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AN INVENTORY OF PHYSICAL AND CHEMICAL CONDITIONS AND BOTTOM FAUNA IN HOUGHTON CREEK, OGEMAW COUNTY, DURING WATERSHED IMPROVEMENT, 1950-1953

By

Robert J. Ellis[1]

Introduction

Early in the summer of 1950, the Lake and Stream Improvement Section of the Fish Division, Michigan Department of Conservation, began the construction phase of the Rifle River Watershed Development Program (Tody and Clark, 1951; Clark, 1953). This work was aimed primarily at (a) checking excessive erosion from farms, roads and stream banks; (b) reducing surface run-off and stabilizing river flow; and (c) lowering peak summer water temperatures. A biological inventory of certain streams of the watershed was initiated in September 1950 by the Institute for Fisheries Research of the Fish Division. Studies dealing with fish were supervised by Howard Gowing and have been reported elsewhere (Gowing, 1952 and 1953). The present author was responsible for the studies of the bottom fauna and its environment.

Studies of the bottom fauna and its environment were conducted on Houghton Creek. This stream was selected for intensive study because, among major

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[1]On Feb. 21, 1958, Mr. Ellis joined the staff of the Oregon Fish Commission.

tributaries to the Rifle River, it had been subject to the greatest amount of run-off and bank erosion, and therefore was scheduled to receive a major portion of the proposed development work. It is the largest tributary to the Rifle River in the watershed development area. The field work for the present study was done from September 1950 to January 1954. From September 1951 to June 1957 the author was employed on a fellowship with the Institute for Fisheries Research.

Objectives

The purpose of this study was to obtain a record of physical and chemical conditions and of the abundance and distribution of bottom fauna in Houghton Creek at the time of watershed development; a similar study should be made at a later date for comparison.

The study area

Houghton Creek is about 10.4 miles long and lies entirely within Ogemaw County. Its origin is in Section 18, T. 24 N., R. 3 E., where it arises from springs and seepage in cedar swamps (Fig. 1). The stream runs generally south for about four miles and then southeast to its junction with the Rifle River. This study concerns that part of the stream from its mouth up to a point (Sta. 1 on Fig. 1) about 300 yards north of the line between Sections 30 and 31 of T. 24 N., R. 3 E. The investigation was restricted to this portion of the stream to make more intensive study possible and because it was believed that this area was most likely to show any changes in bottom fauna and its environment which might result from the watershed development work.

Figure 1.--Map of Houghton Creek showing stream areas which were mapped, and sampling sites.

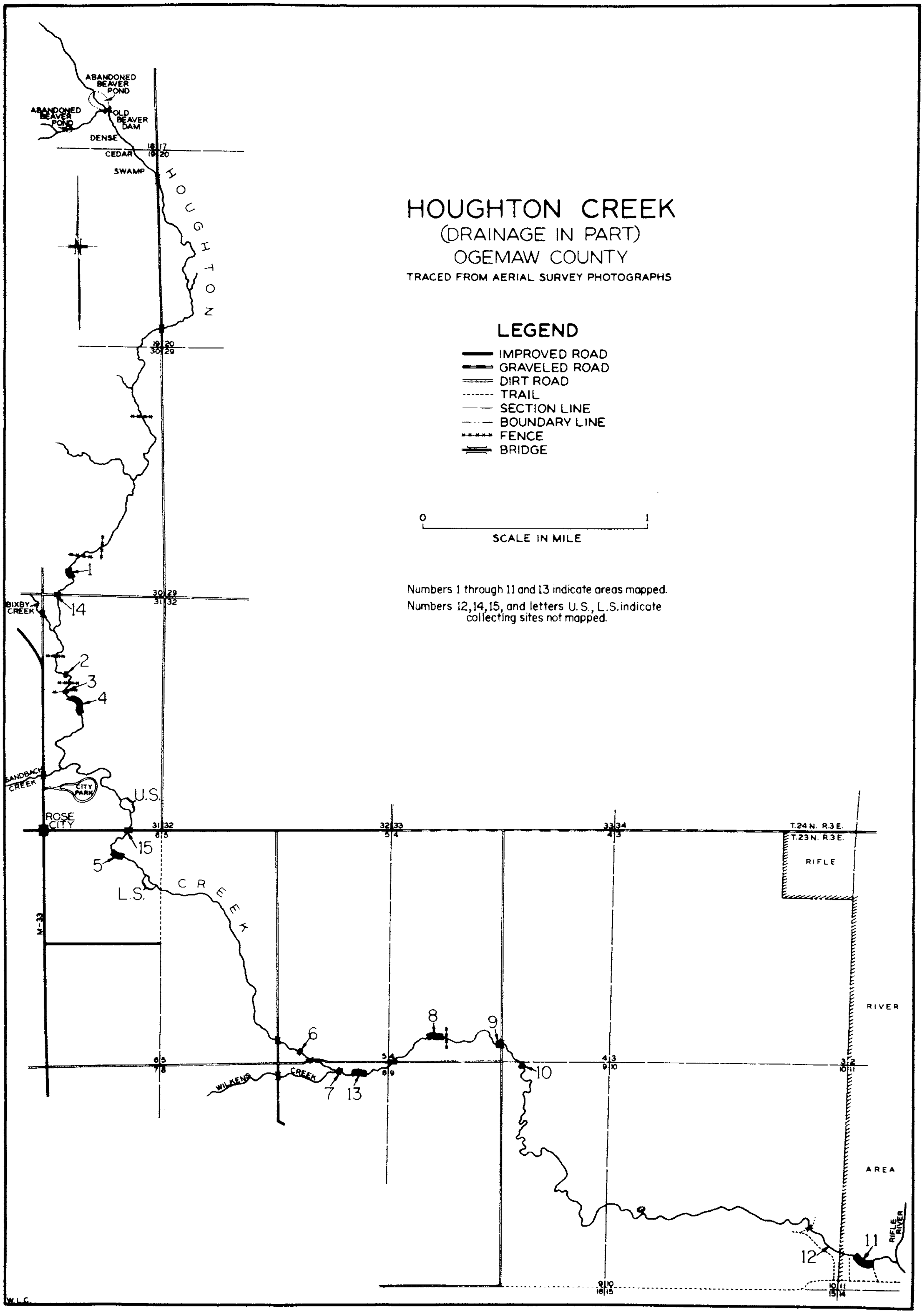

HOUGHTON CREEK
(DRAINAGE IN PART)
OGEMAW COUNTY
TRACED FROM AERIAL SURVEY PHOTOGRAPHS
LEGEND
IMPROVED ROAD
GRAVELED ROAD
DIRT ROAD
TRAIL
SECTION LINE
BOUNDARY LINE
FENCE
BRIDGE
0
1
SCALE IN MILE
Numbers 1 through 11 and 13 indicate areas mapped.
Numbers 12,14,15, and letters U.S., L.S. indicate collecting sites not mapped.
ABANDONED BEAVER POND
ABANDONED BEAVER POND
OLD BEAVER DAM
DENSE
CEDAR
SWAMP
HOUGHTON
CREEK
BIXBY CREEK
SANDBACK CREEK
CITY PARK
ROSE CITY
M-33
U.S.
L.S.
WILKENS CREEK
T.24N. R3E.
T.23N. R3E.
RIFLE
RIVER
AREA
RIFLE RIVER
W.L.C.

Figure 1

Physical survey

Bottom soils and stream morphometry

In 1950, at the outset of this study, I examined the entire length of Houghton Creek, while walking in or along the stream channel, and made notes of physical characteristics of the stream such as bottom types, trout spawning areas, etc.; the locations of these features were recorded on maps traced from aerial photographs. These field notes and maps are in the files of the Institute for Fisheries Research.

With the aid of the notes from the initial survey, eleven areas of the stream (at sites 1 to 11 in Fig. 1) were selected for intensive study. These areas were chosen to represent the different bottom types and physical conditions to be found throughout the length of the stream. In the fall of 1950, during the period October 31 to November 17, a two-man crew, using plane table, alidade, compass and steel tape, mapped each of the eleven areas in detail, showing bottom types, cover, and channel depths along selected transects. In 1952, from September 2 to September 7, eight of the eleven study areas were remapped; and in 1953, from October 14 to November 10, six of the eight areas remapped in 1952 were remapped again. Also, in 1953, November 13-14, a new study area (at site 13, Fig. 1) was mapped for the first time.

The reduction from eleven study areas mapped in 1950, to eight mapped in 1952, to six plus one mapped in 1953, was a concession to limitations in time available for mapping; however, it was concluded that the seven study areas (including area 13), which were mapped in 1953, constituted a representative and adequate sample for Houghton Creek as a whole. Remapping in 1952 and 1953 was done to determine the extent of change which might be taking place in the stream during this initial period of three years. Most of the watershed improvement work was done in 1951 and 1952.

The six stream areas which were mapped in 1950 and remapped in 1952 and 1953 were at sites 1, 4, 5, 7, 8, and 11 (see Fig. 1). Maps for these six areas, and for area 13, are included in the present report. The original field maps for the remaining five areas are on file, for possible future reference, in the Ann Arbor office of the Institute. Of the seven areas for which maps are included in the present report, for all but one the maps are too large to be included on a single sheet; such maps are divided into sections designated as A, B, C, etc. (with A at the upstream end of each area). Thus, stream maps included in the present report involve the following:

Area	Length of area: linear feet of stream	Map sections	Year mapped		
1	240	A, B	1950,	1952,	1953
4	664	A, B, C, D, E, F	"	"	"
5	456	A, B, C, D	"	"	"
7	116	A	"	"	"
8	480	A, B, C, D	"	"	"
11	528	A, B, C, D	"	"	"
13	600	A, B, C, D, E, F			1953

On these maps, water depths along transects are given in inches. Major bottom soil types are shown by different Zipatone patterns. These maps (or the larger tracings on file at the Institute) could be used for planimeter measurements of the areas of different bottom soil types to detect major changes which might take place in Houghton Creek over a period of years. If the Rifle River Watershed Improvement work has been, or will be a major factor in reducing upland erosion, and in reducing the stream-scouring effects of floods, changes in stream-bottom soil types might be expected to occur. The preparation of these maps, as a record of stream conditions at the start of the watershed improvement work, is one of the principal contributions of the present study.

In the six study areas which were mapped in 1950 and remapped in 1953, there were some minor changes in kind and distribution of bottom soils during this three-year period. The extent of these changes has not been determined quantitatively by planimeter measurements, and it is not known whether these changes were caused by the watershed improvement work in its early stages. To allow for the latter possibility, measurements of changes in bottom soils which might be made in the future, for the six study areas involved, would have to start with the maps prepared during the fall of 1950.

In addition to the detailed mapping of bottom soils in short sections of stream, described above, a general inventory of bottom soils throughout the lower 7.2 miles of Houghton Creek was made during July of 1952. The 7.2 miles of stream was traversed on foot, mostly walking in the stream channel. Major types of bottom soils were recorded. The area of each patch of a particular soil type was delimited by pacing its length and measuring its width with a 6-foot rod (calibrated in 1-foot intervals). The data from this study are summarized for four sections of stream (divisions of the 7.2-mile stretch) in Table 1; the limits of the four sections are described in footnotes to the table. The most obvious difference in distribution of bottom soils among the four sections was the preponderance of gravel in the upper section and of sand in the lower section. The percentages of the other substrate categories were not greatly different among the sections (Table 1).

Table 1.--Percentage of area of stream bottom covered by various soil types in the lower 7.2 miles of Houghton Creek, July, 1952

Stream section		Percentage of each bottom type						
Number	Length (miles)	Clay	Sand	Silt	Sand over gravel	Gravel in slow or deep water	Gravelly riffle	Vascular aquatic plants[1]
I	1.2	12	8	4	6	30	40	Trace
II	1.8	10	22	8	4	35	21	Trace
III	1.2	11	41	8	3	27	10	Trace
IV	3.0	5	72	9	4	9	Trace[2]	Trace

[1] Vegetation comprised 0.4 percent in IV, 0.1 percent in II, and less than 0.1 percent in I and III.

[2] Less than 0.5 percent.

Location of sections (see Figure 1):

I - From a point about 300 yards above the east-west road bridge at the northern boundary of section 31 downstream to the south boundary fence of the Rose City Park.

II - From the south boundary of the Rose City Park downstream to the north-south road bridge near the middle of section 5.

III - From the north-south road bridge near the middle of section 5 downstream to the north-south road bridge near the middle of section 4.

IV - From the north-south road bridge near the middle of section 4 downstream to the confluence of Houghton Creek and the Rifle River.

Locke (1951) described the bottom types in Houghton Creek in 1941 as follows: "Sand predominates in the extreme headwaters but is replaced by gravel and rubble as the stream approaches Rose City. Rubble, gravel, sand, and clay occur in the central section. Sand and silt are the predominant bottom types in the lower section; although a few gravel and rubble areas are found above the mouth." This description agrees very well with the observations made during the present study, eleven years later.

This general survey of bottom soils in the lower 7.2 miles of Houghton Creek, made during 1952, will also be valuable for comparison with conditions in future years.

In the lower, 7.2-mile stretch of Houghton Creek which was studied, stream width varied greatly within short distances, but the average width increased gradually toward the mouth. The figures in Table 2 are average widths for the stream within the area studied. These figures were derived from measurements made at irregular intervals during the "walking survey" in 1952.

Stream flow

Stream flow measurements (Table 3) at nine stations (Fig. 2) on Houghton Creek and two of its tributaries were made by personnel of the United States Geological Survey at Grayling, Michigan, in October 1951 and October 1952. These data show that Houghton Creek increases in volume from the uppermost study area to the mouth of the stream. The greatest increases are due to the entrance of waters from tributary streams, but spring seepages are also common along the length of the stream.

Houghton Creek is subject to flooding, but no extensive scouring of the stream bottom was observed during this study.

Table 2.--Approximate average stream widths, in the lower 7.2 miles of Houghton Creek, by Section, progressing downstream

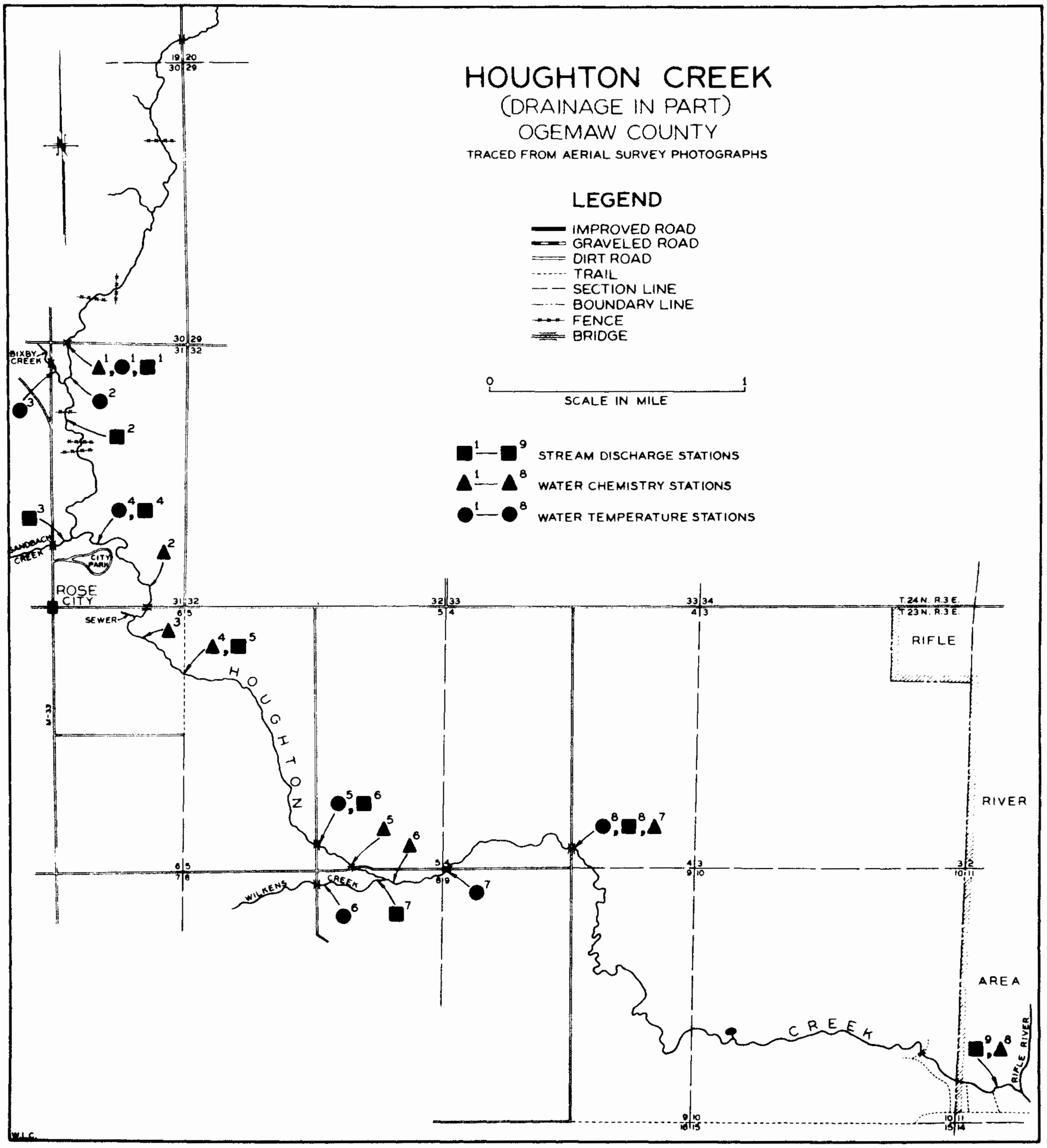
Section number	Approximate average width in feet
30	18*
31	20
5, 6	22
8, 4	24
9, 10, 11	28

*Applies only to the lower 300 yards of the stream in Section 30.

Table 3.--Stream discharge in cubic feet per second at various points on Houghton Creek and two tributary streams. Determinations made by the Grayling, Michigan, office of the U.S.G.S. Station locations are given in Figure 2

Station number	Discharge in cubic feet per second	
	Oct. 20, 1951	Oct. 25, 1952
1	6.2	6.2
2	7.6	8.1
3 (Sandbach Cr.)	7.8	5.2
4	16.3	15.2
5	17.8	15.6
6	17.6	15.2
7 (Wilkens Cr.)	16.2	16.9
8	35.6	34.8
9	36.0	35.0

Figure 2.--Map of Houghton Creek showing location of stream discharge, water chemistry, and water temperature stations.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WATER CHEMISTRY STATIONS
WATER TEMPERATURE STATIONS
BIXBY CREEK
SANDBACK CREEK
CITY PARK
ROSE CITY
SEWER
HOUGHTON
WILKENS CREEK
CREEK
RIFLE
RIVER
AREA
RIFLE RIVER
T.24N. R.3E.
T.23N. R.3E.
M-33

Figure 2

Discharge data, commencing with July 18, 1950, are available from the U.S.G.S. gaging station located on Houghton Creek about 725 yards above its mouth; copies of records are in the Institute files.

During the period of this study, a saw mill was in operation on Sandbach Creek, a tributary of Houghton Creek. This mill utilized water from an impoundment to drive a turbine. When the turbine was in operation, there was a sharp increase in the volume of water entering Houghton Creek from Sandbach Creek. The turbine was usually shut off during the noon hour and in the late afternoon, hence there was a rise and fall in the water level and current velocity of Houghton Creek twice a day during most week days. On June 15, 1955 the mill burned down. Thereafter the flow of Sandbach Creek was not subject to wide daily fluctuation.

Water temperatures

Since July 18, 1950 the U.S.G.S. has operated a thermograph at the stream gaging station located on Houghton Creek about 725 yards above its mouth. Yearly summaries of these data are on file at the Institute. Also, during the summer of 1953, maximum and minimum water temperatures at study area 4 (see Fig. 1) were recorded almost daily by the author. These data are in the Institute files. Table 4 contains weekly maximum and minimum water temperatures for 1953 at area 4 and at the U.S.G.S. gaging station. Two conclusions may be drawn from this table: (1) summer water temperatures in 1953 were rarely above the upper optimum (61°-66° F.) for growth of brown trout (Brown, 1946); (2) water temperatures recorded at study area 4 (above Rose City) and near the mouth of the stream were very similar, though the stations are about five miles apart.

