JOB COMPLETION REPORT

As required by

FEDERAL AID IN FISHERIES RESTORATION ACT

TEXAS

Federal Aid Project No. F-7-R-12

Fisheries Investigations and Surveys of the Waters of Region I-A

Job No. D-3 Limnological and Game Fish Problems

Investigation on Buffalo Springs Lake

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ABSTRACT

In 10 months of 1964, 39,085 fishermen paid to fish at Buffalo Springs Lake near Lubbock. Season passes were bought by 714 people. One thousand and one fishermen were interviewed about their catches. They caught 3,915 fish totaling 1,107.25 pounds. A computed 176,642 fish weighing 52,375 pounds or 232.74 pounds per surface acre were removed from this lake in 1964. A contour map was completed and the vegetative growth affecting fish populations is outlined in this report. The bottom type was not mapped but it has a thick layer of black muck over most of the bottom.

Benthos and plankton studies were not undertaken. Forage production was studied by seine sampling and stomach analysis.

Water quality was studied extensively and many data were gathered but no certain answers were obtained. Fish died when exposed to a toxic layer of water which developed in the spring of the year and shifted readily up or down during the summer. Large physical and chemical changes occurred quite rapidly in the upper lake when rains occurred. Detrimental effluent from city storm drains, sewage disposal plant, dump grounds, and from industrial plants in Lubbock entered the lake.

Game fish did not reproduce in the lake in 1964.

Dissolved gases, hydrogen sulfide and ammonia nitrogen, were always present in copious amounts in the toxic layer when it was present. The pH rose to 9.0 in the fall of the year and dissolved oxygen levels fluctuated widely up and down each day of the year. Numerous fish died from unknown causes. (Believed to be from the stresses applied by the above mentioned factors reducing their resistance to diseases already in the population). Dead fish contained DDT and its metabolites in moderate quantities but not enough to be the cause of death.

General cleanup of the watershed to produce better water quality is needed. The thermal stratification should be broken up to prevent formation of the toxic zone. Accelerated control measures should be applied to the sago pondweed, beginning earlier and removing decaying weeds more quickly.

A drastic reduction of the bullhead and bluegill population after the water quality and weed problem are overcome would allow the development of excellent game fishing in the lake.

JOB COMPLETION REPORT

State of Texas

Project No. F-7-R-12 Name: Fisheries Investigations and Surveys of the Waters of Region I-A

Job No. D-3 Title: Limnological and Game Fish Problems Investigation on Buffalo Springs Lake

Period Covered January 1, 1964 - December 31, 1964

Objectives:

General:

To correlate game fish productivity with physical, chemical and environmental factors present in Buffalo Springs Lake.

Specific:

1) To map accurately by contour, vegetation, and bottom type.

2) To determine benthos, plankton and forage production.

3) To determine water quality as related to fishery maintenance.

4) To measure productivity of game fish as demonstrated by survey and fisherman harvest.

5) To determine what levels of dissolved gas, pH, and temperature exist in this lake seasonally.

6) To chart fish location and relative population density in the lake at specific localities at various times of the year.

7) To make bacterial counts on the lake water.

Procedures:

Mapping

The bottom contours of the lake were mapped using a sonic depth determining device where water was deep enough for its use. A transect across the lake was established between known points on a map. By careful observation this transect was established on the lake. Timed runs were made with a motor boat on these transects. Depths were recorded at 5- or 10-second intervals depending on boat speed and then plotted on the transect on a map. These soundings produced known depths and like depths were connected with contour lines. The final copy of the map was produced by an engineering firm in Lubbock.

Vegetation

Plants of each type were gathered and classified to the extent permitted by personnel and literature available. Most plants are classified to genus unless they are quite common and easily recognized. Attention was only given to submerged plants and aquatic plants which were quite obvious on the water's edge because time to carry the study further was unavailable. A plant hook was used in an attempt to bring plants up from depths where collection by hand was impossible, however, no plants occurred at these depths. Circuits of the lake in a boat were conducted to observe the extent and type of vegetative growth and changes in areas occupied by plant growth.

Bottom Type

Bottom types were not mapped due to lack of time and equipment. Observations indicated a heavy muck over the majority of the lake bottom.

Benthos and Plankton

Benthos studies were not made this year due to lack of time and equipment.

No equipment was ever made available for accurate plankton analysis and this phase of the study is lacking. Neither zooplankton nor phytoplankton were examined.

Forage Production

Forage production was measured by seine samples and stomach analysis of predacious fish species taken by gill nets. Seining was done with 40-foot one-fourth inch mesh seines and with 20-foot one-eighth inch mesh seines.

Water Quality

Water quality analysis was conducted in the field and in the laboratory. All water samples were collected with a Kemmerer water sampler according to standard collecting procedures. Depth of sampling was determined by a 12-inch pulley and a revolution counter. Line was held on a metal storage windlass. Subsurface temperatures were taken by pouring water from the Kemmerer sampler into a Styrofoam bucket and taking the temperature with a thermometer.

Dissolved oxygen samples were collected and fixed in the field, using Hach's packaged dry chemicals, and titrations were run in the laboratory. Carbon dioxide and hydrogen sulfide concentrations were determined in the field using the Hach method. Turbidity was measured in the field with a Secche disk and a Jackson turbidimeter was used in the laboratory. Measurements of pH were made with a Hellige comparator in the field and in the laboratory.

Facilities for determining Biochemical Oxygen Demand (B.O.D.),dissolved solids, ammonia nitrogen, nitrate, nitrite, and sulfate contents were not available at Slaton. In order to obtain this information, samples were sent to the State Health Department Laboratory in Austin.

State Chemist Charles Ezell traveled to Buffalo Springs Lake twice and conducted chemical analyses in the field.

Water temperatures were determined at 3-foot intervals from the surface to the lake bottom in two locations. These measurements were made once a week beginning July 28, 1964, and are presently being continued. While temperatures were being determined, samples were taken to determine pH and turbidity at the surface, mid, and bottom depths. The depth where hydrogen sulfide occurred was also noted.

Measurements of water flow into and out of the lake were made once a week beginning in August. These measurements were made by timing a floating cork, with an x-shaped aluminum vane suspended about 24 inches below the cork, through a culvert of known length and volume at the lake entrance. The vane was approximately 4 by 5 inches in width and depth. Outflow was measured by obtaining average stream width and depth to obtain volume. Rate of flow was obtained by timing a floating twig over a measured distance in several areas to arrive at an average. Embody's formula was then used to determine flow figures.

Productivity

Game fish productivity was measured by seining, gill nets, and fisherman harvest by creel census.

Fish location and relative population density in the lake at various times of the year were derived by comparison of total catch in the different netting zones by nets and by fishermen.

Original plans included the use of fish traps to capture fish for marking to avoid the injuries which are sustained in gill nets. Two types of traps were tried and abandoned because they caught too few fish. Study of the fish population was therefore conducted by netting, seining and visual observations.

Nine regular netting stations were established and netted once a month during the last week of the month. This report covers data from March through October except for the month of September when the program was interrupted to aid in the rotenone treatment of Lake McClellan.

Single units of standard survey gill nets were used at all stations except No. 1 where 2 units of standard survey gill nets were set. The nets were fished submerged along the bottom contours in most areas. Examination of the contour map will reveal the depths of areas where nets were set. Nets 1 and 3 were attached to buoys about 100 feet from shore. All nets were set perpendicular to the shoreline except number 8 which was set at an angle of approximately 45 degrees to the shorelire pointing downstream.

Fish which were in good physical condition when removed from the nets were marked by punching holes in their fins with a one-hole paper punch. Fish taken from net No. 1 were marked by punching one hole in the caudal fin. Fish from net No. 2 were marked by punching one hole in the dorsal fin, and fish from other nets were marked by punching holes in other fins or combinations of fins.

This method of marking was used until tagging equipment became available in August. After the tags were available all largemouth bass (Micropterus salmoides), carp-goldfish hybrid (Cyprinnus carpio crossed with Carassius auratus), crappie (Pomoxis annularis), white bass (Roccus chrysops), black bullheads (Ictalurus melas), and channel catfish (Ictalurus punctatus), which appeared strong enough to survive were weighed and measured before being tagged and released. Sunfish were not tagged unless they were unusually large. Those fish which appeared too weak to survive were kept and autopsied for sex, weight, length, parasites, and stomach contents.

Beginning in May, seining with 20-foot and 40-foot seines was done in conjunction with netting surveys in an effort to capture young-of-the-year game fish. Visual observations of areas where nesting of game species might occur were made each time project personnel were at the lake. In addition to incidental observations, circuits of the lake were conducted in a boat with the specific purpose of locating spawning areas and nests.

Creel Census

Creel censuses were conducted twice a month on a non-scheduled basis. When time was available a census was run. A State vehicle was parked beside the road with a sign approximately 50 feet away from the truck, in the direction from which traffic was coming. The sign read, "Fishermen Please Stop". All fishermen who stopped, whether successful or not, were questioned about the bait they were using, the length of time they had fished, the area of the lake where they fished, and if they were successful, their catch was examined.

Examination was done by separating species and weighing and counting individuals of like species. No lengths were taken.

At first, voluntary creel census cards were devised and handed out at the entrance gate to all fishermen entering the lake. These forms requested the same basic information as was obtained by the personal interviews. Fishermen were asked to deposit these cards in a box, at automobile window height, as they left the lake. Results were so uncertain that this method of sampling creels was abandoned.

Bacterial Study

Dr. Kuhnley, a bacteriologist on the staff of Texas Technological College in Lubbock was contacted in an attempt to obtain cooperative aid in this phase of the study. He advised against this phase of the study because techniques for obtaining the wanted information are not entirely reliable. In his opinion the information desired would not produce useful data and no qualified individual was available to conduct a study.

Findings:

Vegetation

Water Quality Criteria, page 304, Section e, "Fish and other Aquatic life", states: "Algae can be severe pollutants to fish in two respects: (a) they can cause heavy fish mortality through direct poisoning or (b) they can be responsible for oxygen imbalance, thereby killing fish through oxygen depletion or oxygen supersaturation of the waters." This phase of possible cause of fish mortality has been ignored and should be investigated because algae growth is at times profuse in the lake.

Two vegetation surveys were conducted on Buffalo Springs Lake. One survey was conducted May 28, 1964, after the sago pondweed (Potomogeton pectinatus) first appeared. Sago pondweed is the major plant affecting fish populations in the lake. Table 1 is a checklist of plants from Buffalo Springs Lake.

Table 1. Checklist of Plants Obtained in Buffalo Springs Lake, May 28 and July 21, 1964.

Common Name	Scientific Name
Sago pondweed	Potomogeton pectinatus
Bulrush	Scirpus validus
Sedge	Scirpus americanus
Sedge	Scirpus sp.
Cattails	Typha latifolia
Eel grass	Eleocharis sp.
Dock	Rumex sp.
Willow	Salix sp.
Grasses (undetermined)	Gramineae
Weeds (undetermined)	Compositae (majority)
Horsetail	Equisetum fluviatile

Sago was growing where the water depth was restricted to 5 feet or less. The growth was new and few plants were mature enough to flower in May. Figure 1 illustrates the approximate extent of sago growth in May.

Plants found along the shoreline, listed in their order of abundance were terrestrial grasses (Gramineae), weeds (mostly Compositae), rushes (Scirpus americanus, Scirpus validus, and another Scirpus sp.), cattails (Typha latifolia), dock (Rumex sp.), willow (Salix Sp.), and horsetail (Equesetum fluviatile).

Only those aquatic plants sufficiently abundant to be easily observed are included. None of the plants listed were profuse except sago pondweed. Much of the shoreline along the upper lake is mowed and plant growth is suppressed.

The second survey on July 21 revealed the same species present. Sago pondweed had spread greatly in most areas and was so dense that an outboard motor could not be operated in it. The extent of the spreading is outlined on the map in Figure 2. Areas covered are approximated from visual observations. No direct measurements were attempted.

No further surveys were conducted specifically to determine plant type or abundance. Observations of the extent and nature of plant growth were made incidental to the monthly surveys of the fish population.

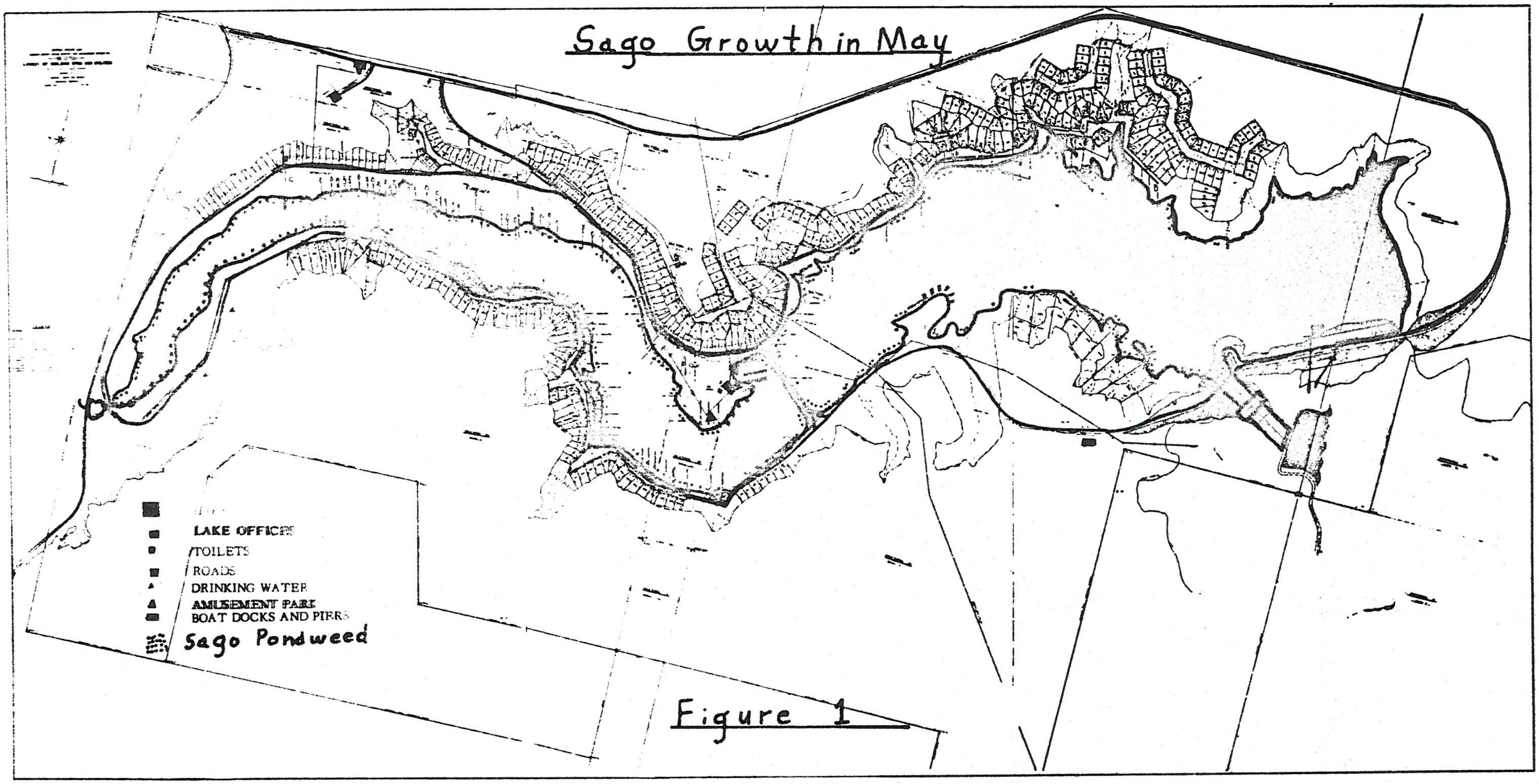

Sago Growth in May
LAKE OFFICES
TOILETS
ROADS
DRINKING WATER
AMUSEMENT PARK
BOAT DOCKS AND PIERS
Sago Pondweed

Figure 1

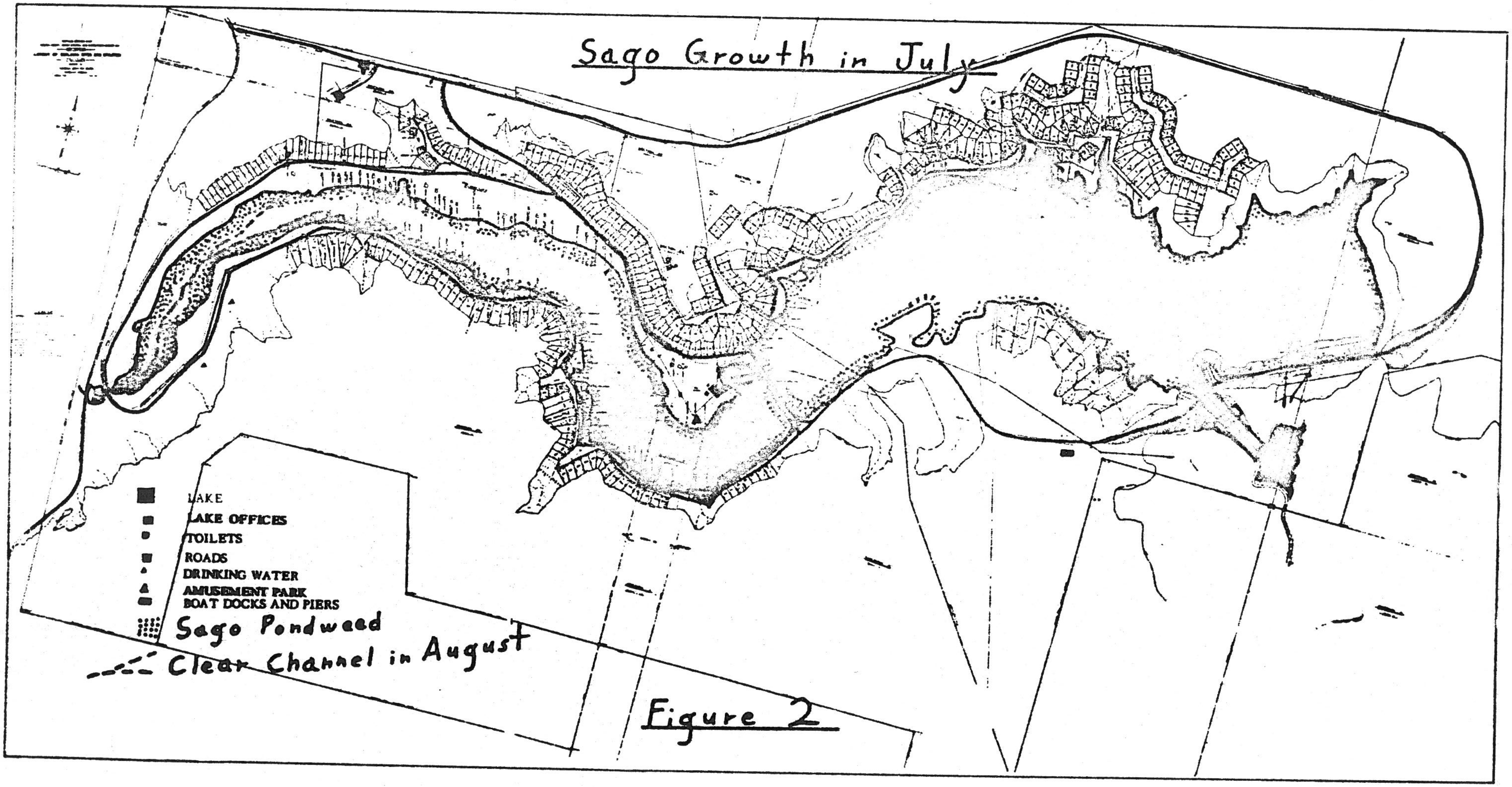

Sago Growth in July
LAKE
LAKE OFFICES
TOILETS
ROADS
DRINKING WATER
AMUSEMENT PARK
BOAT DOCKS AND PIERS
Sago Pondweed
Clear Channel in August

Figure 2

In August the entire upper end of the lake, from the culvert at the west end of the lake to the first fishing dock on the north shore, became choked with sago pondweed except for a small channel which is outlined as dashed lines on the map in Figure 2.

