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Aquatic Biota of Bank Stabilization Structures on the Missouri River, North Dakota

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AQUATIC BIOTA OF BANK STABILIZATION STRUCTURES ON THE MISSOURI RIVER, NORTH DAKOTA

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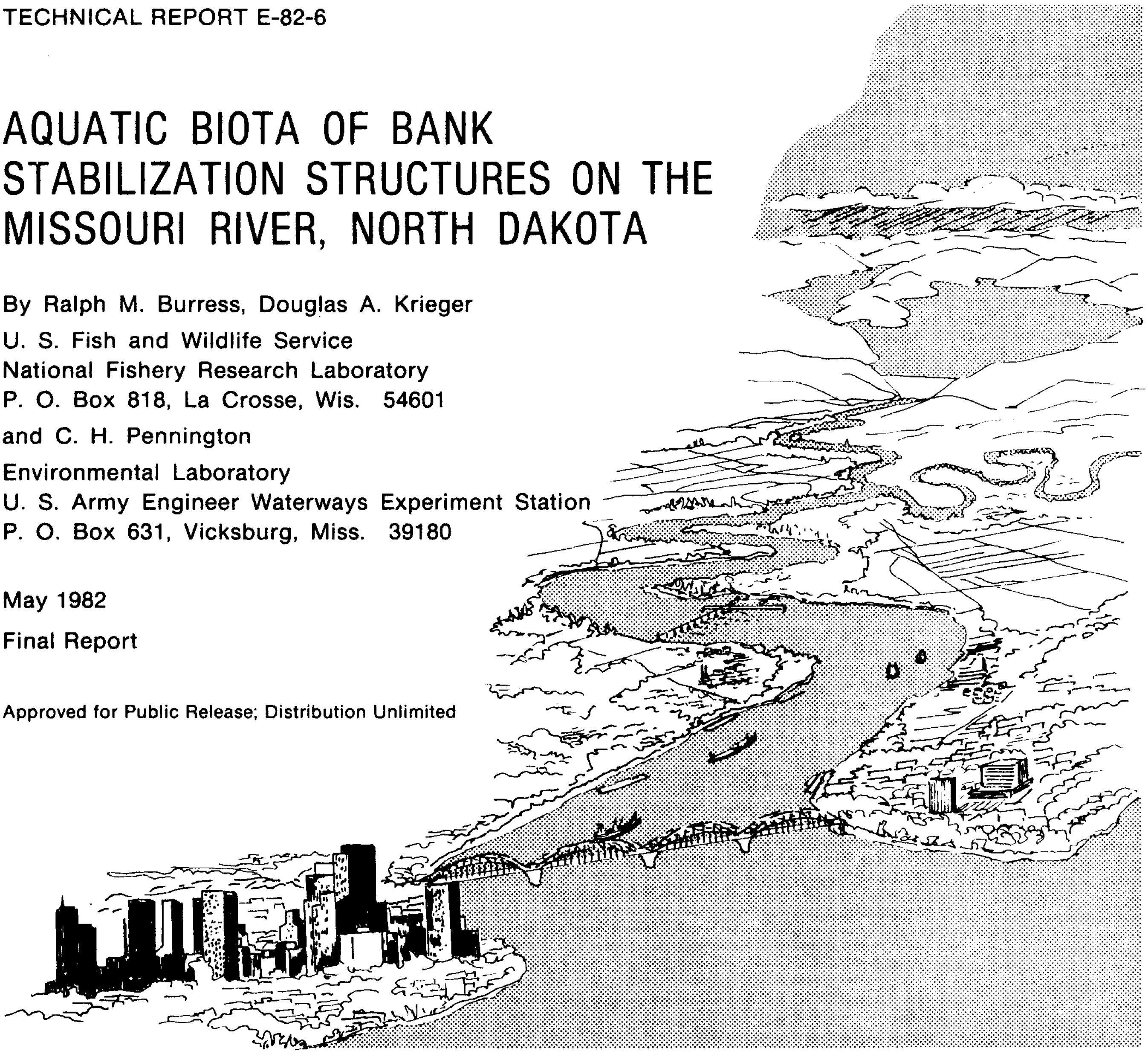

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Biological and physical data were collected from nine habitats on the Missouri River near Washburn, North Dakota. Sampling was conducted from mid-July to mid-October 1979 to compare the relative values of the habitats for fish and macroinvertebrates.

Benthic samples included 11 families, among which oligochaetes (63 percent) and dipterans (34 percent) were numerically dominant. About half of the
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166 samples taken at both structured and natural locations contained organisms, but 55 samples taken from mud or mud-fine sand substrates yielded 93 percent of the organisms collected. Although the numbers of taxa per station were not significantly different, there were significant differences in the mean numbers of organisms per station. Densities were greatest at two locations that included extensive areas of backwater (L-head dikes at Location DFH and wing dikes at Location DFW), and least at a revetted location (RVD) where the substrate was largely fine sand.

Rock fauna samples included 22 families, with dipterans (nearly 60 percent), trichopterans (33 percent), and oligochaetes (7 percent) comprising all but a fractional percentage of the organisms collected. The average numbers of dipterans, trichopterans, and ephemeropterans tended to increase as current velocities increased to 70 cm/sec, but oligochaetes were most numerous at current speeds of 11 to 30 cm/sec. Maximum density occurred at the stone-faced earth core dike (Location DFE) where the sample contained twice as many families and more than six times as many organisms/m^2 as were found in the most productive benthic sample (Location DFH). There were statistically significant differences among stations in both the numbers of taxa and organisms/m^2. Densities were highest at Location DFE, where algal growths on the rocks were heaviest and the average current velocity was highest, and lowest at the hardpoints (Location DFP) where algal growths were sparsest and average current velocity was lowest.

Among the 26 species of fish collected, five species comprised nearly two-thirds of the catch. They included carp (18.3 percent), white bass (15.6 percent), white sucker (13.7 percent), yellow perch (10.2 percent), and river carpsucker (7.8 percent). Half of the species collected (13) were represented by fewer than ten specimens. Seven species were found at only two of nine locations, and five others were found at only one location. Of all the habitats sampled, dike fields had the most diverse fish community.

There were marked differences in the catch rates by hoop net and seine among the locations, but the differences were not significant. The mean numbers of species of fish taken at different locations by gill nets and electrofishing were different. Differences in the mean number of fish taken per station by gill nets at different locations were different but there was no difference among electrofishing samples.

PREFACE

The work described in this report is part of the Environmental and Water Quality Operational Studies, Work Unit VA, conducted by the U. S. Army Engineer Waterways Experiment Station (WES) for the Office, Chief of Engineers, U. S. Army. This work was partially funded by the U. S. Army Engineer District, Omaha, under Cooperative Agreement No. 14-16-0009-78-946.

The work was a cooperative effort between the U. S. Fish and Wildlife Service, National Fishery Research Laboratory, La Crosse, Wis., and the Waterways Habitat and Monitoring Group (WHMG), Environmental Systems Division (ESD), Environmental Laboratory (EL), WES. The study was conducted to determine the role of Section 32* bank stabilization structures on the ecology of the Missouri River near Washburn, N. Dak.

The report was prepared by Messrs. Ralph M. Burress and Douglas A. Krieger of the U. S. Fish and Wildlife Service and Dr. C. H. Pennington, WES, under the supervision of Dr. Thomas D. Wright, Chief, WHMG, Mr. Bob O. Benn, Chief, ESD, and Dr. John Harrison, Chief, EL.

The authors express their appreciation to Mr. Walter C. Deane of the Omaha District office for additionally providing grain-size analyses of sediment samples and dietary analyses of fish stomach contents. Special thanks are due Dr. W. B. Gallaher, former Chief, WHMG, for his assistance in selection of study areas and sampling methods, and to Mr. James A. Grimes of the WES for accomplishment of all phases of electronic data processing. We are also indebted to Mr. R. W. Branning and his staff at Garrison Dam, Riverdale, N. Dak., for field support and

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* In recognition of the serious economic losses occurring throughout the Nation due to streambank erosion and failures, the U. S. Congress passed the Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251 (as amended by Public Law 94-587, Section 155 and Section 161, October 1975). This legislation, called the Section 32 Program, authorized a 5-yr effort to study the causes of streambank erosion and failures, to evaluate the effectiveness of existing and new methods of bank protection, and to prepare documented guidance for the engineer and layman confronted with streambank protection problems.

provision of data on daily discharges from Lake Sakakawea. Special thanks are expressed to Mr. W. H. Kunesh and his staff at Garrison Dam National Fish Hatchery, Riverdale, N. Dak., for providing work space and assisting with maintenance of field gear on numerous occasions. Messrs. R. J. Cordes and R. S. Eng deserve special recognition for their contributions in carrying out all phases of field and laboratory work. Mr. Fred C. June is acknowledged for his assistance with the literature review.

COL John L. Cannon, CE, was Commander and Director of WES during conduct of the field study. COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE, were Commanders and Directors of WES during preparation and publication of this report. Mr. F. R. Brown was Technical Director of WES.

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CONTENTS

AQUATIC BIOTA OF BANK STABILIZATION STRUCTURES ON THE MISSOURI RIVER, NORTH DAKOTA

PART I: INTRODUCTION

1. In 1884, Congress established the Missouri River Commission to improve navigation on the river by removing obstructions, installing bank revetments, and constructing pile dikes. Early revetments usually were woven of willow brush, poles, or lumber and ballasted with rock, whereas pile dikes were made of single or multiple rows of clusters of three piles that usually were connected by stringers (Funk and Robinson 1974). Later, more durable revetments and dikes were constructed of field stone or broken rock. Although structures of this kind were effective, they often tended to be unattractive in appearance and were thought to reduce the quality of riparian and aquatic habitats.

2. In 1974 and 1976, Congress passed legislation authorizing the U. S. Army Corps of Engineers to develop and demonstrate new or improved bank stabilization methods which would prevent bank erosion without drastically altering the river environment or its aesthetic qualities. In 1978, new types of bank stabilization structures were built in the Missouri River near Washburn, N. Dak., and a short-term field study was planned to provide a preliminary evaluation of the habitats thus created.

3. The major objective of this pilot survey was to document composition, relative abundance, and spatial distribution of fishes and aquatic macroinvertebrates associated with the Section 32 demonstration project area and the reference areas near Washburn, N. Dak.

4. The location of the sampling stations and choice of sampling methods were made in conjunction with a contract between U. S. Army Engineer Waterways Experiment Station (WES) and U. S. Fish and Wildlife Service. Initial study plans specified that sampling would be started in the spring of 1979. However, the combination of an unusually severe, prolonged winter and abnormally high and rapid runoff from snowmelt

resulted in high discharge rates from Garrison Dam. This condition forced postponement of the starting date, which allowed time for collection of only one complete group of samples at each location. Collection of samples was begun in mid-July, and the field portion of the study was completed in the second week of October.

PART II: STUDY AREA

General

5. The Missouri River originates in southwestern Montana, flows through Montana, North Dakota, South Dakota, Iowa, Nebraska, Kansas, and Missouri, and joins the Mississippi River just above St. Louis, Missouri. A system of six main-stem dams, authorized by the Flood Control Act of December 22, 1944 (Public Law 524, 78th Congress, 2nd Session), as part of the Pick-Sloan Plan for the comprehensive development of the Missouri River Basin, was constructed on the upper river for the primary purpose of flood control; other project purposes include hydroelectric power generation, navigation, and irrigation.

6. Annual inflow into the Missouri River system is normally marked by two high-water stages: one in the spring as a result of snowmelt within the basin and a second arising from mountain snowmelt and basin rainfall in June. Discharge in the main-stem reservoir system is controlled at the six dams, and storage regulation is primarily accomplished by the three upstream reservoirs--Lakes Fort Peck, Sakakawea, and Oahe. The reservoir system first reached full operating levels in 1968.

7. Lake Sakakawea, the middle and largest storage reservoir on the upper Missouri River, is in west central North Dakota. It was formed by the closure of Garrison Dam in April 1953. Filling began in December 1953, and the reservoir was put into operation in 1955. Maximum operating pool was reached in 1957. At maximum normal operating pool, the reservoir has a surface area of 149,000 ha and a gross storage capacity of $2.98 \times 10^{10} m^3$.

8. The study area is underlain by the Tertiary Tongue River formation of the Fort Union group. The Fort Union group was covered by a relatively thin layer of glacial till formed during the Kansan Period. Much of the glacial ground morain has been eroded and the Tertiary beds have been exposed (Leonard 1930).

9. The river between Garrison Dam and Bismark, N. Dak., flows through forested bottomland typical of that before the impoundment of

Lake Sakakawea. The meandering streambed consists mostly of sand, and numerous sandbars are exposed during low-water conditions. Terrain on one or both sides of the river is characterized by low hills, "breaks," and low buttes; in a number of places wide bottoms border the river. The forested bottomland is bordered by pasture and irrigated croplands. Soils of the area are loams and sandy loams of the Havre-Banks Soil Association; alluvial fans include Chernozem and Regosol soils. Vegetation along the river consists mainly of willow, plum, green ash, and cottonwood; upland vegetation is primarily mixed buffalo and blue gramma grasses (Kuchler 1964). Industrial and municipal wastes from Stanton and its associated power plants, Washburn, and Bismarck-Mandan enter the river. Additional nutrients and chemicals are contributed by feedlot and other farming operations.

10. Sediment enters the river chiefly by surface drainage from adjacent farmlands and from bank erosion. Neel, Nicholson, and Hirsch (1963) reported that the heavy suspended sediment load (in terms of dry weight) at Bismarck averaged less than 1 percent of volume. Turbidity of the river is largely associated with small, flattened clay particles that effectively absorb light. Turbidity contributions by bank erosion are particularly heavy during windy weather and during high discharges from Garrison Dam. Increased irrigation has added considerable turbidity to the river in recent years. The river is generally clear under ice cover, and turbidity is reduced under low discharges.

11. Variable water releases for power generation at Garrison Dam caused daily fluctuations in water level of up to 1.35 m and 0.6 m at the upper and lower ends, respectively, of the study area. The mean daily discharge rates (in m^3/sec) ranged from 731 (17 July) to 442 (7 October). Mean discharge rates declined each month throughout the sampling period: 17-31 July, 669; August, 589; September, 488; and 1-8 October, 468.

Sampling Locations

12. The nine locations selected for study included six bank

stabilization structures and three locations unaltered by structures. All locations were between river miles 1349 and 1366, 37 to 63 km downstream from Garrison Dam. The nine study locations are listed consecutively downstream (Table 1) and extended from about 18 km above to 8 km below Washburn, N. Dak. (Figure 1). All are above the area of disturbance associated with installation of additional structures during the summer of 1979.

13. The bank stabilization structures included an earth core dike, three hard point dikes, two revetments, two wing dikes, and four L-head dikes. Fieldstone and broken rock were used to construct the structures. The earth core dike was riprapped with rock, but the other structures were composed entirely of rock. Rock sizes were quite variable, ranging from about 0.2 to 1.0 m in maximum dimension. The smallest structures were the hard point dikes, which reached out into the river no more than 20 m. The largest structure was the upper revetment, which was approximately 500 m long. The natural areas studied included two widely separated areas of natural bank and a chute behind two small islands.

14. To facilitate identification of sampling stations at each location, transects were established and marked with posts driven into the riverbank. The number of transects per location ranged from 4 to 21 and were placed to give adequate coverage of a location. A total of 75 transects were laid out in parallel fashion approximately perpendicular to the shoreline. The transects were usually spaced at intervals of about 90 to 120 m between selected points above and below the various structures and throughout the natural areas. Individual sampling stations along each transect were identified with reference to their distance offshore from the posts. The distance between successive sampling stations (e.g., A01, A02, A03) was slightly more than 15 m. Since there were marked differences in length and habitat diversity among transects, the numbers of stations per transect varied considerably. A total of 166 sampling stations were used during the study. Aerial photographs of all but one of the nine locations were obtained (Appendix A). These views illustrate not only the size and shape of the structures and natural areas but also their relationship to other environmental

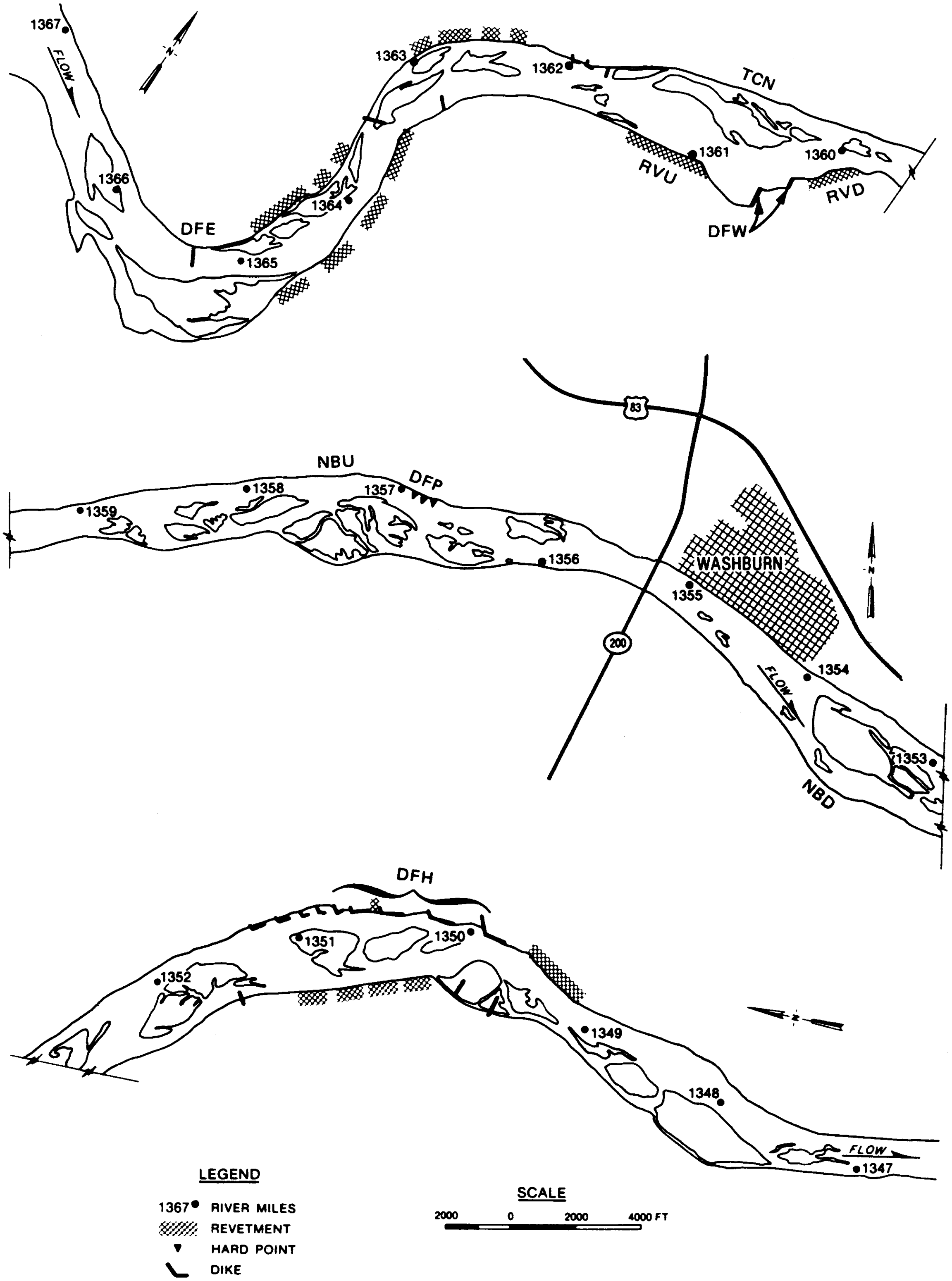

Figure 1. Map of study area--Missouri River near Washburn, N. Dak.

features such as channels, sandbars, areas of sediment deposition, and shoreline configuration. The location of transects and of stations where the different kinds of sampling gear were used are marked on the photographs as an aid to orientation.

Stone-faced earth core dike (DFE)

15. The uppermost location centered around this dike which was built on the left bank at river mile 1365 in 1978 (Figure A1). A corrugated metal pipe (termed an environmental culvert) about 76 cm in diameter was installed near the off-shore end of the dike. Its purpose was to carry a continuous flow of fresh water through the dike to enhance environmental conditions in the backwater area. However, the pipe had become clogged with debris so that the flow of water was greatly reduced. A large sandbar formed behind the outer half of the dike, leaving an elongated, shallow backwater along the shore. Nine transects were established from a point about 100 m above the dike to about 800 m below. The substrate consisted of fine sand in 22 percent of the samples and medium sand in the remainder. The fine sand substrates were confined to areas near the shore where current velocities were relatively low. Water depths at sampling stations along the nine transects ranged from 0.3 m at the shore to maximums of 1.5 m in the backwater area and 3.4 m at the offshore end of the dike. Current velocities recorded at the different sampling stations throughout the entire study period ranged from 4 cm/sec in the backwaters to 100 cm/sec at the end of the dike.