Locke (1951) in the 1941 survey of Houghton Creek concluded that parts of the central and lower sections should be planted with trees and shrubs to

Table 4.--Weekly maximum and minimum water temperatures at two locations on Houghton Creek, Ogemaw County, 1953

(Area 4 temperatures were recorded on a maximum-minimum thermometer)

Weekly period		U.S.G.S. gaging station Maximum °F	U.S.G.S. gaging station Minimum °F	Area 4 Maximum °F	Area 4 Minimum °F
January	1-7	38	32	..	..
	8-14	39	32	..	..
	15-21	40	33	..	..
	22-28	38	32	..	..
	29-Feb. 4	35	32	..	..
February	5-11	37	34	..	..
	12-18	37	32	..	..
	19-25	38	32	..	..
	26-Mar. 4	38	33	..	..
March	5-11	40	33	..	..
	12-18	40	34	..	..
	19-25	42	33	..	..
	26-Apr. 1	48	38	..	..
April	2-8	48	40	..	..
	9-15	..[1]	..	..	..
	16-22	50	37	51	36
	23-29	52	41	52	40
	30-May 6	56	43	..	..
May	7-13	62	49	62	45
	14-20	59	46	59	44
	21-27	60	48	60	46
	28-June 3	59	50	58	50
June	4-10	61	52	63	51
	11-17	63	54	62	52
	18-24	66	54	66	52
	25-July 1	65	57	66	54
July	2-8	67	56	66	52
	9-15	63	54	64	52
	16-22	67	58	64	55
	23-29	63	53	61	50
	30-Aug. 5	63	57	60	56
August	6-12	62	55	60	53
	13-19	61	52	61	52
	20-26	63	54	62	51
	27-Sept. 2	64	58	66	54
September	3-9	63	51	63	48
	10-16	57	49	57	46
	17-23	54	47	52	44
	24-30	54	48	54	46
October	1-7	54	44	53	46
	8-14	51	43	51	42
	15-21	52	47	..	..
	22-28	52	43	..	..
	29-Nov. 4	47	41	..	..
November	5-11	43	38	..	..
	12-18	47	41	..	..
	19-25	47	40	..	..
	26-Dec. 2	40	36	..	..
December	3-9	43	38	..	..
	10-16	39	32	..	..
	17-23	38	32	..	..
	24-31	37	32	..	..

[1] No records.

reduce the water temperatures of the lower sections of the creek. However, the brown trout is now the most abundant game species in the lower half of the stream, and reduction of existing water temperatures would not seem to be desirable for this species.

Maximum water temperatures (Table 5) at eight stations (Fig. 2) on Houghton Creek and two of its tributaries were recorded in 1951 by Frank Snyder of the U. S. Soil Conservation Service at Rose City. These data tend to substantiate the conclusion that water temperatures in Houghton Creek were not too high for good growth of brown trout.

Pollution

The following discussion of pollution refers to conditions prevailing during the period 1950-1957. Conditions may have changed somewhat since 1957.

The headwaters of Houghton Creek receive pollution from only one or two septic tank outlets.

There are several sources of pollution in the vicinity of Rose City. About 50 feet above the entrance of Sandbach Creek a drain from a group of tourist cabins enters the stream. Sandbach Creek receives a drain from another group of cabins on the west side of highway M-33. During the period 1950-1957 the Rose City Park discharged the outlet of its septic tank into Houghton Creek. The Rose City Park is owned by the city and contains 5 tourist cabins, parking space for about twenty house trailers, and toilet facilities for users of the park.

The major source of pollution of Houghton Creek is a storm sewer entering about 325 yards below the road bridge east of Rose City. This sewer carries raw domestic sewage from Rose City. From about March 1949 to August 1951, the Rose City Cooperative Dairy also discharged waste waters into this storm sewer. The principal product of this dairy was cheese.

Table 5.--Maximum water temperatures (°F.) for Houghton Creek and two tributaries during late summer, 1951. Data collected by Frank Snyder, U.S.S.C.S., Rose City, Michigan

Station[1]	Aug. 9-16	Aug. 16-23	Aug. 23-25	Aug. 25-27	Aug. 27-31	Aug. 31-Sept. 8	Sept. 24	Sept. 24-Oct. 12
1	64	62	63	66	65	65	64	63
2	63	60	61	65	64	63	60	59
3	63	61	60	65	62	..	..	..
4	..	65	70	68	70	66	62	..
5	..	64	65	68	70	..	..	..
6	..	61	61	..	..	..	..	..
7	..	63	63	68	67	67	62	65
8	66	63	63	66	..	..	..	..

[1] See Figure 2.

During October 1950 and October 1955, the Michigan Water Resources Commission conducted surveys to determine the effects of discharge from the Rose City storm sewer. These surveys indicated that the amount of pollution was not sufficient to deplete the dissolved oxygen enough to harm fish life. However, for five miles below Rose City, the water was judged to be unfit for swimming or drinking.

Locke (1941) studied Houghton Creek, and he recorded "no pollution" on stream survey data forms. However, Locke observed a great abundance of isopods and amphipods in the stream below Rose City in 1941, and recent studies by the present writer have shown that the abundance of these organisms is associated with the Rose City sewage. Presumably pollution was entering Houghton Creek during 1941 but Locke did not regard it as significant. The writer was informed by residents at Rose City that the domestic sewage from the storm sewer has flowed into the stream since about 1930.

Water chemistry

Water samples were collected at eight stations on Houghton Creek (Fig. 2) on seven dates during 1952 (Nov. 28) and 1953 (Feb. 26, May 28, July 2, July 31, Aug. 25 and Nov. 27). Three groups of samples were analyzed in the Lansing office of the Michigan Department of Health, and five sets of samples were analyzed in the laboratory of the Institute for Fisheries Research. The data from these analyses on alkalinity, phosphorus and nitrogen are summarized in Table 6.

The pH and methyl orange alkalinity were quite uniform throughout the length of Houghton Creek during 1952-53, and were within the range of values for Houghton Creek found by Locke (1951) during 1941.

The amounts of soluble phosphorus, total phosphorus, and total nitrogen increased from station 2 to station 3, apparently due to the inflow of the sewage from Rose City. The changes in total phosphorus and total nitrogen

Table 6.--Chemical analysis of water from Houghton Creek, 1952-53.

Water chemistry stations are indicated on Figure 2

Station	pH[1]	Methyl orange alkalinity[2]		Soluble phosphorus[3] (ppm.)		Total phosphorus[2]		Total nitrogen[2]	
		Range	Average	Range	Average	Range	Average	Range	Average
1	8.5	188-197	192	0.002-0.004	0.003	0.013-0.060	0.026	0.06-1.15	0.55
2	8.4	161-185	169	0.002-0.008	0.005	0.013-0.080	0.037	0.27-0.50	0.40
3	8.3	164-185	168	0.004-0.049	0.018	0.022-0.140	0.078	0.20-0.85	0.58
4	...	162-185	168	0.010-0.027	0.016	0.027-0.160	0.080	0.40-0.75	0.53[6]
5	...	167-185	171	0.008-0.013	0.012	0.026-0.160	0.078	0.22-1.00	0.64
6	8.3	170-185	173	0.005-0.013	0.010	0.025-0.130	0.065	0.22-1.20	0.54
7	8.3	172-190	176	0.009-0.012	0.010	0.024-0.100	0.060	0.35-0.50	0.45[6]
8	8.3	169-195	181[4]	0.006-0.012	0.010[5]	0.022-0.080	0.044[4]	0.15-0.65	0.43

[1]Single determinations made on July 27, 1952 by author.

[2]Seven determinations. Those on November 28, 1952, and February 26 and May 28, 1953 were made in the laboratory of the Michigan Department of Health. Those on July 2, July 31, August 25 and November 27, 1953 were made in I. F. R. laboratory.

[3]Based on four sets of samples collected on July 2, July 31, August 25, and November 27, 1953; analyses by I. F. R.

[4]Location of site 8 for November 27, 1953 not certain.

[5]Analysis available only for July 31 and August 25, 1953.

[6]Three determinations, on November 28, 1952, and February 26 and May 28, 1953, by Michigan Department of Health.

downstream from the sewer outfall appeared to be largely due to dilution. The soluble phosphorus, however, decreased rapidly above Wilkens Creek; this was probably due largely to biological uptake.

Biological survey

Stream vegetation

Locke (1951) observed that vascular aquatic plants were confined to small beds in the lower section of Houghton Creek in an area above the mouth. He recorded (on stream survey data forms) the presence of Anacharis (Elodea) and Potamogeton vaginatus.

During the present study Anacharis sp. and Ranunculus trichophyllus commonly occurred together to form dense beds, especially in that part of Houghton Creek in Section 10. The observed upper limit of these two forms was near Rose City. Potamogeton vaginatus was generally sparse, except in the lower third of Houghton Creek where some of the deeper water had extensive beds. Chara was abundant in the lowermost abandoned beaver pond in Section 18 (Fig. 1), common in Section 30, and sparse below Section 30. An occasional small dense bed consisted of a mixture of Chara and Anacharis. The aquatic moss, Fontinalis, was abundant in many spots in Houghton Creek where a permanent, solid substrate was available.

In the fall of 1950, filamentous algae was abundant below the Rose City sewer outfall, especially from a short distance below the sewer to the beginning of a dense swamp, about a mile downstream. From this point to the mouth it was common. It was observed that the abundance of algae below Rose City during the summer had declined considerably by 1953. This decline may have been due to the fact that waste waters from the dairy were not discharged into the stream after August 1951. Locke (1951) did not mention the occurrence of heavy growths of algae in Houghton Creek during 1941; this was before the dairy commenced operation.

Bottom fauna, quantitative studies

Quantitative samples of bottom fauna were collected from various bottom soil types over the study area. The data from these samples, in conjunction with the data on the proportions of different bottom soil types in different areas of the stream, will serve as one method of measuring the ability of the stream to produce bottom fauna. The present sampling was done during the period from November 1950 to April 1954, and no detailed analysis is made to detect changes in the bottom fauna over this period. Rather, a comparison of these data from the present study with similar data collected in later years will supply information on the effects of the watershed development program on the bottom fauna.

In November and December of 1950, twenty-four samples of bottom fauna were taken at 11 different locations; bottom soils at sampling sites were gravelly riffles, shifting sand, and clay. In this initial sampling, sand and clay produced comparatively small amounts of bottom fauna; therefore the sampling of these substrates was not continued. Six stations on gravelly riffles, including four which were sampled during 1950, were sampled in December of 1951, 1952, and 1953. Areas of silt and vegetation were sampled in 1953. Sampling of bottom fauna was done at the same stations where bottom soils were mapped in detail (see Fig. 1 for locations).

The quantitative samples of bottom fauna were collected in three ways: (1) A Surber-type stream bottom sampler was used in shallow, flowing water to take one-square-foot samples, and with a slight modification to take one-half-square-foot samples. (2) A 24-inch section of 7-inch (diameter) stove pipe was used to collect samples in beds of vegetation and in areas of slowly moving or standing water with silt bottom. (A circle of 7-inch diameter has an area of 0.267 sq. ft.; the samples taken with the 7-inch pipe are listed here as 1/4-square-foot samples.) The pipe was pushed into the bottom and the enclosed material was removed. (3) Bottom fauna in aquatic moss was sampled as follows: a moss-covered stone was lifted carefully from the water; a 3-inch by 3-inch patch of moss was outlined by scraping away the surrounding vegetation; and the last step was to scrape off and save the patch of moss and its organisms.

In processing bottom samples, organisms were hand sorted from the debris, except in the case of samples containing much silt. Samples with silt were washed through a Tyler screen, of 32 meshes per inch. Samples were preserved in 85 percent alcohol; and counts and volume determinations on organisms were made in the laboratory during 1957. The volume of organisms in each sample was determined by water displacement, using small glass cylinders graduated in tenths of milliliters.

The data from all the quantitative bottom samples collected during this study, and data on a pertinent series of samples taken at stations U.S. and L.S. (Fig. 1) as part of another study (Ellis and Gowing, 1957) are given in tables in an appendix to this report. No attempt has been made to define any quantitative changes in the bottom fauna during the period (1950-1953) covered by this study. The present data will be of value for comparison with samples collected in the future.

The sampling of bottom fauna included a one-square-foot sample on gravelly riffles each winter (mostly in December) from 1950 through 1953 at each of five stations (sites 1, 4, 5, 7, and 12); the number and volume of organisms in each sample are given in Table 7. For the bottom fauna samples listed in Table 7, data for the four yearly samples from each site were combined, and the proportion of the total volume represented by each major type of organism in the bottom fauna was computed for each site (Table 8). Three groups--Trichoptera, Asellus, and "all others"--together made up over 50 percent of the volume of the combined sample for each site. These groups have distributions which are of special interest.

Table 7.--Number and volume (in milliliters) of bottom organisms in a one-square-foot sample from gravelly riffles at each of five sites on Houghton Creek during each winter (mostly December) from 1950 to 1953

Site	1950		1951		1952		1953		Mean	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
1	1,063	3.92	716	1.65	656	1.58	...[2]	1.80	811	2.24
4	335	0.59	412	0.77	443	1.24	515	1.01	426	0.90
5	708	5.39	1,522	8.27	1,096	3.87	2,213	5.82	1,384	5.83
7	339	5.59	450	1.51	477	2.09	676	2.38	486	2.89
12	1,089[1]	4.67[1]	813	3.88	1,337	8.04	...[2]	7.43	1,079	6.00

[1] Sample collected March 20, 1951.

[2] Sample was lost before organisms were counted.

Table 8.--Percentage of the total volume of organisms represented by the major groups of the bottom fauna in bottom samples collected from gravelly riffles at five sites in Houghton Creek. Samples taken each winter, 1950 through 1953, are combined. Table 7 involves the same samples

Group	Sample sites 1	4	5	7	12
Trichoptera	26	34	14	54	68
Ephemeroptera	14	21	14	6	8
Plecoptera	2	7	1	1	1
Diptera	11	7	18	34	11
Asellus	0	0	46	5	5
Gammarus	1	2	3	trace	1
All others	46	29	4	trace	6

The abundance of Asellus has been found to be closely associated with the concentration of sewage in Houghton Creek (Ellis, unpublished); and in these bottom samples the abundance of Asellus was greatest at site 5 (below the Rose City sewage outfall) and fell off sharply at sites 7 and 12. The abundance of Trichoptera increased from site 1 downstream to site 12, with the exception of site 5 where Asellus was so abundant. The proportion of net building caddis flies (Trichoptera, in part) increased downstream from site 1, to the extent that at site 12 Hydropsyche and Cheumatopsyche were the dominant animals in numbers and volume. The "all other" group (mostly riffle beetle larvae and adults, aquatic earthworms, and snails) showed a marked decrease from site 1 to site 12.

The abundance of bottom fauna for different bottom soils is summarized in Table 9, from data on the original samples given in appendix tables. For this summary the stream is divided into the section "above Rose City sewer" and the section "below Rose City sewer"; the stream below Rose City has more bottom organisms on each bottom soil type (except clay), presumably due to the fertilizing effect of the sewage. Beds of vegetation (both Fontinalis moss on rocks and higher aquatic plants) contained the most organisms both above and below Rose City. Silt was second in number of bottom organisms; gravelly riffles was third, and clay and sand had by far the fewest organisms. A majority of the organisms in silt were Tubificidae, which may be used very little as food by trout; a series of trout stomachs from Houghton Creek contained no tubificids.

The abundance of bottom fauna on different substrates should be considered in relation to the amount of the different substrates in the stream (Table 1). For example the high productivity of weed beds loses much of its significance because weed beds occupied only a small fraction (less than 0.5 percent) of the stream area. Silt occupied (in 1952) only 4 percent to 9 percent of the stream area, so that the rich fauna in this substrate is not of major significance.

Table 9.--Average and range in number and volume (in ml) of bottom organisms per square foot for different bottom soil types in Houghton Creek, computed from samples taken during present study (1950-1953). Sample size was 1/16 square foot on Fontinalis moss, 1/4 square foot on higher aquatic plants and on silt, and mostly 1 square foot for other bottom soil types. Samples were all collected during fall and winter except those on "vegetation" below the Rose City sewer which were collected in July and November

Part of stream	Habitat	Collection sites[1]	Number of samples	Bottom organisms per square foot: Range		Bottom organisms per square foot: Average	
				Number	Volume	Number	Volume
Above Rose City sewer	Gravelly riffle	1, 4, U.S.	20	142-1,344	0.44-3.92	626	1.61
	Vegetation	U.S., 15	3	1,776-5,328	6.56-20.68	3,866	11.75
	Silt	4, U.S.	4	328-1,180	0.84-6.12	622	2.94
	Clay	1, 2, 4	4	7-96	0.01-0.07	60	0.04
Below Rose City sewer	Gravelly riffle	7, 12, L.S.	20	312-1,644	1.51-12.38	833	5.10
	Deep gravel	8, 9, 11, 13	5	159-432	0.31-1.31	244	0.77
	Vegetation	5, 9, 11	6	492-15,808	2.42-38.40	5,160	15.02
	Silt	5, 11	4	568-1,600	1.48-43.80	928[2]	13.32
	Clay	5	1	...	...	38	0.05
	Sand	6, 8, 10, 11	5	1-202	trace-0.35	50	0.08

[1] See Figure 1 for location.

[2] The average number does not include sample with largest volume, 43.80 ml/ft^2, because no count was made of Tubificidae in this sample.

Gravelly riffles, gravel in deep water, sand, and clay are the principal bottom soil types (Table 1); gravel, especially in riffles, contained many times as much bottom fauna as did sand or clay. Gravel is the predominant soil type in the upper part of Houghton Creek, but there is a marked displacement of gravel by sand as one proceeds downstream. The result is that the upper part of the stream is much richer in bottom fauna than is the lower part, with some modification of the trend just below the Rose City sewer outfall. The predominance of sand in Houghton Creek below Section 8 (of T. 23 N., R. 3 E.) is apparently related to low gradient and slow current. The production of bottom fauna in this lower third of Houghton Creek could be increased by encouraging aquatic plants such as *Anacharis*, *Ranunculus*, *Potamogeton*, and *Hippurus*. The reduction of peak flows during floods, which is one aim of the watershed development work, should favor the growth of aquatic plants.

Bottom fauna, qualitative studies

Qualitative collections of the bottom fauna were made to give additional information as to the species present and their distribution. These samples were collected with a wire-mesh scap net, and by hand picking from logs, stones, etc., lifted from the water. About 175 such collections were obtained.

Adult forms of insects which have aquatic larvae were collected to learn the seasons of emergence, distribution, and as an aid in identifying the immature forms. These collections were made with air net, by hand picking from objects along the shore, and by use of electrically powered, portable light traps. About 1,000 such collections were made. The work on the collections of adult insects has been nearly completed for the Trichoptera and the Plecoptera. These studies will appear as separate reports. The preliminary data on species composition and time of emergence are in the Institute files.

The collections of adult insects were deposited in the Museum of Zoology of the University of Michigan. They were subsequently transferred to the Academy of Natural Sciences in Philadelphia, but would be available for further study if needed.

Acknowledgments

Some of the records included in the present report were supplied by the United States Geological Survey, United States Soil Conservation Service, Michigan Water Resources Commission and Michigan Department of Health. Mr. W. L. Cristanelli did the drafting, application of Zipatone, and photography on the maps and figures. Mr. Howard Gowing helped me in much of the field work.

INSTITUTE FOR FISHERIES RESEARCH

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Report approved by G. P. Cooper

Typed by M. S. McClure

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Appendix A

Locations of areas mapped for bottom soils and depths, and notes on mapping

In 1950 eleven sections of the stream were mapped, areas 1 through 11. In 1952 eight of these sections were remapped (areas 1, 4, 5, 7, 8, 9, 10, 11). In 1953 six of the eight sections mapped in 1952 were remapped (areas 1, 4, 5, 7, 8, 11) and one new section was mapped (area 13). The field maps were drawn to a scale of one inch equals four feet; the maps show bottom types, cover, and water depths along selected transects across the stream. The areas mapped (see Fig. 1) were selected to represent different physical conditions throughout the 7.2 miles of stream under intensive study. By comparing these maps with maps of the same areas made at a later date, changes in the substrate or contours could be detected.

The original maps (size about 24" x 36") were made in the field by a two-man crew using plane table, alidade, compass, and steel tape. In the laboratory, tracings were made from the original maps. These tracings were photographed, and reduced-size prints (16" x 20") were made. The bottom soils were delimited by use of "Zipatone" on these 16" x 20" prints, and the maps were further reduced photographically for use in this report.