Lubbock County Water Control and Improvement District No. 1 has an aquatic plant mowing machine and in mid-July began mowing the sago pondweed. Mowed plants drifted to the shore and were removed, dried, and burned. Mowing operations began in the lower lake to allow freedom of movement of water skiers and progressed to the upper lake. Areas where mowing suppressed growth of sago pondweed are noted in Figure 3. Mowing allowed easier access by fishermen. The mowed sago was cut at approximately 3 feet below the water surface and remowed as regrowth occurred.

These plants provide dense cover for small fish which allows overpopulation by fish species of small average size. The large percentage of bluegills in the fish population is a partial reflection of the dense growth of sago pondweed. The sago pondweed remained abundant in the lake in areas noted in Figure 2 until mid-November when it began regressing. By the middle of December the lake appeared void of submerged plants.

This introduces a second manner of affecting the fish population. The dead plants use oxygen for decay, release organic wastes into the lake and provide additional chemical pressures for the fish to withstand. The pH readings became quite high, ranging from 8.8 to 9.0 throughout the lake in the fall.

Water Quality

It is certain that this annual growth and die off of sago pondweed adds to the water quality problems of the lake.

State Health Department records were utilized to determine the average quality of the surface water entering Buffalo Springs Lake during 1963. Table 2 contains the averages of readings as calculated for three different sites. Site 1 was at 50th Street, site 2 at the entrance to Buffalo Springs Lake, and site 3 was at the Dam. These averages do not indicate the extreme fluctuations which occurred during the year. They do indicate, however, the conditions which must exist in a lake which receives this borderline quality water.

Table 2 Average Water Quality at Sites 1, 2 and 3 From State Health Department Records for 1963.

pH	Sulfate	Chlorine Demand	B.O.D.	Ammonia Nitrogen	Nitrite	Nitrate	Total Alkalinity
Site 1							
7.99	356.09	7.33	5.88	0.43	0.37	31.24	369.04
Site 2							
8.43	417.64	8.38	6.44	1.80	0.22	0.98	322.88
At Dam Site 3							
8.72	328.00	7.44	3.32	0.59	<0.1	0.36	249.55

During 1963, Leuter's Feed Lots were permitting run-off from their cattle pens to enter the upper V-8 Ranch lake, an impoundment on the Double Mountain Fork of the Brazos River above Buffalo Springs Lake. The V-8 Ranch lies between Lubbock and Buffalo Springs Lake. This ranch has four lakes impounded on this stream, ranging from an estimated 30-acre lake down to a 5-acre (or less) lake.

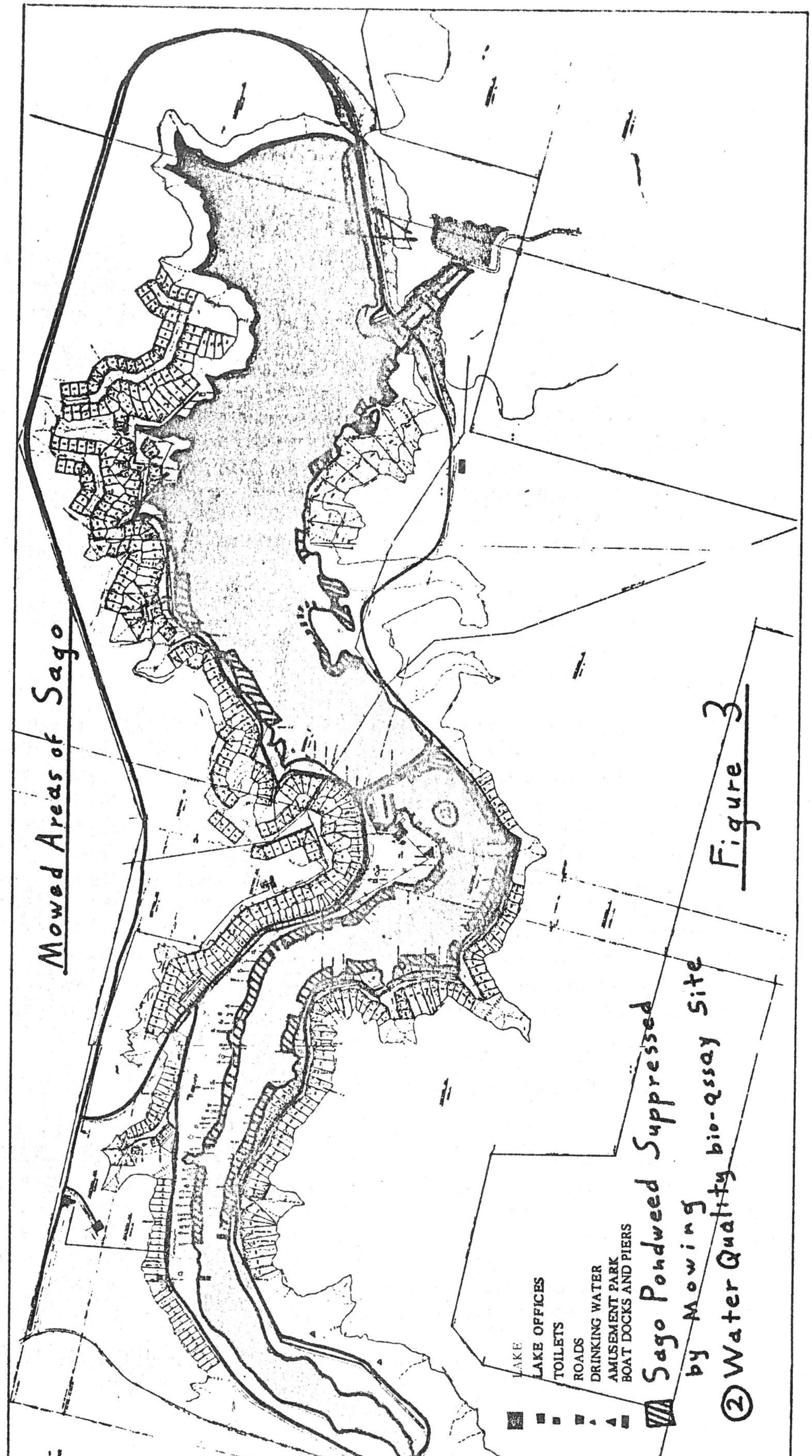

Mowed Areas of Sago
LAKE
LAKE OFFICES
TOILETS
ROADS
DRINKING WATER
AMUSEMENT PARK
BOAT DOCKS AND PIERS
Sago Pondweed Suppressed by Mowing
② Water Quality bio-assay site

Figure 3

Flow in the lakes on the V-8 Ranch is slow and the amount of natural treatmen occurring in these lakes is not known. Bottom sampling was not conducted, however, deep layers of black muck were observed in these lakes while sampling for water quality.

In places the stream flows swiftly between lakes on the V-8. Most of these areas are narrow and shaded by weeds and rushes which reduce the natural treatment afforded. Natural treatment would be improved if the stream bed were wider, shallower, and vegetation were kept down to prevent shading of the water.

The lakes act as oxidation ponds and shock load ponds for Buffalo Springs Lake during average flow. When rains occur, however, sediments in these lakes are stirred up and accompany fresh run-off material from the city's storm drains, industrial plants, and garbage dump into Buffalo Springs Lake. Dilution of wastes by rainwater is an alleviating factor; however, Buffalo Springs Lake acts as a catchment and fermentation basin for the great majority of undesirable material from the watershed. This is because its current flow is slow, even during high water settleable solids and many associated materials tend to settle out in its basin.

Open File Release No. 51, February 1955, of the United States Department of the Interior, Geological Survey, provided information concerning porosity of soils in the area above Buffalo Springs Lake.

Paragraph 2, page 9 states: "The channels of both the Double Mountain Fork and Yellowhouse Creek contain alluvial materials capable of absorbing and transmitting considerable quantities of water. Some of the water used for watering lawns, washing streets, and for other purposes is undoubtedly absorbed by this alluvial material in the city of Lubbock and may be the source of part of or all the small flows present in the Double Mountain Fork above the sewage disposal plant. This seepage water, no doubt, is somewhat polluted from various sources and the nitrate content should be greater than that of Lubbock city water but less than that of seepage water in the vicinity of the sewage disposal plant". The author of the release later demonstrated this statement to be accurate. This soil allows seepage from any dirt storage area where polluted water is stored and would allow percolation from fields irrigated with polluted waters in this area.

Water quality has improved since the data in Open File Release 51 were being gathered in 1953.

The conditions on the watershed still combine to produce a very rich water quality in Buffalo Springs Lake. The lake develops a thermal and chemical stratification, and during the summer of 1964 a layer of toxic substances, including the high levels of ammonia nitrogen (up to 6.5 ppm) and hydrogen sulfide (well over 5 ppm) existed at varying levels below the surface. This stratification existed sporadically from mid-April until September when cool weather caused the thermal layeration to disintegrate.

Weekly scheduled determinations of temperature and pH and the depth of the layer of toxic substances were begun July 28, 1964, and are presently being continued.

Sample sites are indicated in Figure 4. Sites had the following depths: W - 7 feet, X - 21 feet, Y - 24 feet, and Z - 52 feet. Site Z has one deep hole as shown on the contour map, Figure 5. The exact location of the 52-foot deep area at site Z was difficult to sample because of its small size; therefore, sampling was done to a depth of at least 40 feet in the general area. Samples taken across the lake at various locations indicated that the upper surface of the hydrogen sulfide containing layer was almost level. Weekly samples at the four sites were taken at 3-foot intervals from the surface to the bottom and measured for temperature and checked for odor of hydrogen sulfide. Odor was used as an indicator of the depth where the layer began. Surface, mid-depth, and bottom (or lowest depth) water samples were analyzed for pH at the lab. Dissolved oxygen measurements were taken sporadically as unusual conditions occurred at the lake.

In July, 114 out of 126 fish caught in net No. 8 were dead (90.48 per cent). Water samples were taken at the surface and at a depth of 8 feet at the site. These samples were extracted at 11:05 a.m. on a sunny morning while a breeze was blowing. Water conditions were undoubtedly worse during the early morning hours. Analysis of the water samples from this area showed dissolved oxygen to be 1.8 ppm at the 8-foot depth. The water temperature was 83° F. at the surface and 80° F. at 8 feet. Dissolved oxygen was 9.7 ppm at 4 feet and 10.9 ppm at the surface. Carbon dioxide was not present at either depth and no odor of hydrogen sulfide gas was noticed. A test with chemicals verified its absence.

State Health Department analysis of a sample from the 8-foot depth, where the dead fish were located, produced the following figures: pH 8.2, ammonia nitrogen 1.2 ppm, conductivity 2,233 micromhos, nitrite nitrogen $<$0.1 ppm, nitrate nitrogen 0.5 ppm, phenolphthalein alkalinity 0. methyl orange alkalinity 264, and B.O.D. 7.0. Water Quality Criteria, page 225, under nitrites states: "1. General. In water, nitrites are generally formed by the action of bacteria upon ammonia and organic nitrogen. Owing to the fact that they are quickly oxidized to nitrates, they are seldom present in surface waters in significant concentrations."

What rate "quickly oxidized" indicates is not known; however, the sample extracted July 20, was held several hours and mailed to Austin for analysis without refrigeration. It is certain that the 0.5 ppm nitrates are the result of a higher nitrite content at the time of sample extraction.

Insufficient on-site chemical analysis has been done. On-site analysis is needed because time and temperatures allow alteration of chemical quality when samples must be shipped to Austin for analysis.

The occurrence of the dead fish in net No. 8 was followed later by live caged fish bio-assays of the toxic layer mentioned earlier. These tests were conducted at site 2 as shown in Figure 3.

Fish introduced into this layer, retained for short periods of time and removed, showed definite signs of distress. Some died within a period of 24 hours.

Three tests of the effects of Buffalo Springs Lake water were conducted with live captive fish in live-nets. The nets were approximately 2 feet deep and 1 foot in diameter. They were suspended from floats at chosen depths.

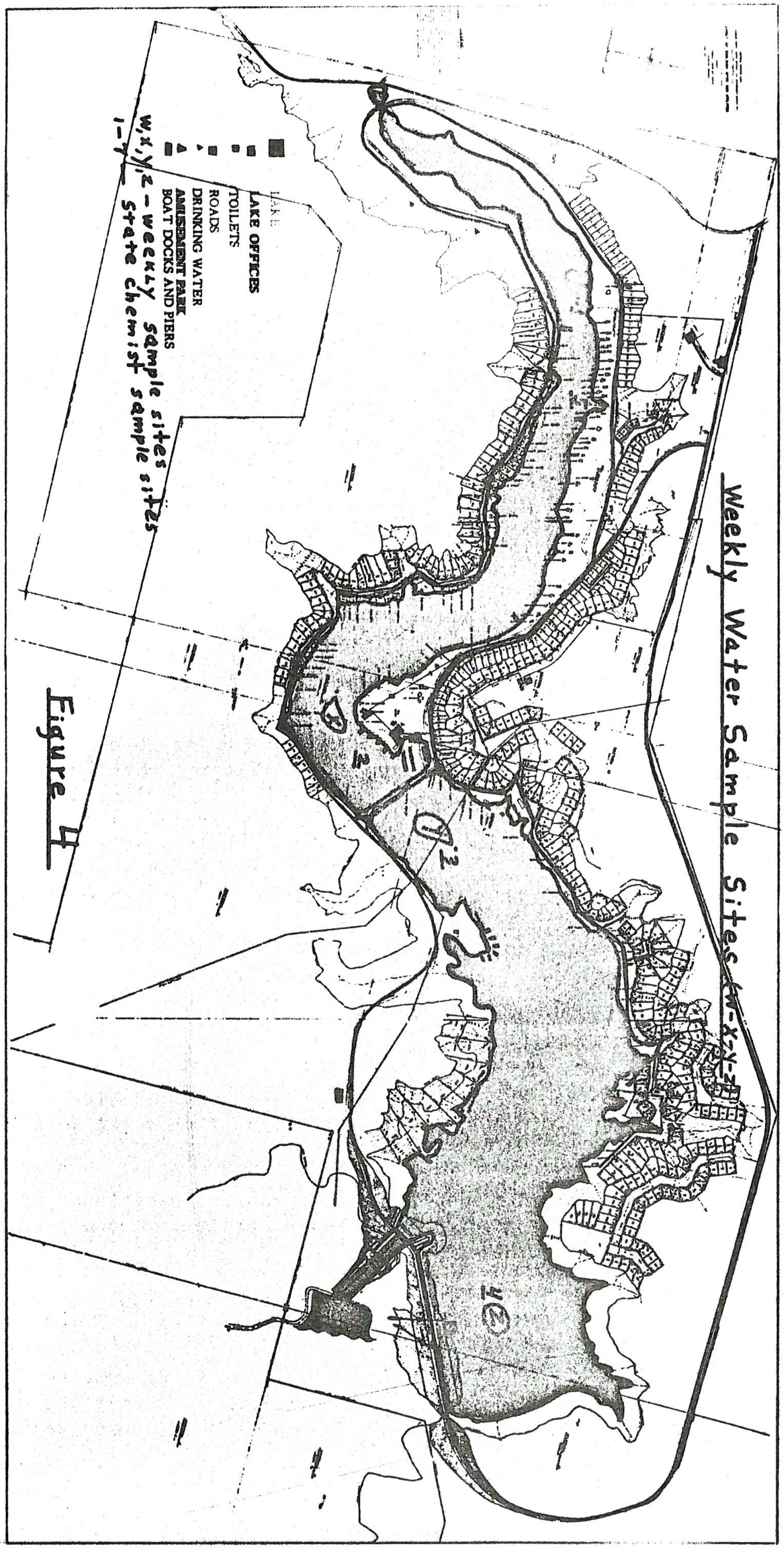

Weekly Water Sample Sites (W-X-Y-Z)
LAKE
LAKE OFFICES
TOILETS
ROADS
DRINKING WATER
AMUSEMENT PARK
BOAT DOCKS AND PIERS
W,X,Y,Z - weekly sample sites
1-7 State chemist sample sites