Stone fill wing dikes (DFW)

16. Two closely spaced wing dikes and their backwater areas constituted the major portion of the second dike field location. These dikes were built on the right bank at river mile 1360 in 1966 (Figures A2 and A3). Nine sampling transects were established in this location. Substrate types in the samples included mud (10 percent), mud and fine sand (33 percent), fine sand (24 percent), and medium sand (33 percent). The mud and mud and fine sand substrates occurred in areas of low current near shore, whereas substrates of fine and medium sand were found in areas of swifter current near or in the channel. Water depths

at sampling stations ranged from 0.9 m near shore to 6.7 m in the backwater area and 5.8 m at the outer end of the lower dike. Current velocities ranged from 2 cm/sec in the backwater to 100 cm/sec at the outer end of the upper dike.

Hard points (DFP)

17. The third dike field studied consisted of a group of three hard points built about 91 m apart at river mile 1356 in 1978 (Figure A4). Nine transects were established at this location. Substrate types in the samples included mud (13 percent), mud and fine sand (33 percent), fine sand (7 percent), medium sand (20 percent), gravel and medium sand (7 percent), and gravel and coarse sand (20 percent). There were no backwaters associated with these short dikes, thus the mud substrates encountered were rather firm and occurred where there were current velocities as high as 45 cm/sec. The two coarsest sediment types were found in or at the edge of the channel. Sample depths ranged from 1.2 m near shore to 6.7 m in the channel above the upstream hard point. Current velocities ranged from 2 cm/sec near the bank to 92 cm/sec in the channel.

L-head dikes (DFH)

18. The fourth dike field investigated was comprised of a group of four L-head dikes and their backwaters, plus a short section of revetment between the second and third dikes (Figures A5, A6, and A7). All were built on the left bank within river miles 1349 to 1351 in 1972. Four transects were located in the area of the two upper dikes, which are considerably shorter than the two lower dikes. Only the first of the upper two dikes had an area of backwater, which was quite small because of extensive sediment deposition. Three transects were located along the short revetment, and two others were laid out along the shoreline between the revetment and the third dike. The third and fourth dikes were considerably longer, with backwaters that had surface areas of about 0.5 and 2.5 ha and maximum depths of not less than 1.2 and 3.7 m, respectively. Twelve transects were located in the area of dikes 3 and 4. Substrates encountered within this dike field were: mud (15 percent), mud and fine sand (27 percent), fine sand (8 percent),

medium sand (38 percent), and coarse sand (12 percent). Deposits of soft mud were found in relatively isolated portions of the backwater areas, whereas the coarse sand substrates occurred only in and near the channel. The remaining substrate types were found in a variety of other habitats throughout the dike field area. Water depths at sampling stations ranged from 0.3 m near the backwater shoreline to 7.9 m in the channel at the outer end of the third dike downstream. Current velocities ranged from zero at several sampling stations in the largest backwater to 100 cm/sec in the channel beside the fourth dike.

Stone fill revetment, upper (RVU)

19. The revetment built on the right bank at river mile 1361 in 1966 was designated as the upper revetment during this study. (No aerial photograph was obtained for this location.) Accumulations of fine sand had created an extensive shoal area along the upper end of the structure, but swift currents prevented deposition of sediment along the lower end. Five transects were established at this location. Substrate samples included mud (11 percent), fine sand (56 percent), medium sand (22 percent), and coarse sand (11 percent). There was no backwater at this location, but an area of rather firm mud was found near the bank on the transect located just above the upper end of the structure. Coarse and medium sands were found along the lower half of the revetment where currents were strong. Sample depths increased from 0.9 m along the edges of two sandbars that lay across the channel from the structure to 7.6 m in the channel near the center of the structure. Water movement was slowest (5 cm/sec) close to shore along the upper end and fastest (105 cm/sec) where the current impinged on the central area of the structure.

Stone fill revetment, lower (RVD)

20. This structure, which also was built on the right bank in 1966, was located below the wing dikes in river mile 1361 (Figure A8). It was somewhat shorter than the upper revetment, was built on a curve in the riverbank, and was bordered by shallower water. However, it was free of sediment accumulation except for a very small area at the upper end. Four transects were established here. One substrate sample that

consisted of fine sand was taken from a place where an eddy at the lower end of the structure had carved out a section of the bank. The remaining samples consisted entirely of medium sand, and they were taken along the length of the structure where currents were more pronounced. Sample depths ranged from 1.5 m along the edges of two sandbars that lay across the channel from the revetment to 4.6 m at two shoreline stations at the lower end of the structure. Both the highest and lowest current velocities at sampling stations were measured along the transect located immediately below the revetment. The velocity in the channel was 45 cm/sec, whereas that in the small "backwater" area created by bank erosion was only 8 cm/sec.

Chute (TCN)

21. This location was a chute along the left bank just opposite the upper revetment and wing dike locations in river mile 1361 (Figure A9). It was about 500 m long, and its width increased from about 30 m at the upper end to about 90 m at the lower end. Six transects were established here. Substrate types included mud (18 percent), fine sand (36 percent), and medium sand (46 percent). With one exception, current velocities over the mud substrates were higher than those at the other sampling stations where the sandy bottoms occurred. The shallowest samples (0.3 m) were collected close to shore near the central section of the area. The deepest samples (3.4 m) were taken quite close to the island at the upper end of the chute.

Natural bank, upper (NBU)

22. An eroding bank on the left bank at river mile 1357 constituted the second of three locations that included no bank stabilization structures (Figure A10). It was designated as the upper natural bank to distinguish it from a somewhat similar bank located downstream from the town of Washburn. The banks here were thickly wooded with cottonwood trees, many of which had fallen into the shallow water. Five transects were established here. Substrate types included mud and fine sand (31 percent), fine sand (15 percent), and medium sand (54 percent). The fine-grained substrates were found near shore, and the coarser grained sediments were in or near the channel. With few exceptions, current

velocities were lower near shore (minimum, 12 cm/sec) than offshore (maximum, 88 cm/sec).

Natural bank, lower (NBD)

23. The other eroding bank studied was a long stretch of bank on the right side of the river just below Washburn within river miles 1353 to 1354 (Figure A11). The bank in the upstream half of this location was heavily wooded, and many trees had fallen into the water. In contrast, the downstream section bordered an open field, and the water was virtually free of fallen timber. Four transects were established in each half of the area. Substrate samples included mud and fine sand (50 percent), medium sand (25 percent), coarse sand (17 percent), gravel and medium sand (4 percent), and gravel and coarse sand (4 percent). Here, too, the fine-grained substrates were found near shore, and the coarser grained sediments were in or near the channel. Current velocities generally were lowest near shore (minimum, 2 cm/sec) and higher in the channel. However, the highest velocity (41 cm/sec) was observed close to the shore where the main channel began to turn toward the left bank near the lower end of the location.

PART III: METHODS

Physical-Chemical Measurements

24. When each biological sample was collected, concurrent measures of dissolved oxygen, conductivity, turbidity, temperature, and current velocity were made. Current velocities were taken about 0.5 m off the bottom. Measurements of the other parameters were taken within 0.5 m of the surface.

25. Dissolved oxygen and temperature were measured with a YSI (Yellow Springs Instrument Company) Model 54 oxygen-temperature meter. Conductivity was measured with a YSI Model S-C-T meter. A Hach Model 2100A turbidimeter was used to measure turbidity in the laboratory. Current velocity was measured using a Teledyne-Gurley Model 665 current meter suspended by a cable.

26. Substrate samples, which were taken in conjunction with each benthic grab sample, were placed in plastic bags and shipped to the U. S. Army Corps of Engineers Missouri River Division Laboratory at Omaha, Nebr., where standard sieve analyses of the samples were performed. Throughout this report the following general terms are used to describe the predominant particle sizes that characterized individual samples: mud (<0.074 mm); fine sand (0.105 to 0.210 mm); medium sand (0.297 to 0.59 mm); coarse sand (0.84 to 2.00 mm); and gravel (4.76 to 25.4 mm).

Macroinvertebrate Sampling

Benthic grab samples

27. During the period 17-27 July, samples of macroinvertebrates and sediments were collected with a 0.05-m^2 Shipek dredge. To aid in determining the spatial distribution and habitat preferences of benthic organisms, samples were taken at various distances from the structures and from areas with different physical characteristics such as depth, substrate type, and current velocity. Benthos samples were washed in a hand-held sieve with No. 30 mesh wire screen (about 0.6-mm mesh).

Organisms were preserved in a 10 percent formalin solution containing rose bengal dye. They were hand-picked under 3-diopter power magnifying lamps and stored in alcohol pending identification. The primary reference works used in identifying the organisms were Pennak (1978), Usinger (1956), Edmonson (1959), and Johannsen (1937).

Rock fauna samples

28. Macroinvertebrates living on submersed rocks were collected from current-swept areas of revetments and from both upstream and downstream sides of dikes and hard points on 22-28 August. At that time, daily water level fluctuations of 0.6 to 1.35 m were commonplace, thus care was exercised to obtain samples from rocks that were submersed at all times. Sampling areas were chosen where the rocks were small enough to be safely moved to the boat deck for collection of invertebrates. Individual sample areas were delineated with an iron frame (called a frame net) that enclosed an area of 0.25 m^2. Rocks enclosed by the frame and those touching two adjacent sides of the frame were removed. Rocks were removed slowly and carefully to minimize dislodgement of organisms. Most of the rocks were small enough to fit into a wide-mouthed, 19-ℓ pail in which they were lifted to the boat deck for collection of invertebrates. Large organisms were removed with forceps, whereas small specimens were removed by brushing and rinsing the rocks and straining the rinse water through the benthos screen. All samples were handled as outlined above.

Fish Sampling

Collection

29. Collections of larval fish were made during hours of daylight and darkness in the period 6-14 August. Samples were taken with standard 0.5-m plankton nets having a 505-μm mesh size. A digital flowmeter (General Oceanics Model 2030) was suspended in the mouth of each net to measure the sample volume. Where there was adequate current, samples were collected by anchoring the boat and holding the nets submerged in place for periods of 5 to 10 min. In areas of standing water behind dikes,

the outboard motor was used to move the boat at a speed of about 75 cm/sec to collect the samples. Samples were preserved, picked, and stored as were the invertebrate samples. Densities of larval fish were reported as number per 100 m^3.

30. A bag seine (13.9 m long by 1.5 m deep with 6.3-mm bar mesh netting) was used to obtain fish samples. Samples were collected at every transect where seining was feasible, but excessive water depths and current velocities prevented seining at many transects. Hauls averaged about 23 m in length, and all samples were taken in daylight hours during the period 16-18 August.

31. From 22 August to 8 October, fish were collected with gill nets, hoop nets, and electrofishing equipment. Wherever physical conditions permitted, each type of gear was fished at each location. Nets were set in the morning and raised approximately 24 hr later (hereafter called overnight sets). All were set on the bottom parallel to the current and were held in position with heavy Wisconsin-type anchors. The experimental gill nets were 106.7 m long by 1.8 m deep and consisted of seven panels 15.2 m long by 1.8 m deep with bar mesh sizes of 1.9, 2.5, 3.2, 3.8, 5.1, 6.4, and 8.9 cm, respectively. The tarred, double-throated hoop nets were of two diameters (0.6 and 0.9 m), but all were 4 m long with 2.5-cm bar mesh and seven fiberglass hoops. Electrofishing was done at night using a 220-v, pulsed d-c boat-mounted boom shocker. Best results were obtained when two men in the bow collected fish with small mesh dip nets while the boat moved downstream at about the speed of the current.

32. Standard units of fishing effort for each gear type were:

- a. One overnight net set for hoop and gill nets.
- b. A 23-m-long haul for the seine.
- c. Ten-minute runs with the electrofisher because sample transects could not be made of uniform length.

The amount of effort expended in each location with each gear type is shown in Table 2.

33. Fish from each net, seine haul, or electrofishing run were placed in separate bags, held on ice, and examined in the laboratory.

Each fish was identified, weighed, and measured (total length). Scale samples or spines were taken from selected species, weights of livers and gonads were determined, and sex and gonad condition were recorded for possible use in a later study. Stomachs containing food were preserved in 10 percent formalin, and sent to the University of South Dakota for analysis.

Stomach analysis

34. Food items of carnivorous fish were removed from their stomachs and individually enumerated. Stomachs from the insectivorous carnivores were handled in one of two ways. If there were only a few items (usually <100) in the stomach, then each item was individually counted. If the stomachs contained a large number of organisms (>100), then a subsample was taken for enumeration.

Statistical Tests

35. Single factor analyses of variance were conducted for significant differences in fish catch per unit of effort and number of fish species taken among locations. Analyses were conducted separately for each gear type. Locations were considered fixed effects, and each unit of effort (e.g. 24-hr net set) served as replication within a particular location. Data from only those locations with more than one unit of effort were included in each analysis of variance, and the data were transformed by natural logarithms to ensure homogeneous variances among locations. Duncan's multiple range test was utilized to indicate individual differences among locations. The error means square from each analysis of variance provided a pooled estimate of error for the test. All computations were made through the Statistical Analysis System (Barr, Goodnight, and Sall 1979).

36. Similar procedures were carried out for the comparisons of invertebrate densities and numbers of species. Separate analyses were performed for each of the three gear types (Shipek dredge, plankton net, and frame net) and the data were log transformed. However, stations rather than units of effort were considered replicates of a location.

At those stations where more than one sample was taken, values were averaged over samples to produce a station replicate of the location. Analyses of variance were conducted on these values.

PART IV: RESULTS

Physical-Chemical Characteristics

37. The mean values for water quality measurements at all locations throughout the study period showed only slight variations for two reasons (Table 3). Lake Sakakawea with its storage capacity of more than 2.98×10^{10} m^3 provided a discharge having uniform limnological characteristics. Furthermore, there was a continuous, rapid exchange of water caused by large flows in the channel and a pronounced diurnal flushing of the backwater areas caused by variable water releases for power generation.

38. The largest differences in water quality parameters were found in the dike areas. Mean water temperatures at all nine locations ranged only from 11.2 to 12.4°C, but surface temperatures in shallow pools behind the dikes occasionally were as high as 16 to 18°C. Turbidity readings generally were low [<2 NTU (nephelometric turbidity units)], but values for samples taken near the bottom in areas behind the dikes sometimes were elevated. Conductivity values at the sampling locations ranged only from 498 to 543 μmhos/cm, with no consistent differences between natural and altered habitats.

Macroinvertebrates

39. The amount of benthic grab sampling conducted at various locations depended on the size and complexity of the habitat. The numbers of grabs taken per location ranged from 7 to 50, with a total of 166 samples (Table 2). These samples included 11 taxa of macroinvertebrates, but oligochaetes (62.7 percent) and dipterans (33.5 percent) were the dominant organisms at each location (Table 4). The 36 frame net samples collected from the bank stabilization structures included 22 taxa. Dipterans (59.5 percent), trichopterans (32.8 percent), and oligochaetes (7.1 percent) comprised 99.4 percent of the total number of organisms (Table 5). In the following sections, data regarding the composition of grab samples at all nine locations are given. Information on frame net

samples taken at the six altered locations also is included to facilitate comparison of the composition of samples from the two types of substrates.

Stone-faced earth core dike (DFE)

40. Benthic grab samples. This dike was the only structure of its kind among the sampling locations, and its backwater area was not characterized by accumulation of mud or finely divided organic matter. Five of the eighteen samples collected contained organisms. The average density among all samples was 85 individuals/m^2, which ranked fifth among all locations (Table 4). Chironomids comprised half of the organisms collected, with oligochaetes (40.7 percent) and nematodes (9.2 percent) making up the remainder. About 96 percent of the organisms were taken in three samples of fine sand from areas where current velocities ranged from 4 to 15 cm/sec (average, 8) (Table 6). The most productive of these samples came from a somewhat sheltered area where the upstream face of the dike joined the riverbank, and the other two were from backwater sites some 100 to 150 m below the dike. The 13 barren samples were collected either upstream from the dike or on the channel side of the sandbar below the dike where current velocities ranged from 25 to 100 cm/sec (average, 65).

41. Rock fauna samples. The average density of 5214 organisms/m^2 at this location was nearly one-third greater than at any other, possibly because of the more profuse growths of algae that covered exposed surfaces of the rocks. Current speeds where the four samples were collected ranged from 25 to 65 cm/sec (average, 53). Chironomids and trichopterans were most numerous here, about 68 and 24 percent of the sample, respectively (Table 5). Of the net spinning trichopterans, *Hydropsyche* larvae and pupae were nearly twice as numerous as those of *Neureclipsis*. *Hydroptila* larvae and pupae were nearly five times more abundant (16/m^2) than at other locations. Oligochaetes were considerably more numerous here than elsewhere, but their percentage composition in the sample (7.3 percent) was near the average for all locations (7.1 percent). The mayfly population, which never exceeded 0.7 percent of the samples at any of the locations, ranked second (tied with RVD) among all

locations. All mayflies were members of the family Heptageniidae. Physid snails and nematodes comprised less than 0.1 percent of the sample and were less numerous than at most other locations. The stoneflies (Isoperla) were found nowhere else, and the hemipterans (Corixidae) were taken at only one other location.

Stone fill wing dikes (DFW)

42. Benthic grab samples. This location, which was second largest in area, included backwater areas that provided favorable habitat for macroinvertebrates. Thirteen of twenty-one samples collected here contained organisms. The average density among all samples was 538 individuals/m^2, which was second highest among all locations (Table 4). Both oligochaetes and dipterans were abundant, but the percentage of oligochaetes (68.5 percent) was more than double that of the dipterans (29.4 percent). Nematodes comprised little more than 1 percent, and a few Hexagenia larvae (0.7 percent) comprised the remainder. Ephemeropterans were not collected in benthic samples at other locations. About 95 percent of the organisms were taken from substrates of mud or mud and fine sand in nine samples from backwater or off-channel stations where average currents did not exceed 8 cm/sec (Table 7). More than 4 percent of the remaining organisms were found in two samples of fine sand that also were taken from a backwater area and at the edge of the channel where the average current was 7 cm/sec. Eight samples that contained no organisms came from stations in the channel where the average current was about 60 cm/sec and the substrates were fine and medium sand.

43. Rock fauna samples. Samples were collected at nine stations where current speeds ranged from 0 to 85 cm/sec (average, 40). The average density of organisms (2136/m^2) ranked third; chironomids (70.3 percent) and trichopterans (20.1 percent) were the most abundant taxa (Table 5). The numbers of Hydropsyche were low; the total trichopteran sample ranked fifth among all locations. Mayflies (entirely Heptageniidae) also ranked fifth and comprised only 0.2 percent of the sample. The single sample taken where there was no current contained the only snails of the genus Gyraulus and the only beetles (Dytiscidae, Deronectes) collected during the study.

Hard points (DFP)

44. Benthic grab samples. Although this was one of the smaller locations and contained no backwaters, there were six types of substrate. The average density among all samples was 40 individuals/m^2, which ranked seventh among all locations (Table 4). Chironomids comprised about 54 percent of the total sample density, fewer oligochaetes were taken here than at any other location (11 percent), and nematodes were absent. Substrates of rather firm mud, mud and fine sand, and gravel and coarse sand that occurred in the channel where currents were 40 to 92 cm/sec afforded habitat for trichopterans which were more numerous here (36 percent) than at the other locations (RVU and NBD) where they were found. Current velocities at the seven stations containing organisms ranged from 23 to 92 cm/sec (average, 50), whereas those for the eight barren stations ranged from 3 to 51 cm/sec (average, 25) (Table 8).

45. Rock fauna samples. Algal growth on hard points was sparse and macroinvertebrate density was less here than at any other location (Table 5). Current velocities at the six sampling stations ranged from 5 to 50 cm/sec; the average (26 cm/sec) was slowest of all. The percentage of dipterans was higher than at other locations (81.4 percent). Black fly larvae (Simuliidae) were more populous here than at other locations combined, and about 92 percent of them were collected in a single sample. Mayflies, which ranked fourth among all locations, were predominantly heptageniids. Fewer trichopterans occurred here than at other locations, but the numbers of nematodes ranked second. Oligochaete numbers ranked a fifth, less than one-third of those of the next larger sample. Physid snails were least numerous at this location, but two other genera (Amnicola and Valvata) were collected here that were collected nowhere else.

L-head dikes (DFH)

46. Benthic grab samples. This location, larger by area than any other, included a variety of habitat substrates. Organisms were found in 29 of the 50 samples, and the average density among all samples was 798 individuals/m^2, which was much higher than that in other locations. Oligochaetes comprised 70 percent of the population sample, followed by

dipterans (nearly 29 percent), and nematodes (1 percent). A few gastropods (0.1 percent), Collembola (<0.1 percent), and Chaoborus sp. (<0.1 percent) were found here that were collected nowhere else (Table 4). All of the 19 samples from mud and fine sand substrates contained benthic organisms and yielded 98 percent of the individuals collected. Average current velocities were <6 cm/sec in the sample areas that were located near shore or in backwaters (Table 9). Two-thirds of the remaining organisms were found in two samples of fine sand taken near shore where the current velocity was 12 cm/sec.

