCKING


RESULTS OF ELECTRO FISHING
7 NOV 1970 89 c f s
X WHITEFISH
□ RAINBOW TROUT
■ CUTTHROAT TROUT
Δ CARP
O SUCKER
CHECK DAM - L
CHECK DAM - U
N NORTH
FLOW
100 FEET
ELEVATION 0.00 AT BASE OF LAST FENCE POST
MAP 10-B Section H
LOW FLOW SHOCKING