Figure 4

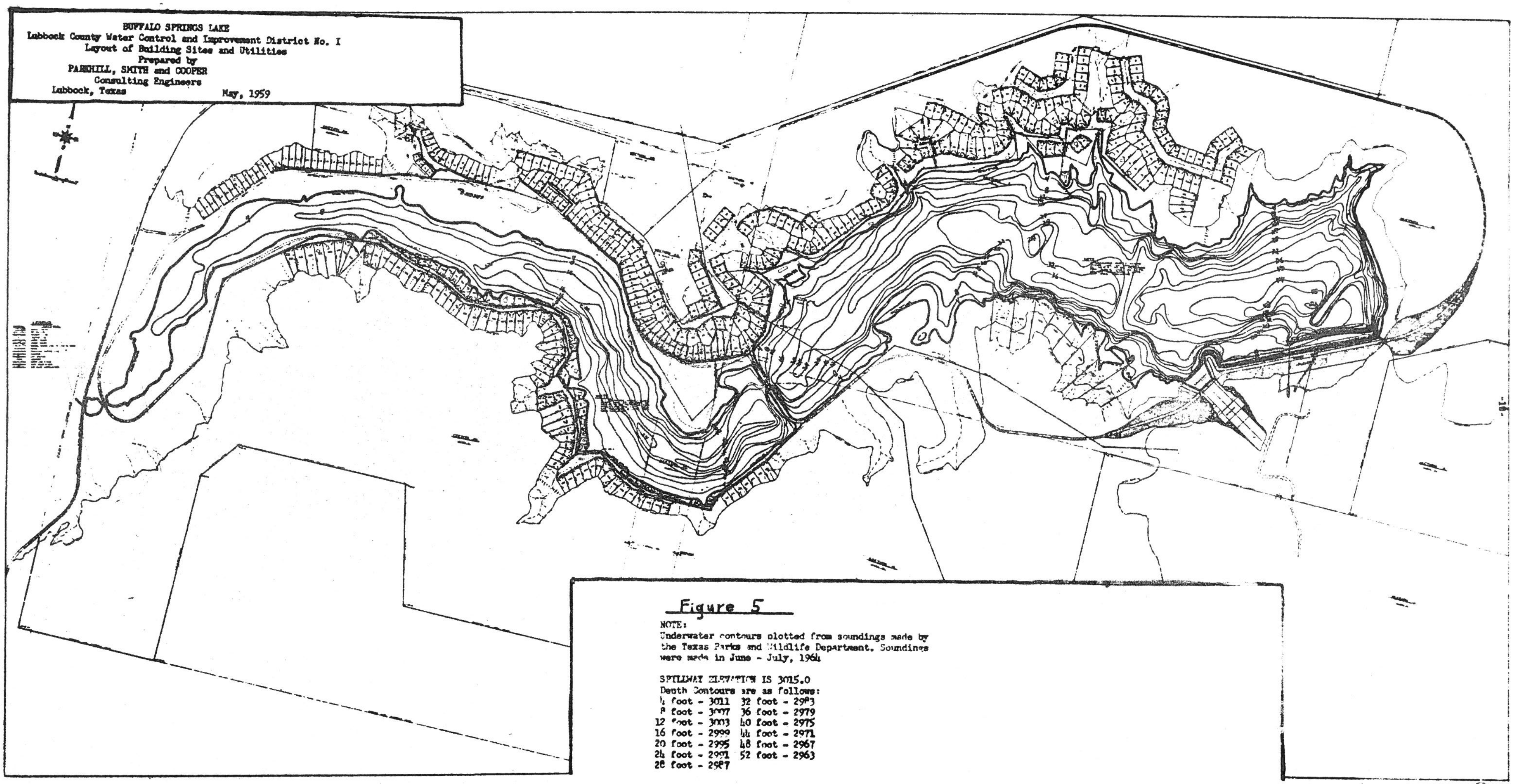

BUFFALO SPRINGS LAKE
Lubbock County Water Control and Improvement District No. I
Layout of Building Sites and Utilities
Prepared by
PARKHILL, SMITH and COOPER
Consulting Engineers
Lubbock, Texas May, 1959
NOTE:
Underwater contours plotted from soundings made by the Texas Parks and Wildlife Department. Soundings were made in June - July, 1964
SPILLWAY ELEVATION IS 3015.0
Depth Contours are as follows:
4 foot - 3011 32 foot - 2983
8 foot - 3007 36 foot - 2979
12 foot - 3003 40 foot - 2975
16 foot - 2999 44 foot - 2971
20 foot - 2995 48 foot - 2967
24 foot - 2991 52 foot - 2963
28 foot - 2987

Figure 5

The depth was measured to the bottom of the nets. These nets were allowed to remain submerged within the toxic layer for measured lengths of time. Test fish were black bullheads of about 5 inches standard length and orangespotted sunfish, (Lepomis humilis) of about 3 inches standard length. Table 3 contains water quality data obtained during the first test on July 8.

Table 3 Water Quality at Site 2, July 8, 1964.

Depth	Temperature	Dissolved Oxygen	Hydrogen Sulfide
Surface	82° F.	9.7 ppm	0.0 ppm
9 feet	78.5° F.	4.3 ppm	0.0 ppm
12 feet	78° F.	0.9 ppm	0.0 ppm
15 feet	77.5° F.	0.0 ppm	2.0 ppm
18 feet	76° F.	0.0 ppm	greater than 5.0 ppm

Control fish were kept in a minnow bucket at the surface and all were in excellent condition after the tests terminated.

In this test, fish were lowered to 9-, 12-, and 15-foot depths. Fish lowered to the 9-foot depth all appeared normal after a total exposure of 3 hours and 37 minutes. These fish were raised to the surface and examined at 10-minute intervals until 3:38 p.m. when varying intervals of longer duration were used. At 6:44 p.m. the tests were terminated.

Fish at the 12-foot depth were examined by the same schedule as the 9-foot depth specimens and all but one sunfish were in good condition at 6:41 p.m. when this net was removed. One sunfish had its head and gills entangled in the cloth mesh of the top of the live net, and was dead. Death of this fish was attributed to suffocation as its gills were rendered inoperative by the mesh were it was entangled. The 2-foot height of the live net would allow these fish to rise to about the 10-foot depth if they desired and they may have done so. Depths to which they were lowered were measured to the bottom of the nets.

Fish lowered to the 15-foot depth (2 sunfish and 4 black bullheads) were examined at 10-minute intervals from 3:05 p.m. until 3:58 p.m. when they were left until 4:12 p.m. When these fish were first examined at 3:15 p.m. (after 10 minutes exposure) they all appeared affected. Their reactions were slow and their color had changed. Yellowing of the skin of the bullheads and blanching of the colors of the sunfish occurred. All fish were alive however.

After 20 minutes exposure the sunfish in the net were dead, all the bullhead were sick, and color changes were intensified.

After 30 minutes, 2 bullheads were very sick and the other 2 less lively than before. At 3:47 p.m., after 40 minutes exposure and 3 trips to the surface for examination, all 4 bullheads were quite sick and their fins reddened or suffused with blood at the bases.

At 3:58 p.m. 1 bullhead was dead and the other 3 were badly distressed with reddened fins and red flecks on the abdomen (many dead or distressed bullheads examined during the die-offs had these same symptoms).

The same conditions were present at 4:12 p.m. At 4:28 p.m. 2 bullheads were dead and the other 2 had lost their equilibrium. At this time all the test fish were removed and replaced with six fresh bullhead specimens and lowered at 4:30 p.m.

The fresh specimens were examined at 5:00 p.m. and then again at 6:41 p.m. when this test terminated. When examined at 5:00 p.m. they had all lost their equilibrium and were olive golden in color and their bellies were reddened. When removed at 6:41 p.m. all were dead.

The next test was conducted July 17, 1964. At this time the water quality was as is expressed in Table 4. As can be seen, no H_2S was present and only 0.5° F. variation in temperature in 17 feet depth was noted. All test fish were left at the 17-foot depth for 30 minutes. None of the fish showed any effects except for a very slight reddening on the stomach and fins, and a very slight lightening in color. No equilibrium loss or any other signs of distress were noted.

Table 4. Water Quality at Site 2, July 17, 1964.

Depth	Temperature	pH	D.O.	H_2S	Ammonia Nitrogen
2 feet	77° F.	8.6	6.0 ppm	0.0 ppm	0.8 ppm
10 feet	77° F.	8.5	4.6 ppm	0.0 ppm	0.4 ppm
17 feet	76.5 ° F.	8.4	3.6 ppm	0.0 ppm	$<$0.2 ppm

The last caged fish bio-assay was conducted August 6, 1964. Test fish were 3 orangespotted sunfish and 4 bullheads per live-net. The location at site 2 was changed slightly to allow submerging the live-nets to a depth that insured exposure of all fish at all times to the effects of the toxic layer. Water quality at the site is shown in Table 5.

Table 5. Water Quality at Site 2, August 6, 1964.

Depth	Temperature	pH	D.O.	H_2S	CO_2
22 feet	79° F.	8.5	0.0 ppm	4.0 ppm	2.0 ppm

Table 6 contains the data from the test. All fish were submerged to 22-foot depth. Each live-net contained 4 bullheads and 3 sunfish.

Table 6. Results of Live Caged Fish Bio-Assays of the Toxic Layer of Water in Buffalo Springs Lake on August 6, 1964.

Net No.	Time	Condition When Removed from Layer	Condition Next Day
1	5 min.	3 sunfish alive, distressed 4 bullheads alive, distressed and swimming upward	3 sunfish alive, color faded 1 bullhead alive, red flecked and 3 bullheads dead
2	10 min.	3 sunfish looked dead, 1 recovered 4 bullheads alive, distressed	3 sunfish dead 2 bullheads dead 2 bullheads alive, red flecked
3	15 min.	3 sunfish looked dead, 1 recovered 4 bullheads alive, distressed	2 sunfish dead 1 alive, fine condition 4 bullheads alive
4	Control on surface - all fish in fine condition.		

Analysis of the results of these tests indicates that prolonged exposure of fish to conditions present in the toxic layer is fatal. It also indicates that short term exposure results in subsequent mortality of the exposed fish.

Lack of oxygen would cause distress and possibly would cause the reddening of the fins and tissues; however, there should be no fatalities due to short term oxygen lack alone.

E. W. Bonn, in his Job No. E-1, Channel Catfish Study, says: "To observe the effects of low oxygen the dissolved oxygen level was intentionally kept below 1.0 ppm for several hours in an experimental jar. The fry stayed near the top of the water while the oxygen was low, but returned to the bottom of the jar as soon as the oxygen level was raised. In another experiment 10 fry were held in Lake Texoma water with less than 1.0 ppm oxygen for 24 hours. All fish were very weak, but all recovered when the oxygen was raised above 3.0 ppm and apparently suffered no immediate ill effects."

Three of the bullheads were submerged in the toxic layer 5 minutes. They were alive but distressed when removed and died later. This indicates that effects other than lack of oxygen were killing the fish. One of the sunfish exposed 10 minutes was distressed when removed from the layer. He appeared to have recovered but died within 24 hours.

The following information was received from State Chemist Charles Ezell concerning ammonia nitrogen content and its effect on fish:

"The following are the results of bio-assays conducted here at the lab in San Marcos:

Concentration (Ammonia Nitrogen)	10 ppm pH 9.1	6 ppm pH 8.9	4 ppm pH 8.0
#1	All dead within 12 hours.	All dead within 12 hours	All dead within 24 hours.
#2	All dead within 12 hours.	All dead within 12 hours.	All dead within 24 hours.
#3	All dead within 12 hours.	All dead within 12 hours.	All dead within 24 hours.
Control	All alive and okay.	All alive and okay.	All alive and okay.

"Water for these bio-assays was from the supply reservoir here on the hatchery. Test animals were also obtained from the hatchery.

"In all of the bio-assays all of the test animals exhibited extreme discomfort almost immediately upon introduction into the test solution. After a short period in the test solution a redness appeared and deepened until death. Just prior to death the test animals would erratically work the water surface making gasping motions with their mouths."

There was no ammonia nitrogen analysis of the Buffalo Springs Lake water when the last live caged fish test was made. If synergistic action of H_2S, ammonia nitrogen, and dissolved oxygen lack is occurring, future tests should include a more complete water analysis in order to indicate this.

Gill netting results indicated that fish enter this toxic layer voluntarily to feed or for other reasons. Fish were repeatedly found dead in the nets on the deeper end within the toxic zone, apparently killed by the conditions existing in the toxic layer.

Data from the State chemist's water analysis of the lake on September 22 and 23, 1964, are shown in Table 7. Temperature gradients for sites X and Z are presented in Table 8. This table contains data indicating depth, temperature, dissolved oxygen, and where the toxic layer occurred. Sample stations are shown in Figure 4. Samples were surface only at stations 5, 6 and 7. Surface, mid and bottom water samples were taken at stations 1 through 4. Care was taken to avoid disturbing bottom sediments when water samples at "bottom" were taken.

Water in the upper lake, at sites 1 and 2 was lacking in hydrogen sulfide although ammonia nitrogen in deleterious amounts was present.

Table 7. Water Quality in Buffalo Springs Lake at 7 Sites and Various Depths as Revealed by Chemical Analysis September 22 and 23, 1964.

Station		Temp.	D.O.	CO_2	Alkalinity	pH	Ammonia Nitrogen	Phenolphthalein Alkalinity	Methyl Orange Alkalinity
1)	top	71.5	5.4	1.0	208	8.8	1.93	29	179
5'	bot	70.0	4.2	2.5	223	8.8	1.89	40	183
2)	top	71.5	5.4	2.0	206	8.7	1.97	38	179
12'	mid	70.5	3.4	0.5	199	8.7	1.95	27	161
24'	bot	70.0	2.2	0.0	195	8.4	1.62	17	178
3)	top	73.0	5.8	0.0	213	8.4	1.50	32	181
12'	mid	71.5	4.8	0.0	215	8.4	1.28	31	184
24'	bot	71.0	2.2	0.0	206	8.2	1.25	29	178
4)	top	73.0	5.6	0.0	220	8.6	1.50	39	181
20'	mid	71.0	2.0	0.0	188	8.4	1.36	20	168
40'	bot	66.0	0.0	1.5	208	7.8	5.85	0	208
5)	top	70.5	5.2	0.5	212	8.9	2.23	33	179
6)	top	75.0	4.2	0.0	202	8.4	1.66	14	188
7)	top	74.0	4.8	0.0	202	8.2	1.17	20	182

		Alkyl Benzene Sulfonate	Phenols
2)	top	0.078	0.012
4)	top	0.133	0.010
5)	top	0.072	0.016
6)	top	0.104	0.008
7)	top	0.104	0.008

Table 8. Temperature Profiles of Sitex X and Z in Figure 4. These were Conditions on September 23, 1964.

SITE X

Depth	Temperature	Dissolved Oxygen
0	71.5	5.4
3	71.5	4.0
6	71.0	3.6
9	70.5	2.0
12	70.5	3.4
15	70.0	1.8
18	70.0	2.0
21	69.9	1.8
24	70.0	2.2

SITE Z

Depth	Temperature	
0	73.0	
3	73.0	
6	72.5	
9	72.0	
12	71.5	
15	71.5	
18	71.0	
21	71.0	
24	71.0	
27	71.0	
30	71.0	
33	71.0	
36	71.0	- Hydrogen Sulfide appeared, strong odor
39	67.0	
40	66.0	

Hydrogen sulfide appeared (strong odor) at the 36-foot depth at site 4 in the lower lake. At all sites ammonia nitrogen was present in amounts over 1.17 ppm, and at the 40-foot depth at site 4 ammonia nitrogen was present at 5.85 ppm.

The layer of toxic substances shifted readily and usually accompanied a 3° (or more) break in temperature. It occurred at pH ranges from 7.8 to 9.0 and temperatures from 62° F. to 80° F. Figure 6 contains data encompassing the ranges of readings of pH, temperature, and depths at which the toxic layer occurred at site Z.

Hydrogen sulfide is toxic to fish in proportion to the amount of unionized hydrogen sulfide in the water. Water Quality Criteria, page 200, paragraph 2, states: "The sources of hydrogen sulfide in water include natural processes of decomposition, sewage, and industrial wastes such as those from tanneries, paper mills, textile mills, chemical plants, and gas-manufacturing works." Few industrial plants on the Buffalo Springs Lake watershed and the H_2S present is formed by anaerobic bacterial action on natural or introduced organic wastes in the lake.

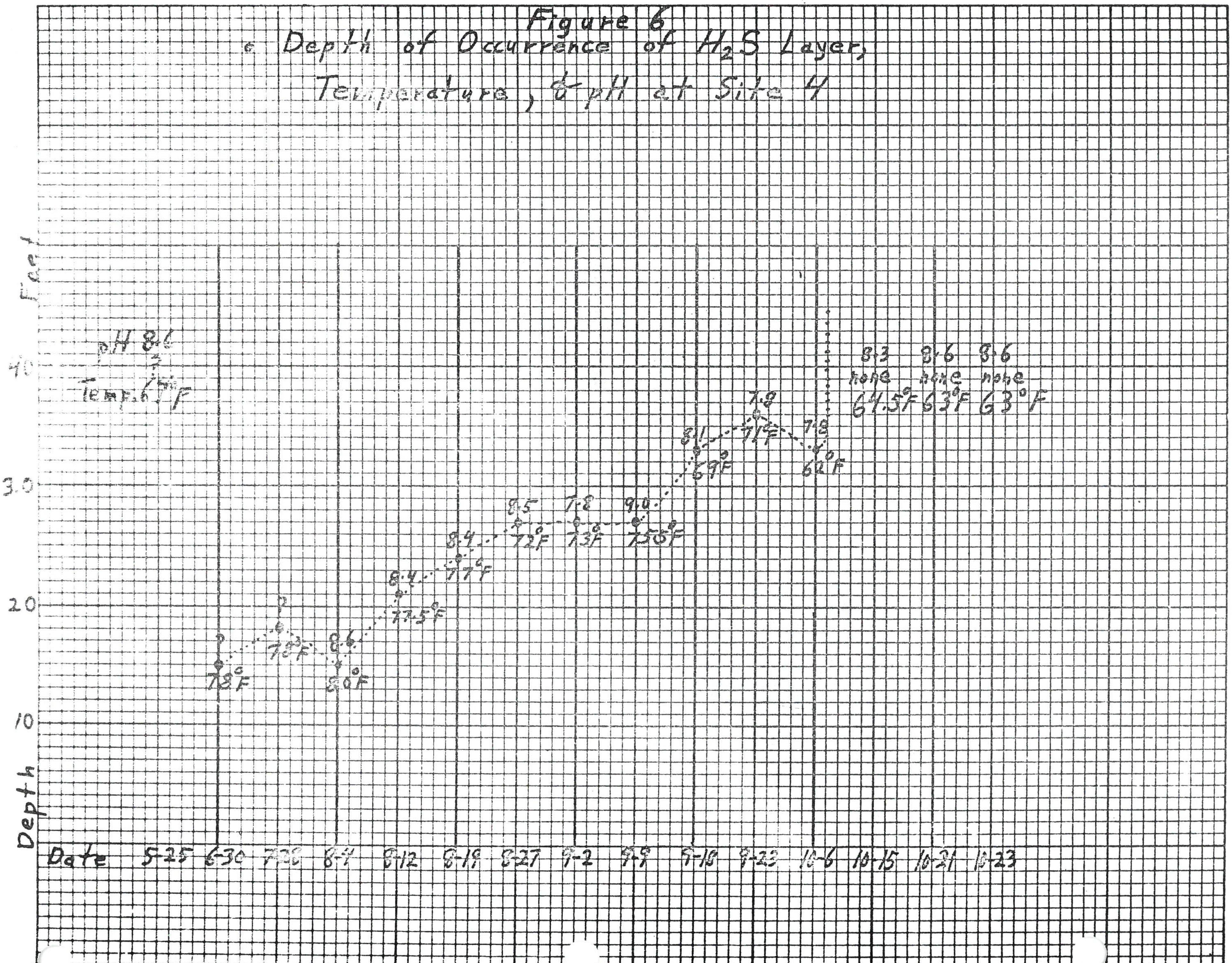


Figure 6
Depth of Occurrence of H_2S Layer, Temperature, & pH at Site 4

The 417.6 ppm average sulfates in the surface water supply (Table 2) provide abundant food for plants, algae, and plankton. This tends to produce corollary pollution by creating a dense algae layer in the upper 2 feet of water. The organic wastes from these growths is another source of materials for bacteria to act upon in producing H_2S.

Ammonia nitrogen is soluble in water to 100,000 milligrams per liter at 20^o C. Hydrogen sulfide is soluble to 4,000 milligrams per liter at 20^o C. and one atmosphere of pressure. At depths of 20 feet and below, pressures are greater and what solubilities, chemical reactions, or varied metabolic effects occur there are not known.