47. Rock fauna samples. Ten stations were sampled. Current velocities ranged from 20 to 65 cm/sec (average, 47). The average density of organisms ($3962/m^2$) ranked second. The percentage of dipterans (66.5 percent) ranked second among all locations as did that of the trichopterans (27.9 percent) (Table 5). Hydropsychids were the most abundant trichopterans, and the number of Hydroptilidae and of Leptoceridae (Ceraclea) was exceeded at only one other location. The number of oligochaetes was almost the same as at DFW (about $189/m^2$), but the percentage of oligochaetes was nearly twice as large at the latter location. Mayflies, more than three times as numerous as at any other location ($26/m^2$), included representatives of three families that were collected nowhere else (Leptophlebiidae, Siphlonuridae, and Caenidae).

Stone fill revetment, upper (RVU)

48. Benthic grab samples. Samples were taken along five transects in a section of river channel immediately in front of the revetment where water depths ranged from 1 to 7 m. Three of nine samples contained organisms. The average density among all samples was 73 individuals/m^2, which ranked sixth among all locations (Table 4). The benthic population was comprised of chironomids (60.7 percent), oligochaetes (24.3 percent), nematodes (9 percent), and trichopterans (6 percent). Trichopterans comprised a higher percentage of the populations here than at any other location with the exception of DFH. The density of organisms was generally higher in the two samples of fine sand than in the single sample of mud (Table 10). Current speeds at three stations where the samples contained organisms ranged from 5 to 25 cm/sec (average, 12),

whereas they were from 5 to 105 cm/sec (average, 52) at the six stations where no organisms were taken.

49. Rock fauna samples. Three samples were collected. Current velocities ranged from 20 to 55 cm/sec (average, 33). The average density, 1816 organisms/m^2, ranked fourth among locations (Table 5). Trichopterans were about equally divided between the dominant genera *Neureclipsis* and *Hydropsyche*. Among minor constituents of the sample, mayfly numbers were least, nematodes ranked third, and physid snails ranked second (tied with RVD). A few Collembola (*Isotomurus*) were present, but were not found at other locations.

Stone fill revetment, lower (RVD)

50. Benthic grab samples. Three transects were established along this short revetment, and a fourth was located immediately below the downstream end of the structure where a small eroded area had created a pocket of relatively quiet water. All six samples taken from the medium sand substrate along the front of the revetment were devoid of benthic organisms. The substrate of the sample from the area of quiet water at the lower end was composed of fine sand. The six organisms recovered from this sample included equal numbers of chironomid larvae, oligochaetes, and nematodes (Table 4). The average density among all samples was about 17 macroinvertebrates/m^2, which was the lowest encountered in the study. The current velocity for the sample that contained organisms was 8 cm/sec, whereas velocities for the other six samples ranged from 30 to 45 cm/sec (average, 36) Table 11.

51. Rock fauna samples. The average density for the four stations sampled was 1323 organisms/m^2 and ranked fifth; samples included the smallest number of taxa collected (Table 5). Current speeds at the four stations ranged from 40 to 65 cm/sec and the average was 51 cm/sec. Trichopterans dominated the sample (nearly 82 percent), but they ranked third in numbers among all locations; more than two-thirds were of the genus *Neureclipsis*. Both chironomids and oligochaetes (slightly less than 15 and 3 percent, respectively) were poorly represented and ranked sixth among all locations. This was the only location where no nematodes were found and, conversely, the only one where baetid mayflies

were collected. Mayflies as a group were numerous enough to rank second (equal to DFE), and physid snails also ranked second (equal to RVU) among all locations.

Chute (TCN)

52. Benthic grab samples. This location differed from the natural banks in that its waters were largely confined to a narrow, somewhat shallow channel and the bottom included areas of rather firm mud. Four of eleven samples contained organisms. The average density among all samples was 138 individuals/m^2, which ranked first among the unaltered locations and third among all locations (Table 4). The benthic sample was unique in that only two taxa were collected: oligochaetes (93.5 percent) and chironomid larvae (6.5 percent). The mud substrate provided suitable habitat for oligochaetes; their density in one of the samples amounted to 1340 organisms/m^2 despite a current velocity of 50 cm/sec. Samples that contained organisms were taken at the wider and shallower downstream end of the chute where current speeds averaged 23 cm/sec (Table 12). All four of these samples were from sandy substrates and were taken near the riverbank at depths of 0.3 to 1.8 m.

Natural bank, upper (NBU)

53. Benthic grab samples. Most samples were taken at depths of 1 to 2 m. Six of thirteen samples contained organisms. The average density among all samples was only 35 individuals/m^2, which ranked eighth. The percentage of chironomids in the samples was higher here than at any other location (82.5 percent); oligochaetes (13.0 percent) and nematodes (4.5 percent) made up the remainder (Table 4). About 80 percent of the organisms were collected from the mud and fine sand substrate in areas where the average current velocity was comparatively high (46 cm/sec). The other 20 percent of the population sample came from a substrate of fine sand in areas of somewhat slower current (average 32 cm/sec). Current velocities ranged from 72 to 88 cm/sec (average, 79) in areas where the seven barren samples were taken (Table 13).

Natural bank, lower (NBD)

54. Benthic grab samples. Depths along transects at this

location ranged from 1 to 8 m. Five types of substrate were represented in the 24 samples collected. Among the 13 samples containing organisms, 10 were from mud and fine sand substrates, and one each came from substrates of coarse sand, gravel and medium sand, and gravel and coarse sand. The proportion of chironomids in the sample (nearly 72 percent) was exceeded only by that at NBU, and biting midges that were taken in small numbers were found nowhere else. The remainder of the sample was comprised of oligochaetes (20 percent), nematodes (nearly 7 percent), and a few caddisfly larvae (0.8 percent). The average density among all samples was 100 organisms/m^2, which ranked fourth among all locations and second among the three natural areas (Table 4). Nearly 96 percent of the organisms were collected from mud and fine sand substrates in areas where current velocities ranged from 2 to 21 cm/sec (average, 10). Currents ranged from 20 to 42 cm/sec (average, 31) where the other three samples that contained organisms were taken. Stations from which the 11 barren samples were collected had currents ranging from 12 to 34 cm/sec (average, 27) (Table 14).

Fish

55. The sampling effort for larval fishes included a total of 152 hauls with the 0.5-m plankton net. Owing to the lateness of the season 63 larval rainbow smelt (*Osmerus mordax*) comprised the entire catch. The numbers of larvae collected at different locations ranged from zero at the earth core dike to 27 at the L-head dikes. Among the eight locations where larvae were taken, the number per 100 m^3 of water sampled ranged from 1.51 at the chute to 3.43 at the upper revetment.

56. The sampling effort for larger fishes consisted of 150 hoop net sets, 17 gill net sets, 49 seine hauls, and 33 electrofishing runs. The catch included 578 fish of 26 species (Table 15). Catch per unit of effort (C/f) was used as an index of abundance of fish in a habitat. Comparisons of C/f were made among habitats and within a habitat type over time. All mean C/f values are the number of fish caught divided by the number of units of fishing effort catching one or more fish for

that gear. The C/f by gill nets and hoop nets is equivalent to catch per net per night. The C/f with seines is catch per seine haul, and the C/f with electrofishing is based on catch per 10-min transect. Different amounts of effort were expended with each gear type at various locations (Table 2).

Habitat comparison

57. A review of the species and numbers of fish taken at each location and the kinds of sampling gear used is presented in this section. Other general comments regarding the fish populations and gear efficiency also are given.

58. Stone-faced earth core dike (DFE). All types of sampling gear were used in collecting 96 fish that represented 10 species (Table 16). The percentages of fish taken by different gear types were as follows: seine, 61.5; gill net, 32.3; electroshocker, 3.1; and hoop net, 3.1. The C/f values for white bass (*Morone chrysops*) and white suckers (*Catostomus commersoni*) taken by gill net and seine were higher here than at other locations. White bass, walleye (*Stizostedion v. vitreum*), northern pike (*Esox lucius*), and a rainbow trout (*Salmo gairdneri*) comprised 53.1 percent of the sample by number (the second highest percentage of game fish taken at any location). All of the white bass taken in this study were juveniles, and nearly twice as many were taken here as at other locations. All but nine (9.4 percent) of the fish were captured in the shallow backwater area that afforded little cover other than a few sparse clumps of pondweed (*Potamogeton* sp.). Adult fish moved into the backwater at night when water levels were higher, but they were virtually absent during the day. Daytime seining showed that the backwater was important as a nursery area for white bass, white sucker, and yellow perch (*Perca flavescens*). More white suckers (mostly juveniles) were taken here than at any other location.

59. Stone fill wing dikes (DFW). This location was one of the larger and more diversified sampling areas and all types of gear were used. Extensive hoop netting took only one fish. However, seine hauls and gill net sets in backwater areas produced well enough that this area yielded the second highest number of species (16) and of fish (127)

sampled at any location (Table 17). Game fish species included white bass, northern pike, sauger (Stizostedion canadense), and walleye. These fish comprised 34.6 percent of the total catch, thereby ranking the game fish population fourth among all locations. Juvenile white bass comprised nearly half of the game fish catch. Gill net C/f for northern pike, river carpsucker (Carpiodes carpio), and goldeye (Hiodon alosoides) was highest at this location. Almost half of all northern pike collected during the study were taken here, as were the two largest pike captured. These nearly trophy size fish were taken by seine in a backwater area that supported several sizeable clumps of pondweed. All of the river carpsuckers taken in the study were adults and 42.2 percent of them were collected here. Seine C/f for river carpsucker, walleye, sauger, spottail shiner (Notropis hudsonius), silvery minnow (Hybognathus nuchalis), and Johnny darter (Etheostoma nigrum) was higher here than elsewhere. Juvenile white sucker and yellow perch also were well represented in the seine sample.

60. Hard points (DFP). The habitat comprised by these three small, closely spaced structures was considerably smaller than the areas sampled at other locations. Only 10 fish of 6 species were captured even though all gears except the seine were employed (Table 18). Game species (walleye, sauger, and northern pike) comprised 70 percent of the catch (highest of all locations). All but one of these game fish were immature specimens taken with the electroshocker. The nongame fish comprising the remainder of the catch were taken in a gill net. These were adult fish and included a river carpsucker, a blue sucker (Cycleptus elongatus), and a shovelnose sturgeon (Scaphirhynchus platorynchus).

61. L-head dikes (DFH). The habitat at this location was widely diversified. Major sampling effort was expended with all types of gear. Of the 205 fish of 22 species that were collected, only 36 were game fish (17.6 percent, ranking seventh among all locations) (Table 19). The largest numbers of eight species of fish were collected here: walleye, channel catfish (Ictalurus punctatus), goldeye, carp (Cyprinus carpio), bigmouth buffalo (Ictiobus cyprinellus), shorthead redhorse (Moxostoma macrolepidotum), burbot (Lota lota), and yellow perch.

Electrofishing C/f for white bass, yellow perch, and bigmouth buffalo was highest at this location. Carp were dominant in both the electroshocker and seine samples and comprised about 40 percent of each. More juvenile carp and white suckers were taken here than in any other location. Single adult specimens of four species were taken here that were captured nowhere else: smallmouth bass (Micropterus dolomieui), rainbow smelt, fathead minnow (Pimephales promelas), and bluntnose minnow (Pimephales notatus).

62. Nearly half of the total catch was taken by seining, but the percentage of juvenile game fish collected was lowest (4.0 percent) among the five locations where seine samples could be taken. This low percentage is in marked contrast to corresponding figures for DFE (62.7 percent) and DFW (38.7 percent). Possible reasons for the disparity will be discussed later in this report.

63. Stone fill revetment, upper (RVU). All types of sampling gear were used in this location. The catch consisted of 44 fish; 10 species were represented (Table 20). Shovelnose sturgeon were dominant in the catch, and constituted more than half of all shovelnose sturgeon captured during the study. Sauger, white bass, walleye, and northern pike comprised 36.4 percent of the catch (third highest percentage of game fish among all locations), and more sauger were taken here than at any other location. The only two paddlefish (Polyodon spathula) taken during the study were collected here. Yellow perch were slightly more numerous in the seine samples than all other species combined.

64. Stone fill revetment, lower (RVD). Physical characteristics of this comparatively small area precluded the use of both gill nets and seine. However, the rate of catch in 0.9-m hoop nets was much higher than in any other location; the rate in 0.6-m hoop nets was exceeded only at TCN and DFH. The total catch was second lowest (16 fish), but 9 species were represented (Table 21). Carp were dominant in the catch (31.3 percent). The combined catch of game species including sauger, white bass, walleye, and northern pike contributed 31.3 percent (fifth highest among all locations).

65. Natural bank, upper (NBU). The catch at this location was

small, consisting of only 22 fish of 7 species (Table 22). Electrofishing C/f for river carpsucker, goldeye, burbot, and blue sucker was higher here than at any other location. This sampling method took all but three fish. Carp and river carpsucker comprised 50.0 and 18.2 percent of the total catch, respectively. Two blue suckers, which represented half of the total number taken during the study, were collected here. The percentage of sport fish was smaller (4.5 percent) than at any other station, and consisted of a single channel catfish.

66. Natural bank, lower (NBD). This area was much larger than the other two natural areas, thus considerably more sampling effort was expended. The catch of 26 fish included 9 species; carp and white suckers were the most numerous (Table 23). Two white bass and a walleye comprised the entire game fish portion of the sample (11.5 percent), which ranked eighth among all locations. More burbot were taken here than in any other location with the exception of DFH. Four sampling transects were established in the upper (wooded) and the lower (cleared) halves of the area to compare catches in a habitat containing numerous submerged trees and one almost devoid of such cover. Equal amounts of effort were expended in each half. Twelve fish (7 species) were taken in the cleared section and 14 fish (5 species) were taken in the wooded section. The major differences in the catches were that black bullhead (*Ictalurus melas*), shovelnose sturgeon, and white bass were taken exclusively in the cleared area, and walleye and goldeye were taken exclusively in the wooded area.

67. Chute (TCN). This area of comparatively shallow water appeared to be nearly devoid of fish during daylight hours. The combination of darkness and greatly increased flows apparently stimulated ingress of fish at night, and more fish were collected here than at the other two natural areas. The catch consisted of 32 fish; 9 species were represented (Table 24). Nearly two-thirds of the catch was taken by electrofishing. White bass, northern pike, and a rainbow trout constituted 18.8 percent of the catch. The game fish population ranked sixth among all locations. Carp were numerically dominant and comprised 25 percent of the catch. The relative success of hoop netting was

considerably higher here than in most other locations. The 0.9-m hoop net and electroshocker C/f of the shorthead redhorse was higher than at any other location. One-third of the total number of shorthead redhorse and 80 percent of the longnose sucker (all juveniles taken by seine) were captured here.

68. Initially, the sampling locations were grouped into dike fields, revetments, or natural habitats to make statistical comparisons of fish populations according to habitat type. However, the variation in catches among the four dike fields was so large that this was not sound. Instead, data for the two largest locations (DFW and DFH) were used to make a comparison of catches taken by seine, gill net, and electroshocker. These comparisons illustrate differences in catch composition and catch rates in different types of habitat within each location and between locations.

69. The two types of habitat sampled by seine in both locations were somewhat similar, but the numbers of fish collected in each were quite different. At the wing dikes, the C/f for three seine hauls made along riverbanks at the rear of backwater areas (backwater shorelines) was only 1.51 fish, whereas the C/f for three hauls in areas near the channel in inlets to backwaters (near-channel stations) was 13.50 fish (Table 25). The major apparent differences in habitats were the virtual absence of current and the presence of a silty substrate along the backwater shorelines. Juvenile white bass, yellow perch, and white suckers were especially numerous in the near-channel stations. At DFH, the C/f for 11 seine hauls along backwater shorelines was 7.53 fish, whereas the C/f for 7 hauls in near-channel stations was only 1.28 fish. As was pointed out earlier, some of the remote backwater sections at the DFH were excellent nursery areas for carp, yellow perch, and white sucker, whereas juvenile northern pike were more numerous at stations near the channel.

70. Gill net catches in the two habitats at the DFH were also compared. The C/f for three net sets made parallel to the channel in areas of open shoreline between dikes (off-channel shoreline) was only 4.00 fish as compared to a C/f of 13.00 fish for two sets made in a

large backwater area (backwater stations) behind the largest dike. Sauger, walleye, and northern pike comprised 62.5 percent of the off-channel shoreline catch, whereas nongame species comprised 61.5 percent of the catch at backwater stations.

71. Comparisons were made of electrofishing catches in three types of habitat within DFH. Analysis of samples collected along the riverbank in the largest backwater area (backwater shoreline), along the open shoreline between dikes (off-channel shoreline), and from areas of deep, fast water quite close to the dike faces (on-channel dike faces) yielded C/f values of 7.50, 10.44, and 12.46 fish, respectively. Nongame species constituted about 70 and 65 percent of the samples in the backwater shoreline and off-channel shoreline areas where currents were slow to moderate, and 83 percent at the on-channel dike faces where currents were fast. Carp were predominant in the catch of nongame species, followed by bigmouth buffalo, goldeye, and white sucker. White bass were most numerous among the game species, with northern pike, walleye, and smallmouth bass equally represented in the catch.

72. The average number of species (Table 26) and average number of fish (Table 27) taken per station at different locations were tested statistically to evaluate what appeared to be marked differences in catches by various gear types. Location means of the log-transformed data were ranked by Duncan's multiple range test and Tables 26 and 27 list these values in descending order from left to right. Means underscored by a continuous line were not different at the 0.05 level of significance. The values in parentheses represent arithmetic location means and are not necessarily in descending order. Both the analysis of variance (ANOVA) tests and the Duncan's multiple range tests showed that there were significant differences in catches by gill nets and electrofishing, whereas there were none in catches by hoop nets or seine in any of the locations.

73. The mean number of species taken by gill net per unit of effort at DFW (5.67), DFE (5.00), and DFH (3.83) dike fields was significantly different than at the downstream natural bank location NBD (0.50) (Table 27). The disparity in mean numbers of fish taken with gill nets

was even more pronounced among the four locations. C/f at DFE (15.50), DFW (13.00), and DFH (6.33) was significantly different and greater than C/f at the downstream natural bank NBD (0.50) (Table 27).

74. The mean number of species taken per station by electrofishing was significantly lower at DFE (0.75) than at the other eight locations (range, 1.00 to 4.00) (Table 26). The differences in mean numbers of fish taken per station were significant, with those at NBU (10.27), DFH (9.69), and TCN (7.86) being much larger than those at RVU (1.25) and DFE (1.00) (Table 27).

Food habits

75. The food contents of the stomachs of 195 fish representing 19 species were analyzed. Most species examined were not collected at all locations and a high number of the fish captured had empty stomachs. Only walleye, northern pike, white bass, burbot, and shovelnose sturgeon are discussed in this report. With regard to food habits, walleye and northern pike were classified as carnivorous species, and white bass, burbot, and shovelnose sturgeon were regarded as insectivorous carnivores.

76. Walleye. Food items of the walleye were predominantly chironomid larvae which comprised 78.9 percent of total numbers. Trichopterans, consisting primarily of *Hydropsyche* sp., ranked second in total numbers (14.1 percent). The third most numerically abundant food item was unidentified fish followed by equal numbers of *Hexagenia* sp. larvae and juvenile white bass.

77. Food of walleye collected from the hard points consisted principally of *Hydropsyche* spp. and some *Hexagenia* sp. larvae (Table 28). Unidentified fish and chironomid larvae, of which *Chironomus* sp. was the major component, were found in stomachs from walleye collected from DFH. Gut contents of walleye captured from RVU consisted primarily of chironomid larvae. Juvenile white bass and unidentified fish were found in equal numbers. Fish from three locations contained unidentifiable organic matter in their stomachs.

78. Northern pike. Corixids were the most numerically abundant food item found in stomachs of the northern pike. Even though frequency

of occurrence was only 7.1 percent (Table 29), the Corixidae comprised 86.5 percent of the total numbers (4.5 percent) of food items consumed. Equal numbers of juvenile percids (Perca flavescens and Etheostoma nigrum) and catostomids were the other food items identified.

79. Only fish were found in stomachs from northern pike collected from DFW. The principal components of the stomach contents were larval and juvenile catostomids. Unidentified fish and percids (P. flavescens and E. nigrum) occurred in approximately equal abundance. Yellow perch and unidentified fish were the only food items found in stomachs removed from fish collected from DFH. Northern pike collected from TCN consumed equal numbers of Corixidae and unidentified fish.

80. White bass. Food items of the white bass were dominated by zooplankton which comprised 41.3 percent of total numbers. The principal constituents of the zooplankton were cladocerans. Chironomid larvae and pupae ranked second in total number (24.8 percent) and were found in 81.0 percent of the stomachs examined. The third most numerically abundant food item was Corixidae (22.6 percent). Other food items of importance included several species of Trichoptera.

81. Food of white bass collected from DFE consisted almost entirely of chironomids and corixids (Table 30). Cladocerans were the principal food items found in stomachs from white bass captured from DFW. A few copepods and some chironomid larvae also were found. Stomach contents of white bass collected from DFH consisted of approximately equal numbers of chironomid larvae and cladocerans. Hydropsychid caddisflies were also an important food item of white bass at DFH. The primary component of food items found in stomachs of white bass captured from NBD was larvae of Hydropsyche sp.