On the small prints which accompany this report, it is difficult to see the difference between certain Zipatone patterns. If, for any future study, it is desirable to make planimeter measurements on areas of different types of bottom soils, the best procedure will be to use the 16" x 20" prints (in Institute files) on which the Zipatone was originally applied.

Mapping of bottom soils was concerned only with materials covering the surface of the stream bottom--the upper 1 to 2 inches. Mixtures of two types, or instances where a thin layer (1 inch or less) of one type covered another type, were so recorded. For example, if gravel was covered by a thin layer of sand, the map shows a mixture of sand and gravel.

Bottom soils were classified subjectively in the field. Some descriptive terms used on the original maps were combined when outlining the bottom types on the finished maps. The bottom soil types and their definitions as used on the finished maps are as follows:

<u>Clay</u>: Firm, very fine particles, inorganic, creamy white.

<u>Silt</u>: Fine particles, usually dark in color, with much organic material.

<u>Sand</u>: Inorganic particles, generally less than one millimeter in diameter.

<u>Sand and fine gravel</u>: A mixture of sand, and inorganic particles ranging in diameter from about two to ten millimeters.

<u>Medium gravel</u>: Particles ranging from about ten to thirty millimeters in diameter.

<u>Coarse gravel and rubble</u>: Particles over thirty millimeters in diameter.

<u>Aquatic plants</u>: Vascular aquatic plants.

<u>Peat</u>: Woody, consolidated, organic material.

The locations of the areas mapped are indicated in Figure 1. A description of the location of each area is also included in this appendix (below). A cedar post, 2 inches in diameter, bearing a numbered brass plate was set in each mapping area in 1950. When possible, these posts were set in locations where they would be protected. The location of each post is indicated on the original field map of each area, and is described below for those areas (1, 4, 5, 7, 8, 11 and 13) for which maps are included in this report, except that no marker was placed in Area 13. The following are descriptions of the locations of areas 1 through 15 as used in this report.

Area 1. In the SE 1/4 of Sec. 30, T. 24 N., R. 3 E. A marker is located 62 feet below the footbridge in front of the main building on Krause's. This marker is a cedar post, bearing brass plate No. 1, located 8 feet east of the east end of transect A-A shown on Area 1 Map A (maps follow P. 34). Approximately 240 feet of stream was included on two maps.

Area 2. The plane table, for the initial setting, was located in the stream at the upper end of the new channel dug by the Lake and Stream Improvement crew, in the NE 1/4 of Sec. 31, T. 24 N., R. 3 E. Approximately 130 feet of stream was included on one map.

Area 3. The plane table was located in the stream 17 feet below a fence across the stream. This area is in the NE 1/4 of Sec. 31, T. 24 N., R. 3 E., approximately 120 feet above the upper end of Area 4. Approximately 100 feet of stream was included on one map.

Area 4. In Sec. 31, T. 24 N., R. 3 E. This area is mostly above Morrison's north fence (the fence crosses Area 4 Map F). A cedar post bearing brass plate No. 4 is set alongside an elm tree 8 feet west of the west end of transect A-A on Area 4 Map F. Approximately 664 feet of stream was included on six maps.

Area 5. In the NE 1/4 of Sec. 6, T. 23 N., R. 3 E. The plane table was located in the stream 5 feet below the first fence above the "city limits" road, one-half mile east of Rose City. This fence is located at the beginning of the exposed clay banks on the south side of the stream. A cedar post with brass plate No. 5 is set along east side of fence post, 6 feet north of north end of transect A-A on Area 5 Map D. Approximately 456 feet of stream was included on four maps.

Area 6. The plane table was located in the stream approximately 120 feet above the first road bridge above the mouth of Wilkens Creek, in S 1/2 of SE 1/4 of Sec. 5, T. 23 N., R. 3 E. Approximately 120 feet of stream was included on one map.

Area 7. At mouth of Wilkens Creek, in the N 1/2 of NE 1/4 of Sec. 8, T. 23 N., R. 3 E. A cedar post, with brass plate No. 7, is set on south side of elm tree, 5 feet north of the north end of transect D-D on Area 7 Map A. Approximately 116 feet of stream was included on one map.

Area 8. The plane table was located on the stream bank, on Smith's property in T. 23 N., R. 3 E., Sec. 4 (SW 1/4), approximately 1,000 feet above the north-south fence which runs along the middle of the SW 1/4 of Sec. 4. A cedar post, with brass plate No. 8, is set between two elm trees, 20 feet south of the south end of transect B-B on Area 8 Map D. Approximately 480 feet of stream was included on four maps.

Area 9. The plane table was located on shore approximately 8 feet upstream from the road fence, in T. 23 N., R. 3 E., Sec. 4 (SE 1/4 of SW 1/4), just above the road bridge at Walters' (this road runs north-south through the middle of Sec. 4). Approximately 96 feet of stream was included on one map.

Area 10. The plane table was set in the stream approximately 100 feet above the first log jam downstream from the north end of Graber's and about 300 feet downstream from the boundary line between Sections 4 and 9, in T. 23 N., R. 3 E., Sec. 9 (NW 1/4 of NE 1/4). Approximately 124 feet of stream was included on one map.

Area 11. In the SW 1/4 of Sec. 11, T. 23 N., R. 3 E. approximately 1,200 feet below Boyer's. A cedar post, with brass plate No. 11, is set 4 feet southwest of the southwest end of transect D-D on Area 11 Map C. Approximately 528 feet of stream was included on four maps.

Area 12. Bottom sampling and collecting site only; not mapped. The bottom sampling site was the first gravelly riffle downstream from the U.S.G.S. stream gaging station, about 100 yards above the west boundary of the Rifle River area.

Area 13. The lower end of this area is about 800 feet above the east-west road bridge on the line between Sections 4 and 9; the area extends upstream for about 600 feet, in T. 23 N., R. 3 E., Sec. 8 (NE 1/4). The area can be located more precisely by a large elm tree, 2.5 feet in diameter, which is 7 feet northeast of the northwest end of transect C-C on Area 13 Map F.

Area 14. Bottom sampling and light-trap collecting site only; not mapped. This area extends downstream about 100 yards from the east-west road bridge on the line between Sections 30 and 31.

Area 15. Collecting site for adult insects only. Adult insects were collected from the walls of the road bridge over Houghton Creek east of Rose City. Also, one sample of bottom fauna, collected in the stream just below the bridge, is listed as site 15.

Upper Sewer site (U. S. in Fig. 1). Bottom sampling site used by Ellis and Gowing (1957), located about 200 yards above the road bridge east of Rose City, and above the sewer outfall.

Lower Sewer site (L. S. in Fig. 1). Bottom sampling site by Ellis and Gowing (1957), located about 100 yards above the boundary line between Sections 5 and 6, and below the sewer outfall.

MAP LEGEND

PRIMARY SOIL TYPES

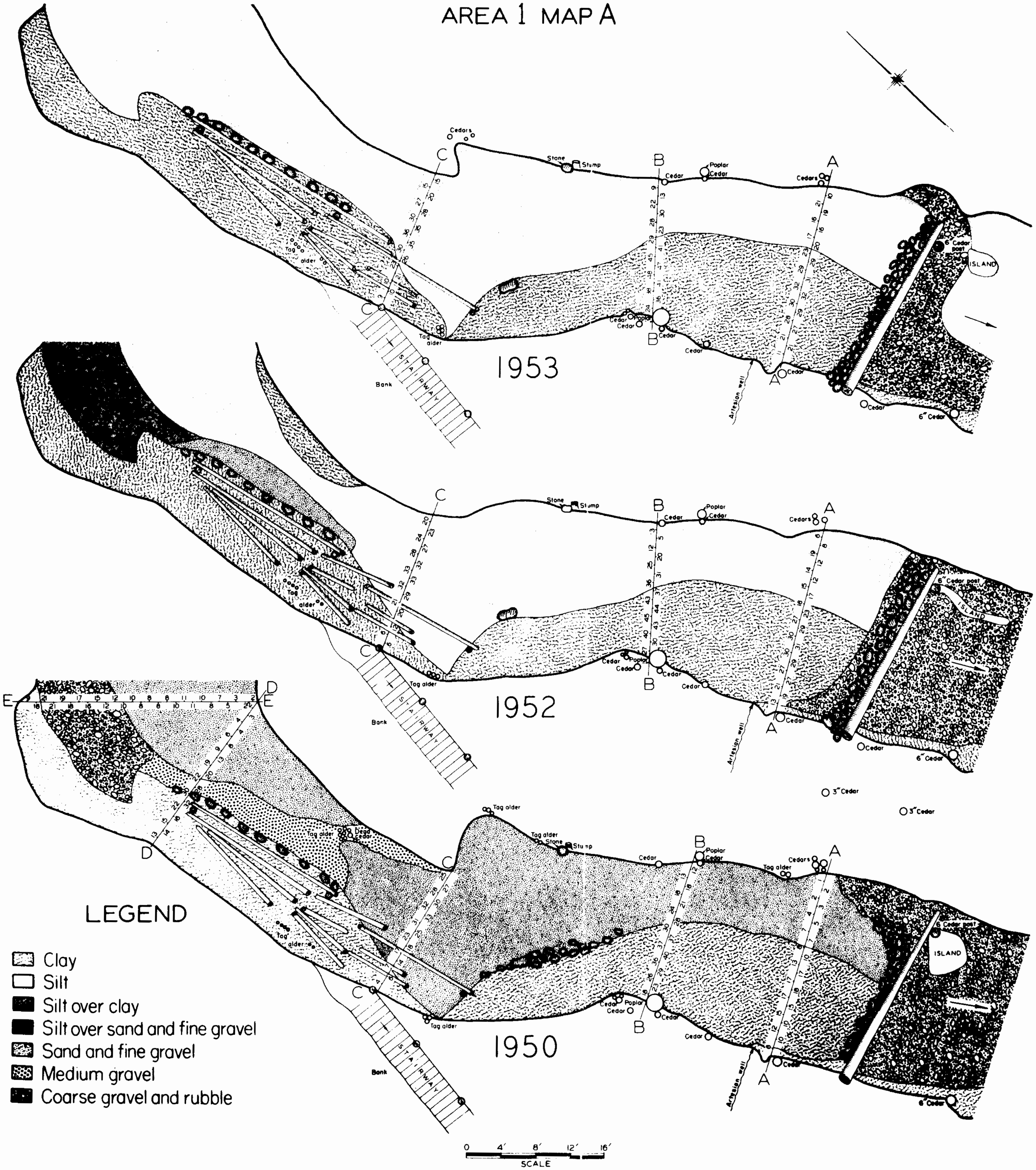
- Clay
- Silt
- Sand
- Sand and fine gravel
- Medium gravel
- Coarse gravel and rubble
- Aquatic plants
- Peat

MIXTURES OF SOIL TYPES

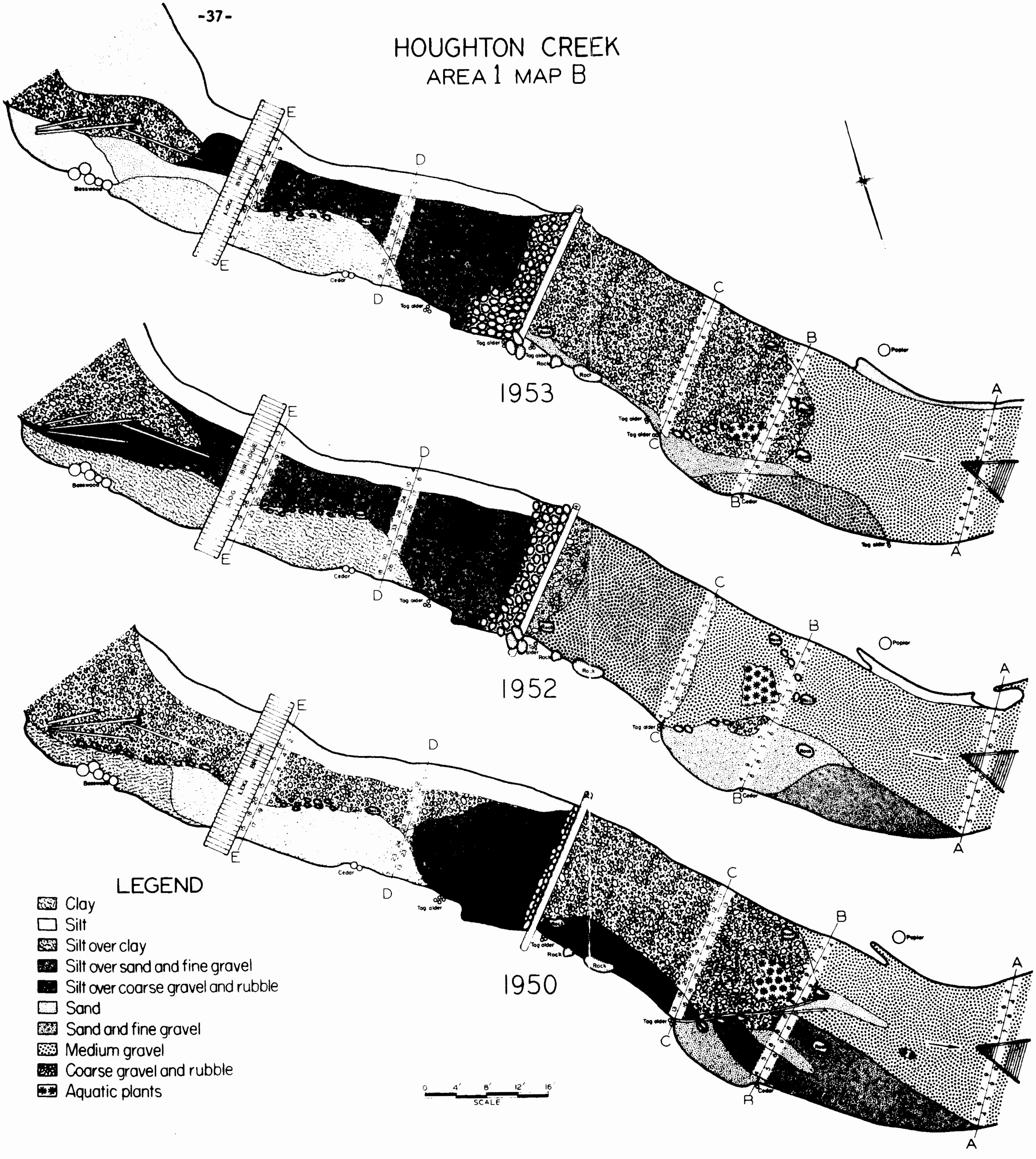
- Clay plus silt
- Clay plus sand
- Clay plus medium gravel
- Clay plus coarse gravel and rubble
- Silt plus sand
- Silt plus sand and fine gravel
- Silt plus medium gravel
- Silt plus coarse gravel and rubble
- Sand plus medium gravel
- Sand plus coarse gravel and rubble
- Sand and fine gravel plus peat