Water Quality Criteria, page 133, section e, states: "According to many references, the toxicity of ammonia and ammonium salts to aquatic animals is directly related to the amount of undissociated ammonium hydroxide in the solution, which in turn is a function of pH as explained under "General" above. Thus, a high concentration of ammonium ions in water at a low pH may not be toxic, but if the pH is raised toxicity will probably increase. Ellis found that the toxicity of a given concentration of ammonium compounds toward fish increased by 200 per cent or more between pH 7.4 and 8.0." Also, two paragraphs later, "The toxicity of ammonia to fish is increased markedly at low tensions of dissolved oxygen."

The behavior and strange death pattern of the fish used in the live caged fish test suggest that synergistic action may be occurring between ammonia nitrogen, hydrogen sulfide, and dissolved oxygen in the toxic zone. Those fish which were submerged the longest period of time survived best. Those fish which were exposed longest became unconscious while in the toxic zone and could not actively attempt escape when removed from the layer. The fish which were still capable of coordinated action swam vigorously upward accelerating their metabolic rates. Fish which actively attempted escape had a high mortality rate.

Ammonia can originate as a direct pollutant but this is not the case at Buffalo Springs Lake.

Water Quality Criteria, page 132, under "Ammonia" states: "in surface or ground waters, however, it generally results from the decomposition of nitrogenous organic matter, being one of the constituents of the complex nitrogen cycle.", and one sentence later, "Rivers known to be unpolluted have very low ammonia concentrations, generally less than 0.2 mg/L as N." N in this case is the total ammonia nitrogen content as NH_3, NH_4OH, and NH_4^+. The test for ammonia as N is the test represented in tables and graphs in this report as ammonia nitrogen.

It can readily be seen from field analysis by the State chemist that ammonia nitrogen is considerably in excess of 0.2 milligrams per liter in Buffalo Springs Lake. One milligram per liter translates roughly into one part per million (ppm).

Flow data were taken each week beginning in August anticipating the feasibility of draining the toxic layer from the bottom of the lake if flow proved to be sufficient to prevent buildup of the layer. It is doubtful that this will be possible because inflow averaged only 7.52 cubic feet per second from August 9, 1964, through November 25, 1964. This average is probably high because several readings were made which were inaccurate and had to be discarded. Light rain occurred on November 16, 17 and 18, increasing the reading for November 18 to

26.46 cubic feet per second which would tend to increase the average considerably for the short term data presently available. These measurements are being continued, and possibly a period of trial drainage from the bottom layer of the lake will be conducted in the spring of 1965 as the layer is forming.

Examination of weather data, obtained from the U. S. Weather Bureau, indicated that surface water temperatures correlated to the average daily temperatures with a few hours lag in attaining those temperatures. In several instances the water temperature lowered when the average daily temperatures did not. Rainfall, in one instance, caused shifting of the thermal gradient in the lake when daily temperatures were fairly stable.

The temperature gradient of the lake water on July 28 was quite steep as illustrated in Figure 7. The odor of H_2S gas appeared at the 18-foot depth at a temperature of 78° F. close to the upper end of the thermocline. The epilimnion occurred from 15 feet to the surface. The thermocline existed from 15 feet to 36 feet and the hypolimnion occurred from 36 feet to the bottom.

The epilimnion is a zone where temperature changes are less than 0.548° F. for each foot change in depth. A thermocline is a zone where temperature changes are in excess of 0.548° F. per foot in depth, and hypolimnion temperature requirements are the same as for the epilimnion.

In all figures showing temperature gradients, anaerobic conditions existed in the area below the upper limit of the toxic zone. Fish could not live in that area. On August 4 (Figure 8) the epilimnion extended to 15 feet and the H_2S layer began at 15 feet. The thermocline extended on down to 33 feet and from 33 feet to the bottom was hypolimnion.

On August 12 (Figure 9) and August 19 (Figure 10) conditions remained fairly stable.

On August 27 (Figure 11) the epilimnion was 21 feet deep, the H_2S layer began at 21 feet and the thermocline continued down to the bottom. It contained an unusual temperature inversion. Reference to weather data did not explain the inversion in terms of daily temperatures. At times during sampling the most intense concentration of H_2S was at the upper limit of the toxic zone. No tests were run to determine if a temperature inversion existed at these times.

On September 2 (Figure 12) the sudden shift of 7° in 3 feet seen on August 27 had smoothed out and general epilimnion temperatures had lowered from about 79° F. to 74° F. The H_2S layer began at 27 feet. The thermocline began at 30 feet and went down to the bottom. The inversion layer remained at 42 feet although it was less abrupt with only a 3 degree rise back to 68° F. at 45 feet.

On September 9 (Figure 13) and September 18 (Figure 14) there was little change in conditions except the loss of the inversion layer and general cooling of the lake water on September 18, following several days of low average daily temperatures.

On October 6 (Figure 15) additional cooling is evident; however, the H_2S layer still appeared at 33 feet at 62° F. The toxic zone disappeared when the

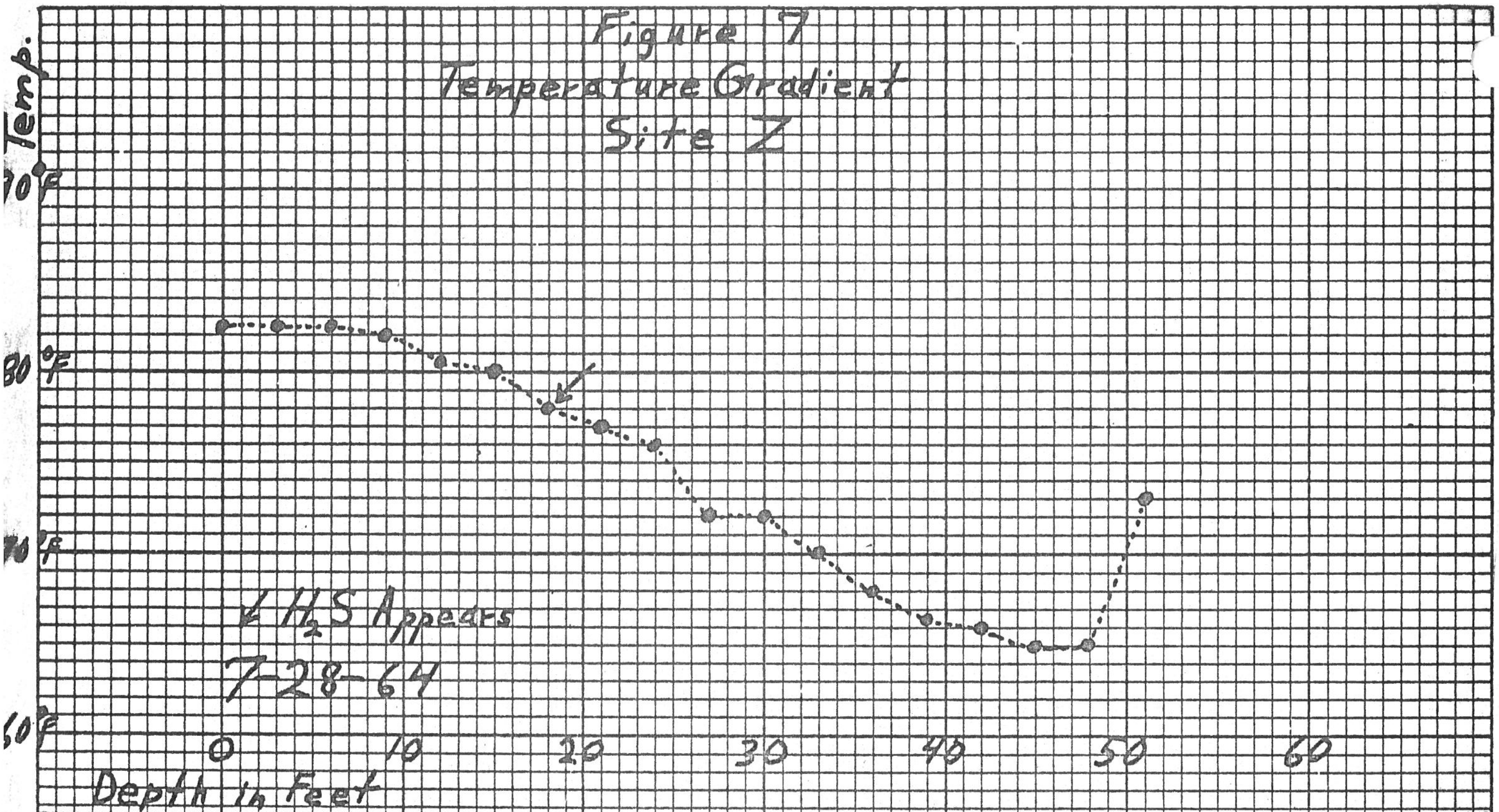


Figure 7
Temperature Gradient
Site Z
Temp.
70°F
80°F
70°F
60°F
↙ H2S Appears
7-28-64
0
10
20
30
40
50
60
Depth in Feet

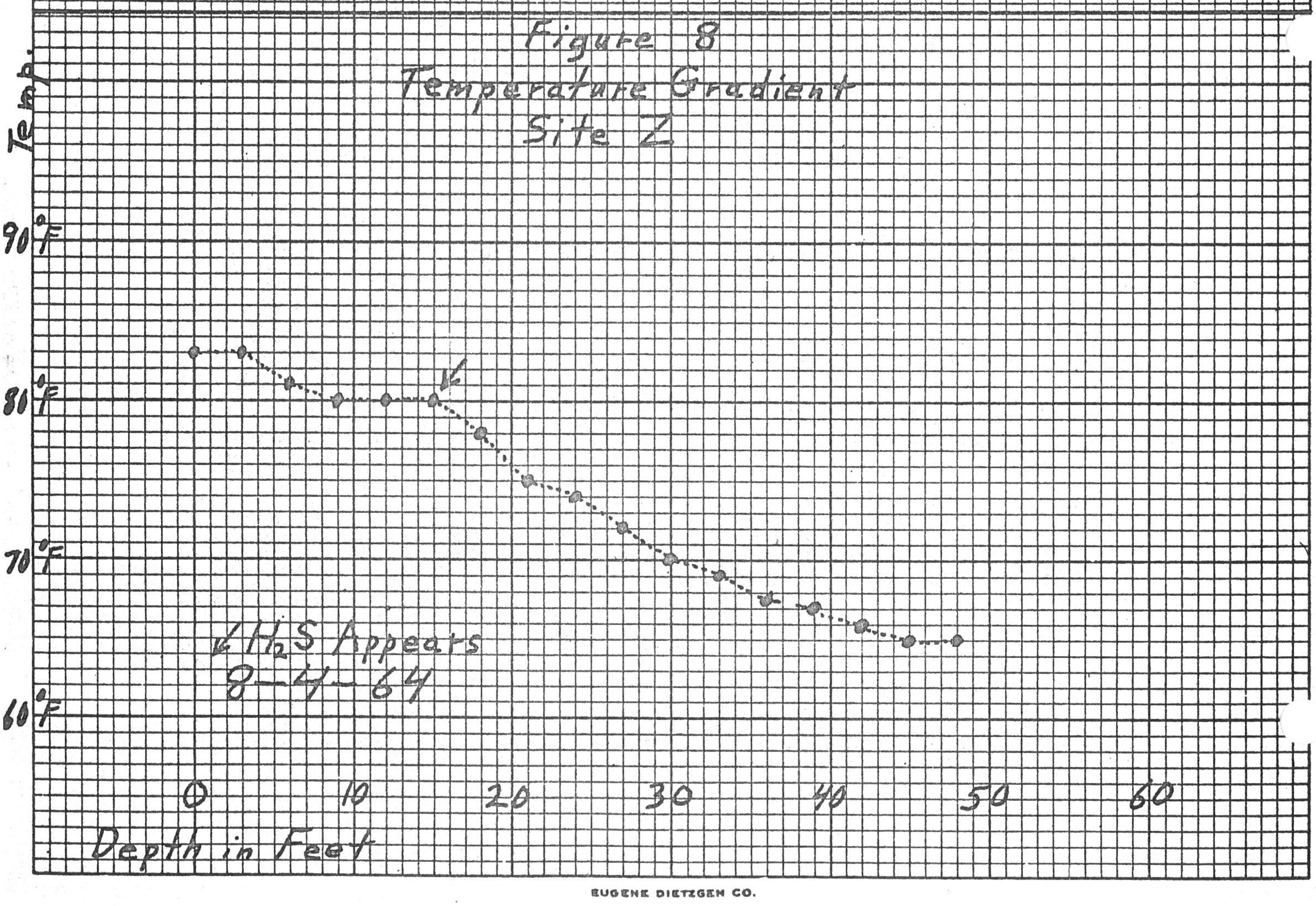


Figure 8
Temperature Gradient
Site Z
Temp.
90°F
80°F
70°F
60°F
↙ H2S Appears
8-4-64
0
10
20
30
40
50
60
Depth in Feet