82. Burbot. The primary constituents in diets of burbot were trichopterans which comprised 94.0 percent of total numbers. Ephemeropteran larvae ranked second in numbers and were found in 25 percent of the burbot examined. Also found were Anura sp. and unidentified fish.

83. Food of burbot collected from DFH consisted almost entirely of Hydropsyche larvae (Table 31). Larvae of Neureclipsis sp. and Hydropsyche simulans were the only food items found in stomachs from burbot

captured from DFW. Anura sp. and unidentified fish were food items of burbot from TCN. The major food item of burbot collected at the RVD was larval Hydropsyche simulans. A few ephemeropteran larvae were also found.

84. Shovelnose sturgeon. The principal animal component of shovelnose sturgeon diets was Oligochaeta, which comprised 50.1 percent of total numbers. Chironomid larvae ranked second in total numbers and occurred in 85.7 percent of the stomachs. Terrestrial invertebrates, the Formicidae, ranked third in total numbers and were present in 28.6 percent of shovelnose sturgeon.

85. Food items of shovelnose sturgeon captured from DFP were predominantly oligochates and chironomids (Table 32). The major food items in stomachs from fish collected from DFH were chironomids and Hydropsyche sp. The principal food items of shovelnose sturgeon from RVU were by far chironomids and oligochaetes. The terrestrial Formicidae were also found in the fish collected from this revetment. Oligochaetes and chironomids were the primary components of stomachs from shovelnose sturgeon collected from NBD.

PART V: DISCUSSION

Physical-Chemical Characteristics

86. Environmental conditions in the nine aquatic habitats studied appeared to be remarkably stable throughout the entire sampling period. Uniformity of water quality conditions was promoted by two principal factors. The first of these was that the physico-chemical characteristics of the discharge from Lake Sakakawea, the largest impoundment on the Missouri River, varied little during the study. Second, the rapid passage of water through the channel and the diurnal flushing of the backwater areas caused by variable releases for power production tended to minimize variations in water quality measurements throughout the study reach.

87. Dissolved oxygen concentrations were consistently high at all locations, sometimes exceeding saturation. Measurements of oxygen in the lake discharge during March 1969-February 1970, as determined by the Corps of Engineers' monitor at Garrison Dam, ranged from about 6 to 14 mg/ℓ and averaged 10.2 mg/ℓ. Values observed in this study were well within this range, and the average values at the altered and natural habitats were only 0.4 mg/ℓ lower (both averaged 9.8 mg/ℓ).

88. Mean conductivity values at the sampling locations ranged from 498 to 583 μmhos/cm. No consistent differences were noted between natural and altered habitats, and the averages in natural and altered habitats were 519 and 513 μmhos/cm, respectively. Conductivity values observed were well within the range of values as measured by the Corps of Engineers' monitor during March 1969-February 1970 (396 to 720 μmhos/cm), but the average value at Garrison Dam was nearly 20 percent higher (618 μmhos/cm).

89. The largest differences in water quality parameters were observed in certain diked areas. Temperatures in the backwaters at DFE, DFW, and DFH sometimes were as much as 6 to 7°C higher than those in the channel nearby. Thus, the average temperature at the altered locations as a group was fractionally higher than that at the natural locations. Differences in turbidity measurements were more pronounced, although

most readings were less than 2 NTU. The average NTU value at the natural locations was slightly less than half that at the altered locations (1.2 versus 2.5). When the bottoms of the backwater areas were exposed by low water levels, the presence of great numbers of holes in the soft sediments gave ample evidence of activity by bottom feeding fish. Thus, it seems possible that some of the higher turbidity readings observed in those areas (5 to 10 NTU) resulted from such disturbances.

Macroinvertebrates

Benthic grab samples

90. Two groups of macroinvertebrates that were taken most frequently constituted 96.2 percent of the benthic sample: oligochaetes (62.7 percent) and dipterans (33.5 percent) (Table 4). The remaining 3.8 percent of the sample was comprised of nematodes at DFE, RVU, DFW, RVD, NBU, and NBD, trichopterans at Locations RVU, DFP, and NBD, a few mayflies (*Hexagenia*) taken at DFW, and a few gastropods (*Amnicola* and *Valvata*) and Collembola (*Isotomurus*) taken at DFH. The highest densities occurred at DFH and DFW, which contained extensive areas of backwater, and the lowest was found at RVD where the substrate was predominantly fine sand. Average densities ranged from 789 and 538 organisms/m^2 at the former locations to only $17/m^2$ at the latter.

91. Most species of aquatic oligochaetes are common in the mud and debris substrate of stagnant pools and ponds (Pennak 1953). The abundance of oligochaetes at all locations appeared to be closely related to the presence or absence of mud substrates. Among the altered locations, highest oligochaete densities were found in soft, mud substrates in the backwater areas at DFW and DFH. At the latter location, mean abundance amounted to 560 oligochaetes/m^2, and the largest single sample contained about $6000/m^2$. Although DFE included a long stretch of backwater, there were no mud substrate samples and oligochaete density was only $34/m^2$. Oligochaete densities at altered locations without backwaters were among the lowest observed (about 4 to $18/m^2$). Among unaltered locations, oligochaete density was highest ($129/m^2$) at TCN where

a firm, mud substrate afforded suitable habitat. Densities at NBD and NBU were about 20 and $5/m^2$, respectively. Of the total number of oligochaetes collected during the study, the percentages taken from each of the seven types of substrates were as follows: mud, 61.9; mud and fine sand, 34.5; fine sand, 3.4; medium sand, 0.1; coarse sand, <0.1; and gravel and medium sand and gravel and coarse sand, 0.0.

92. Chironomids comprised about 99.7 percent of the dipterans sampled; a few phantom midges (Chaoborus sp.) and biting midges (Bezzia sp.) were found in single locations. Among the altered locations, total abundance of dipterans ranged from $6/m^2$ at location RVD to $228/m^2$ at DFH. At the latter location, a single sample from a mud-fine sand substrate contained 1480 chironomid larvae/m^2. Among the unaltered locations, dipteran abundance ranged from $9/m^2$ at TCN to $73/m^2$ at NBD. Overall, the percentages of dipterans collected from different substrate types were as follows: mud, 22.6; mud and fine sand, 65.4; fine sand, 9.8; medium sand, 1.7; coarse sand, 0.0; gravel and medium sand, 0.2; and gravel and coarse sand, 0.3.

93. Nematodes were the third most numerous group of macroinvertebrates collected, comprising 2.4 percent of the total benthic sample. They were generally more abundant at the altered locations where total abundance ranged from about $9/m^2$ at DFH to $0/m^2$ at DFP. Total abundance at the unaltered locations ranged from about $7/m^2$ at NBD to $0/m^2$ at TCN. The percentages of nematodes collected from four types of substrates were as follows: mud, 22.9; mud and fine sand, 47.9; fine sand, 25.0; and medium sand, 4.2.

94. Trichopterans, which were collected at three locations, were the only other organisms that comprised a significant percentage of the total sample (1.1 percent). Mean densities ranged from $0.8/m^2$ at NBD to $14/m^2$ at DFP. At DFP, trichopterans comprised 36.0 percent of the sample; most specimens were taken from muddy substrates in deep water (4.2 to 6.5 m).

95. The benthic fauna described by Neel (1974), who investigated the effects of warmed water on the river biota in the vicinity of power plants some 16 km upriver from the present study area, was closely

similar in composition to the findings in this report. Benthic populations in both areas were dominated by oligochaetes (63 percent in Neel's study, 66 percent here) and dipterans (33 and 32 percent, respectively). Gordian worms comprised the third largest taxon (2.9 percent) in Neel's study, but were not taken here. Nematodes were third in numerical abundance (2.4 percent) in this study.

96. Slightly more than half of the samples collected during this study contained no organisms. In an early study conducted in the lower end of the Missouri River, Berner (1951) attributed the paucity of the macroinvertebrate fauna in the channelized area to shifting substrate, fluctuating water levels, swift current, and absence of aquatic vegetation. The relationship between current velocity and the presence or absence of organisms in samples from each of our nine sampling locations was found to be fairly consistent.

97. The average current velocities at 118 sampling stations in the altered locations and at 48 sampling stations in the unaltered locations were nearly the same (39 and 40 cm/sec, respectively). However, average current velocities at stations with or without organisms were 25 and 49 cm/sec, respectively. Further analysis of the relationship between current speed and the numbers and kinds of organisms taken at different stations revealed that 56 percent of the organisms collected were taken at stations with current speeds of 0 to 5 cm/sec and that only 7 percent were taken at stations where current speeds exceeded 15 cm/sec. Current influences distribution of the benthic fauna in many ways. In this instance, it seems likely that the more important influences included direct physical action on organisms, effects on substrate composition and stability, and possibly the deposition of drift organisms in areas where water movement is slowed.

98. ANOVA and Duncan's multiple range tests showed no significant differences ($P \leq 0.05$) in the numbers of taxa of benthic invertebrates collected per station at the nine sampling locations (Table 33). However, there were highly significant differences ($P \leq 0.01$) in the mean numbers of organisms per station (Table 34), depending largely on physical characteristics such as current velocity and substrate type. On

the basis of mean numbers of benthic organisms per station, diked locations DFH and DFW ranked first and second, and yielded about 9 and 6 times more organisms/m^2 than the third-place location. Two natural locations, TCN and NBD, ranked third and fourth. Among the remaining locations, DFE ranked fifth, RVU was sixth, NBU and DFP tied for seventh place, and RVD was last.

Rock fauna samples

99. The dikes, revetments, and hard points in the study area comprise a very small portion of the available macroinvertebrate habitat, but the current-swept rocks where most samples were taken supported more kinds and far greater numbers of macroinvertebrates per unit area than did the stream substrate.

100. Although several of the same taxa were taken in benthic and rock fauna samples, the composition of the assemblages was quite different. Whereas oligochaetes were numerically dominant in the grab samples (63 percent), dipterans dominated the rock fauna samples (60 percent). Dipteran densities were lowest at the revetted locations (RVD and RVU with 193 and 510/m^2, respectively), and highest at the diked locations (DFW, DFP, and DFE with a range of 1501 to 3572/m^2). Simuliids, which constituted about 16 percent of the dipteran sample at DFP, were some 55 times more numerous there than at any other location.

101. Whereas the percentage of trichopterans in the benthic grab samples was only 0.45 percent, it was nearly 28 percent in the rock fauna samples, an increase of more than 60 fold in numbers. Hynes (1970) stated that the net-spinning, passive feeding forms such as simuliids and trichopterans are adapted to areas of current, and are often abundant just below lakes which provide a rich food supply of plankton. The highest density of trichopterans (1244/m^2) occurred on the algae-covered rocks at DFE and the lowest (89/m^2) on the hard points where the average current speed (26 cm/sec) was the lowest of all.

102. Oligochaetes, the third most numerous taxonomic group, constituted nearly 7 percent of the population, or less than one-tenth their abundance in the grab samples. The highest density (378/m^2) again occurred at DFE and the lowest (35/m^2) at RVD. The importance of the

algal growths in providing favorable habitat for invertebrates at DFE is underlined by the fact that oligochaete densities in the grab samples were much higher in areas of little or no current, whereas the average current velocity at DFE was the highest of all (53 cm/sec). The main differences among the numerically minor constituents of benthic and rock fauna samples were decreased numbers of nematodes and gastropods in the latter, plus the addition of small numbers of ephemeroptera, plecoptera, hemiptera, and coleoptera that were absent from the former.

103. The results of ANOVA and Duncan's multiple range tests showed that there were significant differences ($P \leq 0.05$) in the numbers of taxa per station at different locations (Table 33). RVU, DFE, and DFH supported nearly half again as many taxa as did DFW and RVD. The analyses showed even more highly significant differences ($P \leq 0.01$) in the numbers of organisms per station (Table 34). Densities at DFE and DFH far exceeded those at DFW, RVD, and DFP. The density of the rock fauna populations at various locations clearly was not related to the age of the structures. DFE and DFP, which were built only a year prior to the study, yielded the highest and lowest numbers of organisms per m^2, respectively. Why profuse growths of algae should have developed on the rocks at DFE while those at DFP remained relatively barren is not clear.

104. As was true of the benthic invertebrates, densities of most groups of organisms in the rock fauna samples varied in relation to current velocity. Disregarding the two highest velocities that included only one sample each, it is clear that the average number of dipterans, trichopterans, and ephemeropterans tended to increase steadily as current velocities increased to 70 cm/sec. On the other hand, oligochaetes were most numerous at current speeds of 11 to 30 cm/sec, and the small numbers of nematodes collected showed no appreciable current preference. Overall, 16 samples taken at current velocities of 0 to 40 cm/sec yielded 5,650 organisms, whereas 18 samples taken at current velocities of 41 to 70 cm/sec yielded 15,418 organisms.

Fish

105. The earliest studies of the fish populations in the North Dakota section of the Missouri River below Garrison Dam were two netting surveys done by Sprague (1961, 1963). In the first, which covered the area between Underwood and Bismarck, 13 species of fish were collected, whereas in the second survey, which was made between Bismarck and the South Dakota line, 25 species were taken. Other studies, which were conducted in areas of the Missouri River as far south as Rulo, Nebr., yielded 40, 46, 50, and 53 species of fish, respectively (Nebraska Game and Fish Commission 1972, Schmulbach, Gould, and Groen 1975, Hesse and Wallace 1976, and Kallemeyn and Novotny 1977). Fifteen species of fish were captured with gill nets or observed 32 km downstream of Garrison Dam in a recent study conducted by Neel (1978). Shovelnose sturgeon and the blue sucker were the most abundant species he collected.

106. During this study 26 species of fish were collected with gill nets, hoop nets, seines, and by electroshocking. Five species, including carp, white bass, white sucker, yellow perch, and river carpsuckers constituted 65.6 percent by number of all fish collected. Half of the species were represented by fewer than ten specimens. Only nine of the 26 species collected were taken in more than half of the sampling locations, seven were taken at only two locations, and five were taken at a single location.

107. Efforts to collect larval fishes in early August yielded only 63 rainbow smelt. Of these, 31 were collected in the daytime and 32 were collected at night. No larvae were taken at the earth core dike. The numbers of larvae collected per 100 m^3 of water at other locations ranged from 1.51 at TCN to 3.43 at RVU. No pattern of distribution of the larvae among locations was evident.

108. There appear to be a few published reports concerning the fish population in the area of the Missouri River that we studied. One of the earliest investigations was conducted by Sprague (1961), who fished gill nets and frame nets in the section of river from Garrison Dam to Bismarck, N. Dak. Our use of hoop nets rather than frame nets

precludes a direct comparison of findings in the two studies, but the similarities and differences in results are of interest. Sprague collected 13 species of fish; for this study 18 species were collected (Table 35). Among the 10 species that were common to both studies, the percentages of the catch comprised by sauger, northern pike, carp, and shorthead redhorse were closely similar. In our catch, the percentages of white sucker and walleye were sharply higher (nearly 4 and 8 times greater), but those of river carpsucker, shovelnose sturgeon, goldeye, and channel catfish were lower by about one- to two-thirds. Also, white bass constituted nearly 10 percent of our sample, whereas the species was not taken in 1960.

109. The kinds and numbers of fish taken at each location were governed to a large degree by the types of sampling gear that could be used and the number of times each gear was fished. Since equal amounts of sampling effort could not be expended at each location, any given species may be over- or underrepresented in a sample because of gear selectivity or the number of times each gear was used. Hoop net catches as a whole almost certainly were depressed because accumulations of current-borne filamentous algae frequently clogged net meshes so extensively that the nets became much more visible and the flow of water through them was distinctly impeded.

110. Dike fields are diverse habitats of standing and flowing water with a wide variety of substrates such as mud, sand, gravel, stone riprap, and vegetation. Of all habitats sampled, dike fields had the most diverse fish community. The 24 species collected in dike fields included six species unique to this habitat. Present only in dike fields were the silvery minnow, spottail shiner, bluntnose shiner, fathead minnow, bigmouth buffalo, and smallmouth bass. The high diversity within the dike fields probably is largely attributable to two major factors: the presence of somewhat more sheltered and diverse habitats in the backwater areas, and the greater efficiency of collecting fish with seines and gill nets in areas with shallow shoreline waters and little or no current. Species diversity and abundance were greatest in the L-head dike field and least at the hard points.

111. As mentioned above, the percentage of juvenile game fish taken by seining was much lower at DFH (4.0 percent) than at DFE (62.7 percent) and DFW (38.7 percent). The disparity may be attributed in part to two distinct differences in habitat conditions. First, strong flows of water occurred for 12 to 24 hours per day in 14 of 17 sampling stations at the earth core and wing dikes, whereas only 7 of 20 stations at the L-head dikes were subject to such flows. Three of the only four juvenile game fish collected at DFH (all northern pike) were taken in areas subject to current daily. Second, cover was comparatively scarce at the earth core and wing dikes, whereas several of the seining stations in protected areas at the L-head dikes included sparse stands of emergent plants (largely Typha sp. and Scirpus sp.). Furthermore, two stations that were nearly isolated during daily periods of low discharge contained considerable amounts of pondweed with an admixture of filamentous algae. These two stations were excellent carp nursery areas, and yielded 92.5 percent of the juvenile carp collected at this location.

112. Hoop nets and electroshockers were the only fish capture devices that could effectively be deployed in the swift-flowing water along the revetted banks. A seine was used twice and a gill net once along RVU with little success. A total of 13 species was captured from the revetted banks, and the paddlefish was unique to this habitat. Species diversity and abundance were approximately the same as those along the natural banks.

113. No unique species were collected from the natural banks. Species diversity and abundance along the natural banks were similar to those along the revetted banks. This was expected because of the similarity of the habitats, the use of the same collecting gears, the similar time of sampling, and the geographical proximity of the revetted bank and natural bank areas. The lower diversity of fish communities in these habitats, compared to the diversity found in dike fields, is associated with the limited habitat diversity and the types of gear that could be fished in these areas. Diversity and abundance of fish were surprisingly low at TCN. For reasons which are not clear, the relative

success of hoop netting was considerably higher here than in most other locations.

114. The numbers of fish collected were too small to make comparisons of food habits of fish from the different habitats within the study area. However, the data indicate that the habitats associated with dike fields and revetted banks harbor a large and diverse assemblage of macroinvertebrates that were found in the stomachs removed from the walleye, northern pike, white bass, burbot, and shovelnose sturgeon.

PART VI: SUMMARY

Macroinvertebrates

115. Eleven families of aquatic invertebrates were represented in the benthic grab samples in which oligochaetes (62.7 percent) and dipterans (33.5 percent) were numerically dominant. Among the other taxa, only nematodes and trichopterans constituted more than fractional percentages of the samples. About 96 percent of the oligochaetes and 88 percent of the dipterans (mostly chironomid larvae) were found in 55 samples taken from mud or mud-fine sand substrates at stations where the average current velocity was about 14 cm/sec. Although these samples represented only one-third of all samples taken, they yielded 93 percent of all the benthic organisms collected. Nearly half of the samples at both structured and natural locations contained organisms. Whereas the numbers of taxa per station were not significantly different ($P \leq 0.05$) among locations, there were highly significant differences ($P \leq 0.01$) in the mean numbers of organisms per station. On the basis of numbers of organisms/m^2, DFH and DFW, which contained extensive areas of backwater, were by far the most productive of all locations.

116. Rock fauna samples included 22 families with dipterans (nearly 59.5 percent), trichopterans (32.8 percent), and oligochaetes (7.1 percent) comprising all but a fractional percentage of the organisms collected. Among the remaining taxa, only the ephemeropterans and the planorbid snails constituted 0.1 percent or more of the sample. Maximum density occurred at the stone-faced earth core dike, where the sample contained twice as many families and more than six times as many organisms/m^2 as were found in the most productive benthic sample. Whereas oligochaetes were most numerous at current speeds of 11 to 30 cm/sec, the average numbers of dipterans, trichopterans, and ephemeropterans tended to increase as current velocities increased to 70 cm/sec.

Fish

117. Nearly two-thirds of the total fish sample, which consisted of 578 individuals representing 26 species, was comprised of five species. They included carp (18.3 percent), white bass (15.6 percent), white sucker (13.7 percent), yellow perch (10.2 percent), and river carpsucker (7.8 percent). Half of the species collected (13) were represented by fewer than ten specimens. Seven specimens were found at only two of nine locations, and five others were found at only one location. Of all the habitats sampled, dike fields had the most diverse fish community.

118. There were no significant differences in the catch rates by hoop net and seine among the locations. Differences in the mean number of fish taken per station by gill nets at different locations were different but there was no difference among electrofishing samples.

119. The relatively small numbers of fish stomachs containing food precluded comparisons of food habits of fish collected in various locations throughout the study area. However, the diverse assemblage of macroinvertebrates inhabiting the dike fields and revetted banks is utilized extensively by the walleye, northern pike, white bass, burbot, and shovelnose sturgeon.