11 20 21 26 27 33 32 39 Depth of water in inches

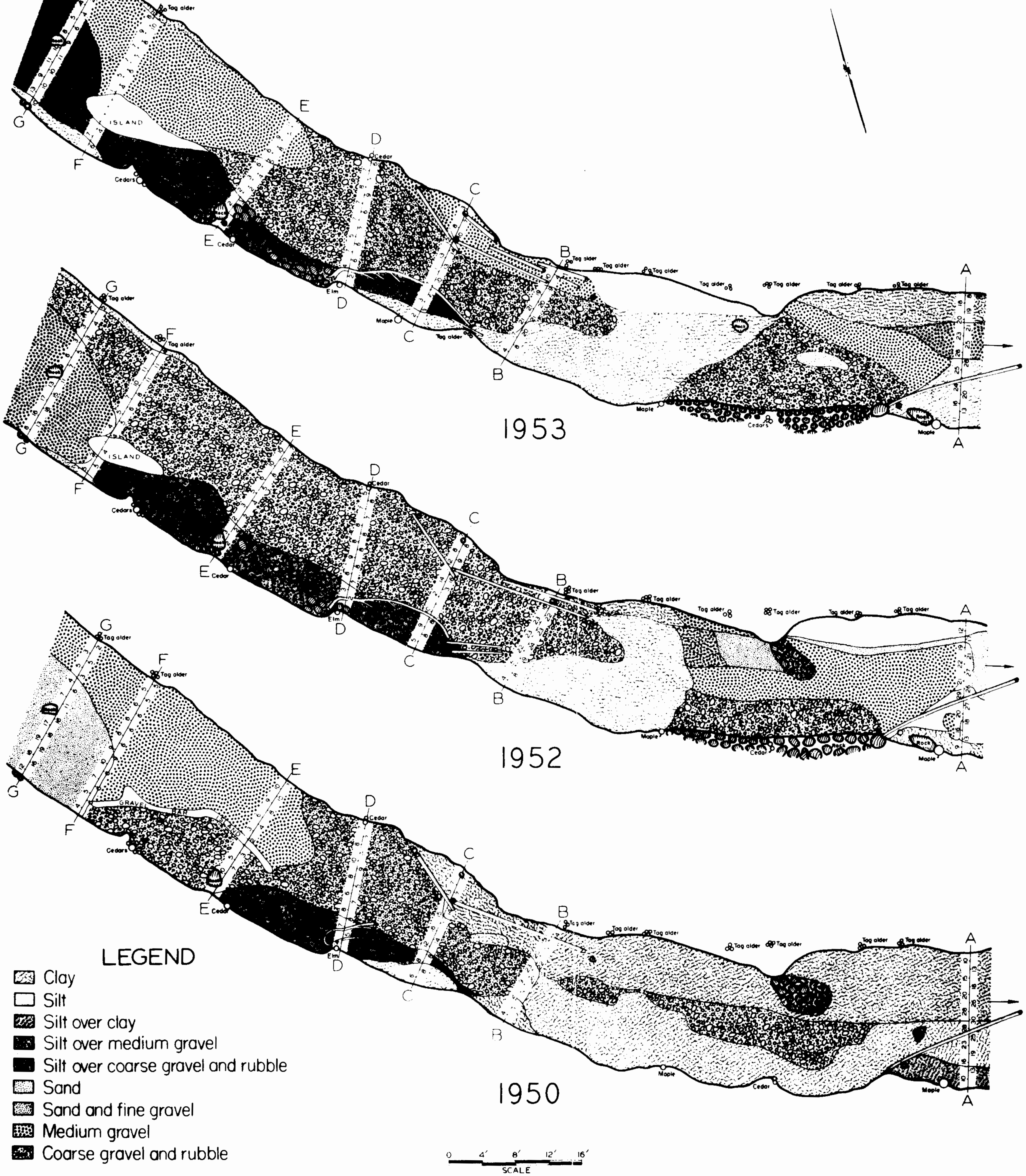
HOUGHTON CREEK
AREA 1 MAP A



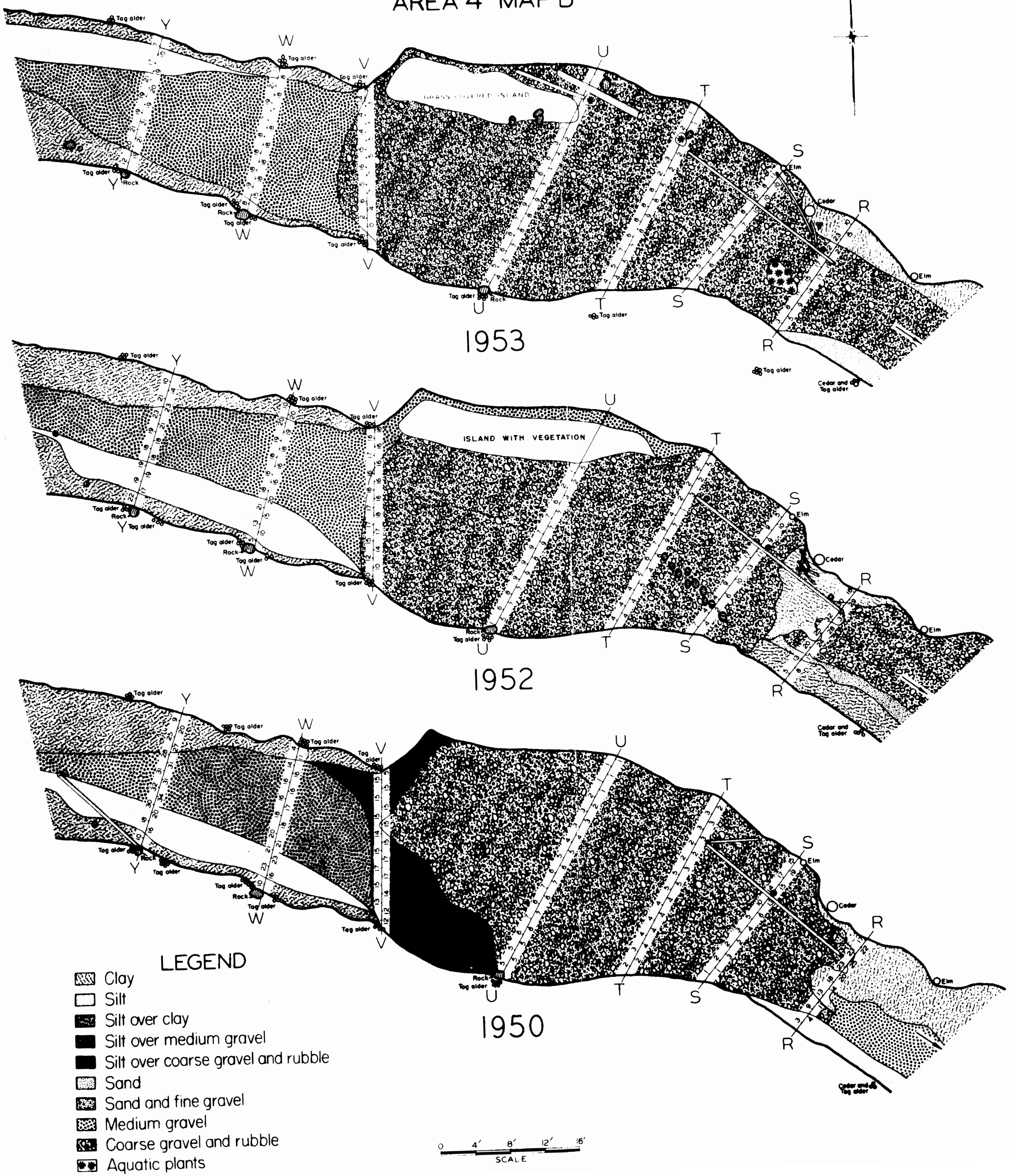
HOUGHTON CREEK
AREA 1 MAP B

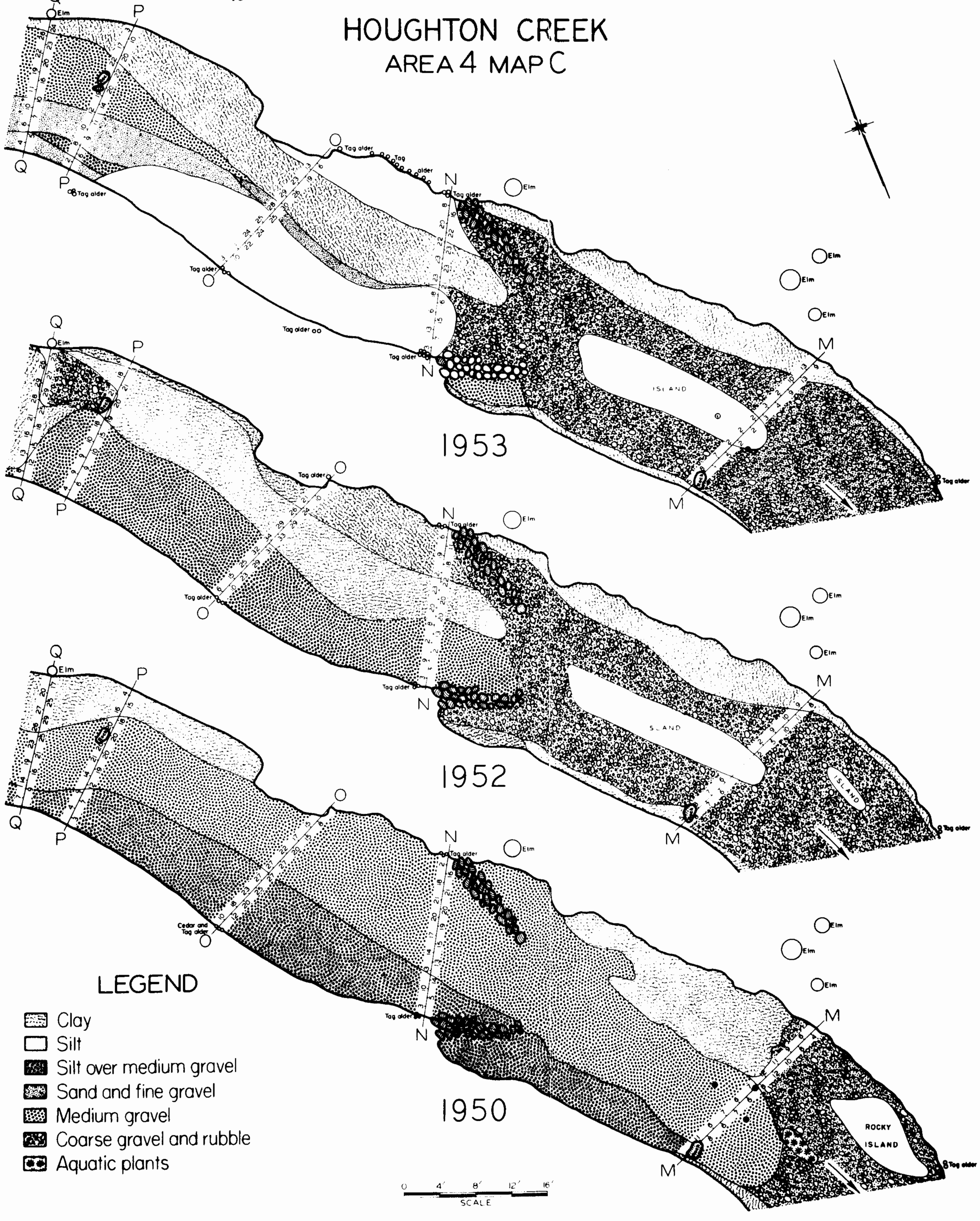


HOUGHTON CREEK
AREA 4 MAP A

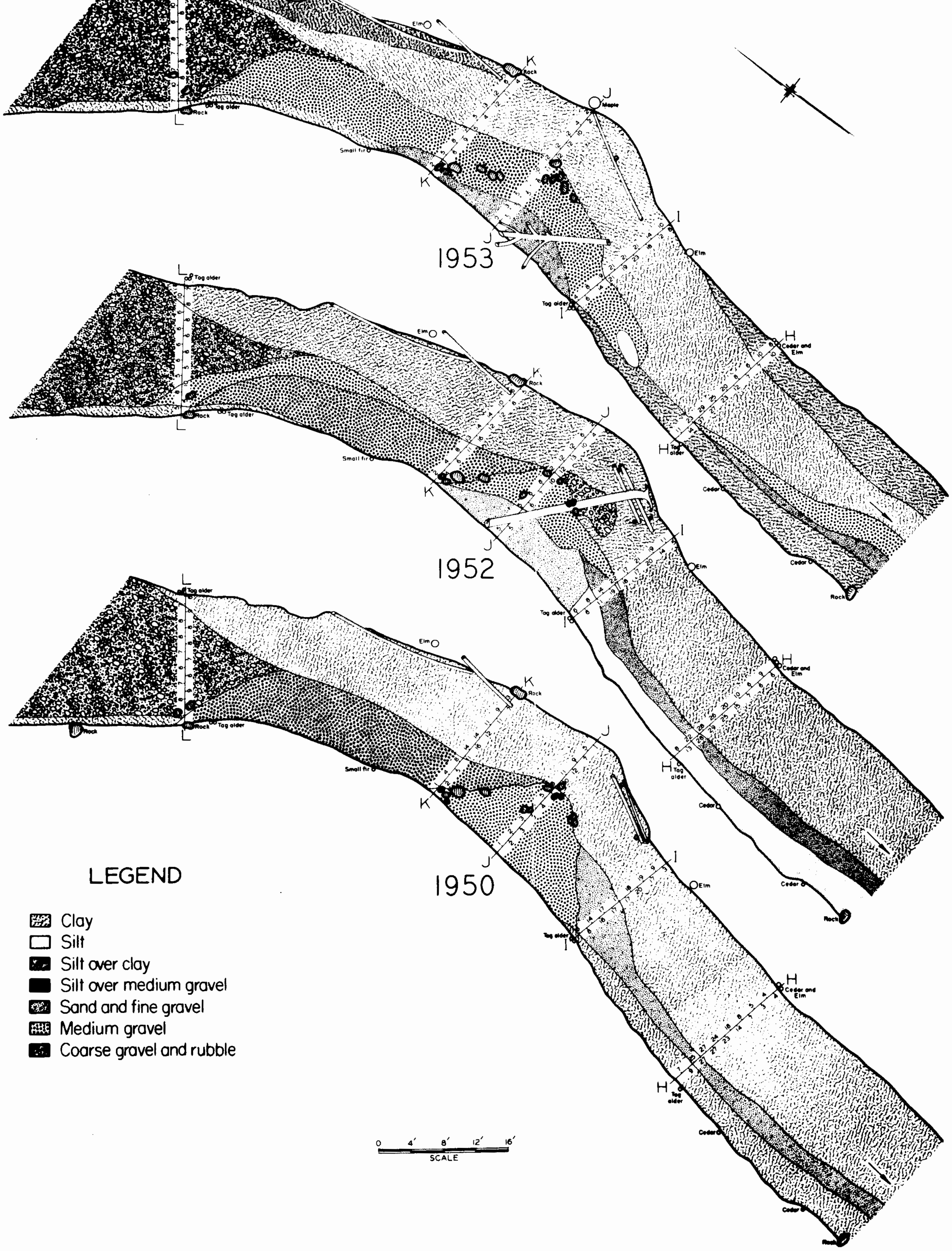


HOUGHTON CREEK
AREA 4 MAP B

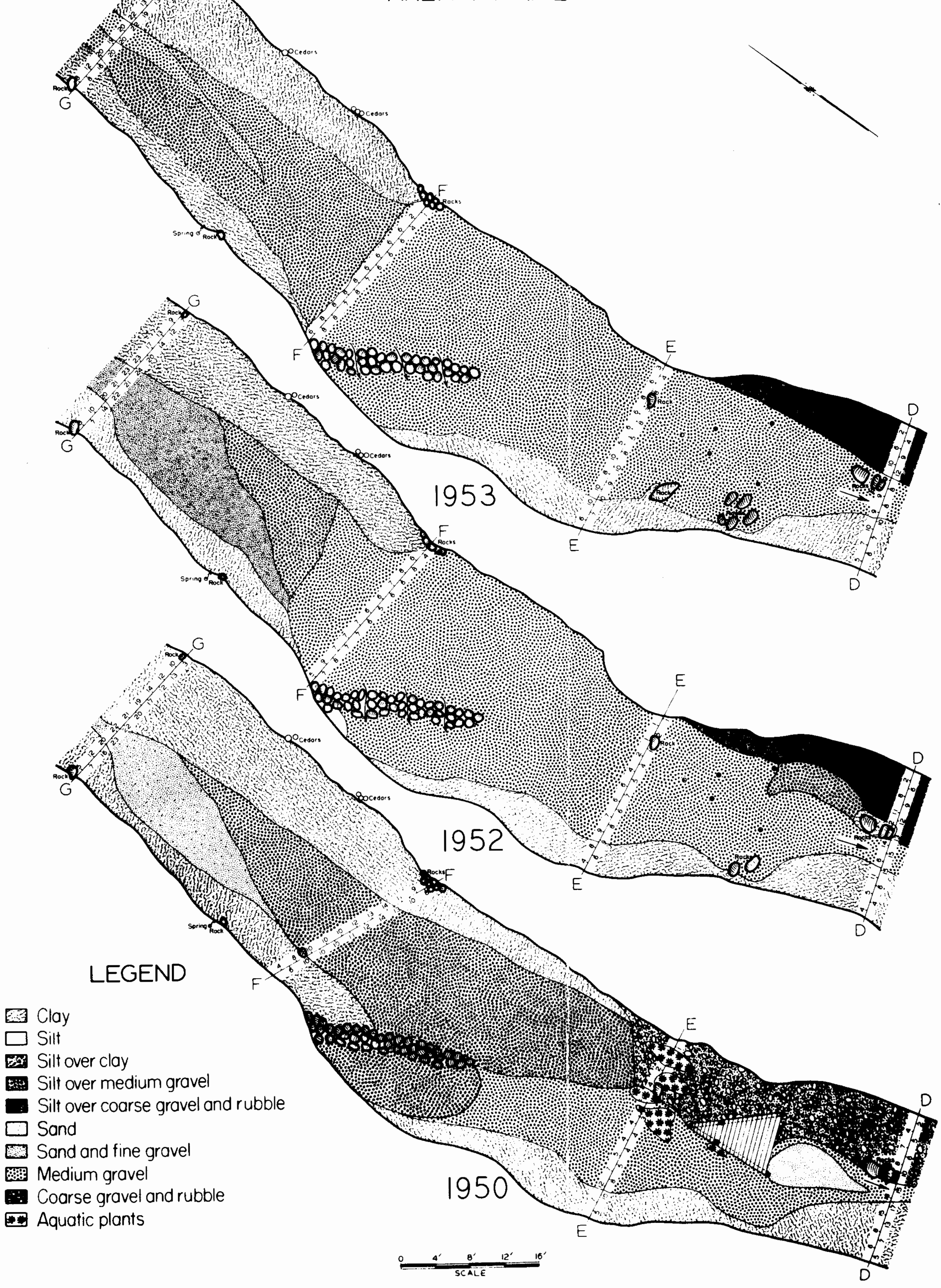


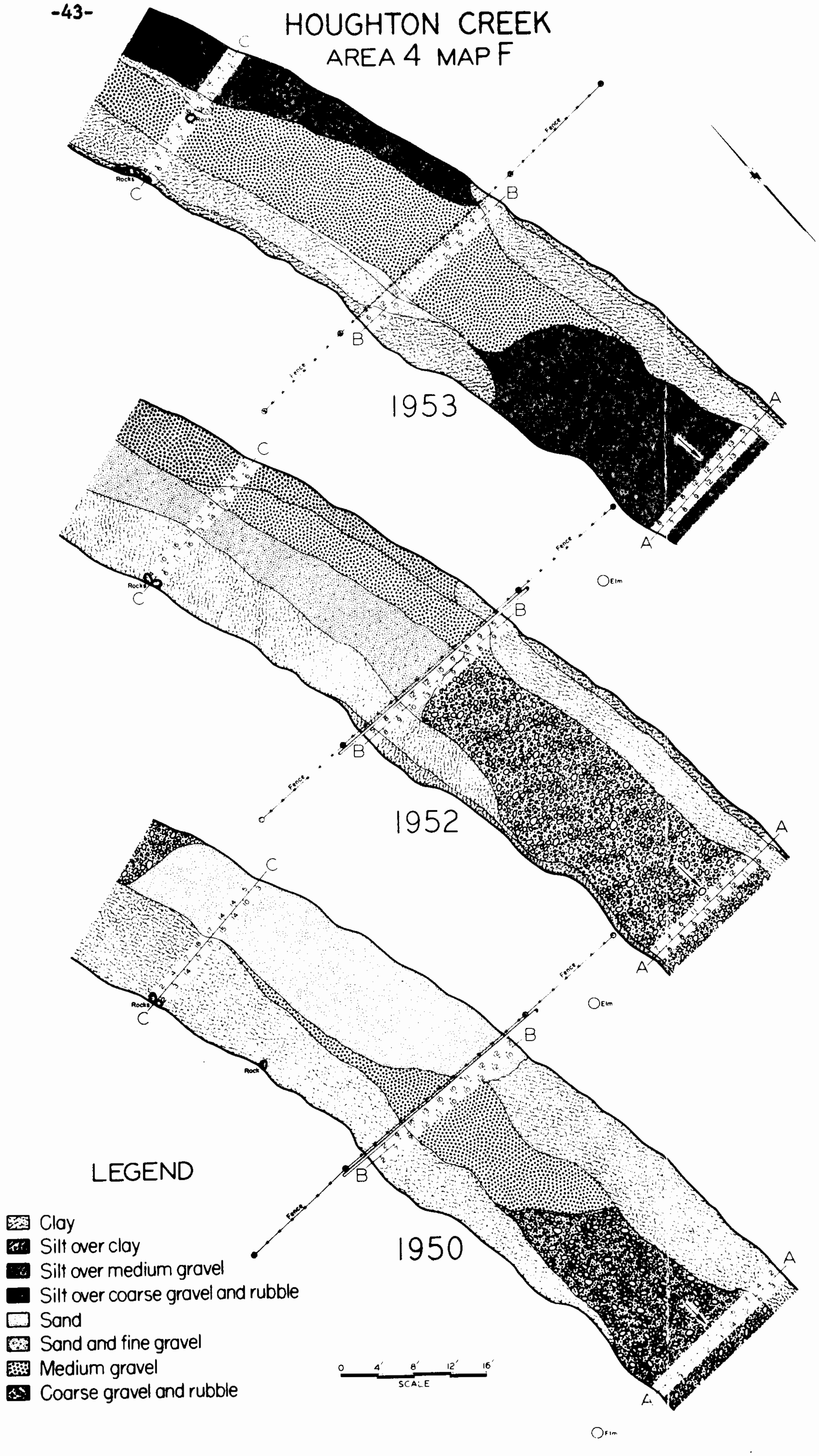

HOUGHTON CREEK
AREA 4 MAP C
1953
1952
1950
ISLAND
ROCKY ISLAND
Elm
Tag alder
Cedar and Tag alder
LEGEND
Clay
Silt
Silt over medium gravel
Sand and fine gravel
Medium gravel
Coarse gravel and rubble
Aquatic plants
SCALE