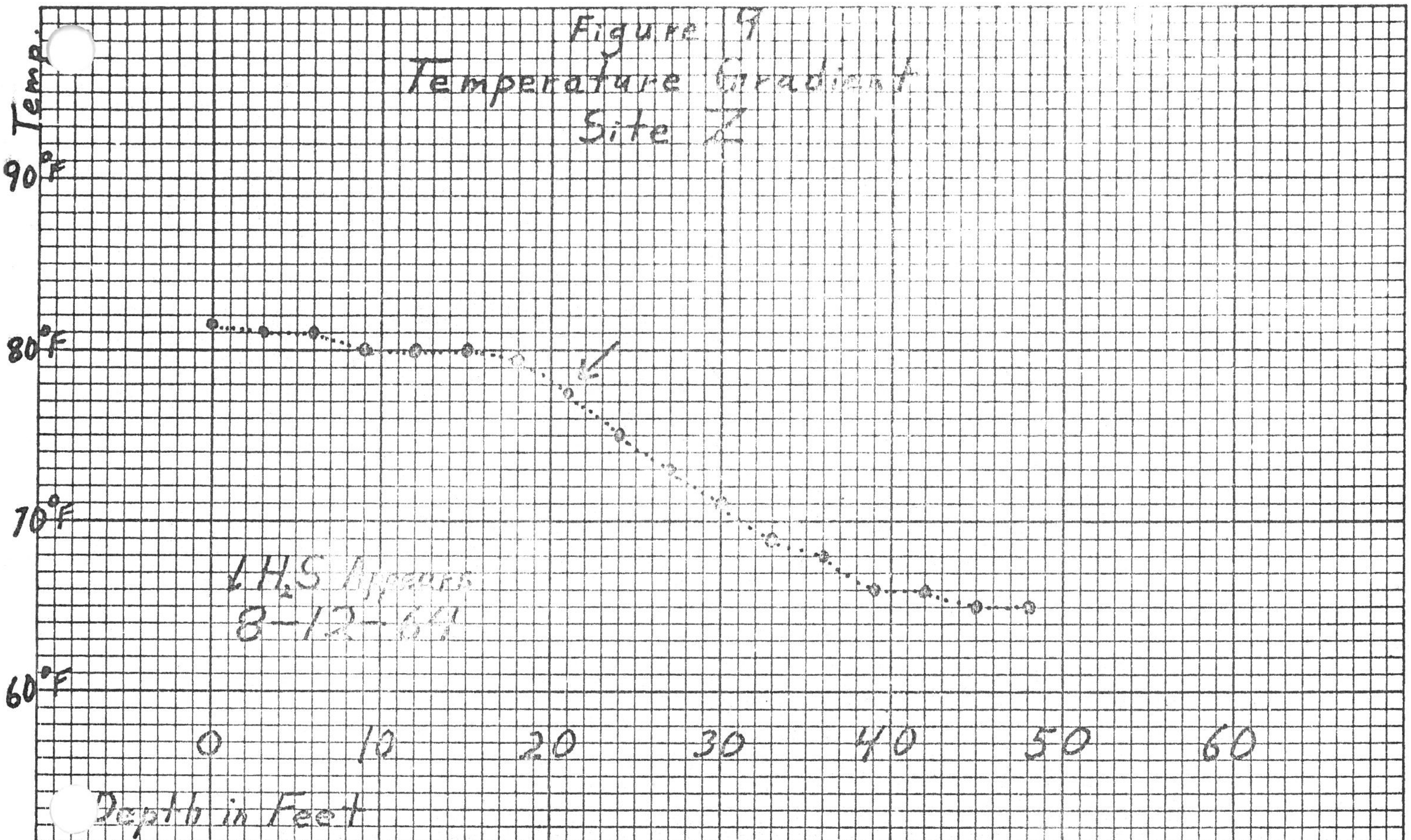


Figure 9
Temperature Gradient
Site Z

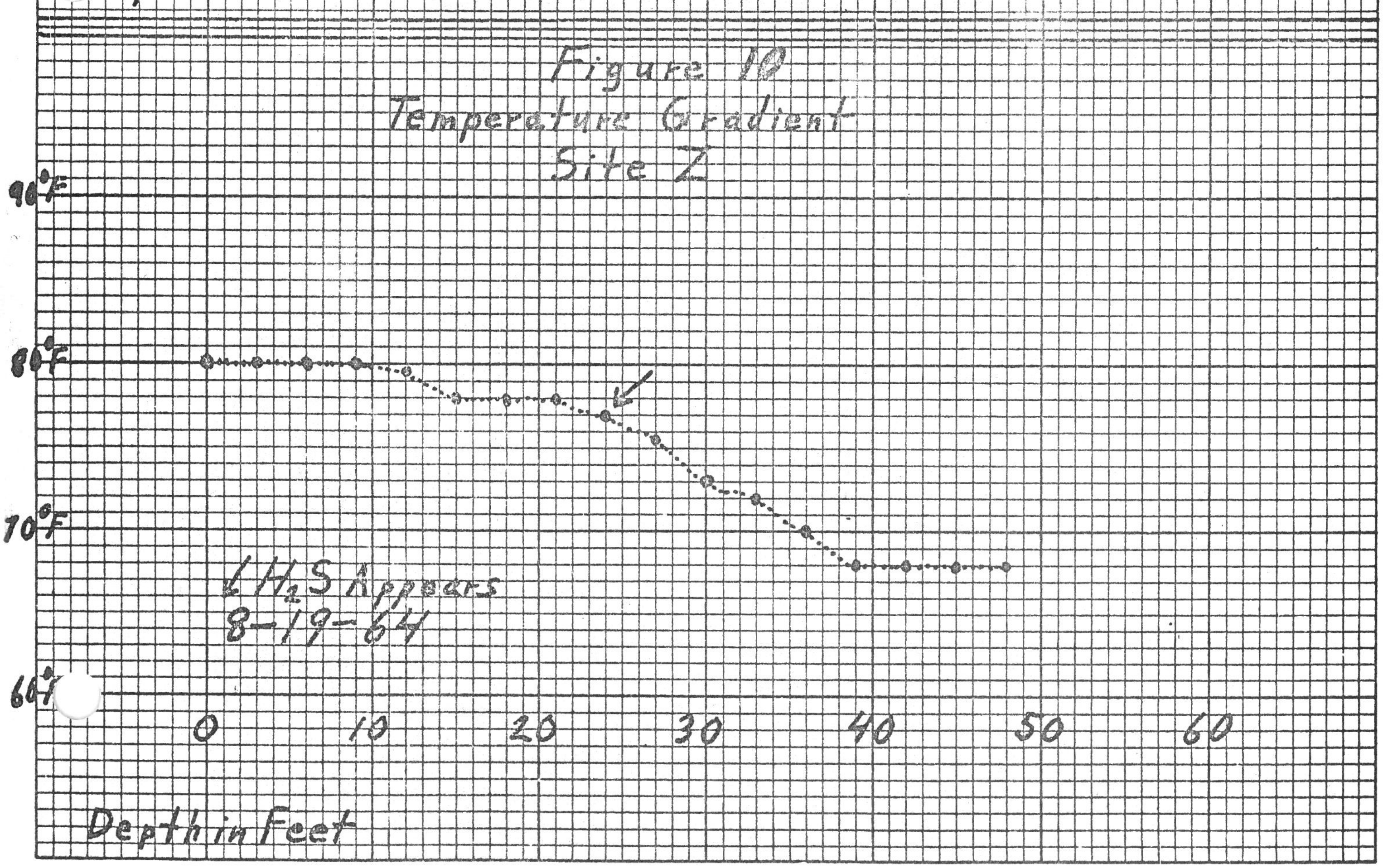


Figure 10
Temperature Gradient
Site Z

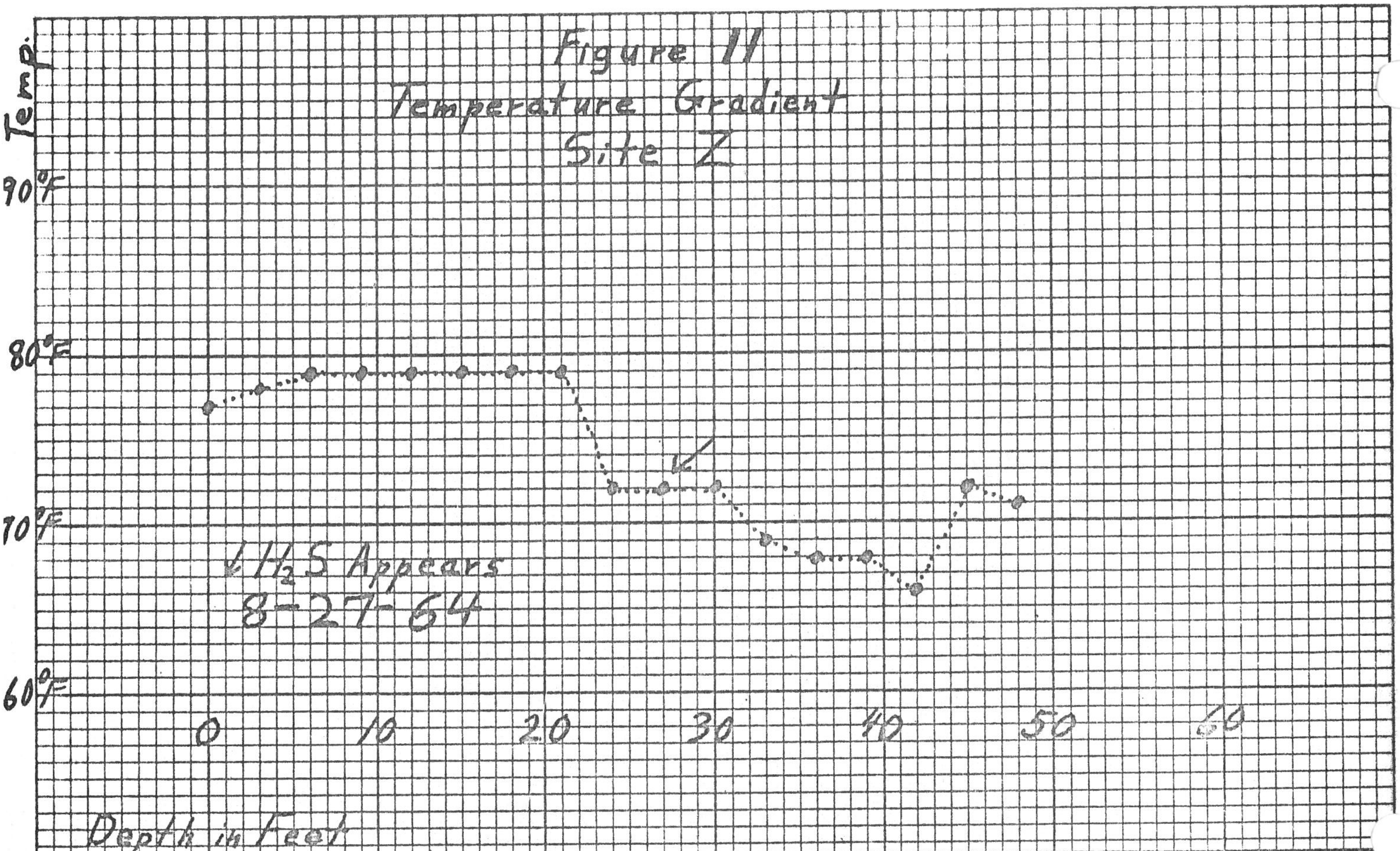


Figure 11
Temperature Gradient
Site Z
Temp.
90°F
80°F
70°F
60°F
0
10
20
30
40
50
60
↙ H_2S Appears
8-27-64
Depth in Feet

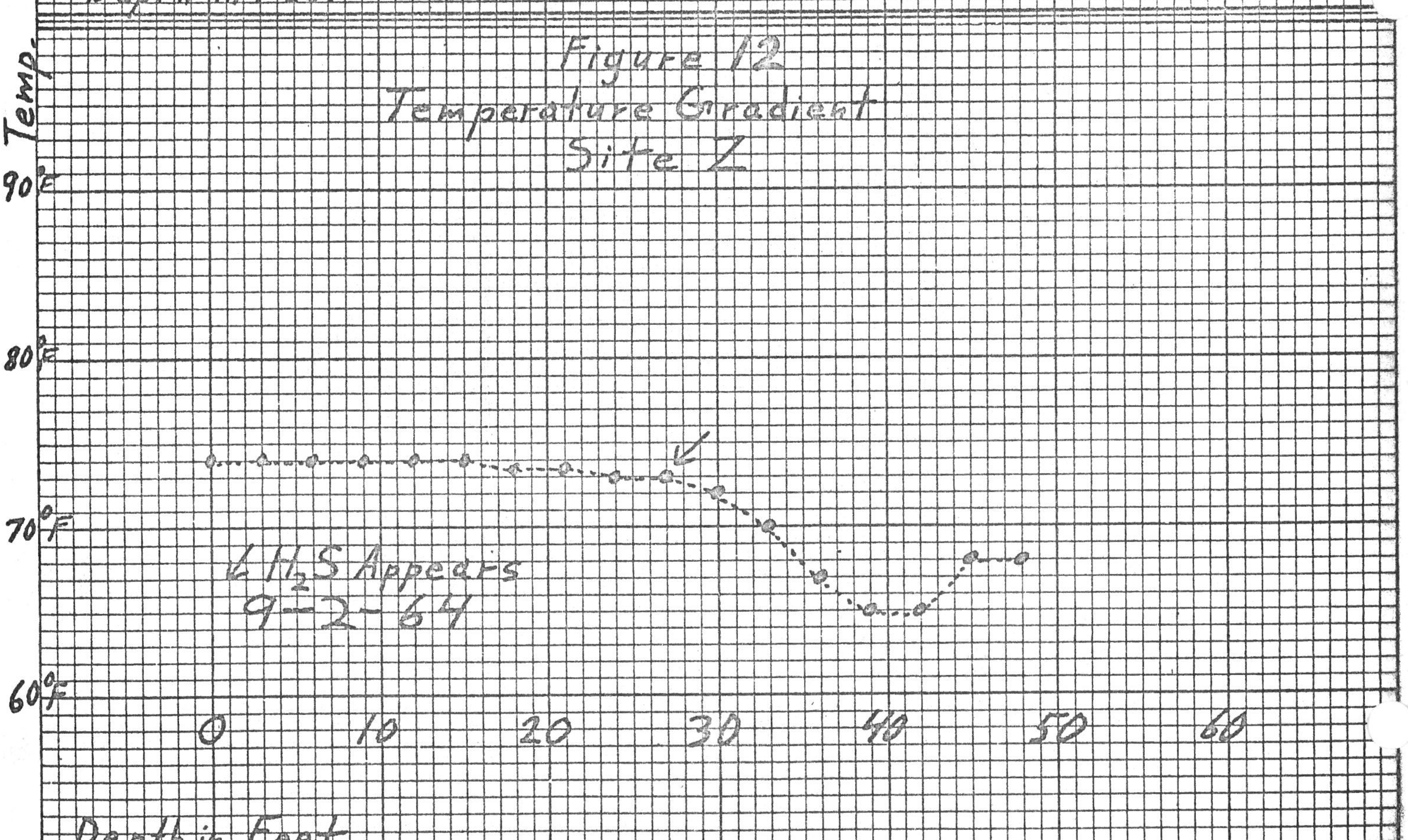


Figure 12
Temperature Gradient
Site Z
Temp.
90°F
80°F
70°F
60°F
0
10
20
30
40
50
60
↙ H_2S Appears
9-2-64
Depth in Feet

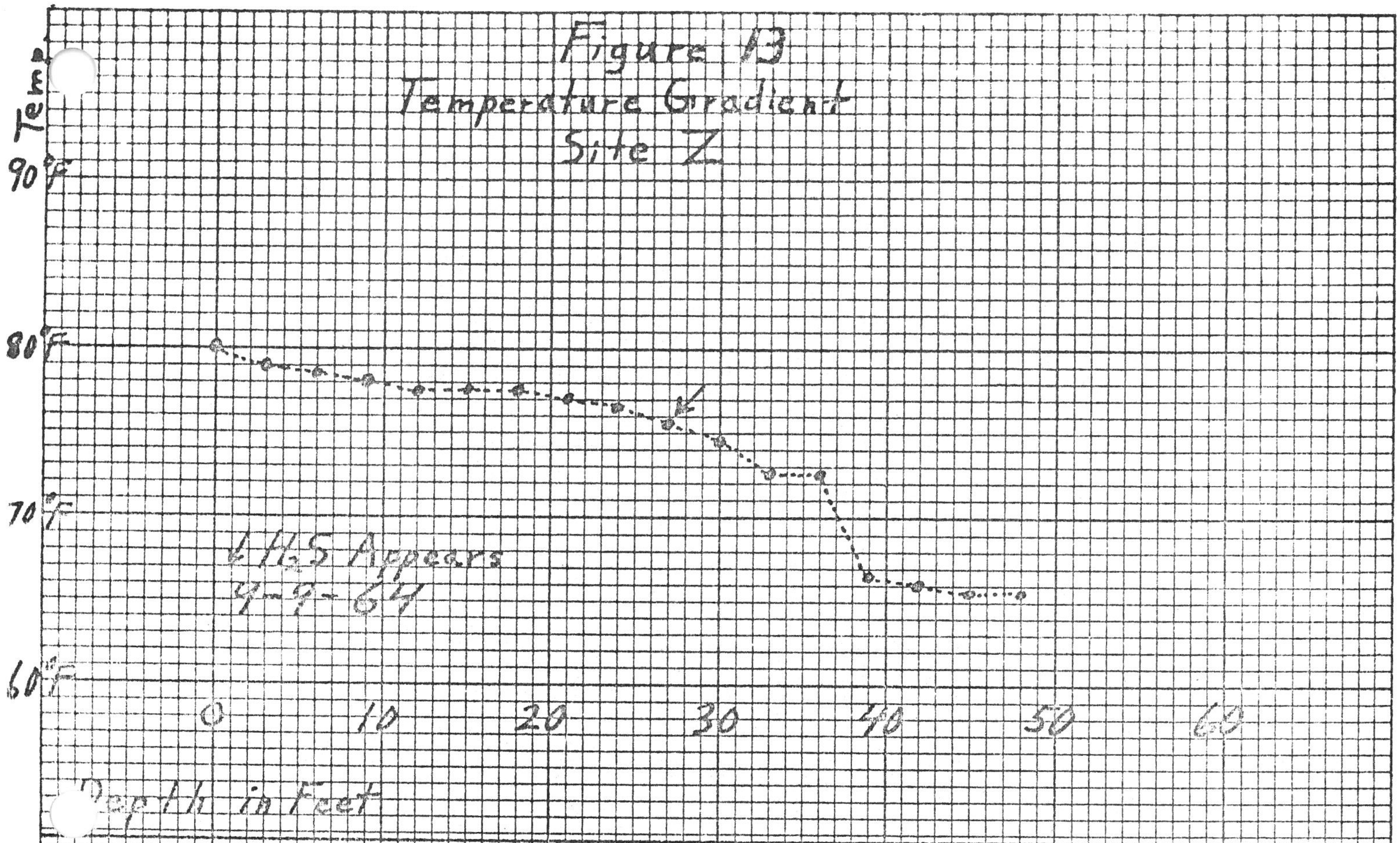


Figure 13
Temperature Gradient
Site Z
Temp
90°F
80°F
70°F
60°F
↓H$_2$S Appears
9-9-64
0
10
20
30
40
50
60
Depth in Feet

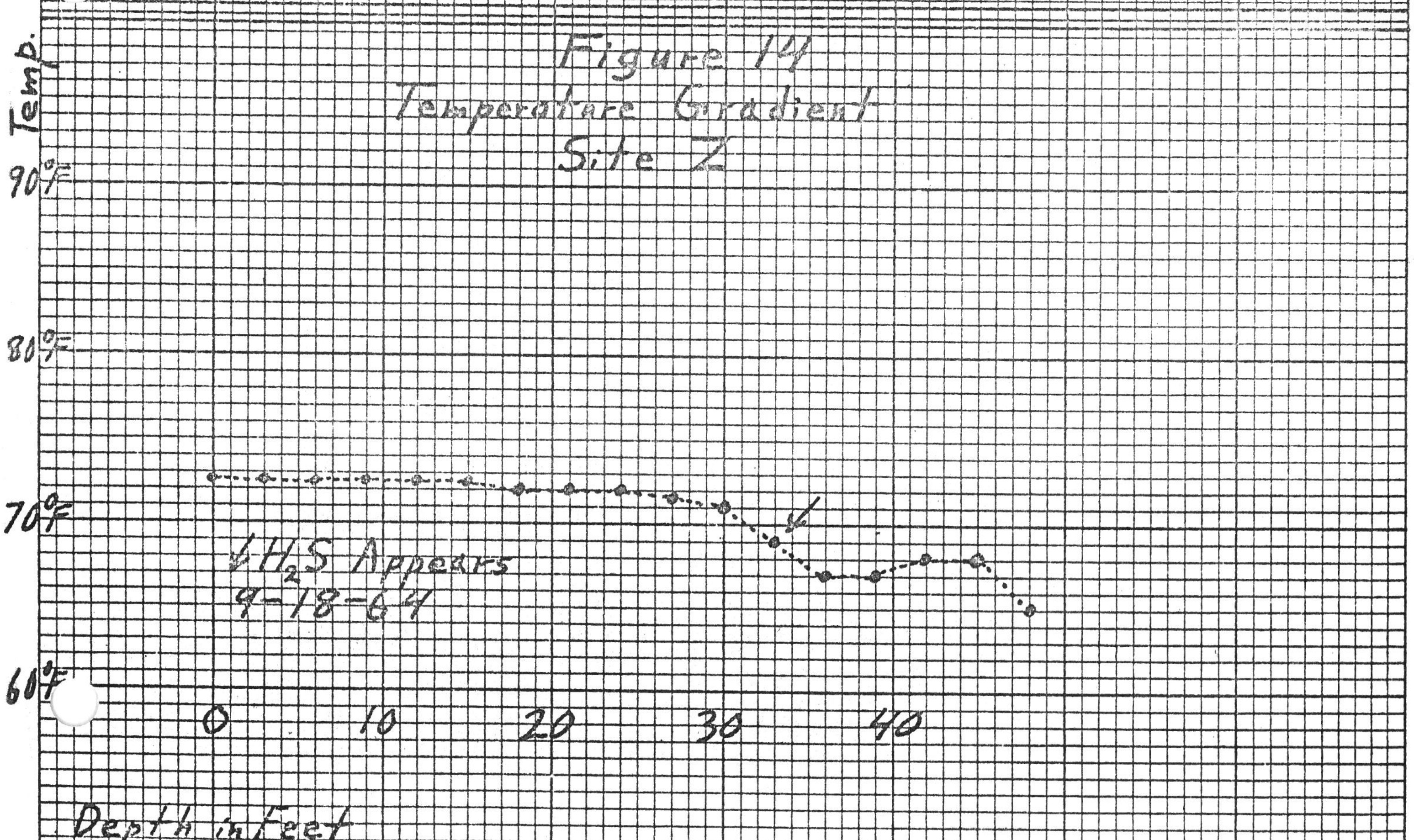


Figure 14
Temperature Gradient
Site Z
Temp.
90°F
80°F
70°F
60°F
↓H$_2$S Appears
9-18-64
0
10
20
30
40
Depth in Feet