Structures

120. Although this pilot survey was not designed to generate the data needed to support a conclusive appraisal of the relative value of the aquatic habitats studied, DFE and DFH may be somewhat better than the other locations. This is indicated by the much higher numbers of macroinvertebrates per unit area and of the greater number of fish collected per unit of effort at DFE and DFH. With regard to the fish, however, consideration must be given to the fact that the relative ease and success of seining and gill netting in the quiet backwaters at these locations increased overall catch rates considerably. It is certain that the backwaters are valuable as nursery areas for several species of fish.

Sampling Methods

121. In general, the methods and materials used in this study proved to be satisfactory. Evaluations of the performance and utility of various types of sampling gear are as follows:

a. The Shipek dredge was superior to the Ponar dredge in that it was much more stable in swift currents. In addition, it took samples more consistently in firm substrates and where accumulations of organic debris were encountered.

b. The frame net method for sampling rock fauna has shortcomings, but it appears that better procedures remain to be developed. Until limnologists devise a method yielding accurate measurement of the surface area of irregularly shaped rocks, attempts to make quantitative measurements of invertebrate biomass seem likely to produce little more than rough estimates.

c. The method of collecting larval fish by using 0.5-m plankton nets mounted on metal handles was found to be much more convenient than the old method of using lead weights to depress the nets.

d. The bag seine used proved to be ideal in that it effectively caught fish ranging from 36 to 880 mm in length.

e. The first trial runs with the electrofishing gear were entirely unproductive. Subsequent shortening of the negative electrodes by about 45 cm enabled the unit to operate effectively in the highly conductive water.

f. Gill nets produced good catches in slack water areas.

g. The catch per unit of effort for hoop nets was considerably lower than for other types of gear. Accumulations of filamentous algae on the nets increased both their visibility and their resistance to flow. Wisconsin-type anchors proved much more effective in preventing net displacement than were the large Danforth anchors initially used.

h. Hoop nets of each size were set 75 times, but the 0.6-m hoop nets took only 16 fish of 7 species whereas the 0.9-m hoop nets took 26 fish of 10 species. All of the species taken in the small nets also were taken by other kinds of gear.

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Table 1

Identification of Structures and Natural Habitats at Each Sampling Location

Location Designation*	Type of Structure or Habitat	Date of Construction
DFE	Stone-faced earth core dike (D1365.15)**	1978
RVU	Stone fill revetment, upper (REV1361.44)**	1966
DFW	Stone fill wing dikes (D1360.16, D1360.36)**	1966
RVD	Stone fill revetment, lower (REV1361.44)**	1966
TCN	Chute (left bank in R.M.1361)	
NBU	Natural bank, upper (left bank in R.M.1357)	
DFP	Hard points (H.P.1356.89, H.P.1356.84, H.P.1356.79)**	1978
NBD	Natural bank, lower (right bank in R.M.1353)	
DFH	L-head dike area (D1350.69, D1350.59, D1350.43, REV1350.5, D1350.09, D1349.65)**	1972

* The three-letter abbreviation will be used in all of the following tables and figures in Appendix A to designate structures and habitats sampled.

** Structure number.

Table 2

Effort Expended in Each Location with Each Type of Sampling Gear

Sampling Location	Hoop Net Sets	Gill Net Sets	Seine Hauls	Electro-shocker Runs	0.5-m Plankton Net Hauls	0.25-m^2 Frame Net Sets	Shipek Dredge Grabs*
DFE	16	2	7	4	16	4	18
RVU	8	1	2	2	8	3	9
DFW	16	3	17	7	12	9	21
RVD	10	--	--	2	10	4	7
TCN	12	1	3	3	12	--	11
NBU	14	1	--	2	12	--	13
DFP	8	1	--	2	12	6	15
NBD	28	2	--	2	18	--	24
DFH	38	6	20	9	52	10	48
Total	150	17	49	33	152	36	166

* A substrate sample was taken in the same location as each benthos sample for determination of sediment grain-size distribution.

Table 3

Mean Values* and Ranges of Water Quality Parameters in Natural and Altered Habitats Around Bank Stabilization Structures, Missouri River, 1979

Location	Dissolved Oxygen, mg/ℓ		Conductivity µmhos/cm		Temperature °C		Turbidity NTU	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Natural habitats								
TCN	9.7	8.3-10.8	519	490-590	11.8	10.8-13.5	1.1	0.9- 1.6
NBU	9.6	9.1-10.1	506	500-520	11.7	10.8-12.2	0.9	0.8- 1.1
NBD	10.2	9.2-11.0	531	490-570	11.7	11.0-12.9	1.5	1.2- 2.3
Average	9.8	8.9-10.6	519	496-560	11.7	10.9-12.9	1.2	1.0- 1.7
Altered habitats								
DFE	9.7	8.3-10.3	498	450-600	11.5	11.0-18.0	1.3	0.9- 1.7
RVU	10.2	8.0-10.9	501	500-510	11.2	10.7-12.3	3.8	1.5- 6.0
DFW	9.7	8.3-10.6	518	490-600	11.7	10.1-16.0	3.2	1.5- 7.2
RVD	9.3	8.4-10.0	543	520-580	12.4	12.0-13.2	2.4	1.8- 5.5
DFP	10.4	9.1-11.0	513	500-550	12.1	11.0-13.0	1.6	0.8- 2.5
DFH	9.6	7.4-10.8	519	480-630	12.4	10.8-17.8	2.9	0.9-10.0
Average	9.8	8.3-10.6	515	490-578	11.9	10.9-15.1	2.5	1.2- 5.5

* Mean values and ranges were derived from the total number of measurements made at each location.

Table 4

Numbers per m^2 and Percentages of Benthic Invertebrates Taken in Grab Samples at Nine Locations, Missouri River, 1979

Organism	Location									Total
	DFE	RVU	DFW	RVD	TCN	NBU	DFP	NBD	DFH	%*
Diptera										
Chironomidae										
Adult	1.2	4.4	2.0			9.2		3.4	4.4	24.6
Larvae	41.2	40.0	156.2	5.8	9.0	20.0	21.4	68.4	222.4	584.4
Chaoboridae										
Chaoborus sp.									0.4	0.4
Ceratopogonidae								0.8		0.8
Other aquatic									0.8	0.8
Total	42.4	44.4	158.2	5.8	9.0	29.2	21.4	72.6	228.0	611.0
(Percent)**	(50.1)	(60.7)	(29.4)	(33.3)	(6.5)	(82.5)	(53.5)	(72.6)	(28.6)	(33.5)
Trichoptera										
Polycentropidae										
Neureclipsis sp.		2.2					5.8	0.8		8.8
Hydropsychidae										
Hydropsyche sp.		2.2					8.6			10.8
Total		4.4					14.4	0.8		19.6
(Percent)		(6.0)					(36.0)	(0.8)		(1.1)
Oligochaeta	34.4	17.8	368.6	5.8	129.0	4.6	4.2	20.0	560.4	1144.8
(Percent)	(40.7)	(24.3)	(68.5)	(33.3)	(93.5)	(13.0)	(10.5)	(20.0)	(70.2)	(62.7)

(Continued)

* Percentage of organisms taken per unit of effort for all locations combined.
** Percentage of organisms taken per unit of effort at individual locations.

Table 4 (Concluded)

Organism	Location									Total
	DFE	RVU	DFW	RVD	TCN	NBU	DFP	NBD	DFH	%
Ctenobranchiata										
Amnicolidae										
Amnicola sp.									0.4	0.4
Valvatidae										
Valvata sp.									0.4	0.4
Total									0.8	0.8
(Percent)**									(0.1)	t†
Nematoda	7.8	6.6	7.6	5.8		1.6		6.6	8.6	44.6
(Percent)	(9.2)	(9.0)	(1.4)	(33.3)		(4.5)		(6.6)	(1.1)	(2.4)
Ephemeroptera										
Ephemeridae										
Hexagenia sp.			3.8							3.8
(Percent)			(0.7)							(0.2)
Collembola										
Isotomidae										
Isotomurus									0.4	0.4
(Percent)									(0.1)	t
Total	84.6	73.2	538.2	17.4	138.0	35.4	40.0	100.0	798.2	1825.0
No. samples	18	9	21	7	11	13	15	24	48	166

** Percentage of organisms taken per unit of effort at individual locations.
† t = trace (less than 0.1 percent).

Table 5

Mean Numbers per m^2 and Percentages of Macroinvertebrates Collected from Rock Structures at Six Locations, Missouri River, 1979

Organism	Location						Total
	DFE	RVU	DFW	RVD	DFP	DFH	Percent*
Diptera							
Chironomidae							
Larvae	3167.2	456.0	1384.8	189.2	529.2	2438.8	8,165.2
Chironomidae sp.	403.2	42.0	115.6	4.0	40.0	197.2	812.0
Simuliidae spp.	2.0	2.0	0.8		110.8		115.6
Total	3572.4	510.0	1501.2	193.2	680.0	2636.0	9,092.8
(Percent)**	(68.5)	(28.1)	(70.3)	(14.6)	(81.4)	(66.5)	(59.5)
Trichoptera							
Polycentropidae							
Neureclipsis pupae	63.2	128.0	95.6	55.2	8.0	72.8	422.8
Neureclipsis sp.	376.0	524.0	196.0	621.2	20.0	473.6	2,210.8
Hydropsychidae							
Hydropsyche pupae	30.0	28.0	0.8	12.0	39.2	40.0	150.0
Hydropsyche sp.	759.2	372.0	135.6	394.0	22.0	514.8	2,197.6
Hydroptilidae							
Hydroptila pupae				2.0		1.2	3.2
Hydroptila larvae	16.0	2.0	0.8			3.2	22.0
Leptoceridae							
Ceraclea		2.0				0.4	2.4
Total	1244.4	1056.0	428.8	1084.4	89.2	1106.0	5,008.8
(Percent)	(23.9)	(58.2)	(20.1)	(81.9)	(10.7)	(27.9)	(32.8)
Oligochaeta	378.0	240.0	189.2	35.2	54.0	188.8	1,085.2
(Percent)	(7.3)	(13.2)	(8.9)	(2.7)	(6.4)	(4.8)	(7.1)
Ephemeroptera							
Baetidae							
Baetis sp.				2.0			2.0
Leptophebiidae							
Traverella						0.8	0.8
Heptageniidae							
Heptagenia spp.	3.2		0.8	2.0	2.0	11.6	19.6
Stenonema sp.	2.0	2.0	3.6	3.2	0.8	1.6	13.2
Heptageniidae spp.	3.2	2.0	0.8	1.2	2.8	2.8	19.6
Siphlonuridae							
Siphlonurinae						0.4	0.4
Caenidae							
Caenis sp.						0.4	0.4
Other aquatic						1.6	1.6
Total	8.4	4.0	5.2	8.4	5.6	26.0	57.6
(Percent)	(0.2)	(0.2)	(0.2)	(0.6)	(0.7)	(0.7)	(0.4)

(Continued)

* Percentage of organisms taken per unit of effort for all locations combined.
** Percentage of organisms taken per unit of effort at individual locations.

Table 5 (Concluded)

Organism	DFE	RVU	DFW	RVD	DFP	DFH	Total Percent
	Location						
Pulmonata							
Physidae							
Physa spp.	1.2	2.0	2.8	2.0	0.8	1.2	10.0
Planorbidae							
Gyraulus sp.			6.4				6.4
Total	1.2	2.0	9.2	2.0	0.8	1.2	16.4
(Percent)**	t†	(0.1)	(0.4)	(0.2)	(0.1)	t	(0.1)
Ctenobranchiata							
Amnicolidae							
Amnicola sp.					2.0		2.0
Valvatidae							
Valvata sp.					0.8		0.8
Total					2.8		2.8
(Percent)					(0.3)		t
Nematoda	1.2	2.0	1.2		3.2	4.0	11.6
(Percent)	t	(0.1)	(0.1)		(0.4)	(0.1)	(0.1)
Plecoptera							
Perlodidae							
Isoperla	4.0						4.0
(Percent)	(0.1)						t
Hemiptera							
Corixidae							
Corixidae spp.	1.2		0.4				1.6
Trichocorixa	1.2						1.2
Total	2.4		0.4				2.8
(Percent)	t		t				t
Coleoptera							
Dytiscidae							
Deronectes			0.8				0.8
(Percent)			t				t
Amphipoda							
Talitridae							
Hyalella spp.	2.0						2.0
(Percent)	t						t
Collembola							
Isotomidae							
Isotomurus		2.0					2.0
(Percent)		(0.1)					t
Total	5214.0	1816.0	2136.0	1323.2	835.6	3962.0	15,286.8
No. samples	4	3	9	4	6	10	36

** Percentage of organisms taken per unit of effort at individual locations.
† t = trace (less than 0.1 percent).

Table 6

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at DFE

	Type of Substrate and Average Current Velocity					
	Fine Sand			Medium Sand		
	No.	Percent	Velocity (cm/sec)	No.	Percent	Velocity (cm/sec)
No. of samples						
With organisms	3		8	2		73
Without organisms	1		25	12		69
Organisms collected						
Diptera						
Chironomidae larvae	35	94.6		2	5.4	
Chironomidae pupae	1	100.0				
Oligochaeta	31	100.0				
Nematoda	6	85.7		1	14.3	
Total organisms	73	96.1		3	3.9	

Table 7

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at DFW

	Type of Substrate and Average Current Velocity											
	Mud			Mud-Fine Sand			Fine Sand			Medium Sand		
	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec
No. of samples												
With organisms	2		8	7		3	2		7	2		46
Without organisms							3		49	5		67
Organisms collected												
Diptera												
Chironomidae larvae	39	23.8		117	71.3		7	4.3		1	0.6	
Chironomidae pupae	1	50.0		1	50.0							
Oligochaeta	191	49.3		177	45.7		18	4.7		1	0.3	
Nematoda				7	87.5					1	12.5	
Ephemeroptera												
Hexagenia larvae	1	25.0		3	75.0							
Total organisms	232	41.1		305	54.0		25	4.4		3	0.5	

Table 8

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at DFP

	Type of Substrate and Average Current Velocity																
	Mud			Mud-Fine Sand			Fine Sand			Medium Sand		Gravel-Medium Sand			Gravel-Coarse Sand		
	No.	Per-cent	Velocity cm/sec	No.	Per-cent	Velocity cm/sec	No.	Per-cent	Velocity cm/sec	No.	Velocity cm/sec	No.	Per-cent	Velocity cm/sec	No.	Per-cent	Velocity cm/sec
No. of samples																	
With organisms	1		45	3		37	1		23	1	65	1		80	1		92
Without organisms	1		20	2		3				2	25				2		51
Organisms collected																	
Diptera																	
Chironomidae larvae	2	13.3		8	53.3		4	26.7				1	6.7				
Oligochaeta				2	66.7		1	33.3									
Trichoptera																	
Hydropsyche larvae	1	16.6		4	66.7										1	16.6	
Neureclipsis larvae	1	25.0		2	50.0										1	25.0	
Total organisms	4	14.3		16	57.1		5	17.9				1	3.6		2	7.1	

Table 9

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at DFH

	Type of Substrate and Average Current Velocity														
	Mud			Mud-Fine Sand			Fine Sand			Medium Sand			Coarse Sand		
	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec
No. of samples															
With organisms	7		5	12		6	3		21	6		47	1		68
Without organisms							2		46	12		50	5		69
Organisms collected															
Diptera															
Chironomidae larvae	153	28.6		356	66.5		16	3.0		10	1.9				
Chironomidae pupae	1	9.1		10	90.0										
Chaoborus sp.	1	100.0													
Other							2	100.0							
Oligochaeta	914	66.6		449	32.7		8	0.6		1	t*		1	t*	
Nematoda	11	55.0		8	40.0		1	5.0							
Ctenobranchiata															
Amnicola sp.				1	100.0										
Valvata sp.	1	100.0													
Collembola	1	100.0													
Total organisms	1,082	55.6		824	42.4		27	1.4		11	0.6		1	t*	

* t = trace (less than 0.1 percent).

Table 10

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at RVU

	Type of Substrate and Average Current Velocity									
	Mud			Fine Sand			Medium Sand		Coarse Sand	
	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Velocity cm/sec	No.	Velocity cm/sec
No. of samples										
With organisms	1		5	2		15				
Without organisms				3		23	2	68	1	105
Organisms collected										
Diptera	3			15	83.3					
Chironomidae larvae	2	16.7								
Chironomidae pupae		100.0								
Oligochaeta	2	25.0		6	75.0					
Nematoda				3	100.0					
Trichoptera										
Hydropsyche larvae	1	100.0								
Neureclipsis larvae	1	100.0								
Total organisms	9	27.3		24	72.7					

Table 11

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities with and Without Organisms at RVD

	Type of Substrate and Average Current Velocity				
	Fine Sand			Medium Sand	
	No.	Percent	Velocity cm/sec	No.	Velocity cm/sec
No. of samples					
With organisms	1		8		
Without organisms				6	36
Organisms collected					
Diptera					
Chironomidae larvae	2	100.0			
Oligochaeta	2	100.0			
Nematoda	2	100.0			
Total organisms	6	100.0			

Table 12

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at TCN

	Type of Substrate and Average Current Velocity								
	Mud			Fine Sand			Medium Sand		
	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec
No. of samples									
With organisms	2		48	1		15	1		31
Without organisms				3		40	4		36
Organisms collected									
Diptera									
Chironomidae larvae	2	40.0		1	20.0		2	40.0	
Oligochaeta	71	100.0							
Total organisms	73	96.1		1	1.3		2	2.6	

Table 13

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at NBU

	Type of Substrate and Average Current Velocity							
	Mud-Fine Sand			Fine Sand			Medium Sand	
	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Velocity cm/sec
No. of samples								
With organisms	4		46	2		32		
Without organisms							7	79
Organisms collected								
Diptera								
Chironomidae larvae	8	61.5		5	38.5			
Chironomidae pupae	5	100.0						
Chironomidae adults	1	100.0						
Oligochaeta	3	100.0						
Nematoda	1	100.0						
Total organisms	18	78.3		5	21.7			

Table 14

Number of Benthic Samples Taken, Numbers and Percentages of Various Groups of Invertebrates Collected from Different Substrates, and Average Current Velocities for Samples with and Without Organisms at NBD

	Type of Substrate and Average Current Velocity													
	Mud-Fine Sand			Medium Sand		Coarse Sand			Gravel-Medium Sand			Gravel-Coarse Sand		
	No.	Percent	Velocity cm/sec	No.	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec	No.	Percent	Velocity cm/sec
No. of samples														
With organisms	10		10			1		32	1		20	1		42
Without organisms	3		12	5	31	3		34						
Organisms collected														
Diptera														
Chironomidae larvae	78	95.1							1	1.2		3	3.7	
Chironomidae pupae	4	100.0												
Ceratopogonidae						1	100.0							
Oligochaeta	25	100.0												
Nematoda	7	100.0												
Trichoptera														
Neureclipsis larvae	1	100.0												
Total organisms	115	95.8				1	0.8		1	0.8		3	2.5	

Table 15

Number of Each Species of Fish Collected from Different Sampling Locations, Missouri River Between River Miles 1351 and 1365 in 1979

		Location									
Common Name	Scientific Name	DFE	RVU	DFW	RVD	TCN	NBU	DFP	NBD	DFH	Total
Shovelnose sturgeon	*Scaphirhynchus platorynchus*		14	2	3			1	1	2	23
Paddlefish	*Polyodon spathula*		2								2
Goldeye	*Hiodon alosoides*			7			2		3	8	20
Rainbow trout	*Salmo gairdneri*	1				1					2
Rainbow smelt	*Osmerus mordax*									1	1
Northern pike	*Esox lucius*	2	1	15	1	1		1		10	31
Carp	*Cyprinus carpio*	2	2	6	5	8	11		7	65	106
Silvery minnow	*Hybognathus nuchalis*			2						1	3
Spottail shiner	*Notropis hudsonius*			4						4	8
Bluntnose minnow	*Pimephales notatus*									1	1
Fathead minnow	*Pimephales promelas*									1	1
River carpsucker	*Carpiodes carpio*	7		19	1	5	4	1	1	7	45
Longnose sucker	*Catostomus catostomus*					4	1				5
White sucker	*Catostomus commersoni*	27	2	19		3			6	22	79
Blue sucker	*Cycleptus elongatus*						2	1		1	4
Bigmouth buffalo	*Ictiobus cyprinellus*			2						8	10
Shorthead redhorse	*Moxostoma macrolepidotum*				1	4				7	12
Black bullhead	*Ictalurus melas*	3		2					1	3	9
Channel catfish	*Ictalurus punctatus*						1			2	3
Burbot	*Lota lota*	2		1	1	2	1		4	8	19
White bass	*Morone chrysops*	46	1	24	2	4			2	11	90
Smallmouth bass	*Micropterus dolomieui*									1	1
Johnny darter	*Etheostoma nigrum*		1	1							2
Yellow perch	*Perca flavescens*	4	7	18						30	59
Sauger	*Stizostedion canadense*		8	3	1			2		5	19
Walleye	*Stizostedion v. vitreum*	2	6	2	1			4	1	7	23
Total		96	44	127	16	32	22	10	26	205	578

Table 16

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at Location DFE

	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Seine			
Species	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f†	Total No. of Fish
Carp	1	493.0	0.50										1	533.0	0.14	2
White bass	8	144.0	4.00	1	152.0	0.28							37	148.6	5.29	46
White sucker	11	210.3	5.50										16	89.5	2.29	27
Yellow perch													4	86.0	0.57	4
River carpsucker	7	432.7	3.50													7
Northern pike	1	310.0	0.50	1	856.0	0.45										2
Walleye	1	452.0	0.50							1	338.0	0.13				2
Burbot							2	535.0	0.25							2
Black bullhead	2	125.5	1.00										1	141.0	0.14	3
Rainbow trout				1	305.0	0.28										1
Total No. fish	31			3			2			1			59			96
No. times gear used	2			4			8			8			7			
Mean No. fish/ unit of effort			15.50			1.00			0.25			0.13			8.43	
Total No. species	7			3			1			1			5			10
Mean No. species/ unit of effort			5.00			0.75			0.25			0.13			1.71	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.
† Basis for C/f: seine, 23-m hauls.