HOUGHTON CREEK
AREA 4 MAP D

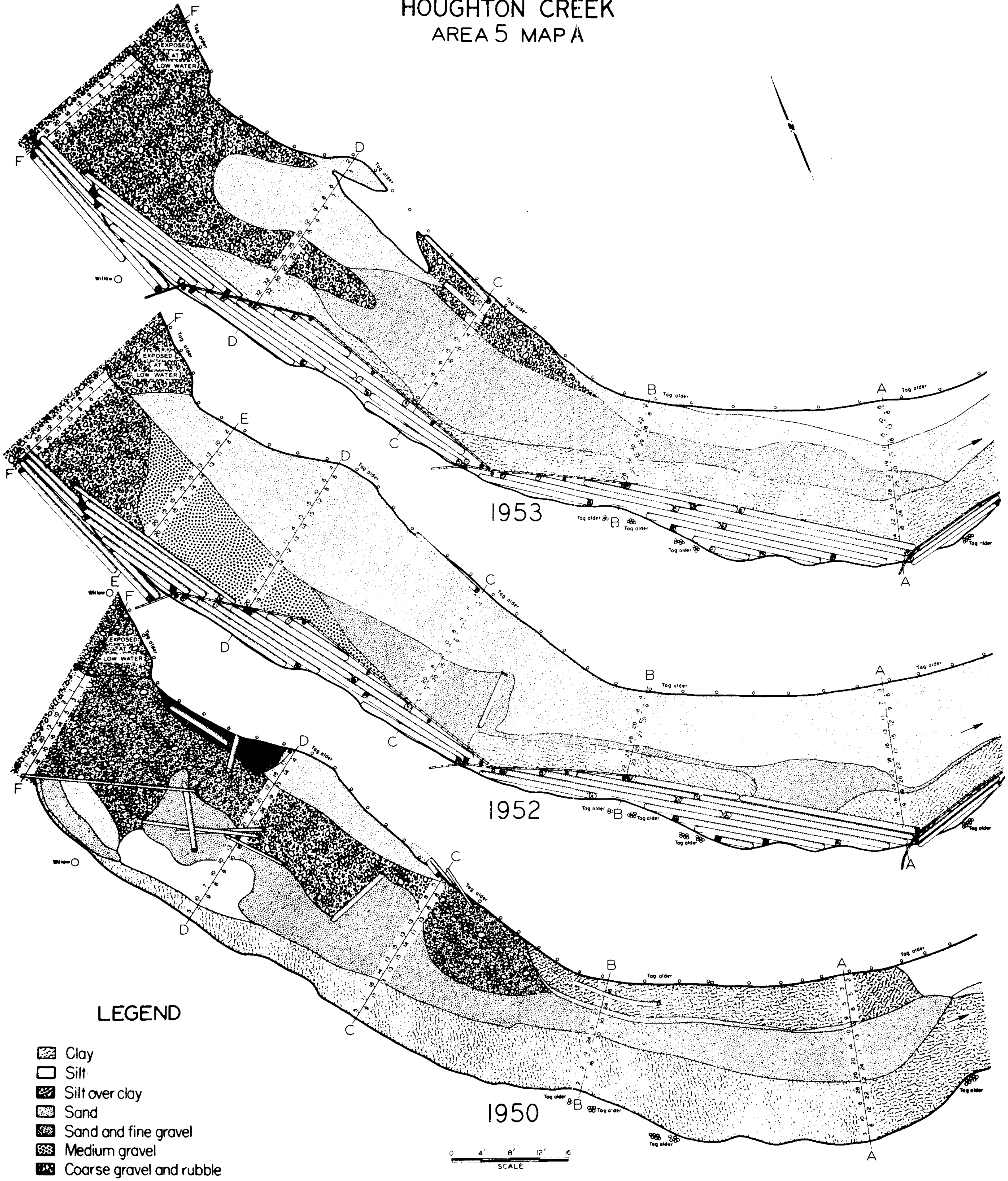


HOUGHTON CREEK
AREA 4 MAP E

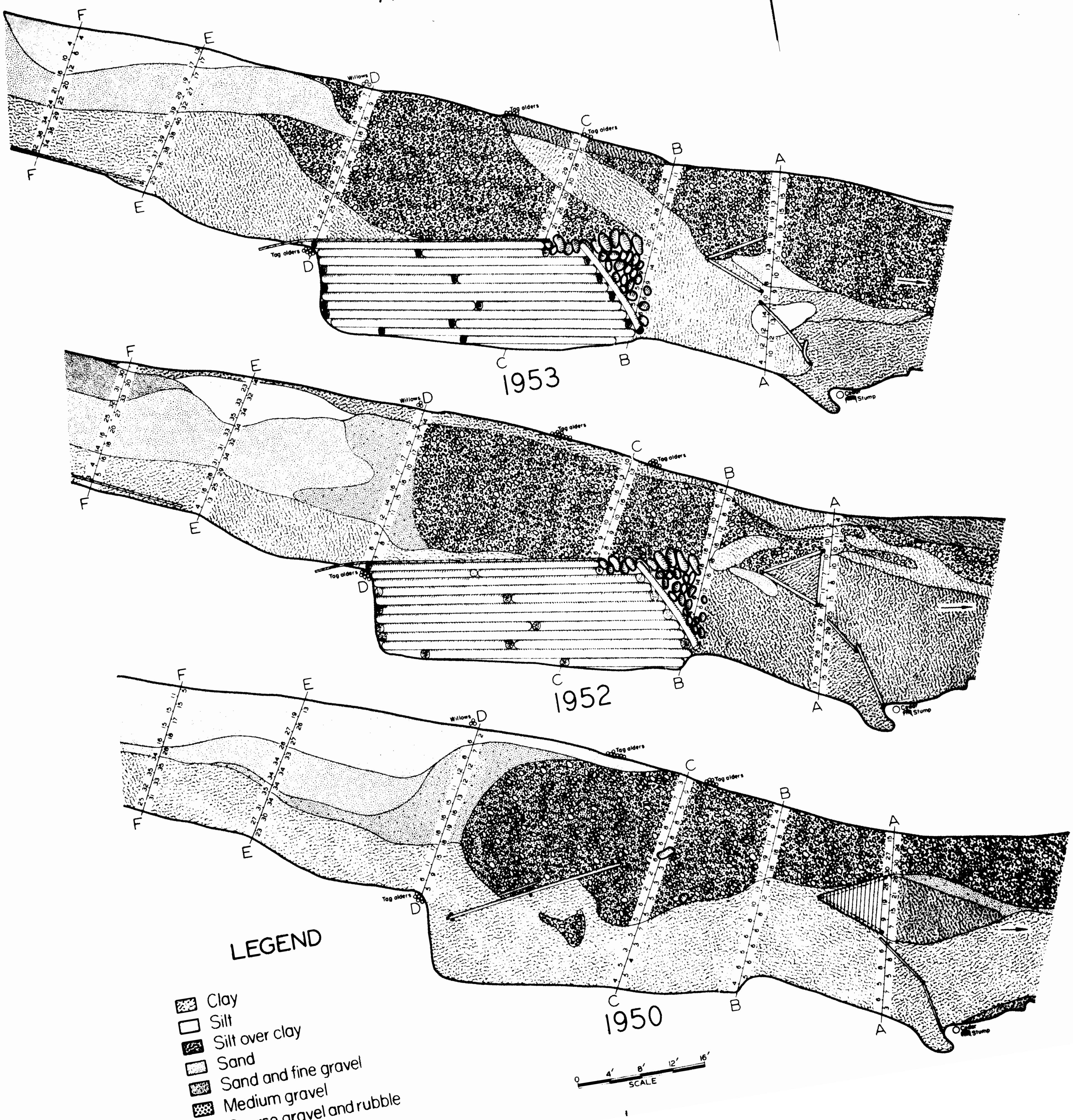



HOUGHTON CREEK
AREA 4 MAP F
1953
1952
1950
A
B
C
Fence
Rocks
Rock
Elm
LEGEND
Clay
Silt over clay
Silt over medium gravel
Silt over coarse gravel and rubble
Sand
Sand and fine gravel
Medium gravel
Coarse gravel and rubble
0 4' 8' 12' 16'
SCALE