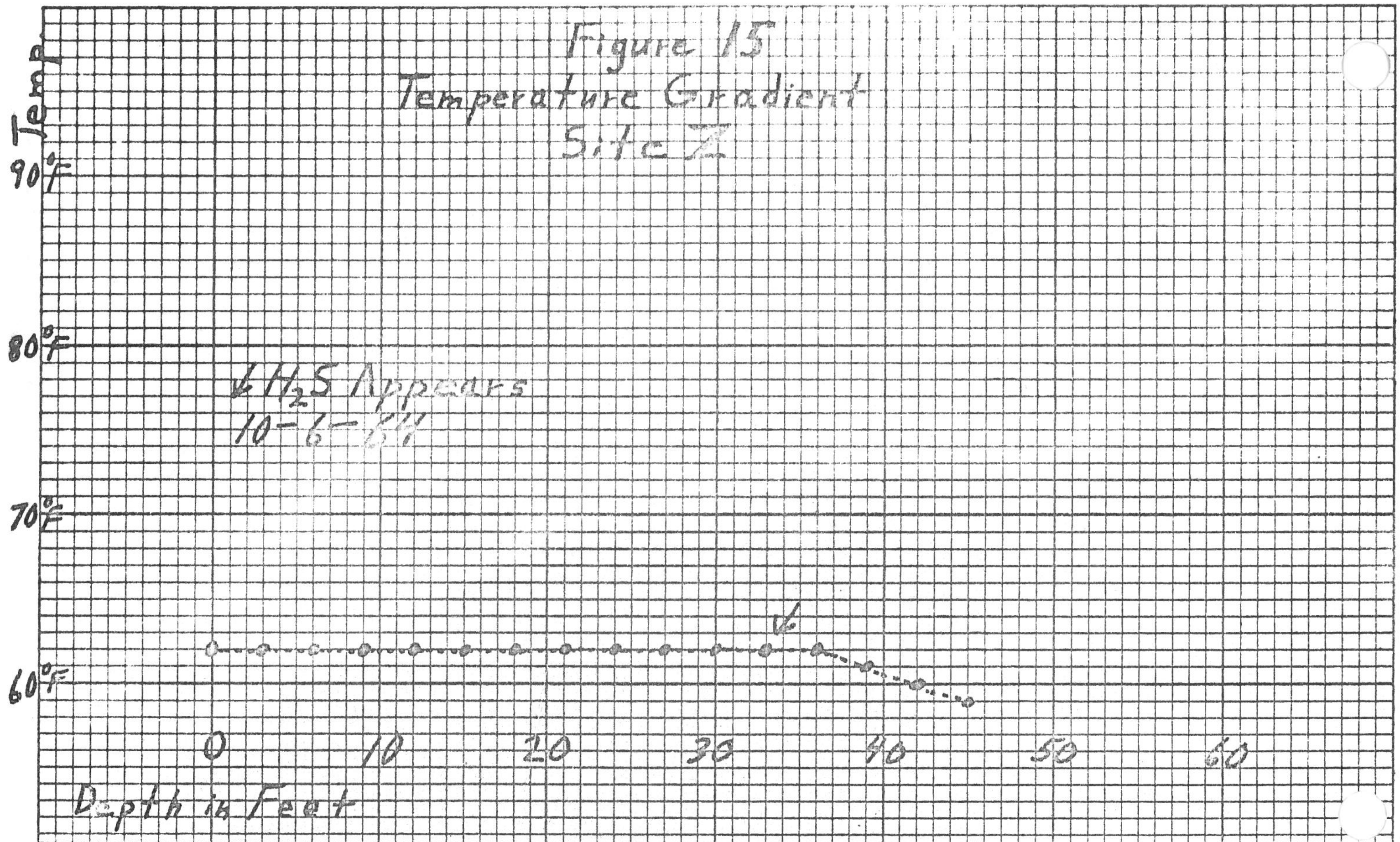


Figure 15
Temperature Gradient
Site Z
Temp
90°F
80°F
70°F
60°F
H_2S Appears
10-6-64
0
10
20
30
40
50
60
Depth in Feet

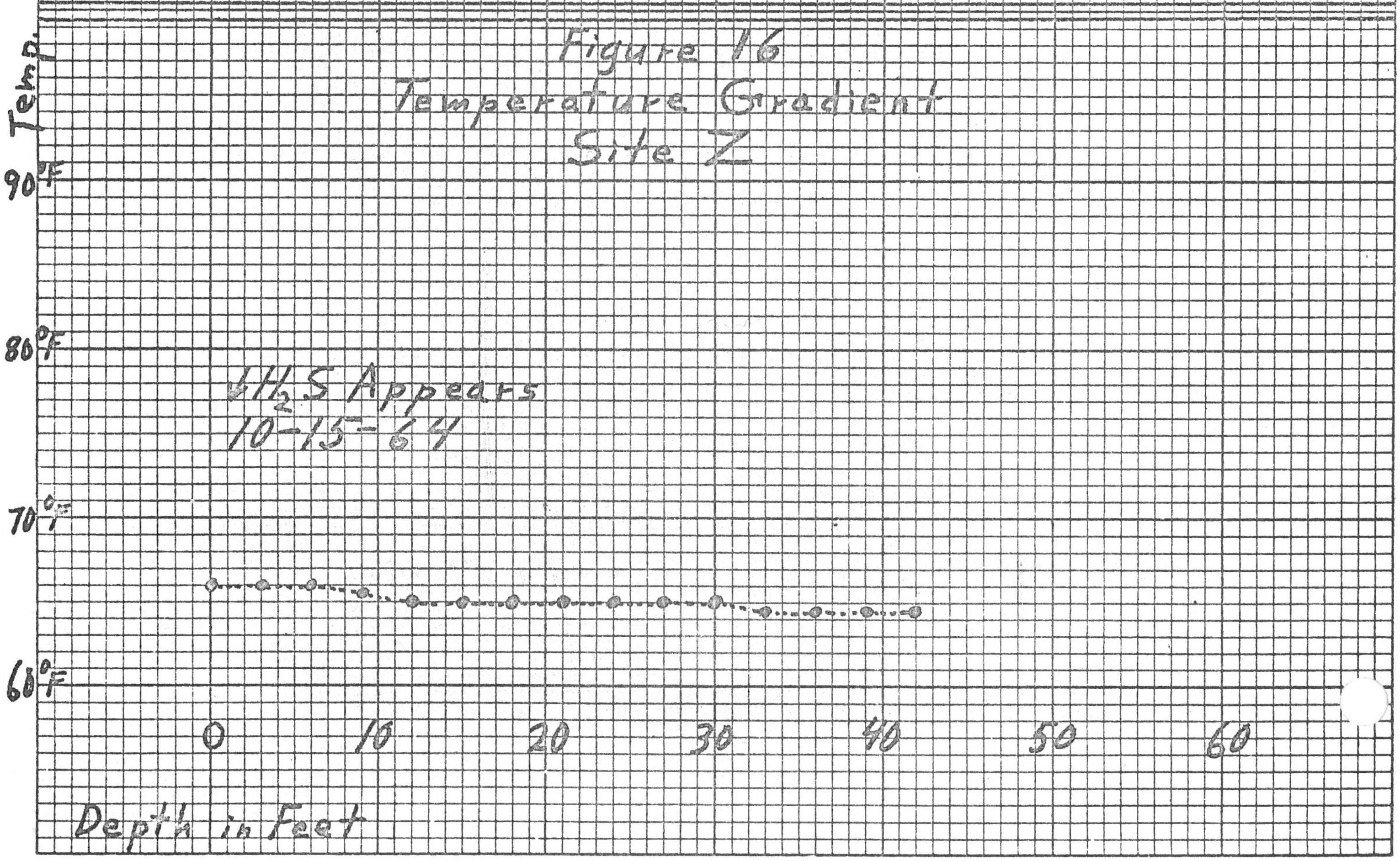


Figure 16
Temperature Gradient
Site Z
Temp
90°F
80°F
70°F
60°F
H_2S Appears
10-15-64
0
10
20
30
40
50
60
Depth in Feet

lake became almost isothermal on October 15, 1964 (Figure 16). The lake became isothermal to within 0.5° F., shown as a straight line in Figure 17, on October 21.

October 15 through October 28 constitutes the period of fall overturn of Buffalo Springs Lake in 1964.

The H_2S layer began between 70° F. and 80° F. at all times except on October 6 (Figure 15) when it began at 62° F. and was gone by odor test 9 days later when the entire lower lake was almost isothermal (Figure 16). The isothermal condition occurred at above 62° F., however, so it is assumed that the isothermal condition of the lake rather than termperature range caused the disappearance of the layer, unless the layer which existed on October 6 was composed of residual gases after rapid bacterial action had already ceased. The lake remained almost isothermal (Figures 17 and 18) until data collection for this report terminated.

Figures 19, 20, 21 and 22 contain pH data. Examination of these figures reveals that pH is above 8.2 the great majority of the time. The different water sample sites shown in Figure 4, have slightly different pH ranges (Figures 19 through 22). The general trend is toward more acid readings in the lower downstream areas or at greater depths.

A fairly wide spread of pH readings occurred at site Z near the dam. As the lake's temperature gradient at this site approached isothermal conditions pH readings became almost equal, as did other readings. At this time of the year the entire lake is suitable for fish survival.

By comparing Figure 22 and 23 it appears that the Ph shift was related to temperatures as shifts occurred in the upper layers of water. The pH rose in the fall as the plant growth died and this may have a bearing on the apparent linkage between temperatures and pH. Bottom temperatures had shifted little and the pH of water at the deeper levels rose. Surface temperatures were lowered and pH remained in the same graphic zone of fluctuation it had occupied for much of the test period.

An interesting relationship is shown in August when unexplained bottom temperature increases occurred. As the temperature went from 65, 65, 68, 71, back to 68, pH ran 7.7. 7.5, 7.3, 7.3, back to 7.7. The H_2S zone shifted from 15, 21, 24, 27, back to 26 feet deep.

During this period of time the mid-depth pH completely reversed this trend. At a temperature of 77° F. (Figure 23), the pH changed to 8.9, becoming more basic (Figure 22) as surface pH dropped to 8.5 from 8.7. As the temperature went down, pH went up and depth of occurrence of the H_2S layer went down. As temperature came up, pH went down and depth of occurrence of the toxic zone came up.

It is proposed that the activity of bacteria forming the H_2S is slower at lower temperatures. The pH is related to H_2S intensity and the more H_2S present the higher the pH. The top layer of the thermocline continued to lower through all the above shifts.

Because of the large shift in pH at a temperature of 72° F., it is proposed that this is the temperature at which the H_2S forming bacteria present in Buffalo

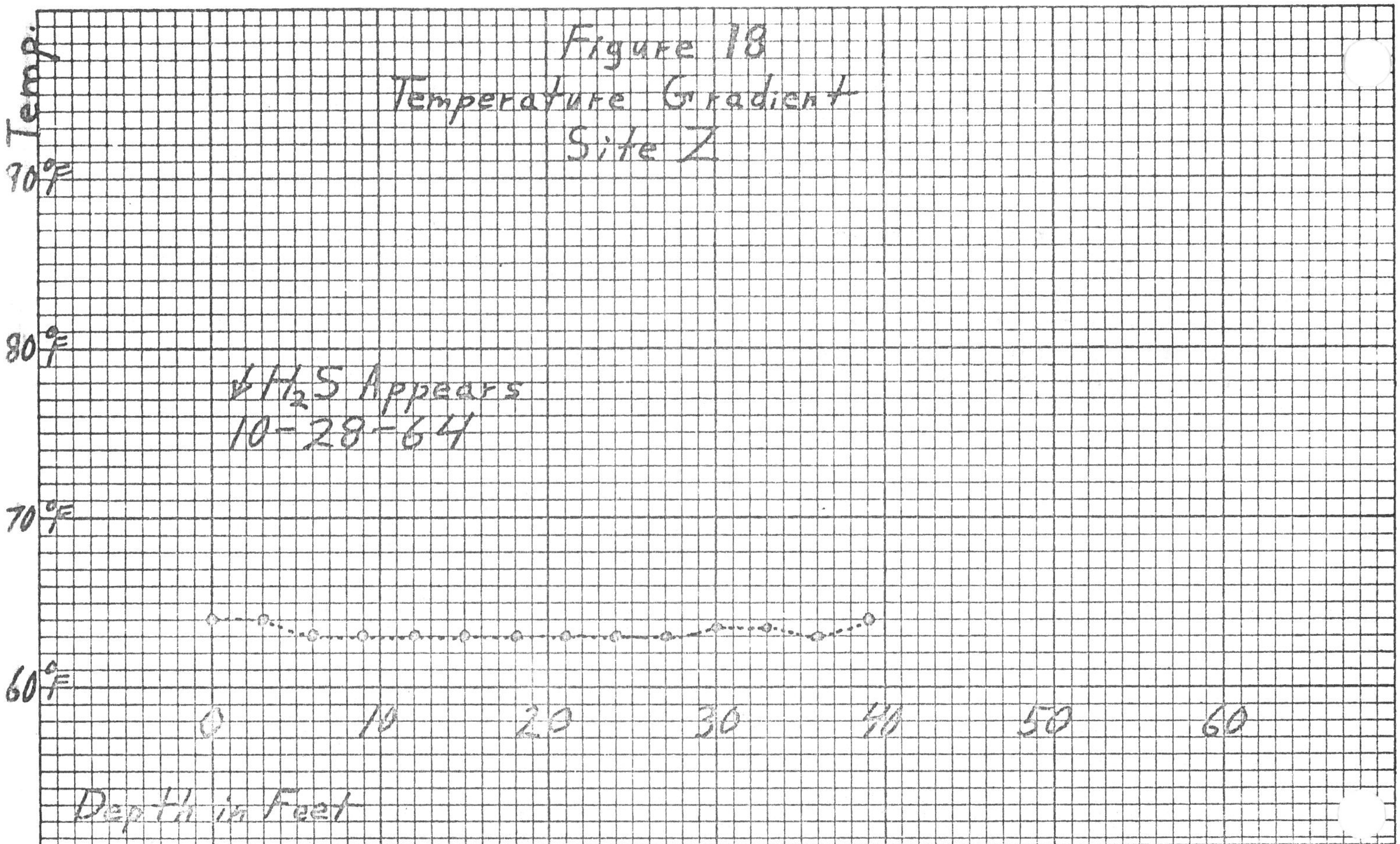


Figure 18
Temperature Gradient
Site Z

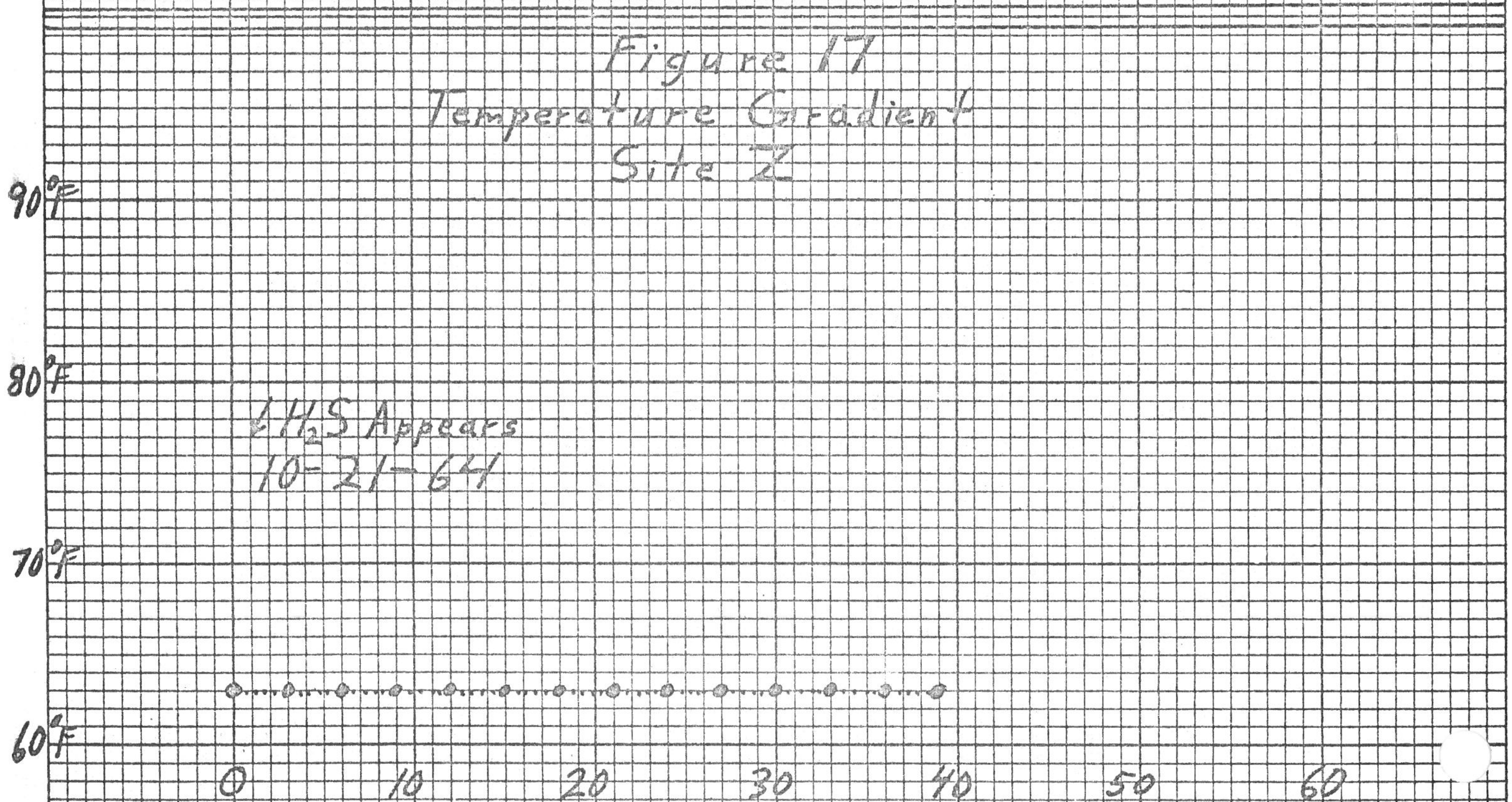


Figure 17
Temperature Gradient
Site Z

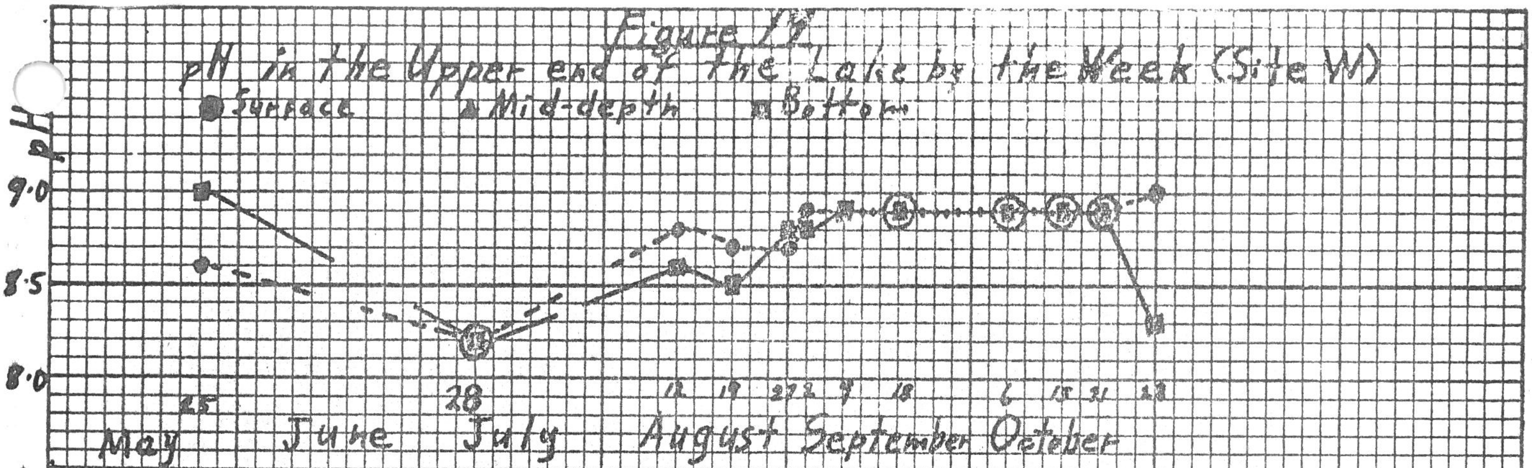


Figure 19
pH in the Upper end of the Lake by the Week (Site W)