Table 17

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at DFW

	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Seine			
Species	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f†	Total No. of Fish
Carp	1	507.0	0.33	4	467.3	0.88							1	512.0	0.06	6
White bass	3	179.0	1.00										21	159.2	1.24	24
White sucker													19	64.4	1.12	19
Yellow perch													18	57.7	1.06	18
River carpsucker	16	429.3	5.33	2	431.0	0.47							1	413.0	0.06	19
Northern pike	6	540.4	2.00	3	363.8	0.53							6	322.6	0.35	15
Walleye	1	434.0	0.33										1	60.0	0.06	2
Shovelnose sturgeon	1	692.0	0.33							1	627.0	0.13				2
Goldeye	7	222.8	2.33													7
Sauger	1	298.0	0.33	1	245.0	0.17							1	174.0	0.06	3
Burbot	1	323.0	0.33													1
Bigmouth buffalo	1	416.0	0.33	1	442.0	0.46										2
Black bullhead	1	180.0	0.33										1	200.0	0.06	2
Spottail shiner													4	69.6	0.24	4
Silvery minnow				1	104.0	0.46							1	126.0	0.06	2
Johnny darter													1	46.0	0.06	1
Total No. fish	39			12			0			1			75			127
No. times gear used	3			7			8			8			17			
Mean No. fish/unit of effort			13.00			2.97			0.00			0.13			4.41	
Total No. species	11			6			0			1			12			16
Mean No. species/ unit of effort			5.67			1.43			0.00			0.13			1.71	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.
† Basis for C/f: seine, 23-m hauls.

Table 18

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at DFP

	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			
Species	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	Total No. of Fish
River carpsucker	1	480.0	1.00										1
Northern pike				1	173.0	0.74							1
Walleye				4	178.7	3.32							4
Shovelnose sturgeon	1	632.0	1.00										1
Sauger				1	218.0	0.74				1	386.0	0.25	2
Blue sucker	1	634.0	1.00										1
Total No. fish	3			6			0			1			10
No. times gear used	1			2			4			4			
Mean No. fish/unit of effort			3.00			4.79			0.00			0.25	
Total No. species	3			3			0			1			6
Mean No. species/unit of effort			3.00			2.00			0.00			0.25	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.

Table 19

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at DFH

	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Seine			
Species	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f†	Total No. of Fish
Carp	4	450.5	0.67	21	466.4	3.80							40	177.8	2.00	65
White bass	3	142.7	0.50	8	156.6	1.47										11
White sucker				2	270.0	0.31	1	425.0	0.06	1	391.0	0.06	18	70.3	0.90	22
Yellow perch				2	108.5	0.26							28	66.1	1.40	30
River carpsucker	4	437.5	0.67	2	418.0	0.26	1	410.0	0.56							7
Northern pike	4	556.6	0.67	2	324.0	0.24							4	196.3	0.20	10
Walleye	4	451.0	0.67	1	173.0	0.36				2	424.5	0.12				7
Shovelnose sturgeon	1	638.0	0.17							1	528.0	0.06				2
Goldeye	4	158.7	0.67	4	364.5	0.88										8
Sauger	5	290.8	0.83													5
Burbot				3	334.3	0.41	4	382.5	0.22	1	420.0	0.06				8
Shorthead redhorse	4	322.5	0.67	2	420.0	0.42				1	432.0	0.06				7
Bigmouth buffalo	4	493.2	0.67	4	485.0	0.78										8
Black bullhead	1	212.0	0.17										2	184.0	0.10	3
Spottail shiner													4	70.4	0.20	4
Blue sucker							1	564.0	0.06							1
Channel catfish							2	233.0	0.11							2
Silvery minnow													1	100.0	0.05	1
Smallmouth bass				1	246.0	0.37										1
Bluntnose minnow													1	27.0	0.05	1
Fathead minnow													1	35.0	0.05	1
Rainbow smelt				1	87.0	0.13										1
Total No. fish	38			53			9			6			99			205
No. times gear used	6			9			19			19			20			
Mean No. fish/unit of error			6.33			9.69			0.50			0.35			4.95	
Total No. species	11			13			5			5			9			22
Mean No. species/ unit of effort			3.83			3.22			0.44			0.35			1.45	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.
† Basis for C/f: seine, 23-m hauls.

Table 20

Number, Average Length, and Catch of per Unit Fish of Effort (C/f) at RVU

Species	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Seine			Total No. of Fish
	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f†	
Carp				1	515.0	0.62							1	47.0	0.50	2
White bass													1	139.0	0.50	1
White sucker													2	60.0	1.00	2
Yellow perch													7	79.8	3.50	7
Northern pike													1	250.0	0.50	1
Walleye	6	381.0	6.00													6
Shovelnose sturgeon	14	578.1	14.00													14
Sauger	8	295.6	8.00													8
Paddlefish	1	955.0	1.00	1	1250.0	0.62										2
Johnny darter													1	33.0	0.50	1
Total No. fish	29			2			0			0			13			44
No. times gear used	1			2			4			4			2			
Mean No. fish/unit of effort			29.00			1.25			0.00			0.00			6.50	
Total No. species	4			2			0			0			6			10
Mean No. species/ unit of effort			4.00			1.00			0.00			0.00			4.00	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.
† Basis for C/f: seine, 23-m hauls.

Table 21

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at RVD

Species	Electroshocker			Hoop nets, 0.6 m			Hoop nets, 0.9 m			Total No. of Fish
	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f**	
Carp	5	441.6	3.73							5
White bass							2	176.5	0.40	2
River carpsucker	1	456.0	0.49							1
Northern pike	1	550.0	1.13							1
Walleye							1	358.0	0.20	1
Shovelnose sturgeon							3	594.0	0.60	3
Sauger	1	285.0	0.49							1
Burbot				1	362.0	0.20				1
Shorthead redhorse	1	345.0	0.49							1
Total No. fish	9			1			6			16
No. times gear used	2			5			5			
Mean No. fish/unit of effort			1.25			0.20			1.20	
Total No. species	5			1			3			9
Mean No. species/unit of effort			3.00			0.20			0.80	

* Basis for C/f: electroshocker, adjusted to 10-min runs.
** Basis for C/f: nets, overnight sets.

Table 22

Number, Average Length, and Catch of Fish per unit of Effort (C/f) at NBU

Species	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Total No. of Fish
	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	
Carp				11	450.3	5.74							11
River carpsucker				4	458.8	2.15							4
Goldeye				2	370.0	1.19							2
Burbot				1	318.0	0.48							1
Longnose sucker										1	371.0	0.14	1
Blue sucker	1	605.0	1.00	1	565.0	0.71							2
Channel catfish										1	380.0	0.14	1
Total No. fish	1			19			0			2			22
No. times gear used	1			2			7			7			
Mean No. fish/unit of effort			1.00			10.27			0.00			0.29	
Total No. species	1			5			0			2			7
Mean No. species/unit of effort			1.00			4.00			0.00			0.29	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.

Table 23

Number, Average Length, and Catch of Fish per Unit of Effort (C/f) at NBD

Species	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Total No. of Fish
	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	
Carp				7	470.3	2.40							7
White bass				2	172.0	0.63							2
White sucker				3	374.6	1.04				3	407.3	0.23	6
River carpsucker				1	398.0	0.32							1
Walleye				1	152.0	0.36							1
Shovelnose sturgeon	1	560.0	0.50										1
Goldeye				3	373.7	1.08							3
Burbot							1	403.0	0.08	3	461.3	0.23	4
Black bullhead							1	209.0	0.08				1
Total No. fish	1			17			2			6			26
No. times gear used	2			2			14			14			
Mean No. fish/unit of effort			0.50			5.84			0.15			0.46	
Total No. species	1			6			2			2			9
Mean No. species/ unit of effort			0.50			4.00			0.15			0.46	

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.

Table 24

Number Average Length, and Catch of Fish per Unit of Effort (C/f) at TCN

Species	Gill Nets			Electroshocker			Hoop Nets, 0.6 m			Hoop Nets, 0.9 m			Seine			Total No. of Fish
	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f**	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f*	No.	Avg Length mm	C/f†	
Carp				8	452.0	3.04										8
White bass				1	145.0	0.26	1	172.0	0.17	1	161.0	0.17	1	181.0	0.33	4
White sucker				1	334.0	0.26							2	111.0	0.67	3
River carpsucker				5	441.0	2.08										5
Northern pike				1	360.0	0.26										1
Burbot				1	370.0	0.26	1	398.0	0.17							2
Shorthead redhorse				3	305.8	1.70				1	428.0	0.17				4
Longnose sucker													4	123.3	1.33	4
Rainbow trout										1	270.0	0.17				1
Total No. fish	0			20			2			3			7			32
No. times gear used	1			3			6			6			3			
Mean No. fish/unit of effort			0.00			7.86			0.33			0.50			2.33	
Total No species.	0			7			2			3			3			9
Mean No. species/ unit of effort			0.00			3.67			0.33			0.50		1.33		

* Basis for C/f: nets, overnight sets.
** Basis for C/f: electroshocker, adjusted to 10-min runs.
† Basis for C/f: seine, 23-m hauls.

Table 25

Catch of Fish per Unit of Effort (C/f) Using Three Sampling Methods in Different Habitats at DFW and DFH

Species	Seine Samples*				Gill Net Samples, DFH**		Electroshocker Samples, DFH†		
	Backwater Shorelines		Near-Channel Stations		Backwater Stations	Off-Channel Shoreline	Backwater Shoreline	Off-Channel Shoreline	On-Channel Dike Faces
	DFW	DFH	DFW	DFH					
Shovelnose sturgeon						0.50			
Goldeye					2.00			0.50	2.15
Northern pike	0.50	0.09	0.50	0.43	1.50	0.50	1.08		
Carp		3.36	0.25	0.14	1.00		1.78	5.06	4.75
Silvery minnow			0.25	0.14					
Spottail shiner		0.36							
Bluntnose minnow				0.14					
Fathead minnow		0.09							
River carpsucker					1.00		0.59		
White sucker	0.17	1.00	3.25	0.29			0.59		0.52
Bigmouth buffalo					1.50	0.50	1.08		1.62
Shorthead redhorse					1.50	0.50		1.27	
Black bullhead		0.18	0.25		0.50				
Burbot									1.22
White bass	0.17		5.00		1.50		1.19	2.52	1.10
Smallmouth bass									1.10
Johnny darter			0.25						
Yellow perch	0.50	2.45	3.50	0.14			1.19		
Sauger	0.17				2.00	0.50			
Walleye			0.25		0.50	1.50		1.09	
Total C/f	1.51	7.53	13.50	1.28	13.00	4.00	7.50	10.44	12.46

* C/f based on 23-m seine hauls; hauls along shoreline of backwater areas contrasted with near-channel hauls in the inlets to backwater areas.

** C/f based on overnight sets; net sets in a large backwater contrasted with sets made parallel to channel near open shoreline between dikes.

† C/f adjusted to 10-min runs; electrofishing runs made along shoreline in a large backwater, along open shoreline between dikes, and in main channel immediately adjacent to dike faces.

Table 26

Results of Analysis of Variance Tests and Duncan's Multiple Range Test Based on Log Transformed Data, Comparing the Numbers of Species of Fish Taken per Unit of Effort by Various Gear* Types at Different Locations on the Missouri River, 1979

Gear Type	Analysis of Variance: Error df	Location df	F	Level of Significance	Duncan's Multiple Range Test Ranked Locations Transformed Location Means (Arithmetic Location Means) Grouping of Locations**								
Gill net	9	3	4.98	≤0.05	DFW 1.88 (5.67)	DFE 1.78 (5.00)	DFH 1.45 (3.83)	NBD 0.35 (0.50)					
Hoop net (0.6 m)	62	8	1.33	N.S.†	DFH 0.29 (0.44)	TCN 0.23 (0.33)	DFE 0.17 (0.25)	RVD 0.14 (0.20)	NBD 0.08 (0.15)	DFP 0.00 (0.00)	DFW 0.00 (0.00)	NBU 0.00 (0.00)	RVU 0.00 (0.00)
Hoop net (0.9 m)	61	8	0.88	N.S.	RVD 0.50 (0.80)	NBD 0.30 (0.50)	TCN 0.30 (0.46)	DFH 0.24 (0.35)	NBU 0.20 (0.29)	DFP 0.17 (0.25)	DFE 0.09 (0.13)	DFW 0.09 (0.13)	RVU 0.00 (0.00)
Seine	44	3	0.91	N.S.	RVU 1.52 (4.00)	DFE 0.89 (1.71)	DFW 0.84 (1.71)	DFH 0.73 (1.45)	TCN 0.69 (1.33)				
Electro-shocker	24	8	2.64	≤0.05	NBD 1.61 (4.00)	NBU 1.61 (4.00)	TCN 1.43 (3.67)	DFH 1.36 (3.22)	RVD 1.35 (3.00)	DFP 1.04 (2.00)	DFW 0.74 (1.43)	RVU 0.55 (1.00)	DFE 0.45 (0.75)

* Catch by various gear types is based on overnight sets for gill and hoop nets, runs adjusted to 10 min for the electroshocker, and 23-m hauls for the seine.

** Locations underscored by a continuous line are not significantly different at the 0.05 level.

† N.S. = not significant.

Table 27

Results of Analysis of Variance Tests and Duncan's Multiple Range Test Based on Log Transformed Data, Comparing the Numbers of Fish Caught per Unit of Effort by Various Gear Types* at Different Locations on the Missouri River, 1979

Gear Type	Analysis of Variance: Error df	Location df	F	Level of Significance	Duncan's Multiple Range Test Ranked Locations Transformed Locations Means (Arithmetic Location Means) Grouping of Locations**								
Gill net	9	3	5.58	$\leq$0.05	DFE 2.74 (15.50)	DFW 2.48 (13.00)	DFH 1.79 (6.33)	NBD 0.35 (0.50)					
Hoop net (0.6 m)	62	8	1.32	N.S.†	DFH 0.31 (0.50)	TCN 0.23 (0.33)	DFE 0.17 (0.25)	RVD 0.14 (0.20)	NBD 0.08 (0.15)	DFP 0.00 (0.00)	DFW 0.00 (0.00)	NBU 0.00 (0.00)	RVU 0.00 (0.00)
Hoop net (0.9 m)	61	8	1.08	N.S.	RVD 0.60 (1.20)	NBD 0.30 (0.50)	TCN 0.30 (0.46)	DFH 0.24 (0.35)	NBU 0.20 (0.29)	DFP 0.17 (0.25)	DFE 0.09 (0.13)	DFW 0.09 (0.13)	RVU 0.00 (0.00)
Seine	44	4	0.67	N.S.	RVU 1.79 (6.50)	DFE 1.73 (8.43)	DFW 1.16 (4.41)	DFH 1.14 (4.95)	TCN 0.88 (2.33)				
Electro-shocker	2	8	3.74	$\leq$0.01	NBU 2.38 (10.27)	DFH 2.18 (9.69)	TCN 2.17 (7.86)	RVD 1.99 (6.32)	NBD 1.90 (5.84)	DFP 1.65 (4.79)	DFW 1.09 (2.97)	RVU 0.63 (1.25)	DFE 0.55 (1.00)

* Catch by various gear types is based on overnight sets for gill and hoop nets, runs adjusted to 10 min for the electroshocker, and 23-m hauls for the seine.

** Locations underscored by a continuous line are not significantly different at the 0.05 level.

† N.S. = not significant.

Table 28

Frequency of Occurrence (%) of Food Items of Seven Walleye Taken in 1979 from Four Missouri River Locations near Washburn, N. Dak.

Food Item	Total	Location DFP	DFH	DFW	RVU
Diptera					
Chironomidae					
Larvae	14.3				50.0
Chironomus sp.	14.3		50.0		
Pseudochironomus sp.	14.3		50.0		
Saetheria tylus	14.3		50.0		
Trichoptera					
Hydropsychidae					
Adult					
Hydropsyche sp.	14.3	50.0			
Larvae					
Hydropsyche simulans	14.3	50.0			
Ephemeroptera					
Ephemeridae					
Larvae					
Hexagenia sp.	14.3	50.0			
Percichthyidae					
Juvenile					
Morone chrysops	14.3				50.0
Unidentified fish	28.6		50.0		50.0
Organic matter	t*	t	t		t
Number of fish sampled	7	2	2	1	2

* t = trace.

Table 29

Frequency of Occurrence (%) of Food Items in Northern Pike Taken in 1979 from Four Missouri River Locations near Washburn, N. Dak.

Food Item	Total	Location			
		DFW	DFH	TCN	RVD
Hempitera					
Corixidae	7.1			50.0	
Percidae					
Juvenile					
Perca flavescens	14.3	14.3	25.0		
Etheostoma nigrum	7.1	14.3			
Catostomidae					
Juvenile	7.1	14.3			
Larvae	7.1	14.3			
Unidentified fish	28.6	28.6	25.0	50.0	
Organic matter	t*	t	t	t	
Number of fish	14	7	4	2	1

* t = trace.

Table 30

Frequency of Occurrence (%) of Food Items of 21 White Bass Taken in 1979 from Four Missouri River Locations near Washburn, N. Dak.

Food Items	Total	Location DFH	DFW	DFE	NBD
Aquatic Organisms					
Diptera					
Chironomidae					
Larvae					
Cricotopus sp.	28.6	50.0	33.3	36.4	50.0
Chironomus sp.	42.8	20.0		72.7	
C. anthracinus	47.6	40.0		27.3	
C. thumni	23.8			27.3	
Cryptochironomus nais	14.3	40.0		9.1	
Paracladopelma sp.	9.5	20.0		9.1	
Procladius sp.	19.0			36.4	
Protanypus sp.	4.7			9.1	
Pseudochironomus sp.	4.7			9.1	
Psectrocladius sp.	4.7			9.1	
Stictochironomus sp.	28.6			54.5	
Pupae					
Pupae	9.5			18.2	
Chironomus sp.	38.1		33.3	63.6	
Orthocladiinae	9.5			18.2	
Dolichopodidae	4.7			9.1	
Trichoptera					
Larvae	4.7				50.0
Hydropsychidae	4.7	20.0			
Adult					
Adult	9.5		33.3		50.0
Hydropsyche sp.	9.5	20.0			50.0
H. betteni	9.5	20.0		9.1	
Pupae					
Hydropsyche sp.	4.7	20.0			
Larvae					
Hydropsyche sp.	4.7				50.0
H. simulans	19.0	40.0			100.0
H. hageni	4.7				50.0
Polycentropodidae					
Adult					
Cernotina sp	9.5			9.1	50.0
Larvae					
Neureclipsis sp.	4.7			9.1	

(Continued)

Table 30 (Concluded)

Food Items	Total	Location DFH	DFW	DFE	NBD
Plecoptera					
Perlodidae					
Larvae					
Hydroperla nalata	4.7			9.1	
Ephemeroptera					
Ephemeridae					
Larvae					
Hexagenia sp.	9.5			9.1	50.0
Heptangeniidae					
Larvae					
Heptagenia sp.	4.7	20.0			
Hemiptera					
Corixidae	66.6	20.0	33.3	90.0	100.0
Collembola					
Hypogastruidae	4.7	20.0			
Zooplankton					
Cladocera					
Cladocera	4.7	20.0			
Daphnia sp.	19.0	20.0	66.0	9.1	
D. pulex	23.8	20.0	66.0	18.2	
D. retrocurva	19.0	20.0	66.0	9.1	
Copepoda					
Cyclopoida					
Diaptomus forbesi	4.7		33.3		
Miscellaneous					
Miscellaneous	t*	t	t	t	t
Inorganic and organic matter (plus plankton)	t	t	t	t	
Number of fish	21	5	3	11	2

* t = trace.

Table 31

Frequency of Occurrence (%) of Food Items of Eight Burbot Taken in 1979 from Five Missouri River Locations near Washburn, N. Dak.

Food Item	Total	Location DFH	DFW	TCN	RVD	NBD
Trichoptera						
Polycentropodidae						
Adult						
Cernotina sp.	12.5	33.3				
Larvae						
Neureclipsis sp.	12.5		100.0			
Hydropsychidae						
Larvae						
Hydropsyche simulans	62.5	100.0	100.0		100.0	
Hydropsyche hageni	25.0	66.6				
Hydropsyche betteni	12.5	33.3				
Ephemeroptera						
Larvae	25.0	33.3			100.0	
Anura	12.5			50.0		
Unidentified fish	12.5			50.0		
Number of fish	8	3	1	2	1	1

Table 32

Frequency of Occurrence (%) of Food Items in 14 Shovelnose Sturgeon Taken in 1979 from Four Missouri River Locations Near Washburn, N. Dak.