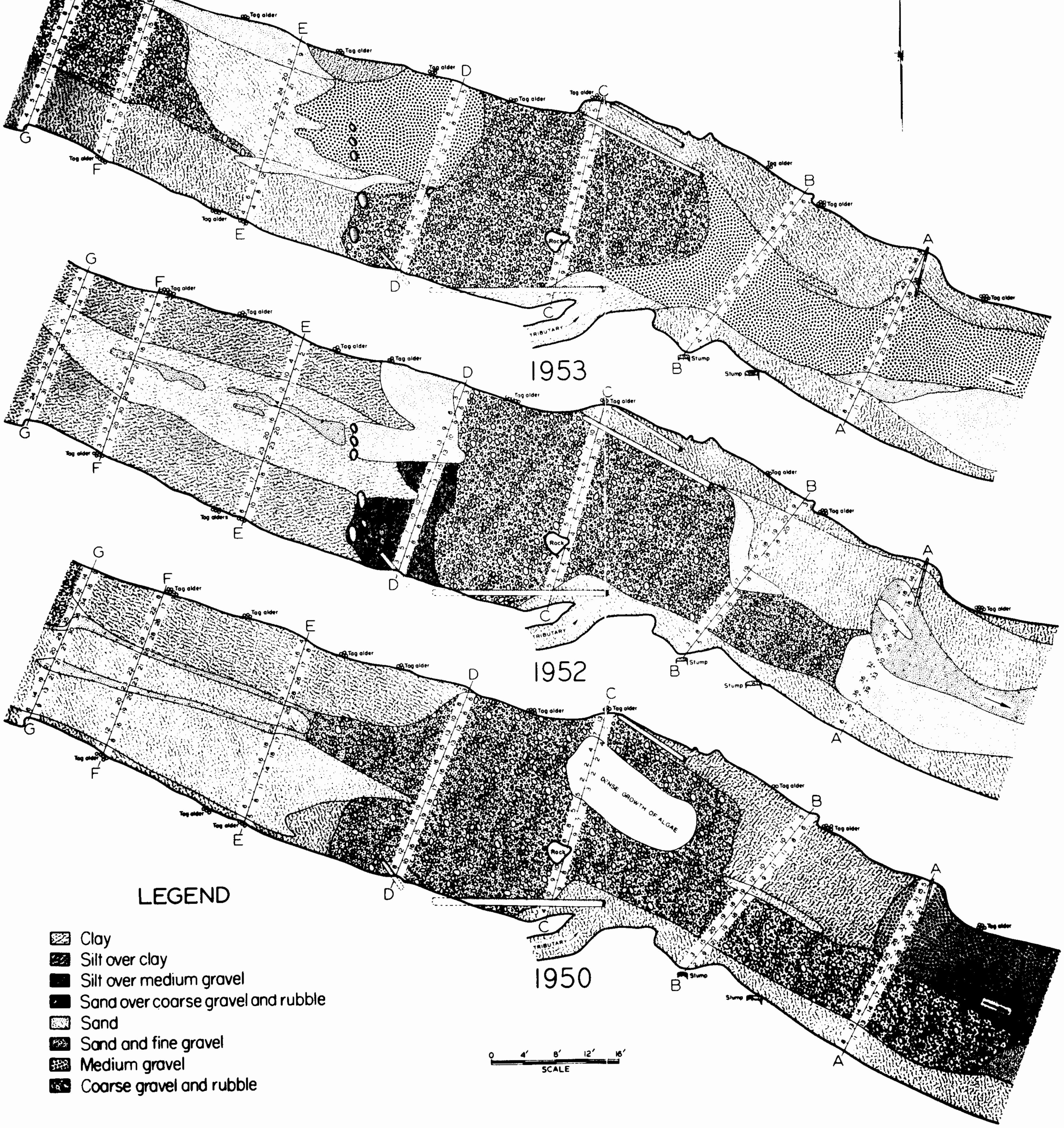
HOUGHTON CREEK
AREA 5 MAP A



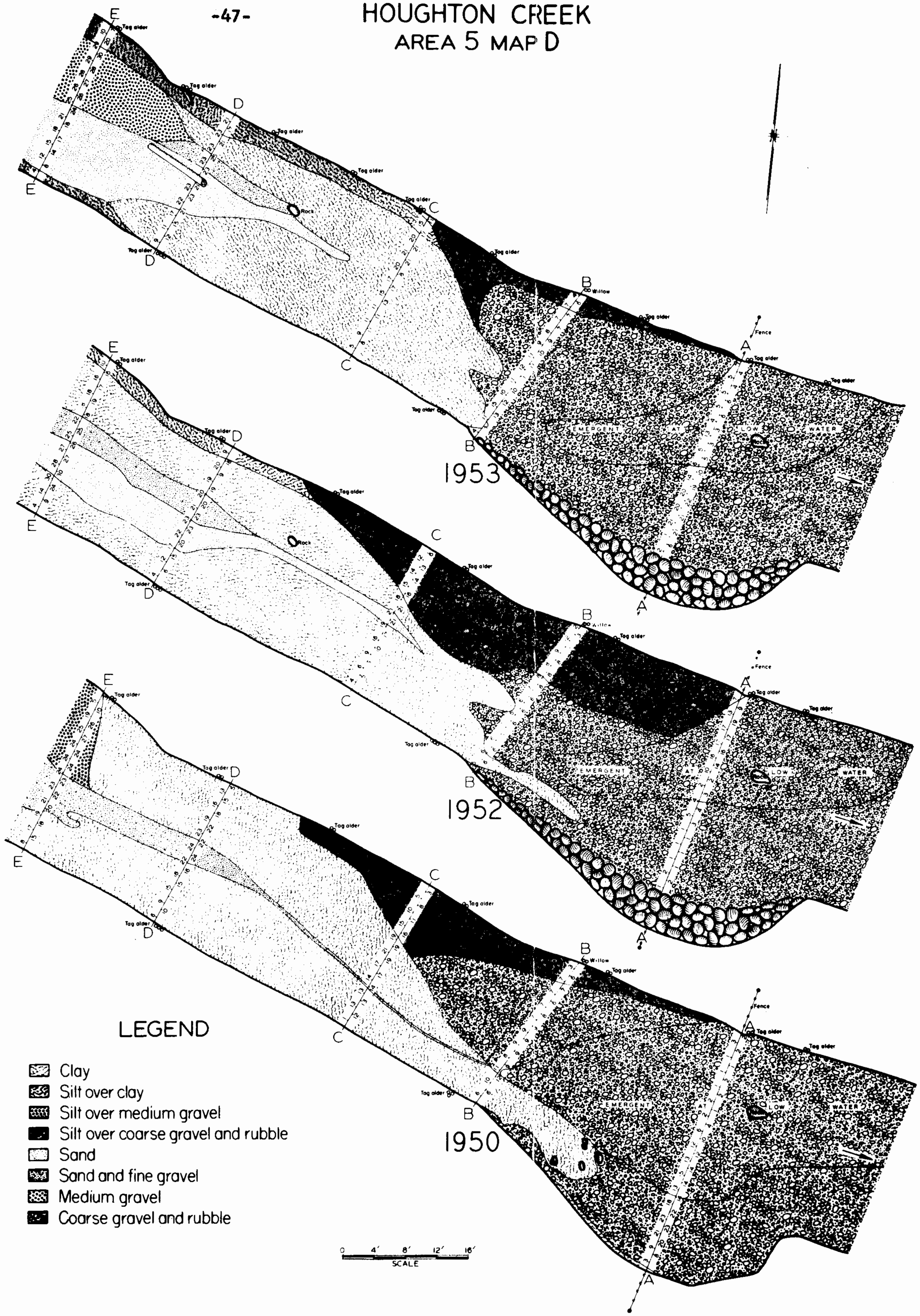
HOUGHTON CREEK
AREA 5 MAP B



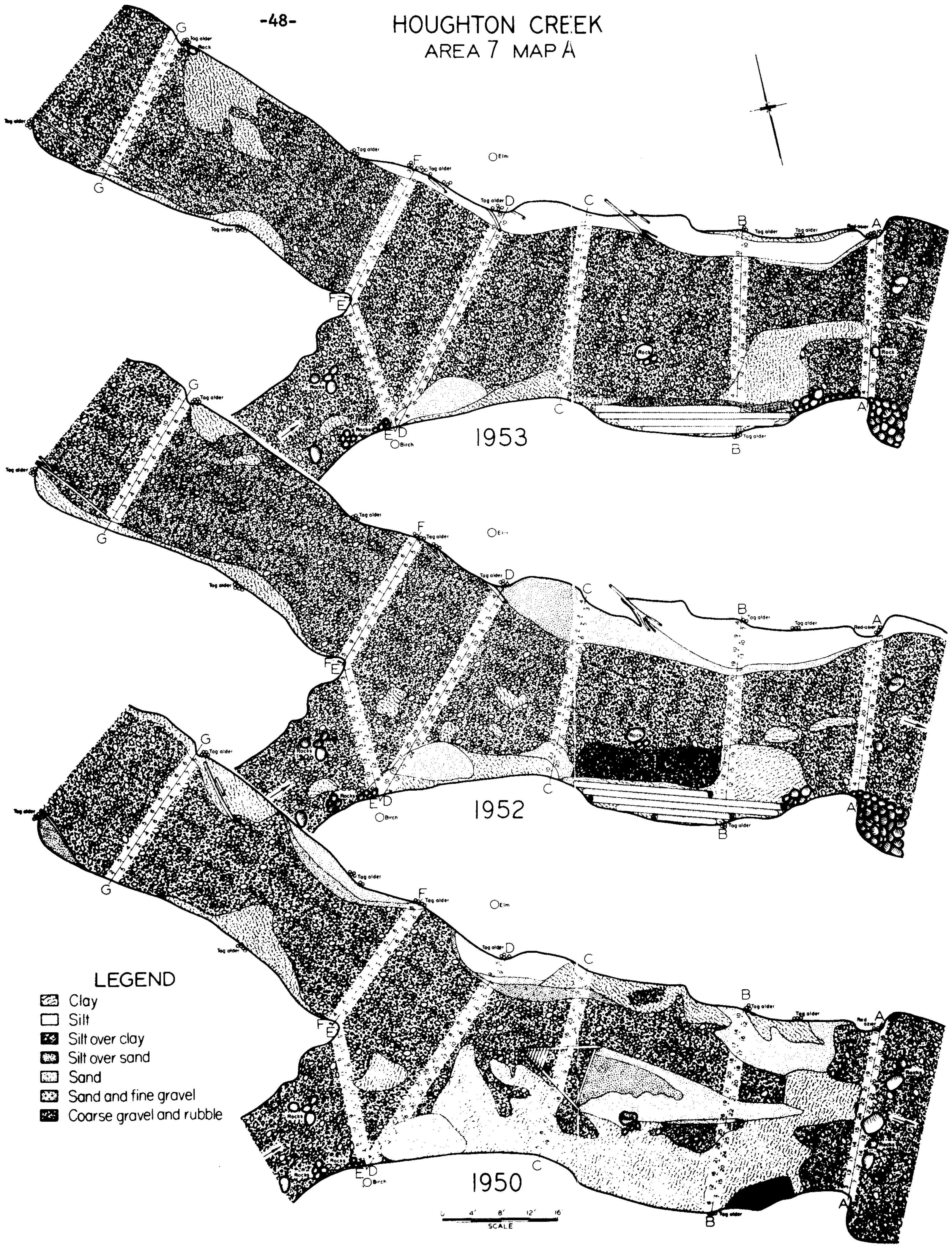
HOUGHTON CREEK
AREA 5 MAP C

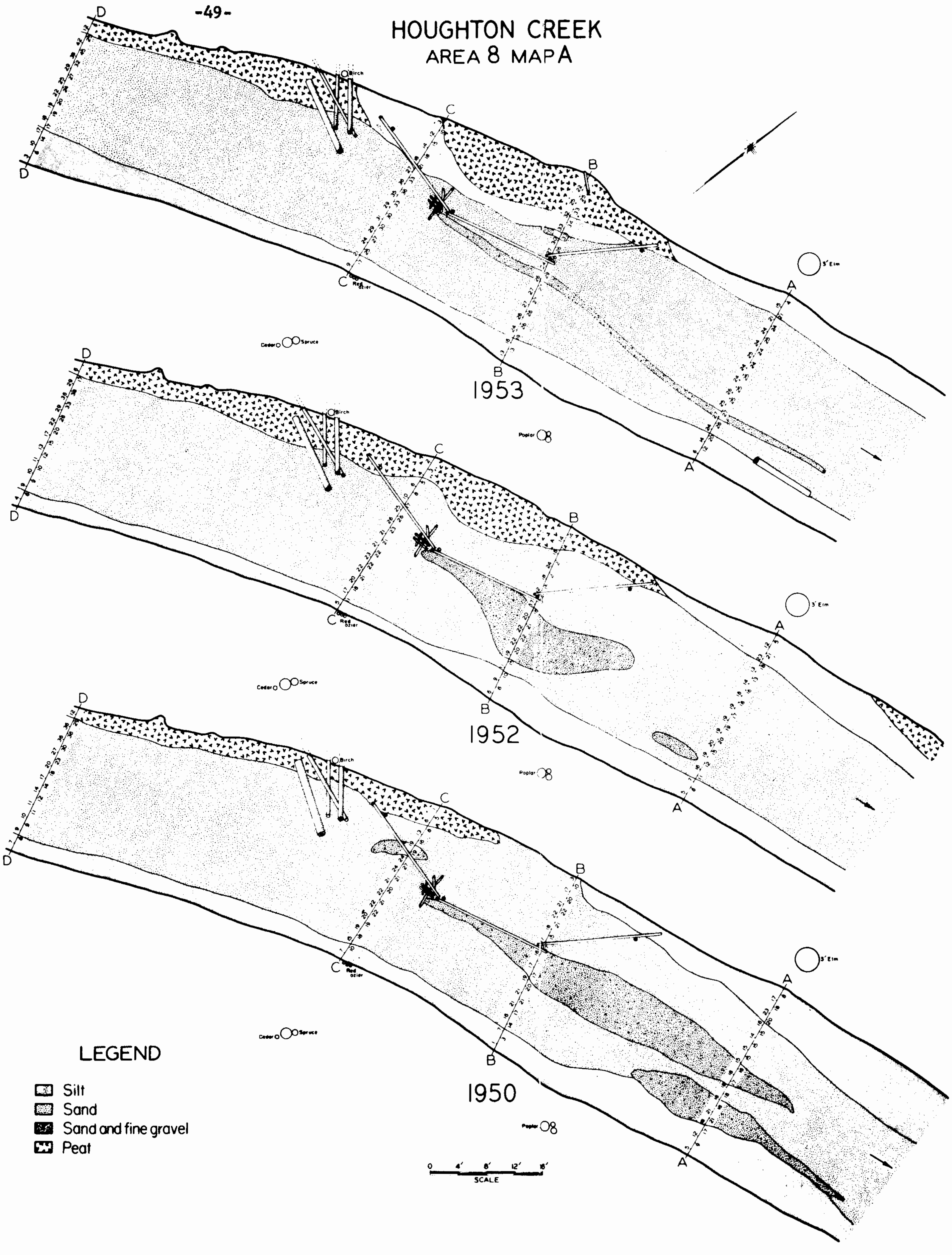


HOUGHTON CREEK
AREA 5 MAP D

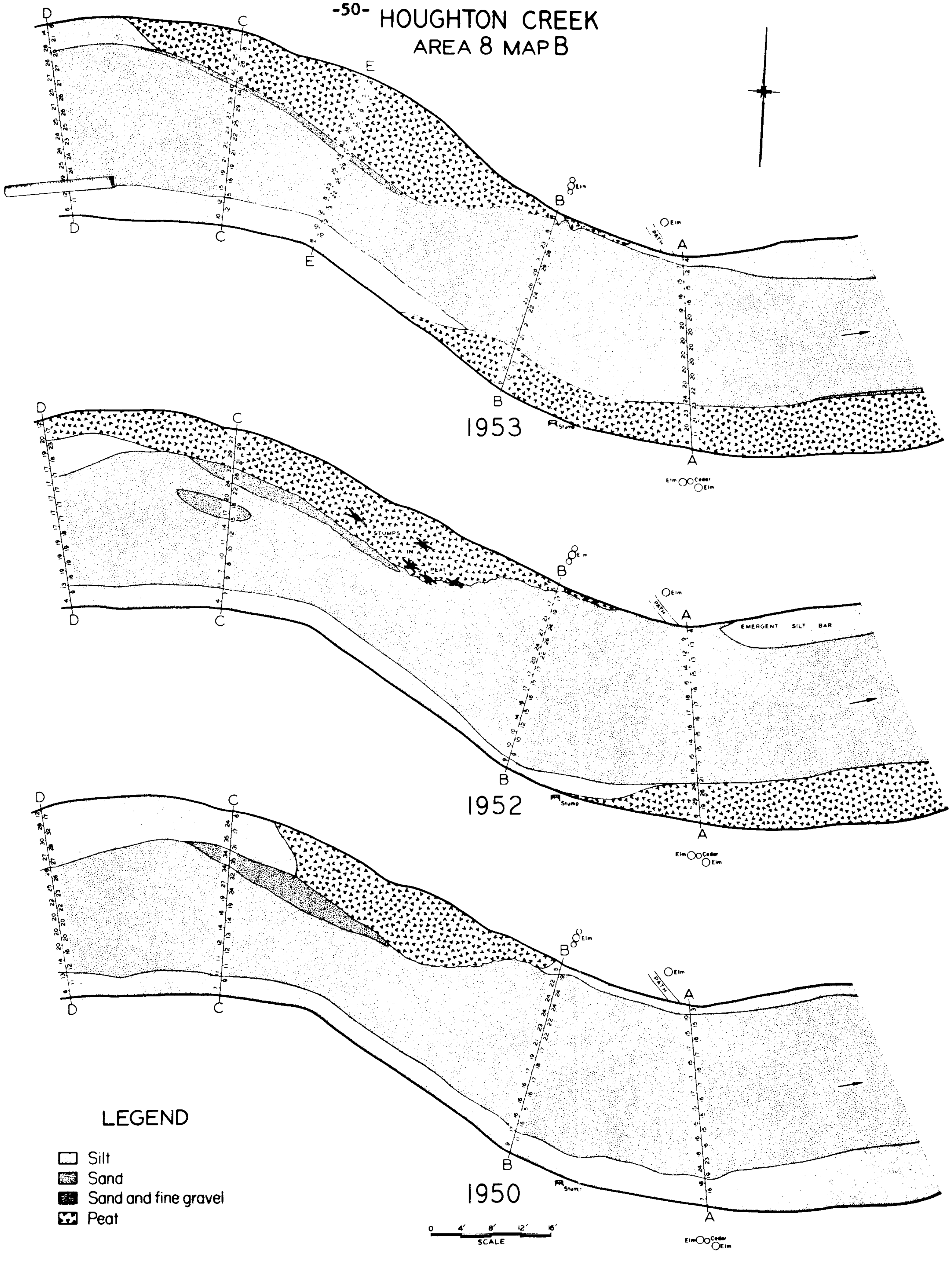


HOUGHTON CREEK
AREA 7 MAP A

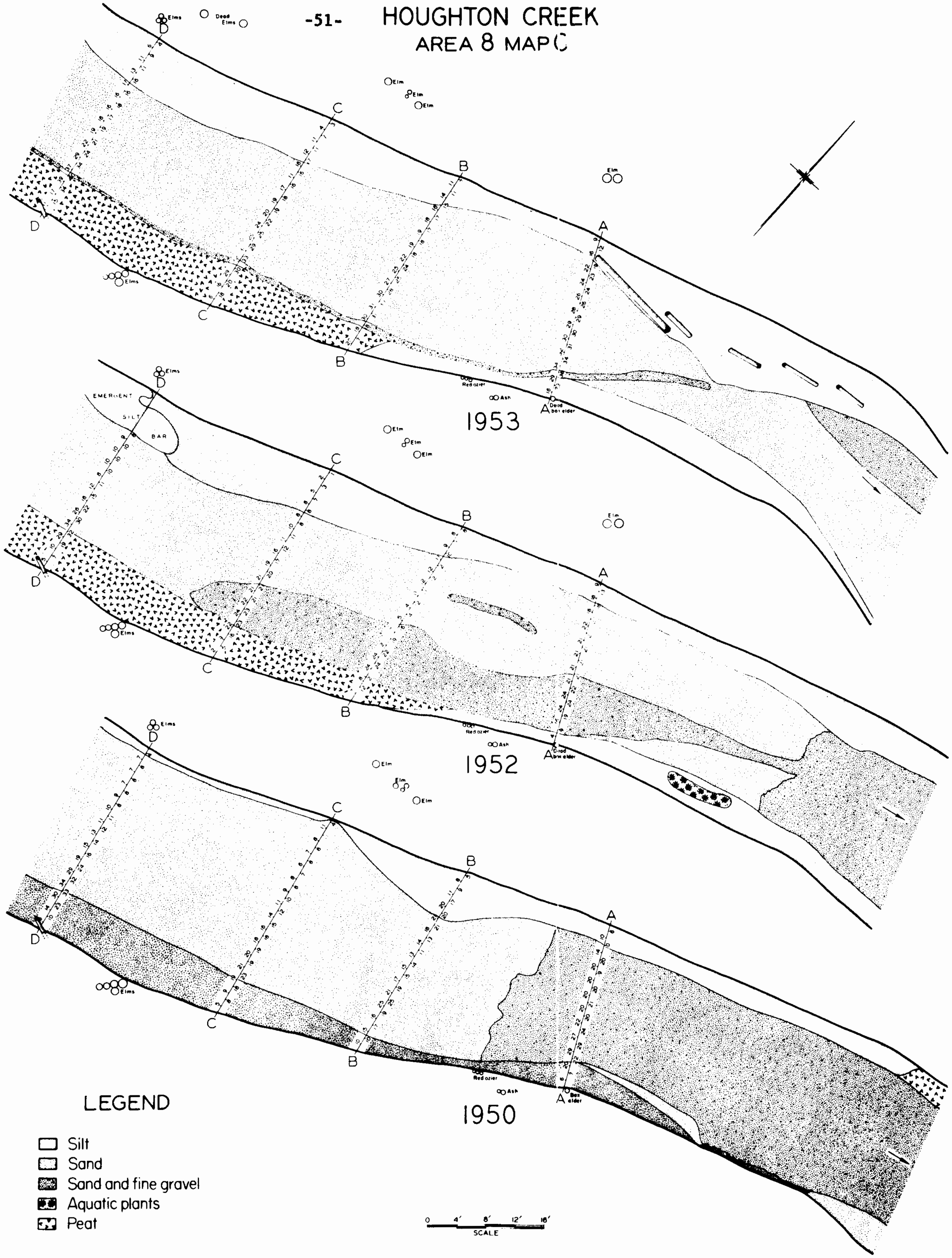



HOUGHTON CREEK
AREA 8 MAP A
1953
1952
1950
Birch
Poplar
Cedar
Spruce
Red ozier
3' Elm
LEGEND
Silt
Sand
Sand and fine gravel
Peat
0 4' 8' 12' 16'
SCALE