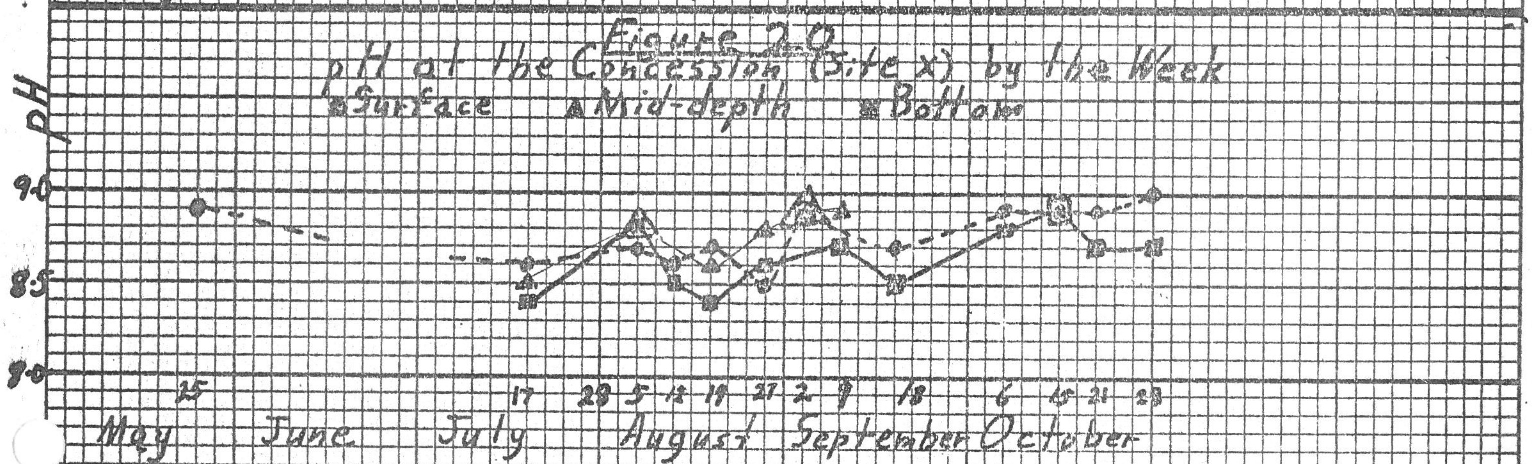


Figure 20
pH at the Concession (Site X) by the Week

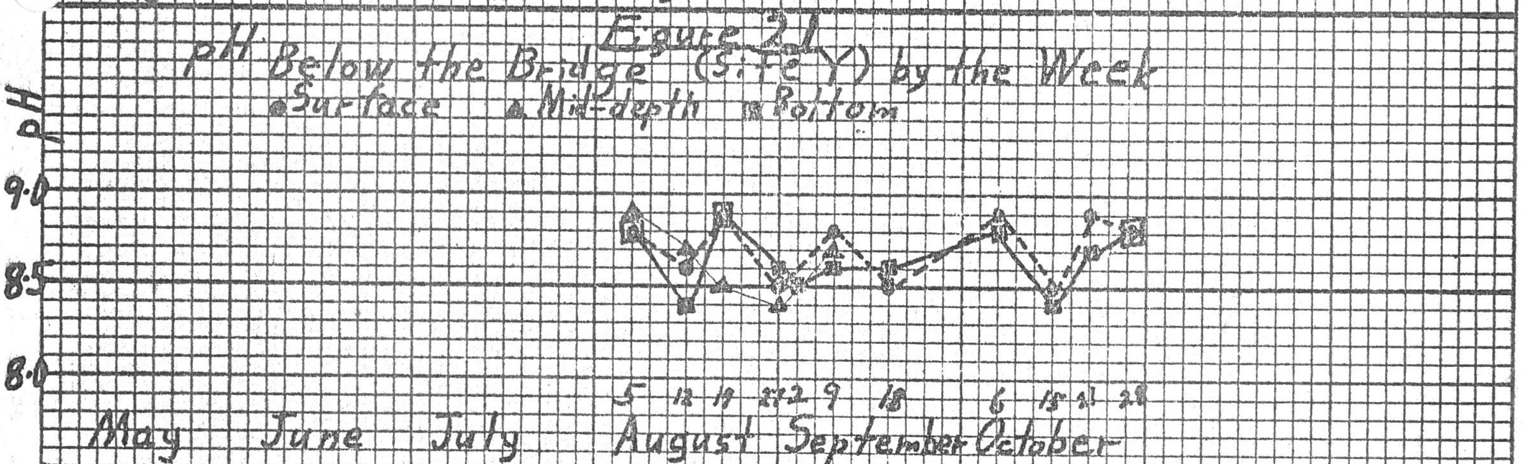


Figure 21
pH Below the Bridge (Site Y) by the Week

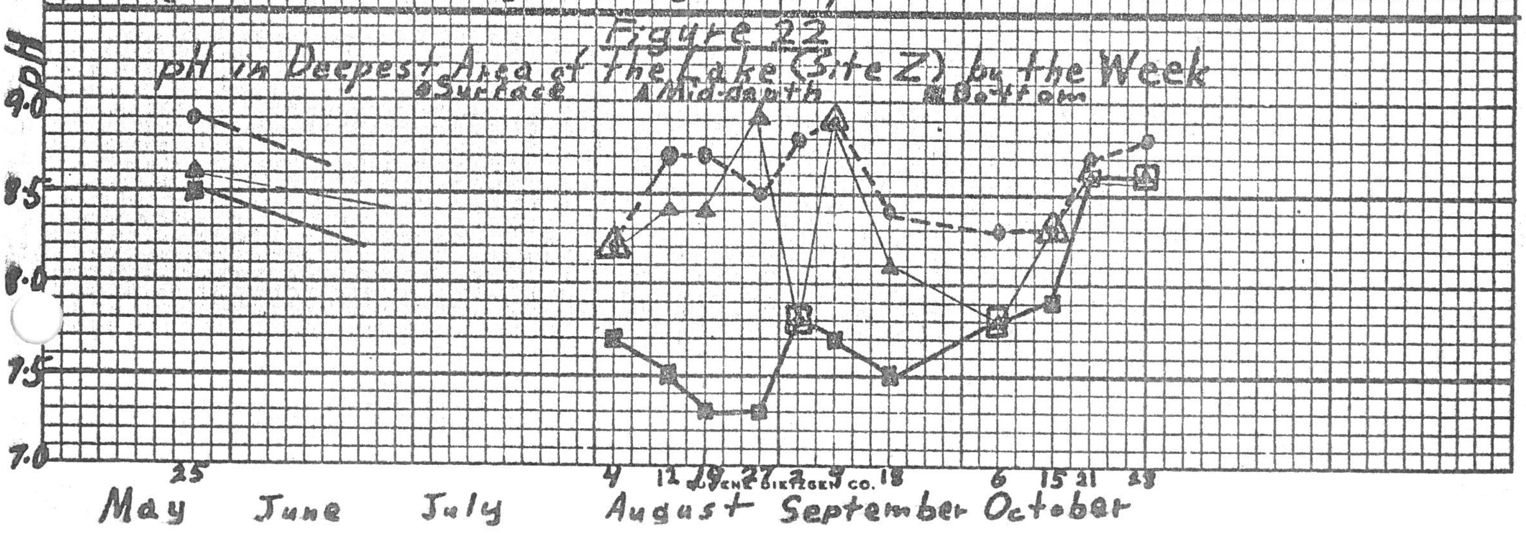


Figure 22
pH in Deepest Area of the Lake (Site Z) by the Week

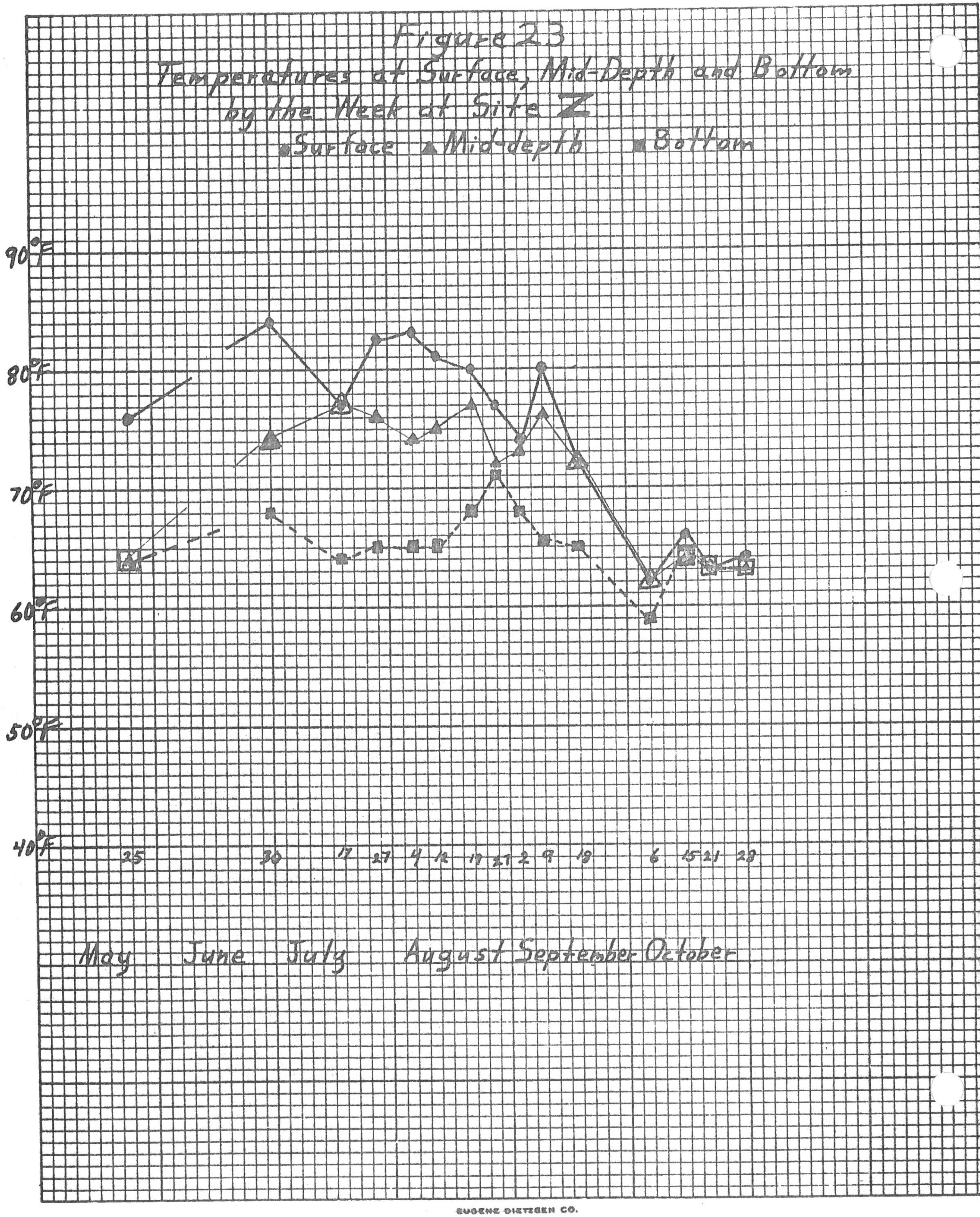


Figure 23
Temperatures at Surface, Mid-Depth and Bottom
by the Week at Site Z
Surface
Mid-depth
Bottom
90°F
80°F
70°F
60°F
50°F
40°F
25
30
17
27
4
12
19
27
2
9
18
6
15
21
28
May
June
July
August
September
October

Springs Lake act most efficiently at that depth. What effect sunlight, depth and pressure, as well as temperature, have on these bacteria is unknown.

Testing of H_2S depth, associated temperatures, and pH was begun earlier in the upper lake because fish mortality was more intense in the upper lake. Fish died off sporadically from March 8, 1964, through the latter part of July. H_2S odor was once detected (not recorded) 12 feet from the surface at site X.

The toxic layer occurred at an average depth of around 18 feet but fluctuations occurred rapidly, and as illustrated by Figures 24 through 39, there were times when H_2S was not present.

The noxious layer occurred from pH readings of 8.6 to 8.8 (Figures 19 and 20) in the upper lake.

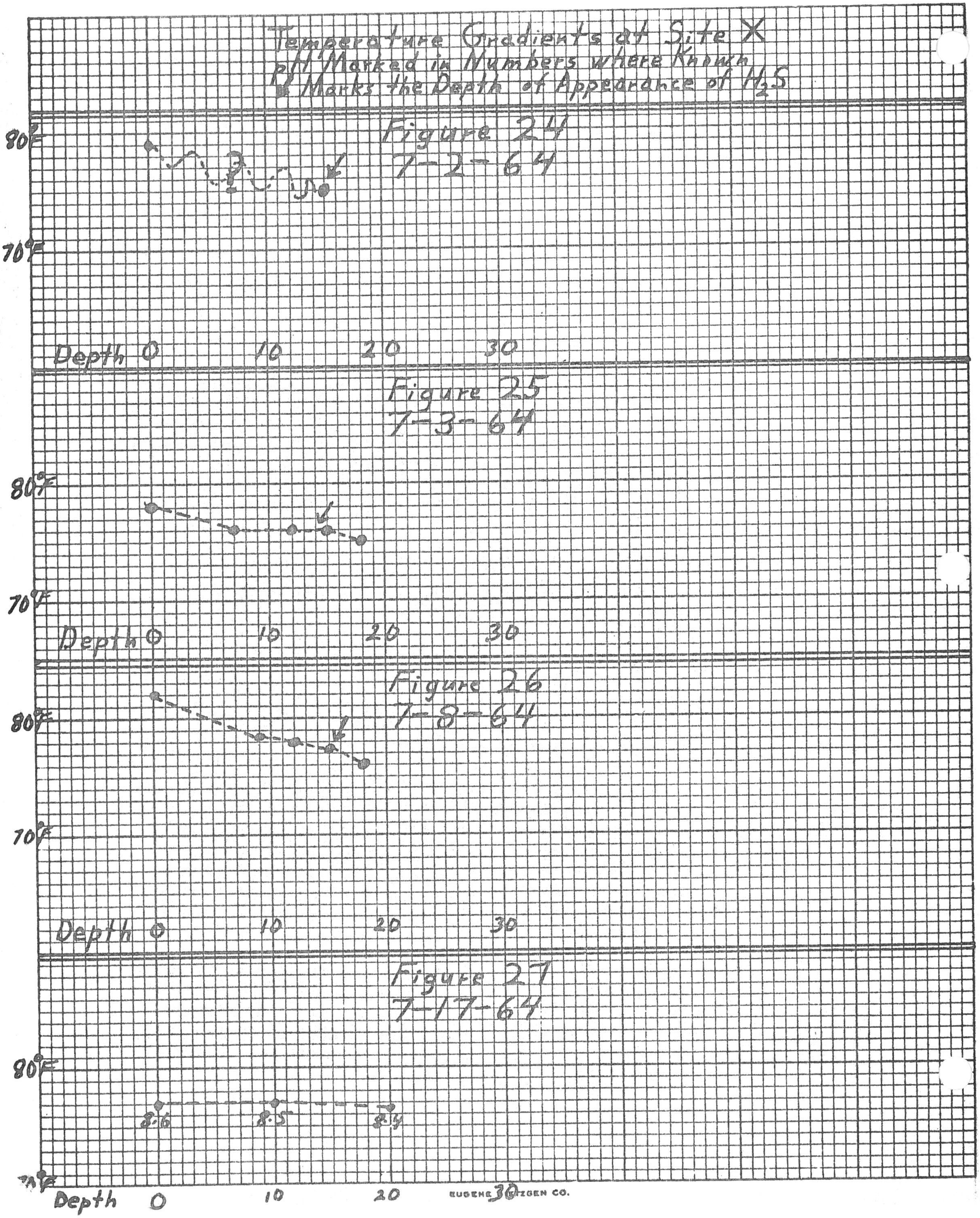
As the plant surveys showed, the upper lake became almost choked with sago pondweed during the summer. H_2S could be collected at any time by disturbing bottom sediments beneath the growths of sago pondweed. It is likely that conditions occurred which were similar to those described in Water Quality Criteria, page 336, paragraph 1: "Sulfate-reducing bacteria liberate H_2S in anaerobic environments. This gas not only corrodes various surfaces, but is also odorous and highly toxic. Such organisms are of the Desulfovibrio desulfuricans type. Springer reports that heavy growths of water weeds may lead to anaerobic conditions, which in turn permit the growth of sulfate-reducing organisms, the H_2S from which can kill oysters."

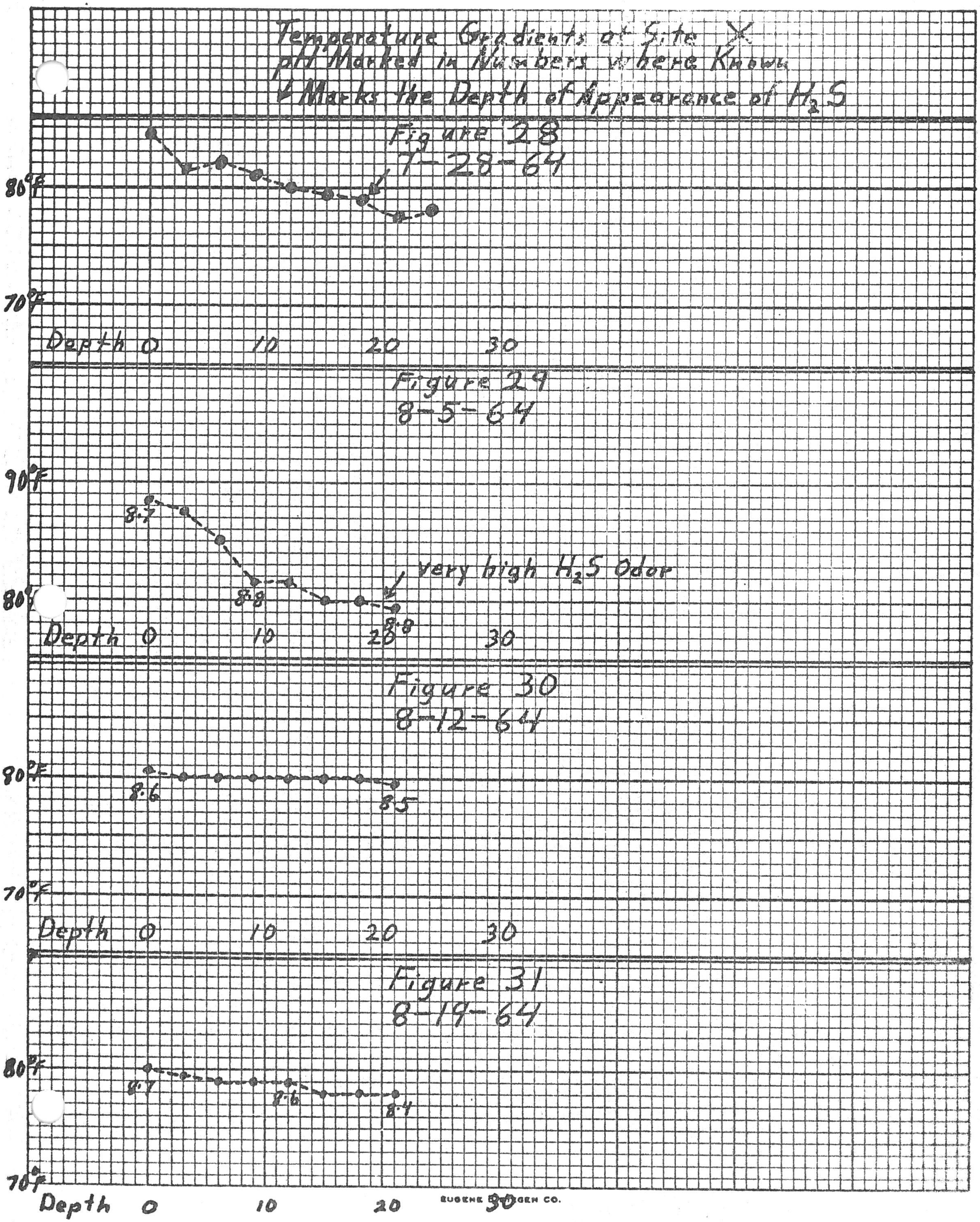
It is realized that Buffalo Springs Lake waters are not saline; however, the other conditions exist and H_2S producing bacteria are present in the bottom sediments beneath the growth of sago pondweed as shown by tests of bottom gases.