Food Item	Total	Location			
		DFP	DFH	RVU	NBD
Aquatic Organisms					
Diptera					
Adult	7.1		100.0		
Larvae	7.1	100.0			
Chironomidae					
Larvae					
Cricotopus sp.	71.4	100.0	100.0	54.5	100.0
Chironomus sp.	4.3		100.0	45.4	
C. anthracinus	28.6		100.0	18.2	100.0
C. thumni	7.1				100.0
Cryptochironomus sp.	7.1			9.1	
Paracladopelma sp.	42.8	100.0	100.0	36.4	
Polypedilum sp.	28.6	100.0		27.3	
Procladius sp.	7.1	100.0			
Parachironomus sp.	7.1			9.1	
Stictochironomus sp.	21.4			27.3	
Pupae					
Pupae	42.8	100.0	100.0	45.4	
Chironomus sp.	42.8	100.0		36.4	100.0
Diamesinae	14.3		100.0	9.1	
Orthocladiinae	7.1			9.1	
Simuliidae					
Pupae	21.4	100.0		18.2	
Dolichopodidae					
Larvae	7.1			9.1	
Trichoptera					
Adult	28.6		100.0	18.2	100.0
Hydropsychidae					
Adult					
Hydropsyche sp.	14.3	100.0	100.0		
Pupae					
Hydropsyche sp.	7.1				100.0
Larvae	14.3			18.2	
Hydropsyche sp.	21.4	100.0		18.2	
Hydropsyche simulans	21.4		100.0	18.2	
Polycentropodidae					
Adult					
Cernotina sp.	14.3		100.0	9.1	

(Continued)

Table 32 (Concluded)

Food Item	Total	Location DFP	DFH	RVU	NBD
Polycentropodidae (Cont'd.)					
Pupae					
Neureclipsis sp.	7.1		100.0		
Larvae					
Neureclipsis sp.	7.1			9.1	
Neuroptera					
Megaloptera					
Larvae	7.1			9.1	
Hemiptera					
Corixidae	14.3	100.0		9.1	
Oligochaeta	38.1	100.0	100.0	45.4	100.0
Terrestrial organisms					
Orthoptera					
Acrididae	28.6		100.0	36.4	100.0
Hymenoptera					
Adult	14.3	100.0		9.1	
Formicidae	28.6		100.0	27.3	
Homoptera					
Cicadellidae	7.1			9.1	
Number of fish	14	1	1	11	1

Table 33

Results of Analyses of Variance and Duncan's Multiple Range Test Based on Log Transformed Data Comparing the Numbers of Taxa of Macroinvertebrates Taken per Station* by Two Sampling Methods at Different Locations on the Missouri River, 1979

	Analysis of Variance				Duncan's Multiple Range Test Ranked Locations Transformed Location Means (Location Means) Grouping of Locations**								
Gear Type	Error df	Location df	F	Level of Significance									
Shipek dredge	142	8	1.73	N.S.†	DFW 0.75 (1.52)	DFH 0.71 (1.44)	NBD 0.54 (1.00)	DFP 0.53 (0.90)	NBU 0.45 (0.79)	RVU 0.38 (0.79)	DFE 0.33 (0.67)	TCN 0.29 (0.45)	RVD 0.23 (0.50)
Frame net	22	5	3.08	≤ 0.05	RVU 2.48 (11.00)	DFE 2.42 (10.50)	DFH 2.40 (10.10)	DFP 2.20 (8.00)	DFW 2.09 (7.29)	RVD 2.09 (7.33)			

(Shipek dredge: all locations underscored by one continuous line. Frame net: RVU–DFP underscored by one line; DFP–RVD underscored by a second line.)

* Based on the following sample sizes for different gear types: Shipek dredge, 0.05 m^2; frame net, 0.25 m^2.
** Locations underscored by continuous lines are not significantly different at the 0.05 level.
† N.S. = not significant.

Table 34

Results of Analyses of Variance and Duncan's Multiple Range Test Based on Log Transformed Data Comparing the Numbers of Macroinvertebrates Taken per Station* by Two Sampling Methods at Different Locations on the Missouri River, 1979

Gear Type	Analysis of Variance: Error df	Location df	F	Level of Significance	Duncan's Multiple Range Test Ranked Locations Transformed Location Means (Location Means) Grouping of Locations**								
Shipek dredge	142	8	3.06	≤0.01	DFH 1.99 (40.75)	DFW 1.93 (26.90)	NBD 0.99 (4.50)	DFP 0.78 (1.75)	NBU 0.71 (1.75)	TCN 0.70 (6.91)	DFE 0.62 (4.22)	RVU 0.61 (2.36)	RVD 0.32 (1.00)
Frame net	22	5	4.89	≤0.01	DFE 6.90 (1,110.50)	DFH 6.88 (990.50)	RVU 6.12 (454.00)	DFW 5.65 (467.93)	RVD 5.51 (326.50)	DFP 5.16 (208.83)			

* Based on the following sample sizes for different gear types: Shipek dredge, 0.05 m^2; frame net, 0.25 m^2.

** Locations underscored by continuous lines are not significantly different at the 0.05 level.

Table 35

Comparison of Net Catches,* Missouri River Between Underwood and Bismarck, North Dakota, 1960, and Nine Locations near Washburn, North Dakota, 1979

Species	Avg Length, mm		Catch Composition percent	
	1960	1979	1960	1979
River carpsucker	368	462	21.98	15.76
Shovelnose sturgeon	495	589	26.37	12.50
Sauger	297	300	8.89	8.15
White bass		156		9.78
Walleye	356	408	1.10	8.70
Northern pike	523	525	6.59	5.98
White sucker	272	368	2.20	8.70
Goldeye	264	199	17.58	5.98
Carp	267	467	4.40	3.26
Bigmouth buffalo		478		2.72
Black bullhead		171		2.72
Longnose sucker		371		0.54
Shorthead redhorse	368	359	3.33	3.26
Blue sucker		601		1.63
Paddlefish		955		0.54
Burbot		421		7.61
Rainbow trout		270		0.54
Shortnose gar	483		1.10	
Channel catfish	338	282	4.40	1.63
Crappie	282		1.10	
Drum	224		1.10	

* Combined gill net and frame net catches in 1960; combined gill net and hoop net catches in 1979.

APPENDIX A: DETAILED MAPS OF THE STUDY AREA SHOWING SAMPLING STATIONS IN THE HABITATS STUDIED

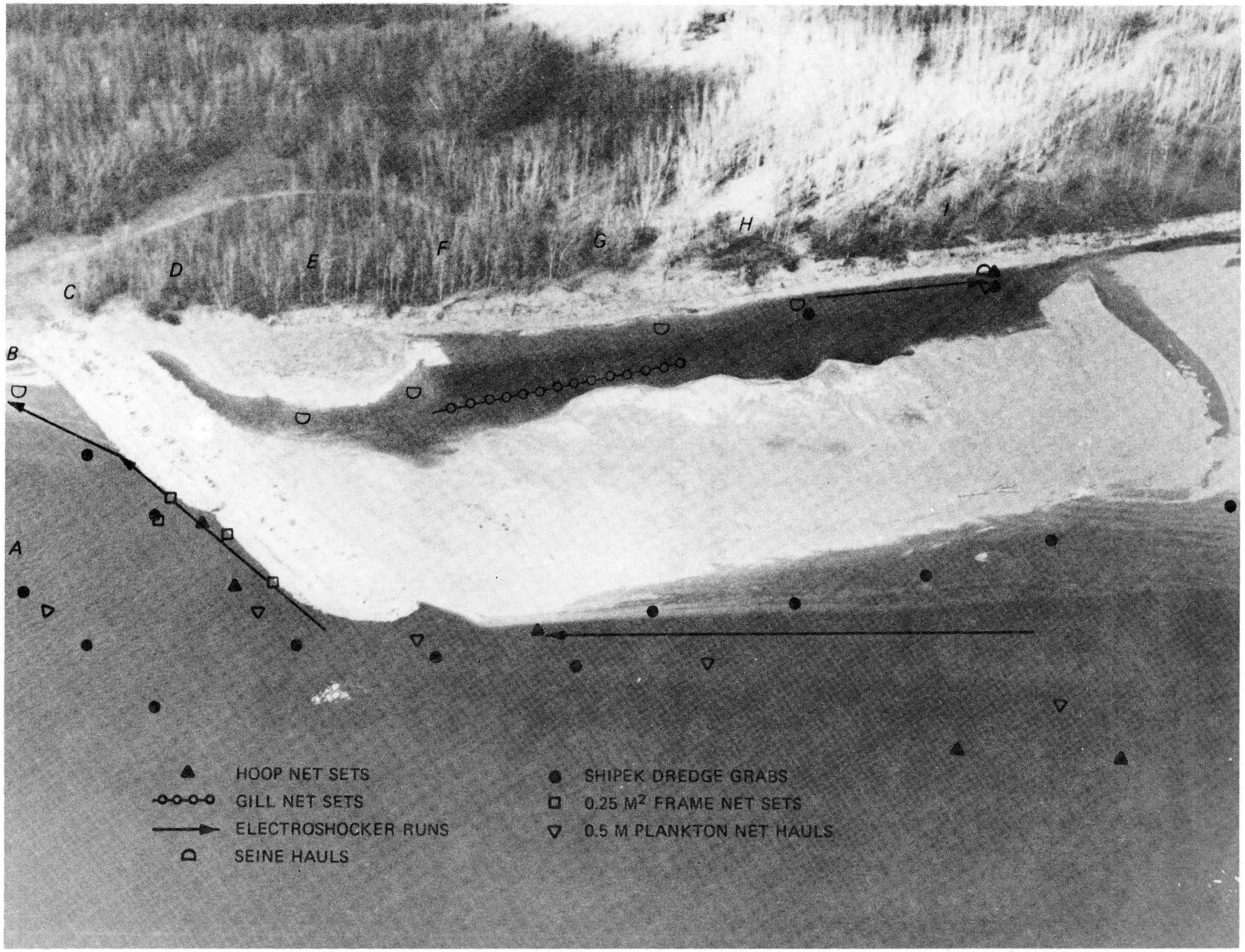

Figure A1. Sampling stations at the stone-faced earth core dikes (DFE)

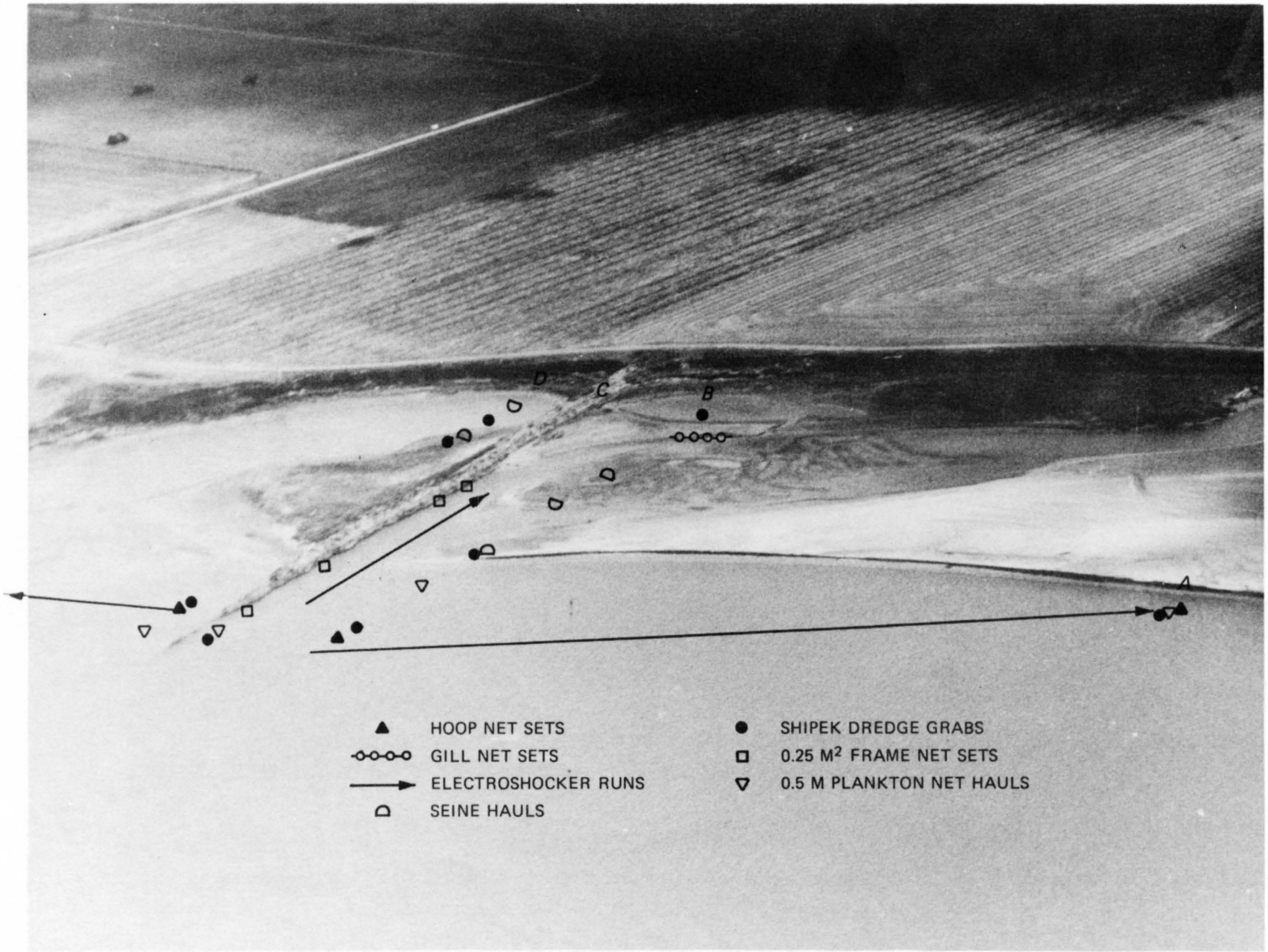

Figure A2. Sampling stations at the stone fill wing dikes (DFW)

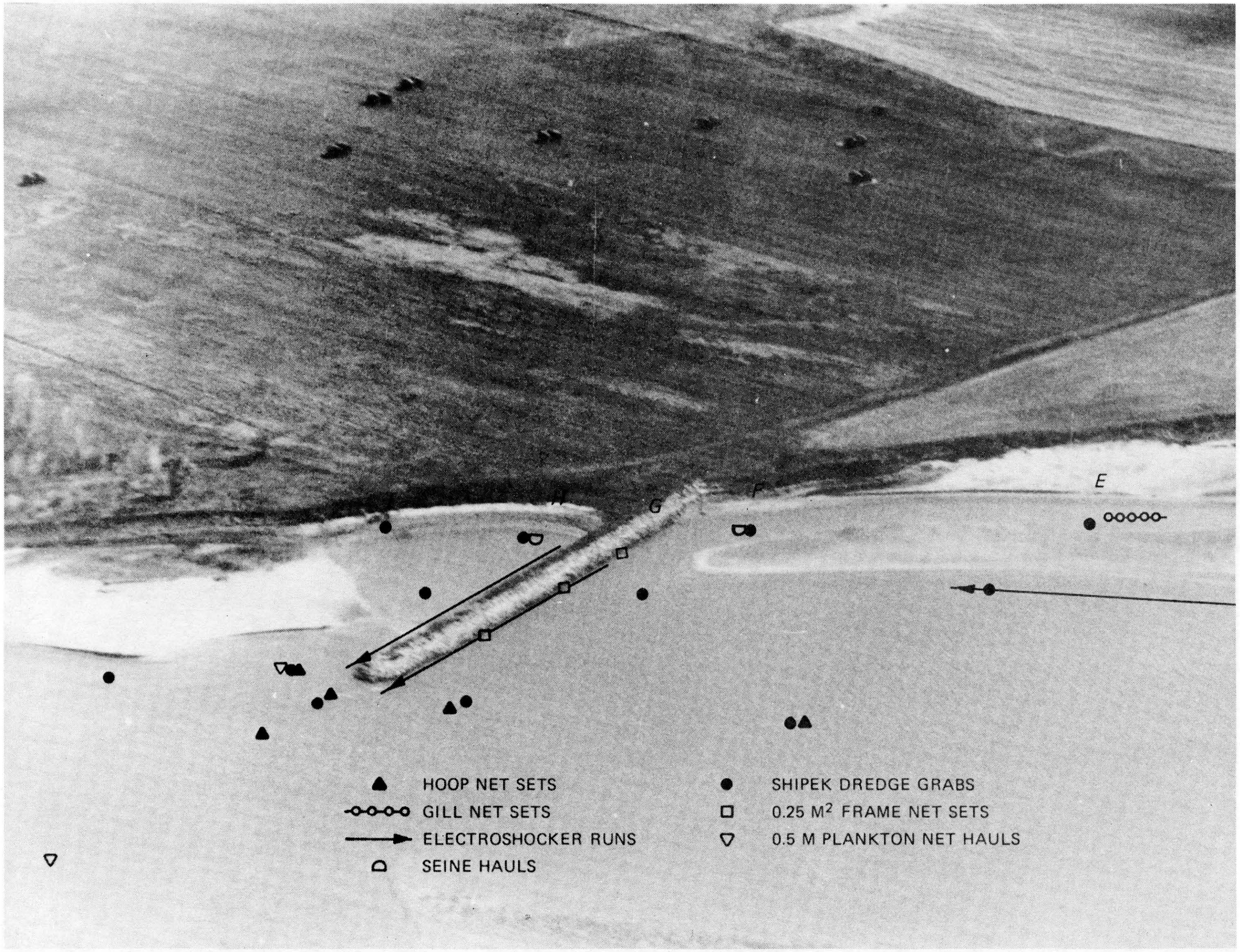

Figure A3. Sampling stations at the stone fill wing dikes (DFW)

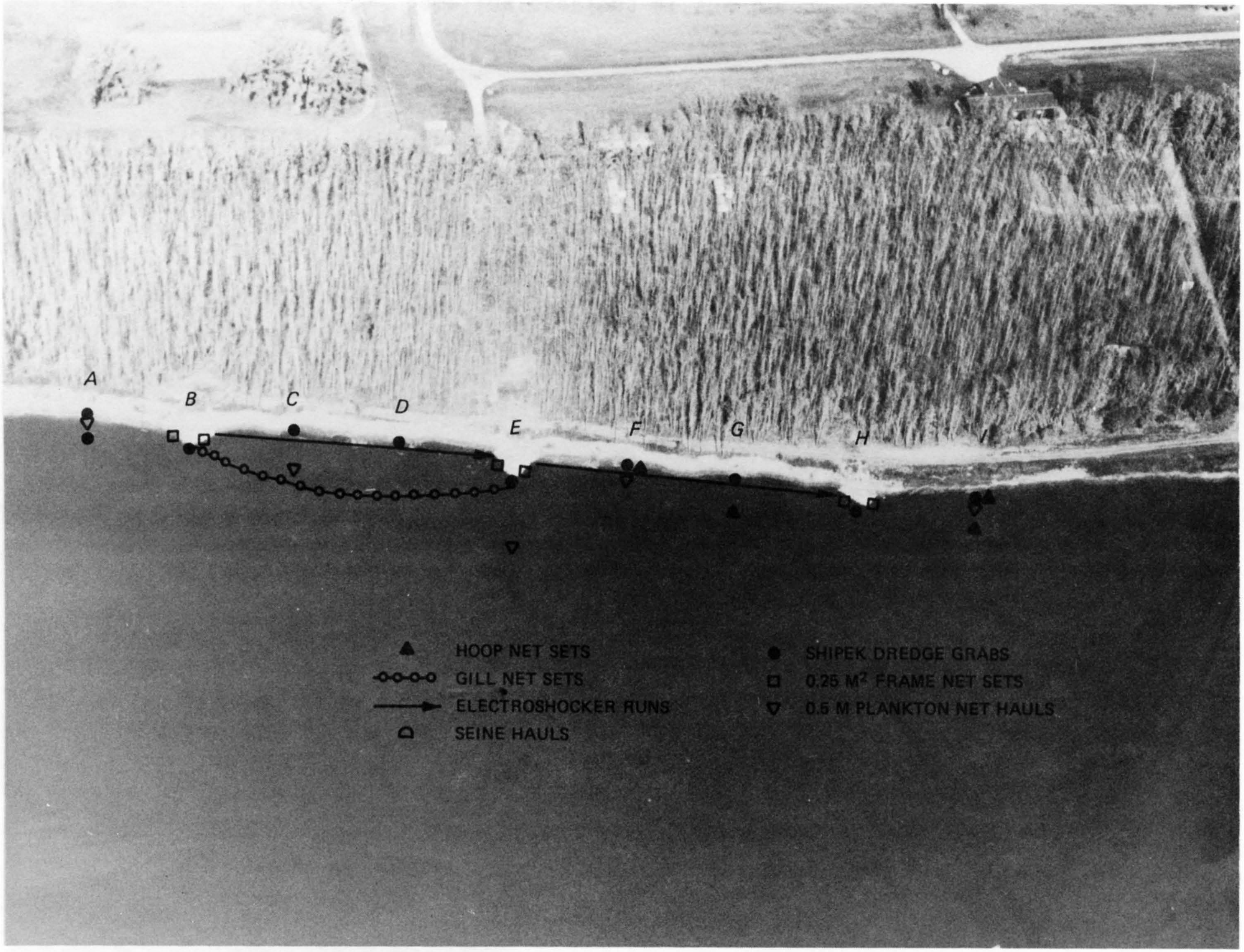

Figure A4. Sampling stations at the hard points (DFP)