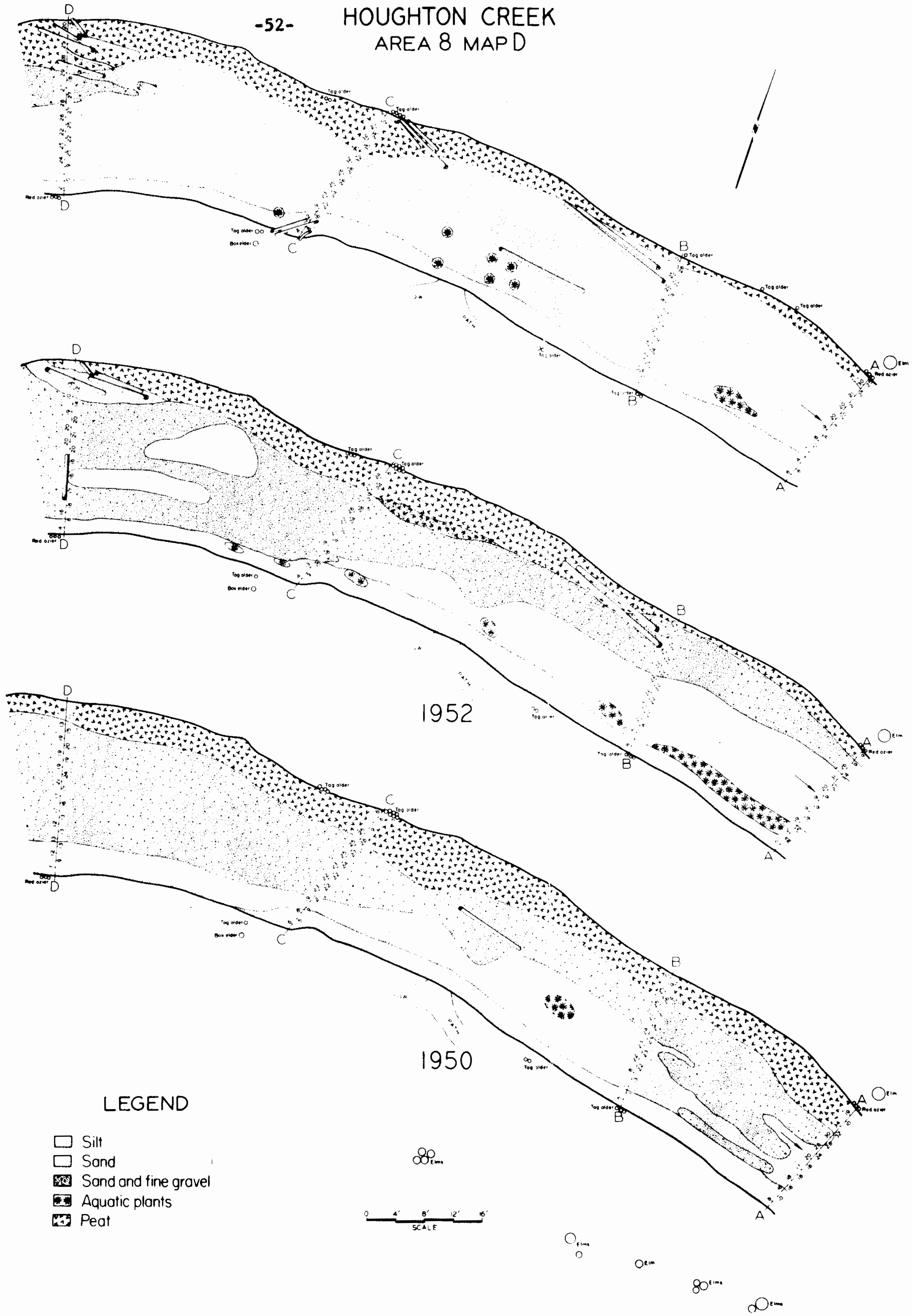
HOUGHTON CREEK
AREA 8 MAP B



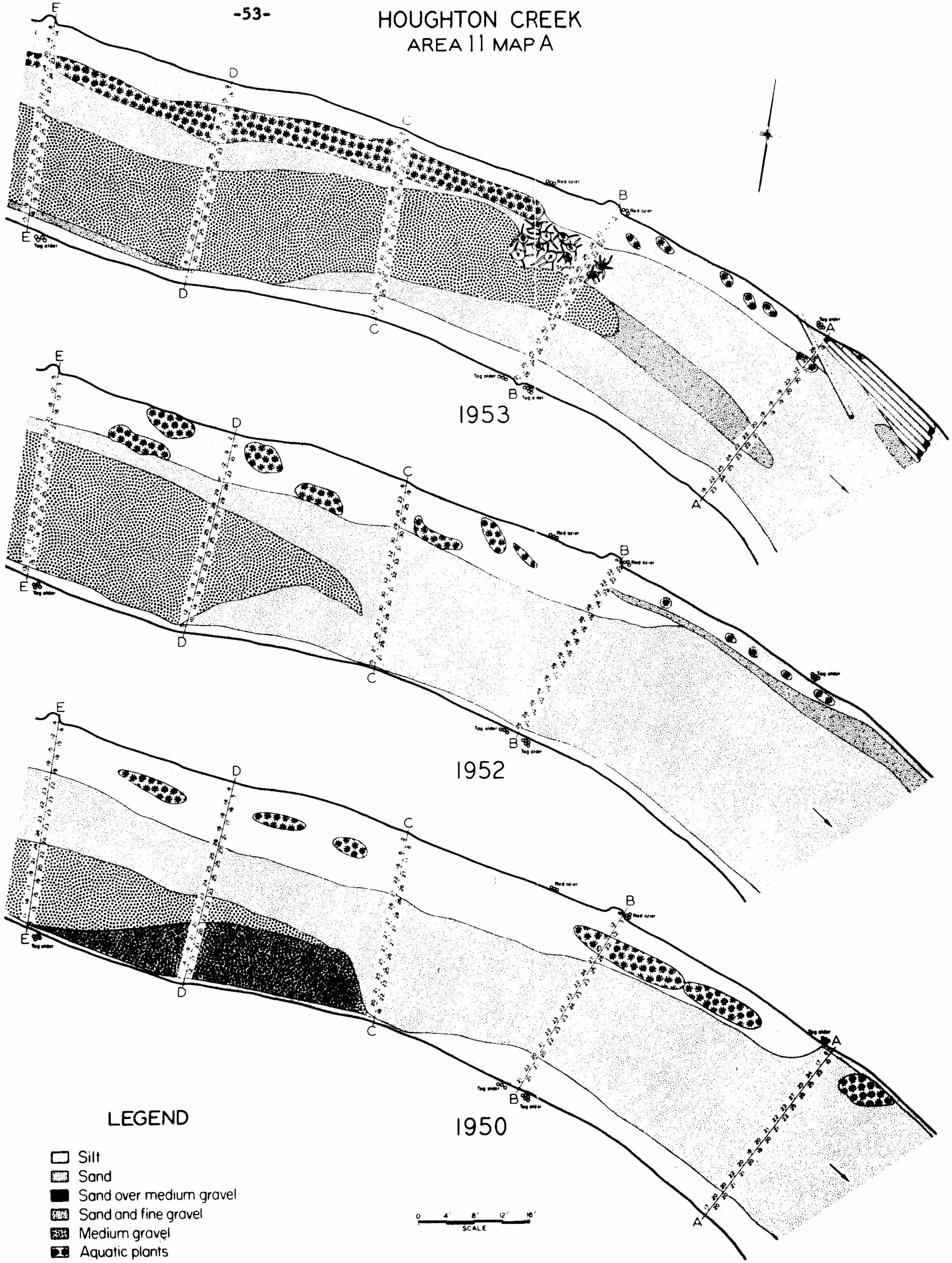
HOUGHTON CREEK
AREA 8 MAP C



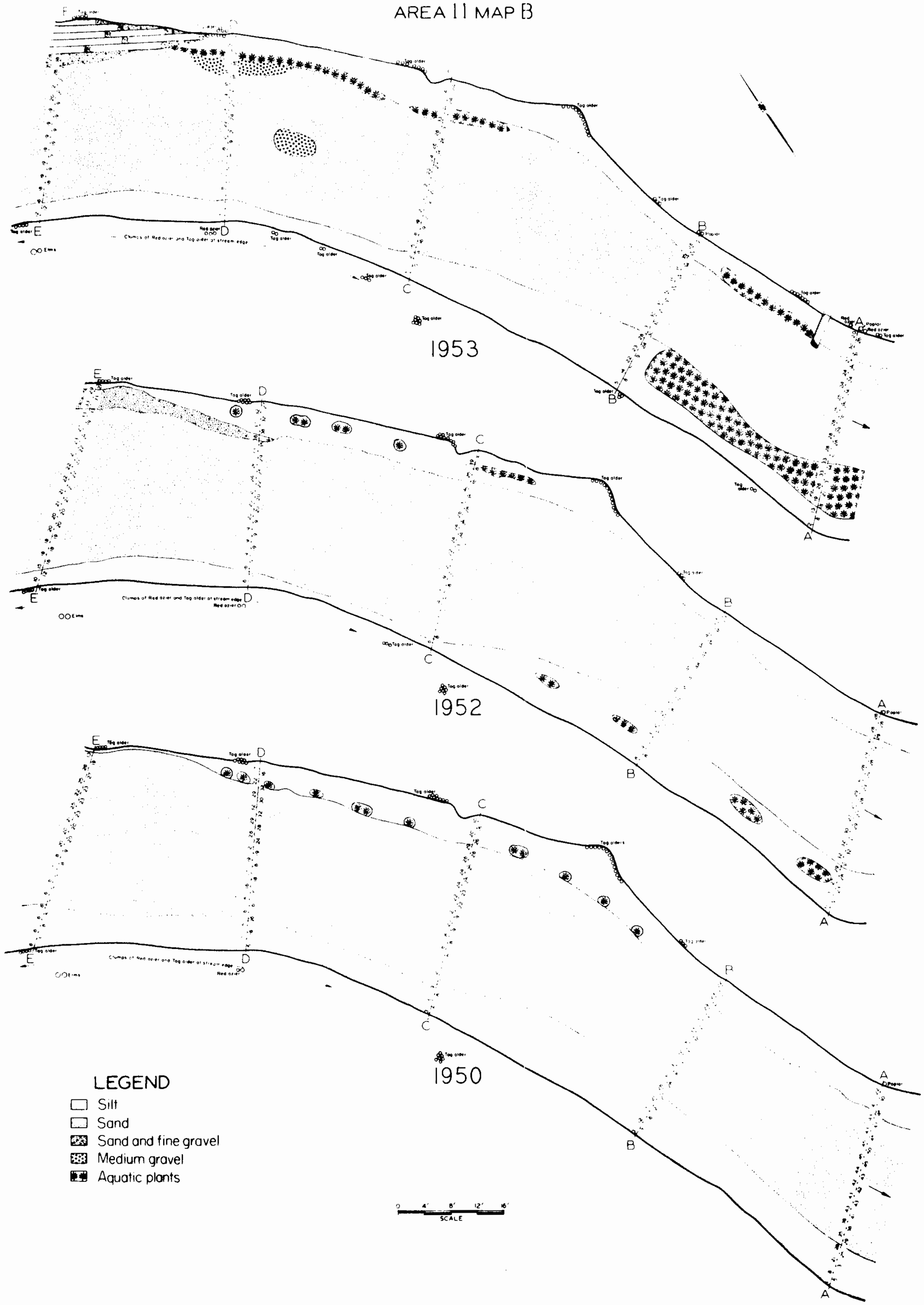
HOUGHTON CREEK
AREA 8 MAP D

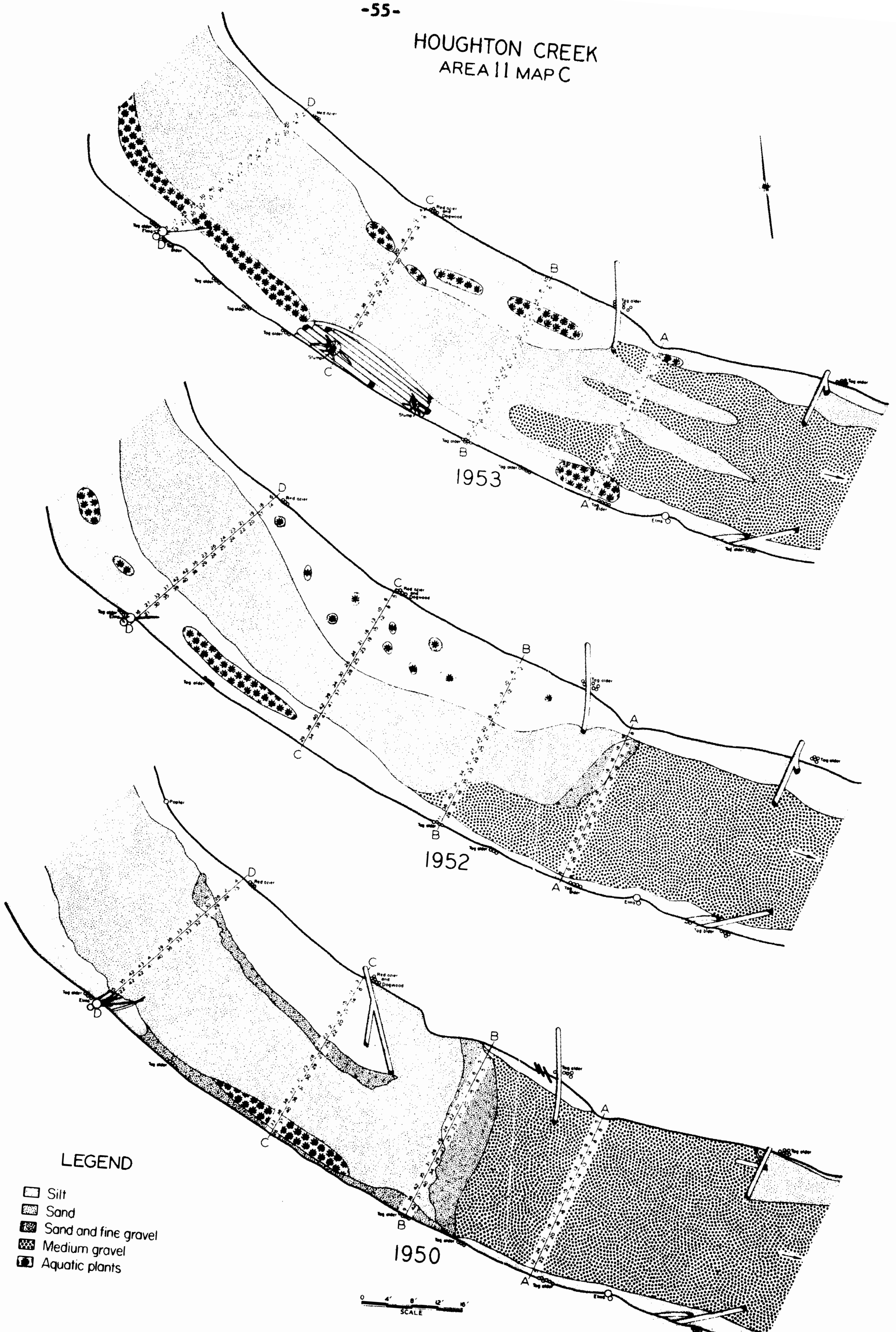


HOUGHTON CREEK
AREA 11 MAP A

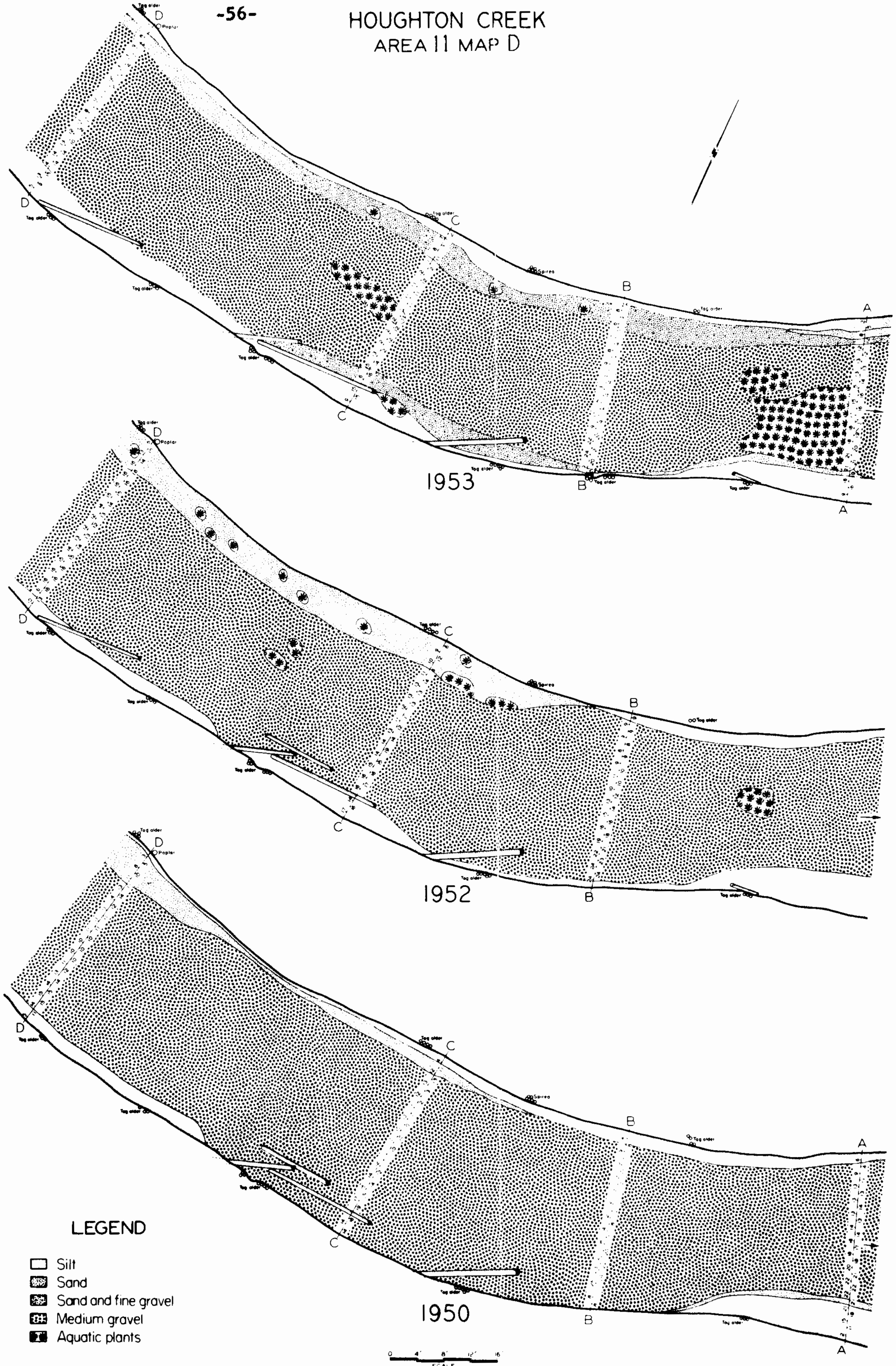


HOUGHTON CREEK
AREA 11 MAP B

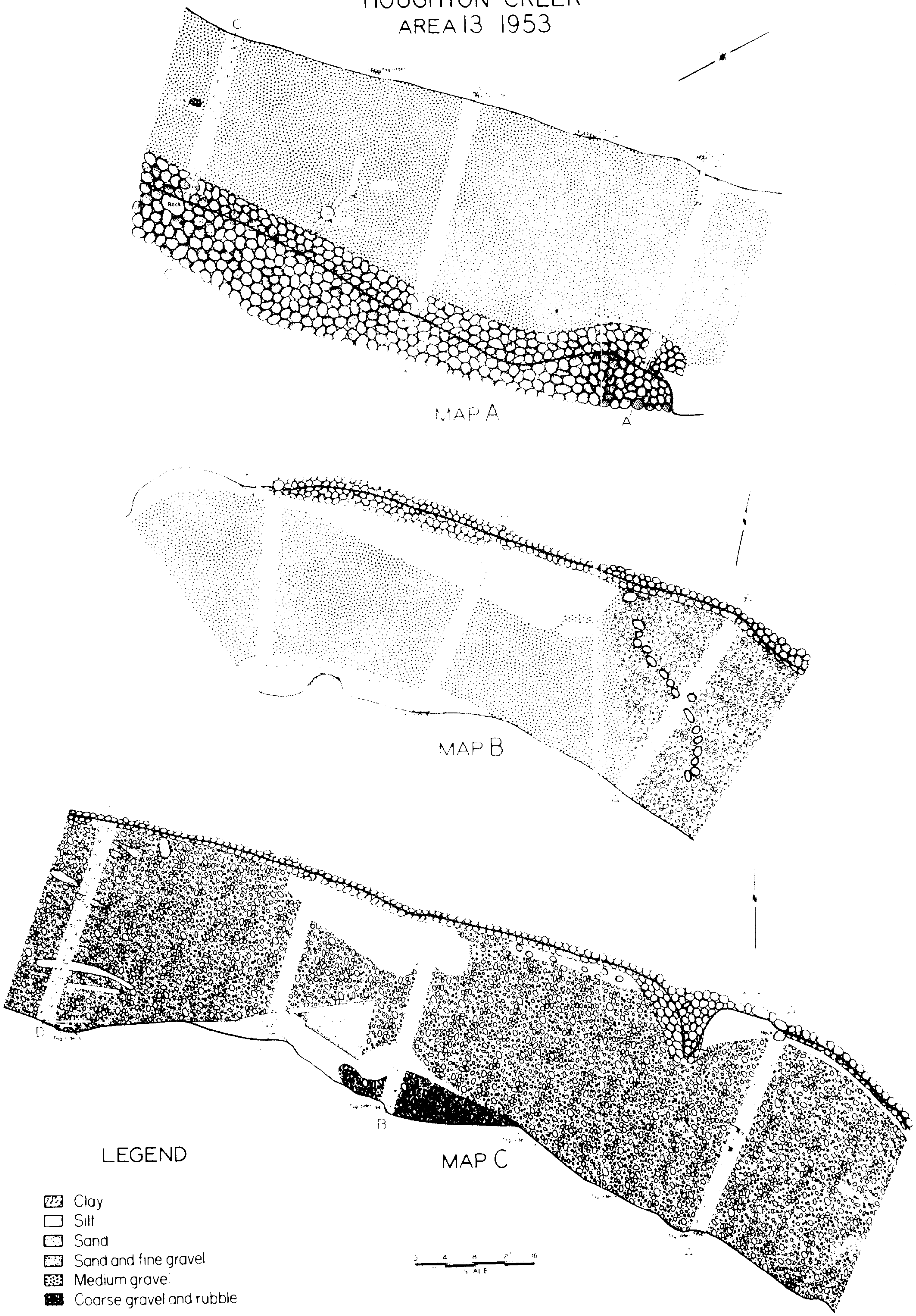



HOUGHTON CREEK
AREA II MAP C
1953
1952
1950
A
B
C
D
LEGEND
Silt
Sand
Sand and fine gravel
Medium gravel
Aquatic plants
SCALE

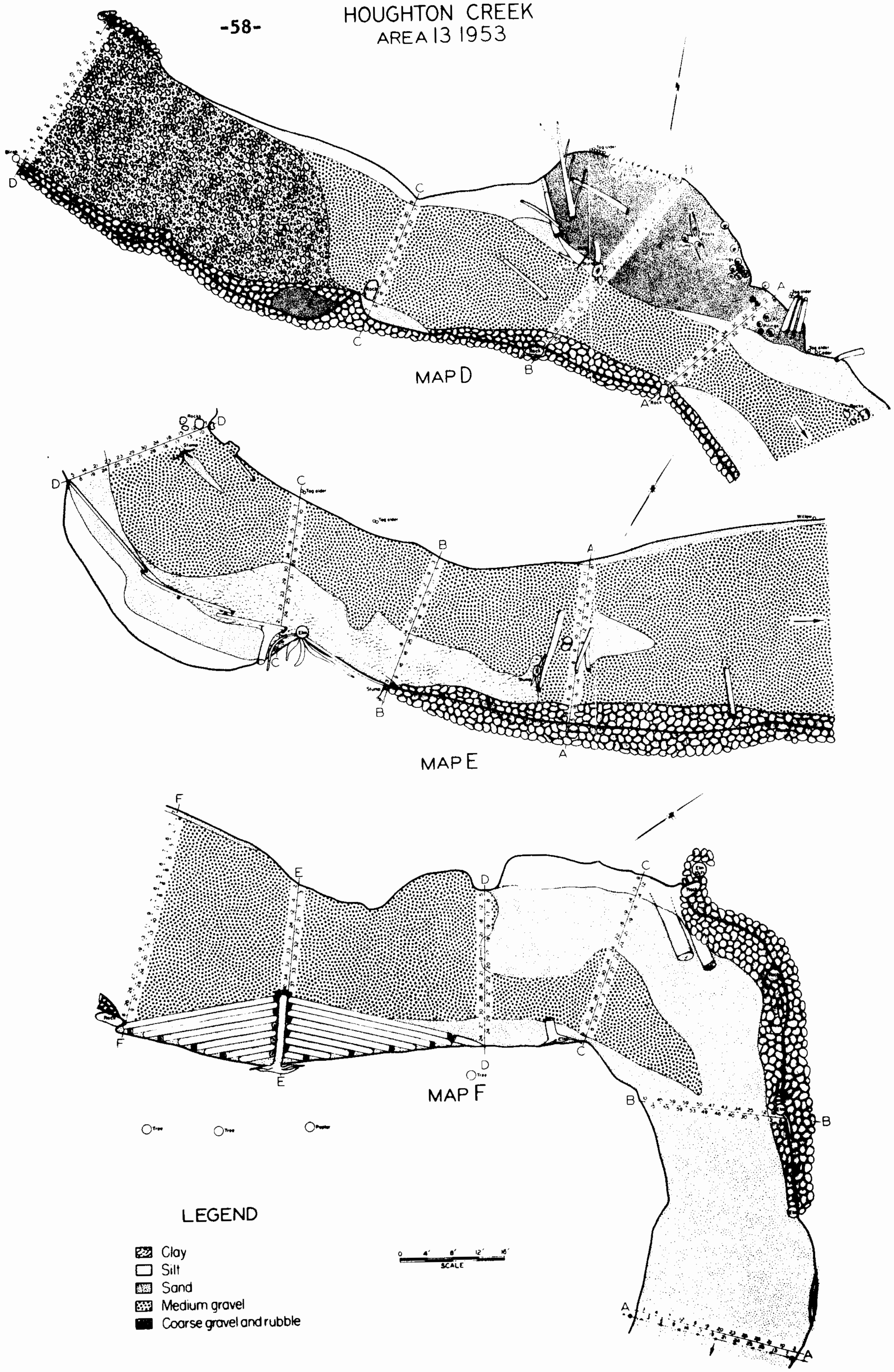
HOUGHTON CREEK
AREA 11 MAP D



HOUGHTON CREEK
AREA 13 1953



HOUGHTON CREEK
AREA 13 1953



Appendix B

Tables listing the number and volume (in ml or cc) of organisms in bottom samples from Houghton Creek. For locations of sampling sites, see Figure 1. Included are all samples taken by Ellis during 1950 to 1953, and the samples taken by Ellis and Gowing (1957) from December, 1953 to April, 1954 in their special study of the effect of the Rose City sewer. Under each date in the tables are listed the numbers and volumes of different types of organisms in a single sample. The size of the sample (area of bottom included by the sample) is given for each sample. Samples on Fontinalis moss were 1/16 sq. ft.; on higher aquatic plants and on silt, 1/4 sq. ft.; on gravel, sand, and clay, mostly 1 sq. ft., some samples 1/2 sq. ft. A July 20, 1953 sample on higher aquatic plants was 1 sq. ft. Under volumes of organisms, Tr = trace, or less than 0.005 ml.

Samples on gravelly riffle, at site 1

Organisms	Date and sample size									
	Dec. 18, 1950 1 sq. ft.		Mar. 23, 1951 1 sq. ft.		Dec. 27, 1951 1 sq. ft.		Jan. 2, 1953 1 sq. ft.		Dec. 15, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	182	0.37	141	0.19	310	0.63	236	0.58	...	0.75
Ephemeroptera	119	0.31	82	0.33	154	0.16	199	0.32	...	0.47
Plecoptera	22	0.12	7	0.01	21	0.01	11	Tr	...	0.07
Diptera	74	0.34	19	0.07	42	0.12	88	0.38	...	0.12
Asellus	...	....	...	....	...	....	...	....	...	....
Gammarus	2	Tr[1]	...	....	3	0.05	...	....	...	Tr
All others	664	2.78	259	1.00	186	0.68	122	0.30	...	0.39
Totals	1,063	3.92	508	1.60	716	1.65	656	1.58	...	1.80

[1] Tr = trace.

Samples on gravelly riffle, at site 4

Organisms	Date and sample size											
	Dec. 11, 1950 1 sq. ft.		Mar. 24, 1951 1 sq. ft.		Sep. 3, 1951 1 sq. ft.		Dec. 29, 1951 1 sq. ft.		Jan. 1, 1953 1 sq. ft.		Dec. 18, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	175	0.22	94	0.32	235	0.90	53	0.09	127	0.60	160	0.32
Ephemeroptera	82	0.14	135	0.33	79	0.07	175	0.13	207	0.27	250	0.21
Plecoptera	4	Tr	7	0.01	2	0.04	103	0.05	30	0.16	31	0.04
Diptera	24	0.06	32	0.05	55	0.08	36	0.07	45	0.05	19	0.07
Asellus	...	....	...	....	...	....	...	....	...	....	...	....
Gammarus	4	0.06	...	....	6	0.04	2	0.02	...	....	...	....
All others	46	0.11	32	0.13	64	0.45	43	0.41	34	0.16	55	0.37
Totals	335	0.59	300	0.84	441	1.58	412	0.77	443	1.24	515	1.01

Samples on gravelly riffle, at site 5

Organisms	Date and sample size							
	Dec. 7, 1950 1 sq. ft.		Jan. 2, 1952 1 sq. ft.		Dec. 29, 1952 1 sq. ft.		Dec. 16, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	45	0.34	125	0.41	224	0.53	648	2.03
Ephemeroptera	11	0.02	532	0.60	606	0.71	1,142	1.80
Plecoptera	...	....	24	0.04	17	0.06	43	0.22
Diptera	59	0.48	56	2.99	72	0.68	73	0.13
Asellus	565	4.41	744	3.50	98	1.23	272	1.52
Gammarus	2	0.01	5	0.04	25	0.62	2	0.02
All others	26	0.13	36	0.69	54	0.04	33	0.10
Totals	708	5.39	1,522	8.27	1,096	3.87	2,213	5.82

Samples on gravelly riffle, at site 7

Organisms	Date and sample size									
	Nov. 29, 1950 1 sq. ft.		Mar. 22, 1951 1 sq. ft.		Dec. 30, 1951 1 sq. ft.		Dec. 30, 1952 1 sq. ft.		Dec. 22, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	139	1.13	126	1.10	351	1.31	327	1.80	505	2.01
Ephemeroptera	118	0.35	38	0.31	27	0.05	74	0.09	83	0.17
Plecoptera	...	....	...	....	...	....	15	0.01	2	0.10
Diptera	18	3.82	79	0.17	30	0.01	38	0.03	74	0.08
Asellus	51	0.27	35	0.17	28	0.12	5	0.11	6	0.01
Gammarus	...	....	2	0.05	5	0.02	1	0.03	...	....
All others	13	0.02	32	0.05	9	Tr	17	0.02	6	0.01
Totals	339	5.59	312	1.85	450	1.51	477	2.09	676	2.38

Samples on gravelly riffle, at site 12

Organisms	Date and sample size									
	Mar. 20, 1951		Nov. 17, 1951		Dec. 28, 1951		May 16, 1952		Aug. 13, 1952	
	1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	285	2.79	224	1.65	446	3.10	101	0.63	95	0.12
Ephemeroptera	169	0.53	20	0.03	90	0.31	135	0.44	44	0.07
Plecoptera	10	0.13	1	Tr	9	Tr	2	0.03	...	....
Diptera	476	0.78	68	0.04	149	0.24	324	0.26	146	0.13
Asellus	72	0.30	23	0.03	41	0.10	2	Tr	312	0.76
Gammarus	2	0.01	1	0.02	6	0.02	1	Tr	76	0.32
All others	75	0.13	49	0.10	72	0.11	69	0.07	157	0.62
Totals	1,089	4.67	386	1.87	813	3.88	634	1.43	830	2.02

Samples on gravelly riffle, at site 12

(continued)

Organisms	Date and sample size									
	Nov. 29, 1952		Dec. 31, 1952		Mar. 4, 1953		May 6, 1953		July 14, 1953	
	1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	615	5.20	881	7.20	676	4.40	133	1.35	317	1.72
Ephemeroptera	67	0.21	96	0.33	129	0.32	95	0.40	170	0.14
Plecoptera	...	....	20	0.03	12	0.08	4	0.06	1	Tr
Diptera	385	0.48	228	0.28	158	0.26	375	0.28	294	0.17
Asellus	18	0.06	...	....	3	0.01	2	0.01	20	0.01
Gammarus	13	0.19	...	....	1	0.07	...	....	3	0.01
All others	162	0.37	112	0.20	55	0.07	121	0.13	82	0.07
Totals	1,260	6.51	1,337	8.04	1,034	5.21	730	2.23	887	2.12

Samples on gravelly riffle, at site 12

(continued)

Organisms	Date and sample size									
	Sept. 11, 1953 1/2 sq. ft.		Sept. 11, 1953 1/2 sq. ft.		Oct. 29, 1953 1/2 sq. ft.		Oct. 29, 1953 1/2 sq. ft.		Dec. 14, 1953[1] 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	454	1.96	715	2.92	426	3.70	579	4.00	...	3.27
Ephemeroptera	52	0.07	62	0.07	55	0.07	41	0.05	...	0.67
Plecoptera	1	Tr	2	0.07	8	0.01	2	Tr	...	0.07
Diptera	38	0.06	72	0.09	88	0.13	154	0.35	...	1.30
Asellus	2	Tr	1	Tr	2	0.01	2	0.01	...	0.85
Gammarus	...	....	...	....	...	....	...	....	...	0.35
All others	56	0.10	101	0.18	76	0.17	192	0.20	...	0.92
Totals	603	2.19	953	3.33	655	4.09	970	4.61	...	7.43

[1] This sample was lost before the re-voluming and counting was done in 1957. These volume figures were found by water displacement in a 15-cc centrifuge tube.

Samples on gravelly riffle, at site 14

Organisms	Date and sample size											
	Feb. 3, 1952		Apr. 9, 1952		June 30, 1952		Oct. 30, 1952		Jan. 3, 1953		Feb. 4, 1953	
	1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	41	0.08	54	0.16	163	0.97	141	0.61	189	0.51	57	0.17
Ephemeroptera	81	0.14	18	0.03	92	0.01	85	0.10	237	0.24	62	0.10
Plecoptera	20	0.14	...	....	10	Tr	7	0.09	24	0.07	10	0.02
Diptera	19	0.06	19	Tr	85	0.10	20	0.07	43	0.54	18	0.12
Asellus	1	Tr	...	....	...	....	...	....	...	....	...	....
Gammarus	2	0.01	...	....	...	....	1	0.01	...	....	...	....
All others	17	0.17	36	0.14	63	0.08	28	0.04	48	0.22	39	0.08
Totals	181	0.60	127	0.33	413	1.16	282	0.92	541	1.58	186	0.49

Samples on gravelly riffle, at site 14

(continued)

Organisms	Date and sample size									
	Mar. 28, 1953 1 sq. ft.		June 10, 1953 1 sq. ft.		Aug. 11, 1953 1/2 sq. ft.		Aug. 11, 1953 1/2 sq. ft.		Sep. 9, 1953 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	229	0.92	128	0.66	196	0.52	135	0.46	197	0.49
Ephemeroptera	229	0.88	32	0.07	39	0.02	6	0.05	64	0.03
Plecoptera	6	0.02	...	....	3	0.01	36	0.02	10	0.08
Diptera	26	0.08[1]	57	0.03	454	0.47	144	0.12	21	0.10
Asellus	...	....	...	....	...	....	...	....	...	....
Gammarus	1	0.02	...	....	...	....	1	0.01	...	....
All others	95	0.22	88	0.45	22	0.06	42	0.23	58	0.15
Totals	586	2.14	305	1.21	714	1.08	364	0.89	350	0.85

[1]Volume after these animals had accidentally been allowed to air dry.

Samples on gravelly riffle, at site 14

(continued)

Organisms	Date and sample size									
	Sep. 9, 1953		Oct. 13, 1953		Oct. 13, 1953[1]		Dec. 8, 1953		Dec. 8, 1953	
	1/2 sq. ft.		1/2 sq. ft.		1/2 sq. ft.		1/2 sq. ft.		1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	187	0.55	391	1.05	...	0.45	259	0.81	59	0.08
Ephemeroptera	49	0.02	238	0.27	...	0.20	285	0.72	55	0.03
Plecoptera	3	0.08	49	0.22	...	0.10	32	0.10	8	0.12
Diptera	11	0.05	25	0.12	...	0.13	32	0.06	5	0.02
Asellus	3	Tr	...	...	...	....	...	....	...	....
Gammarus	1	0.01	1	0.01	...	....	...	....	...	....
All others	39	0.17	111	0.23	...	0.05	103	0.12	8	0.12
Totals	293	0.88	815	1.90	...	0.93	711	1.81	135	0.37

[1] This sample was lost before the re-voluming and counting done in 1957. These volume figures were found by water displacement in a 15-cc centrifuge tube.

Samples on gravelly riffle, and gravel in deep water, at miscellaneous sites

Organisms	Habitat, site number, date and sample size									
	Gravelly riffle 3 Dec. 14, 1950 1 sq. ft.		Gravelly riffle 6 Dec. 6, 1950 1 sq. ft.		Deep gravel 8 Dec. 5, 1950 1 sq. ft.		Gravelly riffle 13 Mar. 22, 1951 1 sq. ft.		Gravelly riffle[1] 13 Dec. 23, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	316	0.98	124	0.75	33	0.14	8	0.01	...	3.67
Ephemeroptera	182	0.24	155	0.86	24	0.04	107	0.25	...	0.90
Plecoptera	9	0.24	6	0.08	4	0.01	2	Tr	...	0.30
Diptera	80	1.71	219	0.64	27	0.51	25	0.07	...	0.07
Asellus	...	....	266	2.50	17	0.11	10	0.14	...	0.05
Gammarus	1	0.01	2	0.02	7	0.09	...	....	...	Tr
All others	93	0.12	46	0.18	47	0.10	5	0.01	...	0.02
Totals	681	3.30	818	5.03	159	1.00	157	0.48	...	5.01

[1] Sample lost before re-voluming and count. These volumes determined by water displacement in a 15-cc centrifuge tube at time sample was collected.

Bottom samples, mostly from habitats other than gravelly riffles

Organisms	Habitat, site number, date and sample size											
	Clay		Clay		Silt		Clay		Clay		Gravelly riffle	
	1		2		4		4		4		4	
	Dec. 21, 1950		Dec. 21, 1950		Dec. 9, 1953		Dec. 20, 1950		Dec. 21, 1950		Dec. 12, 1950	
	1 sq. ft.		1 sq. ft.		1/4 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	15	0.01	...	....	...	....	1	Tr	1	Tr	73	0.25
Ephemeroptera	44	0.04	6	Tr	7	0.14	79	0.06	44	0.02	94	0.13
Plecoptera	...	....	...	....	1	Tr	...	....	...	....	11	0.19
Diptera	28	Tr	1	Tr	77	0.25	6	0.01	4	Tr	52	0.11
Asellus	...	....	...	....	...	....	...	....	...	....	...	....
Gammarus	...	....	...	....	...	....	...	....	...	....	4	0.03
All others	9	0.01	...	....	46	0.13	...	....	1	Tr	114	0.18
Totals	96	0.06	7	0.01	131	0.52	86	0.07	50	0.03	348	0.89

Bottom samples, mostly from habitats other than gravelly riffles

(continued)

Organisms	Habitat, site number, date and sample size											
	Silt		Silt		Vegetation		Vegetation		Silt		Vegetation	
	4		4		U.S.		U.S.		U.S.		15	
	Dec. 11, 1953		Dec. 11, 1953		Sep. 16, 1953		Sep. 16, 1953		Dec. 9, 1953		Nov. 12, 1953	
	1/4 sq. ft.		1/4 sq. ft.		1/16 sq. ft.		1/16 sq. ft.		1/4 sq. ft.		1/4 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	...	....	4	0.02	21	0.07	14	0.04	...	....	60	0.18
Ephemeroptera	3	0.23	15	0.04	85	0.10	120	0.18	...	....	25	0.05
Plecoptera	...	....	...	....	42	0.05	22	0.01	...	....	33	0.45
Diptera	36	0.12	49	0.07	86	0.06	98	0.13	7	0.17	32	0.45
Asellus	...	....	...	....	31	0.10	4	0.01	92	0.17	254	3.40
Gammarus	...	....	2	0.03	1	0.01	...	....	...	....	11	0.24
All others	75[1]	0.33	12	0.05	15	0.02	75	0.13	196[1]	1.19	29	0.40
Totals	114	0.68	82	0.21	281	0.41	333	0.50	295	1.53	444	5.17

[1] Number of organisms is approximate, includes many broken tubificids.

Bottom samples, mostly from habitats other than gravelly riffles

(continued)

Organisms	Habitat, site number, date and sample size									
	Vegetation[1]		Vegetation		Silt		Clay		Sand	
	5		5		5		5		6	
	July 28, 1953		July 28, 1953		Nov. 24, 1953		Dec. 21, 1950		Dec. 20, 1950	
	1/16 sq. ft.		1/16 sq. ft.		1/4 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	...	0.08	44	0.14	...	....	...	....	1	0.02
Ephemeroptera	...	Tr	3	Tr	...	....	8	0.02	...	....
Plecoptera	...	Tr	1	Tr	...	....	...	....	...	....
Diptera	...	0.02	43	0.07	6	Tr	29	0.03	3	0.27
Asellus	980	2.20	445	0.60	1	Tr	1	Tr	3	0.05
Gammarus	18	0.08	20	0.03	...	....	...	....	1	Tr
All others	...	Tr	46	0.07	?	10.95	...	....	12	0.01
Totals	998	2.40	602	0.91	7	10.95[2]	38	0.05	20	0.35

[1] Sample lost before counting. Volumes determined by water displacement in a 15-cc centrifuge tube.

[2] This volume, determined at time sample was taken, was determined by water displacement in a 15-cc centrifuge tube; included only 0.20 ml organisms other than Tubificidae. Tubificids not counted.

Bottom samples, mostly from habitats other than gravelly riffles

(continued)

Organisms	Habitat, site number, date and sample size									
	Sand		Vegetation		Deep gravel		Sand		Deep gravel	
	8		9		9		10		11	
	Dec. 20, 1950		Nov. 17, 1953		Dec. 1, 1950		Dec. 19, 1950		Nov. 28, 1950	
	1 sq. ft.		1/4 sq. ft.		1 sq. ft.		1 sq. ft.		1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	...	....	22	0.02	16	0.07	...	....	57	0.43
Ephemeroptera	...	....	9	0.18	20	0.03	1	Tr	11	0.01
Plecoptera	...	....	28	0.66	3	Tr	2	Tr	1	Tr
Diptera	...	....	35	0.69	79	0.17	1	Tr	333	0.82
Asellus	...	....	369	2.70	3	0.01	...	....	...	....
Gammarus	...	....	28	0.27	...	....	...	....	...	....
All others	1	Tr	31	1.42	52	0.03	...	....	30	0.05
Totals	1	Tr	522	5.94	173	0.31	4	0.01	432	1.31

Bottom samples, mostly from habitats other than gravelly riffles

(continued)

Organisms	Habitat, site number, date and sample size									
	Deep gravel 11 Mar. 21, 1951 1 sq. ft.		Deep gravel 11 Sep. 2, 1951 1 sq. ft.		Sand 11 Dec. 19, 1950 1 sq. ft.		Sand 11 Sep. 2, 1951 1 sq. ft.		Vegetation[1] 11 July 20, 1953 1 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	30	0.37	140	0.72	2	Tr	...	....	3	0.05
Ephemeroptera	29	0.12	53	0.07	9	Tr	...	....	19	0.02
Plecoptera	...	....	1	Tr	...	....	...	....	...	....
Diptera	152	0.27	226	0.21	3	Tr	196	0.07	82	0.57
Asellus	2	Tr	1	0.01	...	....	...	....	35	0.17
Gammarus	1	Tr	...	....	...	....	...	....	3	0.01
All others	15	0.01	21	0.02	8	Tr	6	Tr	350[2]	1.60
Totals	229	0.77	442	1.03	22	0.01	202	0.07	492	2.42

[1] Bed of *Anacharis* and *Ranunculus*.

[2] One crayfish, 1.10 ml; and many tubificids.

Bottom samples, mostly from habitats other than gravelly riffles

(continued)

Organisms	Habitat, site number, date and sample size									
	Vegetation[1]		Silt		Vegetation[1]		Silt		Silt	
	11		11		11		11		11	
	Nov. 25, 1953		Dec. 10, 1953		Dec. 10, 1953		Dec. 11, 1953		Dec. 11, 1953	
	1/4 sq. ft.		1/4 sq. ft.		1/4 sq. ft.		1/4 sq. ft.		1/4 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	10	0.11	...	....	17	0.17	2	0.02	2	0.02
Ephemeroptera	14	0.07	...	....	50	0.15	3	0.16	1	Tr
Plecoptera	2	0.02	...	....	5	0.07	...	....	...	....
Diptera	58	0.74	...	....	291	0.30	105	0.09	121	0.24
Asellus	23	0.20	...	....	47	0.40	4	0.03	8	0.09
Gammarus	...	....	...	....	4	0.07	2	Tr	4	0.02
All others	170[2]	0.13	400[2]	1.60	44[2]	0.32	26	0.07	18[2]	0.03
Totals	277	1.27	400	1.60	458	1.48	142	0.37	154	0.40

[1] Bed of *Anacharis*.

[2] Number of organisms is approximate, includes many broken tubificids.

Bottom samples from gravelly riffles at upper sewer site (U.S.)

Organisms	Date and sample size											
	Nov. 29, 1953 1/2 sq. ft.		Nov. 29, 1953 1/2 sq. ft.		Nov. 29, 1953 1/2 sq. ft.		Nov. 29, 1953 1/2 sq. ft.		Dec. 1, 1953 1/2 sq. ft.		Dec. 1, 1953 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	46	0.24	52	0.13	126	0.37	44	0.16	65	0.50	40	0.15
Ephemeroptera	247	0.30	168	0.15	345	0.79	182	0.43	121	0.17	165	0.23
Plecoptera	28	0.16	8	0.01	26	0.07	21	0.17	17	0.04	17	0.12
Diptera	9	0.03	8	0.01	44	0.08	30	0.13	19	0.05	30	0.05
<u>Asellus</u>	2	0.01	15	0.04	35	0.22	2	0.01	6	0.03	13	0.13
<u>Gammarus</u>	...	....	...	....	...	....	...	....	...	....	...	....
All others	3	0.01	11	0.02	96	0.16	43	0.06	16	0.20	41	0.05
Totals	335	0.75	262	0.36	672	1.69	322	0.96	244	0.99	306	0.73

Bottom samples from gravelly riffles at upper sewer site (U.S.)

(continued)

Organisms	Date and sample size									
	Dec. 2, 1953 1/2 sq. ft.		Dec. 1, 1953 1/2 sq. ft.		Mar. 30, 1954 1/2 sq. ft.		Mar. 30, 1954 1/2 sq. ft.		March 30, 1954 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	117	0.52	160	0.59	46	0.23	22	0.06	37	0.07
Ephemeroptera	212	0.19	194	0.28	79	0.35	30	0.12	80	0.22
Plecoptera	18	0.02	21	0.07	9	0.02	3	0.01	...	....
Diptera	18	0.05	25	0.05	7	0.02	11	0.02	12	0.03
Asellus	11	0.06	30	0.30	1	Tr	...	....	...	....
Gammarus	...	....	2	0.02	...	....	...	....	1	Tr
All others	18	0.01	19	0.03	3	Tr	5	0.01	37	0.02
Totals	394	0.85	451	1.34	145	0.62	71	0.22	167	0.34

Bottom samples from gravelly riffles at upper sewer site (U.S.)

(continued)

Organisms	Mar. 30, 1954 1/2 sq. ft.		Mar. 31, 1954 1/2 sq. ft.		Mar. 31, 1954 1/2 sq. ft.		Mar. 31, 1954 1/2 sq. ft.		Mar. 31, 1954 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	91	0.24	91	0.50	105	0.45	118	0.28	111	0.56
Ephemeroptera	200	0.52	79	0.22	197	0.61	28	0.06	43	0.13
Plecoptera	13	0.08	4	0.01	5	0.01	8	0.03	3	Tr
Diptera	38	0.07	26	0.02	82	0.20	9	0.01	15	0.07
Asellus	5	0.02	...	....	6	0.02	...	....	2	0.04
Gammarus	...	....	...	....	...	....	...	....	...	....
All others	84	0.10	6	0.01	58	0.07	19	0.01	11	0.01
Totals	431	1.03	206	0.76	453	1.36	182	0.39	185	0.81

Bottom samples from gravelly riffles at lower sewer site (L.S.)

Organisms	Date and sample size											
	Dec. 3, 1953 1/2 sq. ft.		Dec. 3, 1953 1/2 sq. ft.		Dec. 3, 1953 1/2 sq. ft.		Dec. 3, 1953 1/2 sq. ft.		Dec. 4, 1953 1/2 sq. ft.		Dec. 4, 1953 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	277	1.04	448	1.26	122	0.80	206	2.22	99	0.14	447	2.12
Ephemeroptera	219	0.23	240	0.38	227	0.28	63	0.13	4	0.02	27	0.01
Plecoptera	8	0.09	8	0.02	16	0.07	6	0.04	1	0.11	...	....
Diptera	7	1.91	9	1.31	9	2.27	8	2.41	1	0.01	6	0.01
Asellus	164	1.00	103	0.56	324	2.10	113	1.19	70	0.62	117	1.37
Gammarus	2	0.07	2	0.04	14	0.06	6	0.10	3	0.02	8	0.15
All others	5	0.13	12	0.01	13	0.05	11	0.10	23	0.88	43	0.90
Totals	682	4.47	822	3.58	725	5.63	413	6.19	201	1.80	648	4.56

Bottom samples from gravelly riffles at lower sewer site (L.S.)

(continued)

Organisms	Date and sample size									
	Dec. 4, 1953 1/2 sq. ft.		Dec. 4, 1953 1/2 sq. ft.		Apr. 1, 1954 1/2 sq. ft.		Apr. 1, 1954 1/2 sq. ft.		Apr. 1, 1954 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	182	1.42	174	1.18	61	0.45	67	0.92	141	1.10
Ephemeroptera	44	0.05	81	0.10	89	0.24	161	0.50	181	0.68
Plecoptera	2	0.01	7	0.03	1	Tr	4	0.03	8	0.40
Diptera	8	0.07	3	0.01	3	Tr	6	0.01	7	0.04
Asellus	21	0.14	50	0.52	19	0.07	50	0.18	38	0.17
Gammarus	6	0.06	7	0.05	1	Tr	2	0.01	2	0.01
All others	16	0.02	11	0.02	13	0.02	23	0.50	10	0.02
Totals	279	1.77	333	1.91	187	0.78	313	2.15	387	2.42

Bottom samples from gravelly riffles at lower sewer site (L.S.)

(continued)

Organisms	Date and sample size									
	Apr. 1, 1954 1/2 sq. ft.		Apr. 2, 1954 1/2 sq. ft.		Apr. 2, 1954 1/2 sq. ft.		Apr. 2, 1954 1/2 sq. ft.		Apr. 2, 1954 1/2 sq. ft.	
	Number	Volume	Number	Volume	Number	Volume	Number	Volume	Number	Volume
Trichoptera	274	1.95	254	1.47	171	1.00	296	1.25	178	0.65
Ephemeroptera	225	0.80	229	0.81	277	1.08	286	0.50	289	0.75
Plecoptera	6	0.07	3	0.04	9	0.03	4	0.03	1	Tr
Diptera	40	0.01	18	0.03	14	0.02	4	0.01	16	0.02
Asellus	56	0.35	125	1.11	121	1.16	55	0.55	33	0.16
Gammarus	3	0.03	17	0.13	8	0.02	4	0.02	5	0.01
All others	8	0.01	18	0.02	11	0.02	21	0.03	23	0.15
Totals	612	3.22	664	3.61	611	3.33	670	2.39	545	1.74