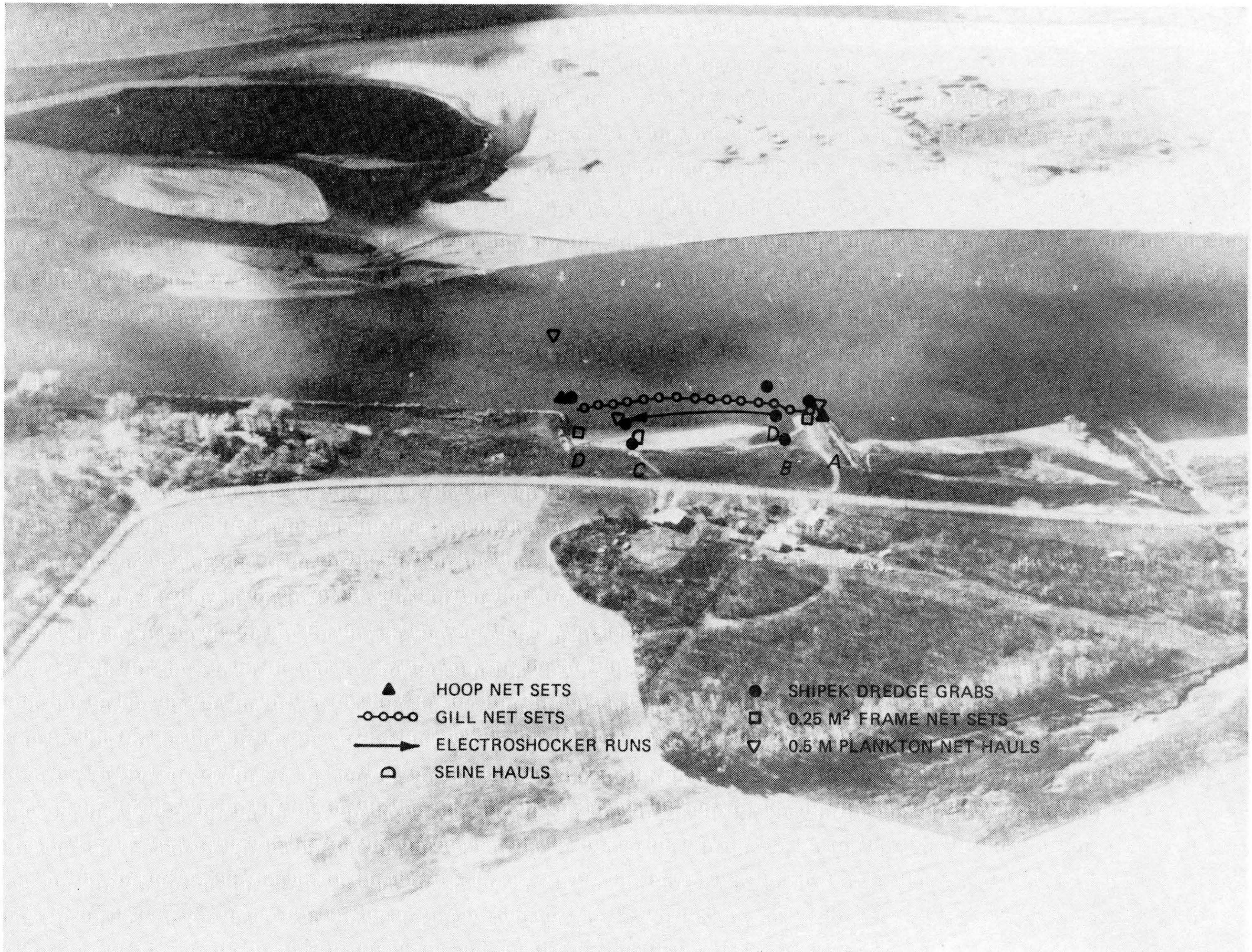

Figure A5. Sampling stations at the L-head dikes (DFH)

Figure A6. Sampling stations at the L-head dikes (DFH)

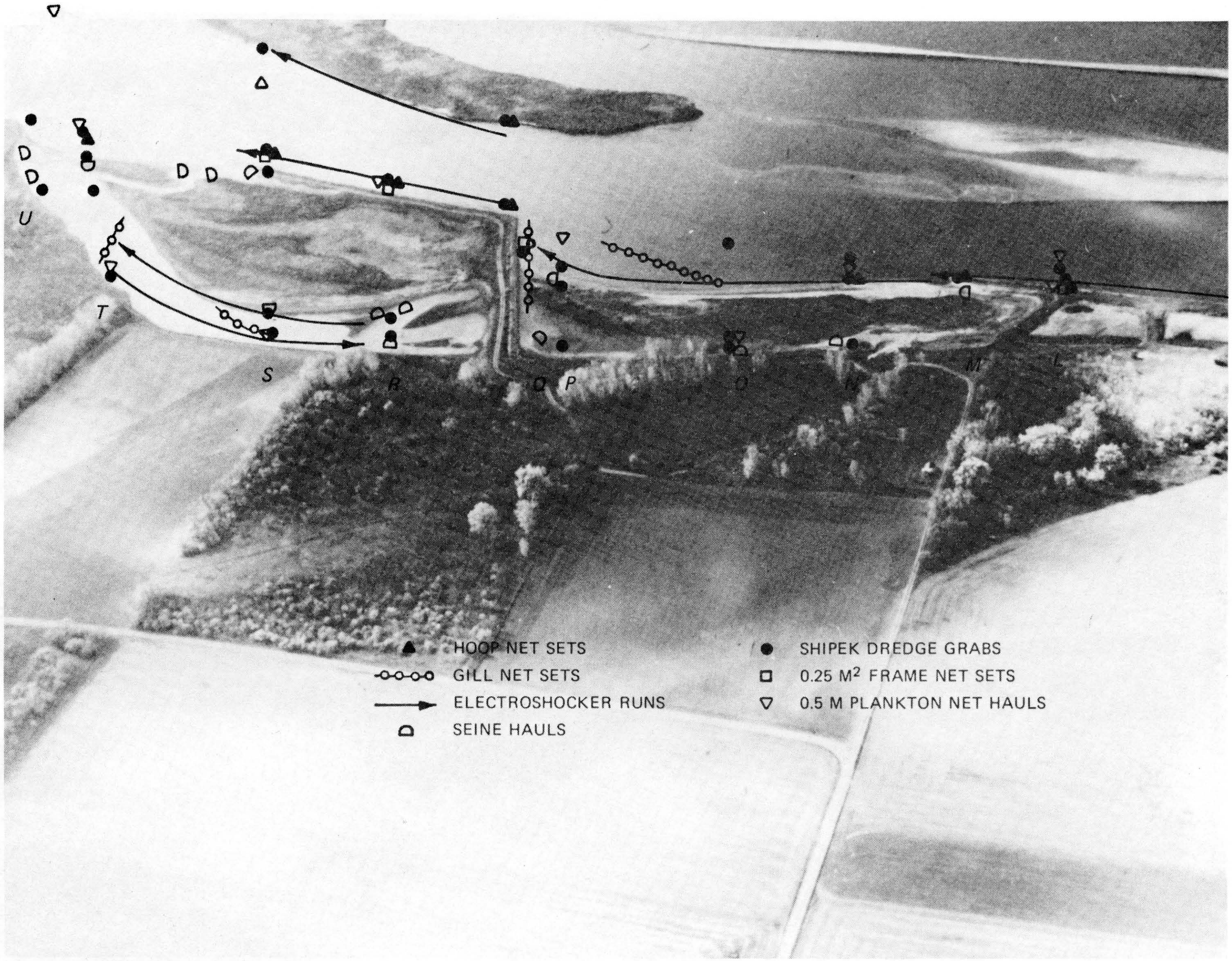

Figure A7. Sampling stations at the L-head dikes (DFH)

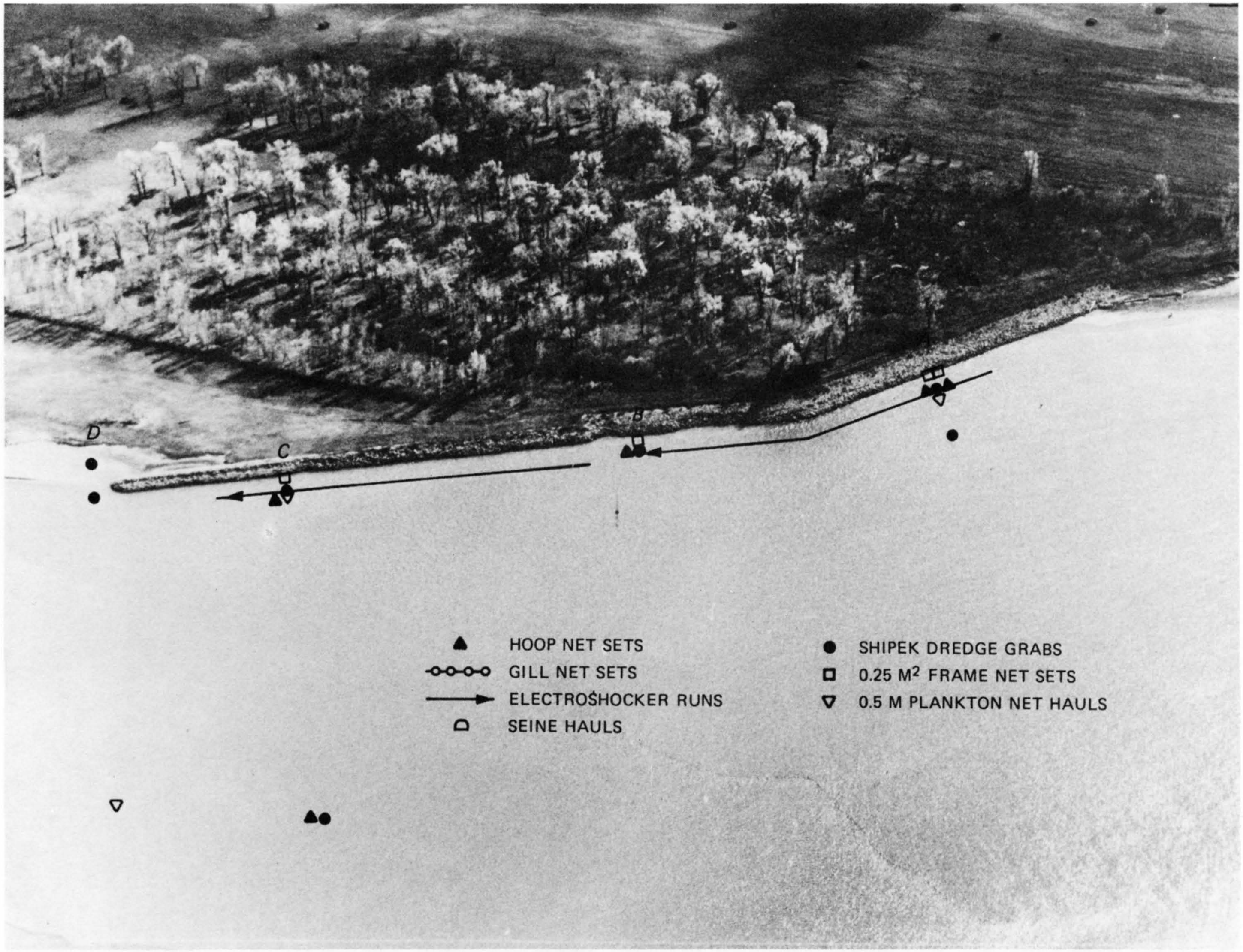

Figure A8. Sampling stations at the stone fill revetment, lower (RVD)

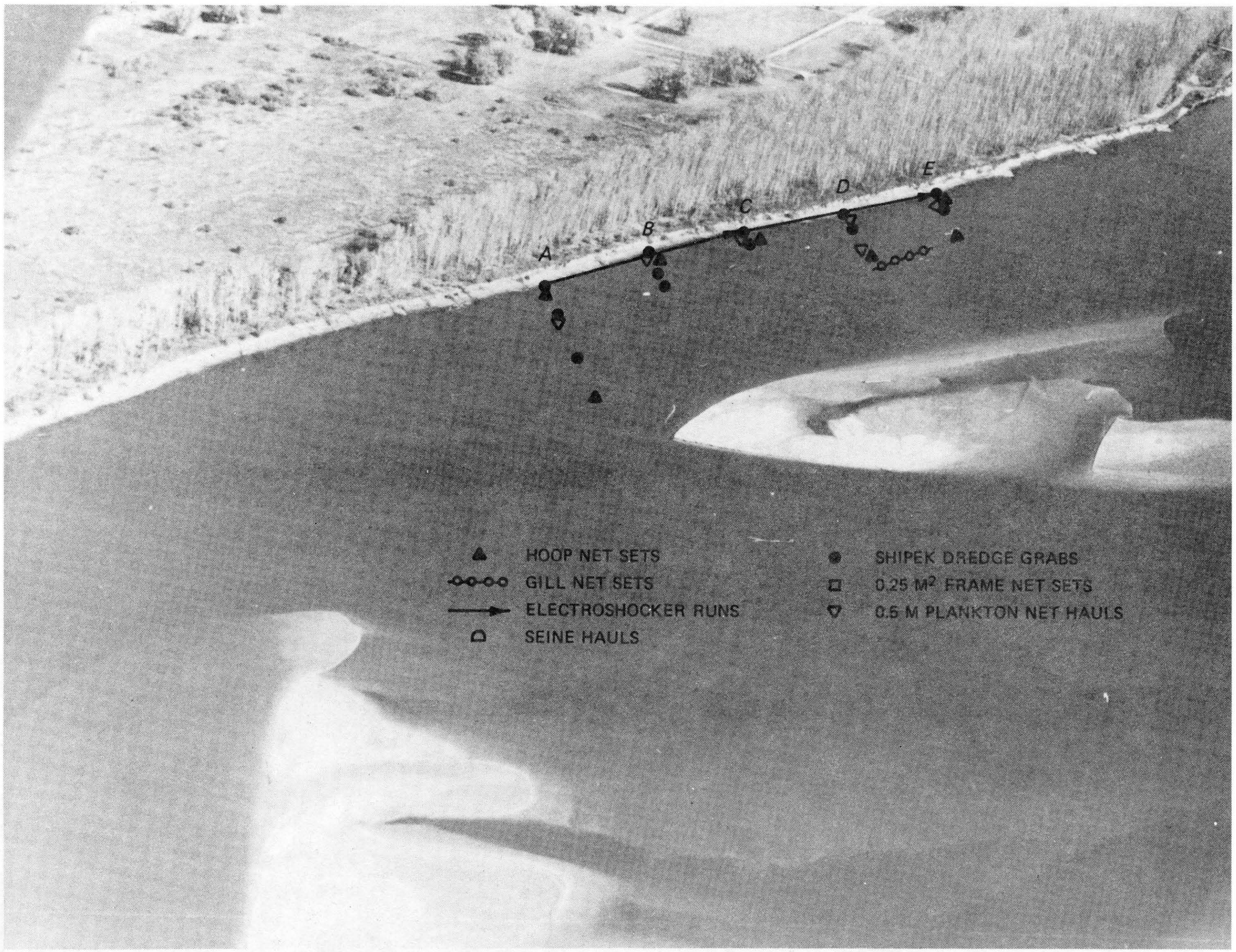

Figure A9. Sampling stations at the chute (TCN)

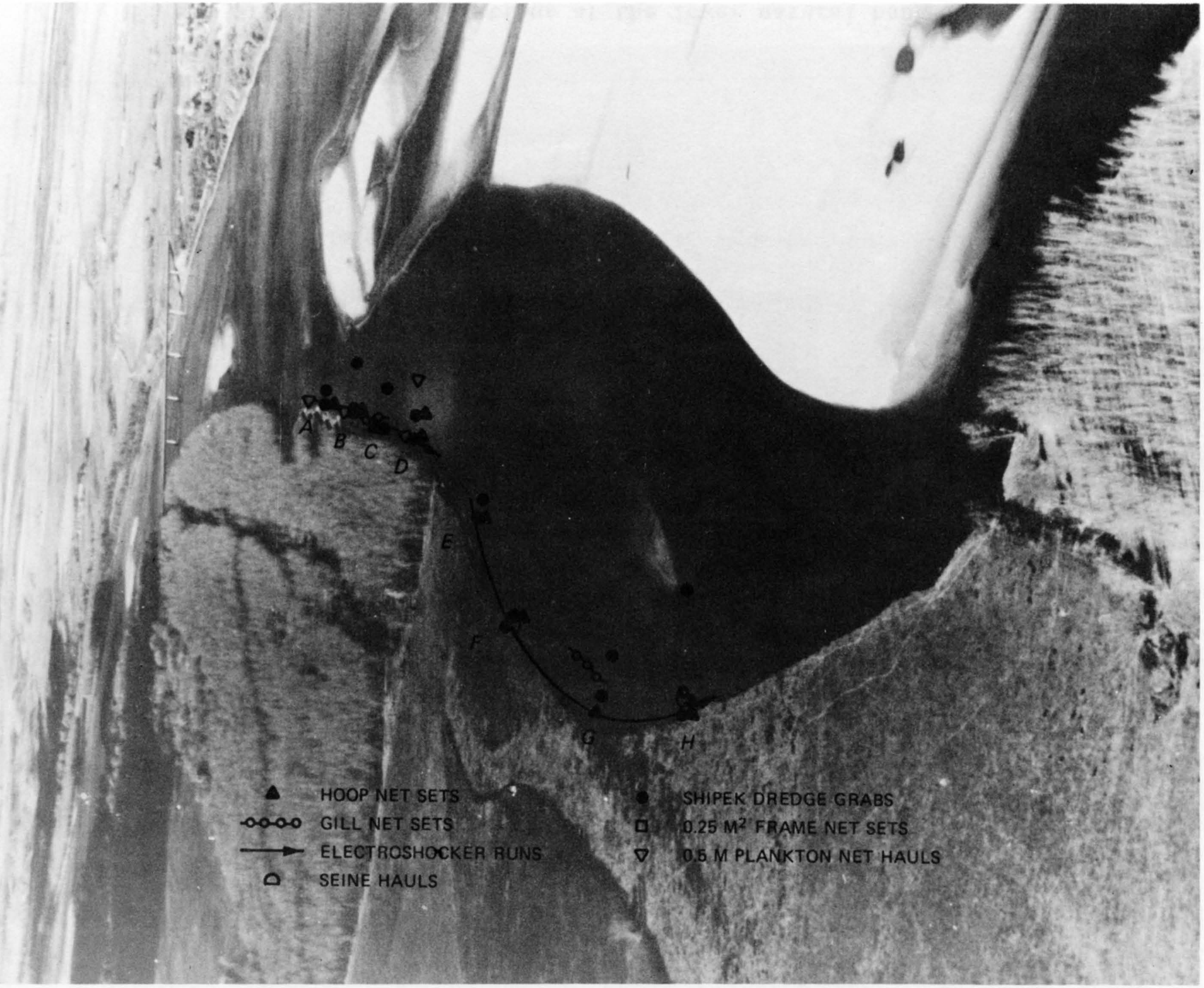

Figure A10. Sampling stations at the upper natural bank (NBU)

Figure A11. Sampling stations at the lower natural bank (NBD)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Burress, Ralph M.
Aquatic biota of bank stabilization structures on the Missouri River, North Dakota / by Ralph M. Burress, Douglas A. Krieger (U.S. Fish and Wildlife Service, National Fishery Research Laboratory) and C.H. Pennington (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
102 p. in various pagings ; ill. ; 27 cm. -- (Technical report ; E-82-6)
Cover title.
"May 1982."
Final report.
"Prepared for Office, Chief of Engineers, U.S. Army and U.S. Army Engineer District, Omaha under Cooperative Agreement No. 14-16-0009-78-946 (EWQOS Work Unit VA)."
"Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."
"Environmental & Water Quality Operational Studies."
Bibliography: p. 49-51.

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Aquatic biota of bank stabilization structures : ... 1982.
(Card 2)

1. Aquatic animals. 2. Fishes. 3. Invertebrates. 4. Missouri River. 5. Sampling. I. Krieger, Douglas A. II. Pennington, C.H. III. United States. Army. Corps of Engineers. Office of the Chief of Engineers. IV. Environmental & Water Quality Operational Studies. V. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. VI. Title VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; E-82-6.
TA7.W34 no.E-82-6