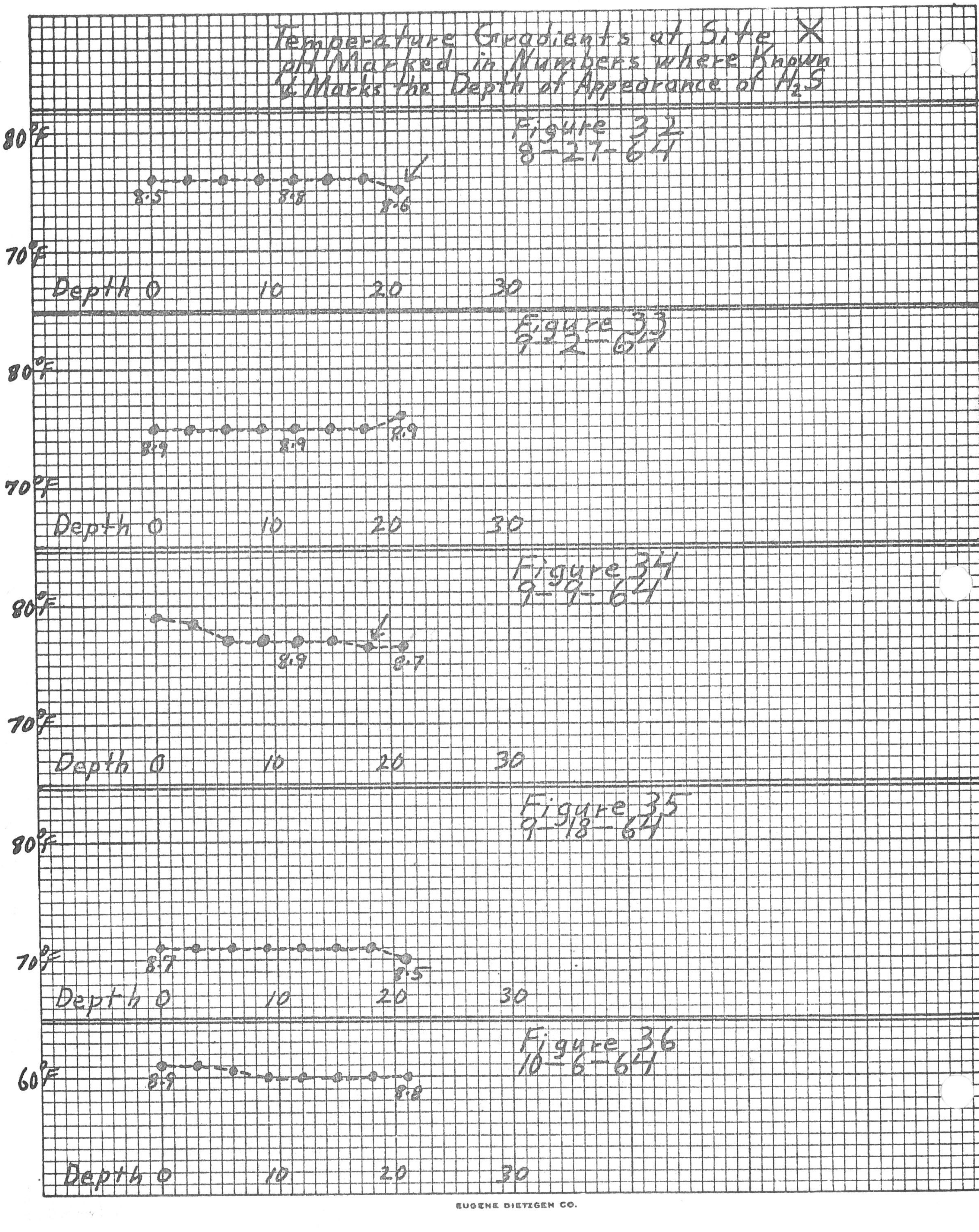
Temperatures shift rapidly in the shallow upper lake which receives the effluent from the shallow V-8 lakes through a small channel. Rainfall and run-off also affect its water quality to a greater extent than the lower lake. This can be understood by examining Figure 40 concerning weather and Figures 29 and 30 concerning water temperatures, pH, and H_2S zone occurrences. Figures 41 and 42 contain weather data from September and October.

The zone is present in Figure 29 on August 5, and absent in Figure 30 on August 12, because rain on the watershed caused flushing of the stagnant water. Average daily temperatures the day it rained and the following day were 76° F. and 81° F. respectively. These temperatures were below that of lake temperatures. Rain run-off displaced the lower water layers and cool atmospheric conditions lowered temperatures of the upper layers of water. Lowered pH is due partly to the effects of lowered temperatures on bacterial action and partly to the dilution factor produced by rainwater.

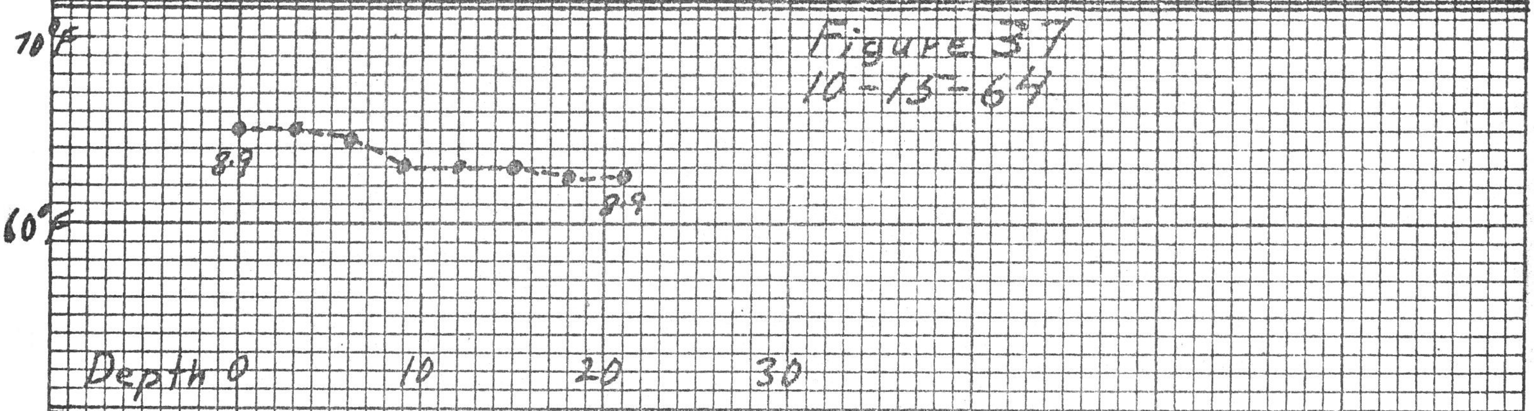
Fifteen days later (Figure 32) H_2S was present at the 21-foot depth at site X. The pH had raised to 8.6 from 8.5 on August 12 (Figure 30) and the temperature was 75° F. Surface temperature shifted downward when average daily temperatures cooled the lake then rose and raised surface water temperatures. On August 30 (Figure 40) 0.01 inch of rain fell and minimum average temperatures remained well below 68° F. for several days.

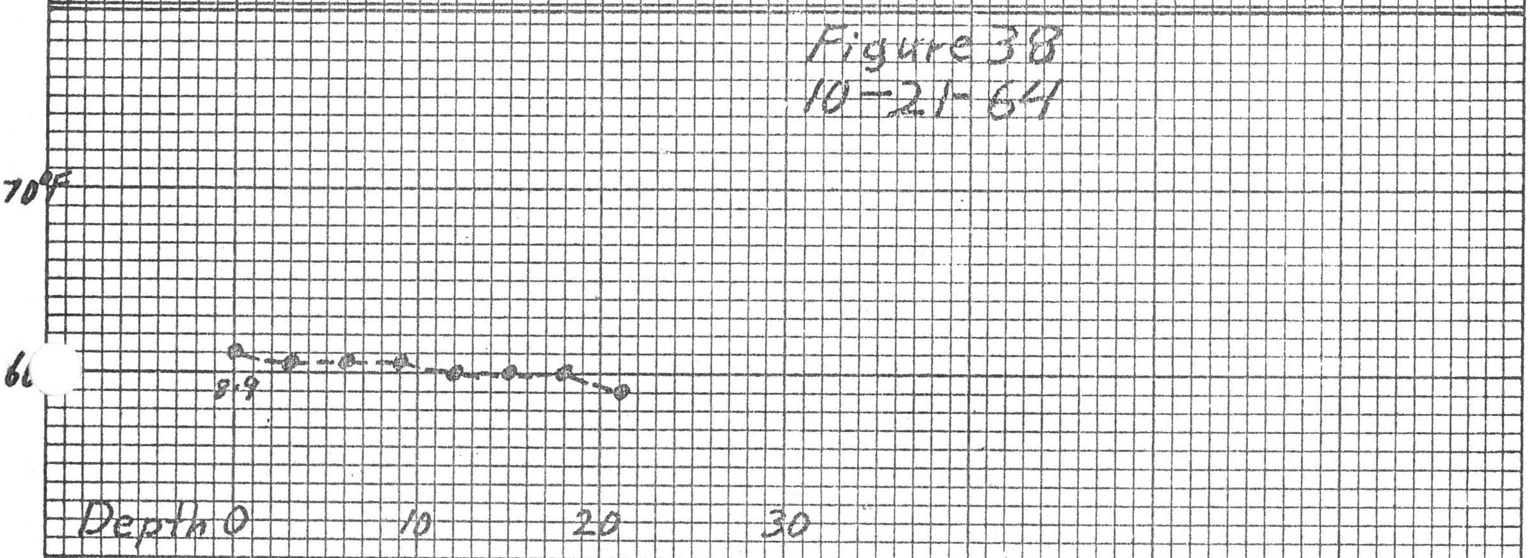

Temperature Gradients at Site X
pH Marked in Numbers where Known
↙ Marks the Depth of Appearance of H₂S
Figure 24
7-2-64
80°F
70°F
Depth 0
10
20
30
Figure 25
7-3-64
80°F
70°F
Depth 0
10
20
30
Figure 26
7-8-64
80°F
70°F
Depth 0
10
20
30
Figure 27
7-17-64
80°F
8.6
8.5
8.4
70°F
Depth 0
10
20
30
EUGENE DIETZGEN CO.

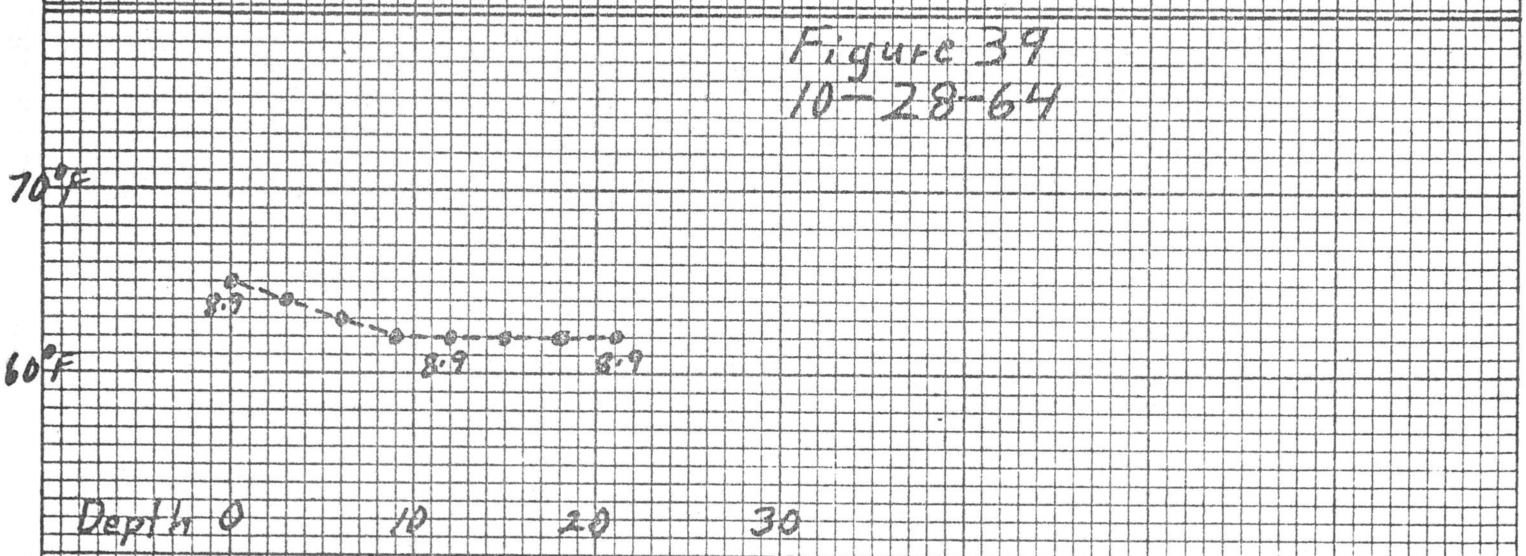

Temperature Gradients at Site X
pH Marked in Numbers where Known
↓ Marks the Depth of Appearance of H_2S
Figure 28
7-28-64
80°F
70°F
Depth 0 10 20 30
Figure 29
8-5-64
90°F
8.7
very high H_2S Odor
80°
8.8
8.8
Depth 0 10 20 30
Figure 30
8-12-64
80°F
8.6
8.5
70°F
Depth 0 10 20 30
Figure 31
8-19-64
80°F
8.7
8.6
8.4
70°F
Depth 0 10 20 30
EUGENE DIETZGEN CO.


Temperature Gradients at Site X
pH Marked in Numbers where Known
↙ Marks the Depth of Appearance of H_2S
Figure 32
8-27-64
80°F
8.5
8.8
8.6
70°F
Depth 0
10
20
30
Figure 33
9-2-64
80°F
8.9
8.9
8.9
70°F
Depth 0
10
20
30
Figure 34
9-9-64
80°F
8.9
8.7
70°F
Depth 0
10
20
30
Figure 35
9-18-64
80°F
8.7
8.5
70°F
Depth 0
10
20
30
Figure 36
10-6-64
60°F
8.9
8.8
Depth 0
10
20
30

Temperature Gradients at Site X
pH Marked in Numbers where Known
↓ Marks the Depth of Appearance of H_2S







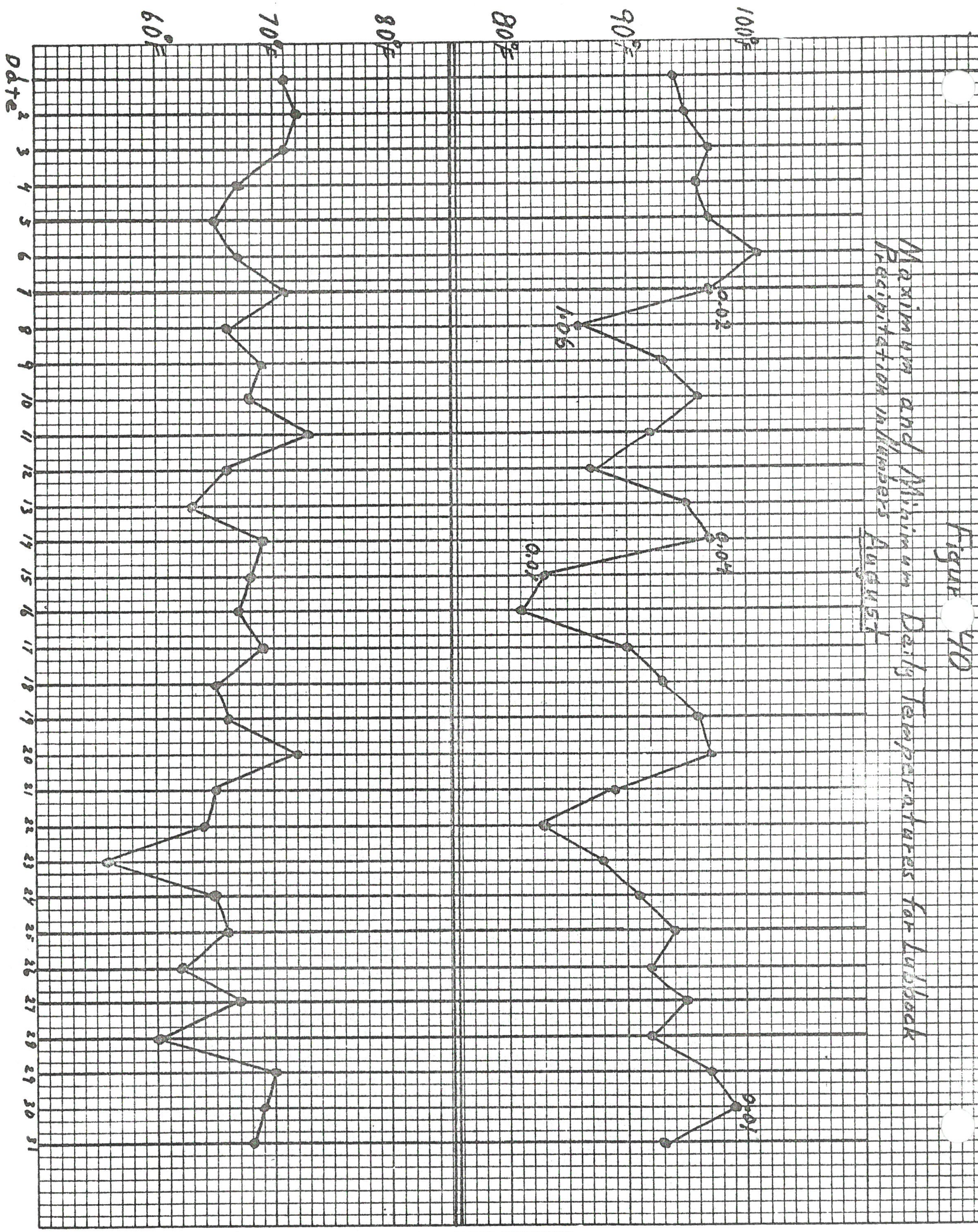
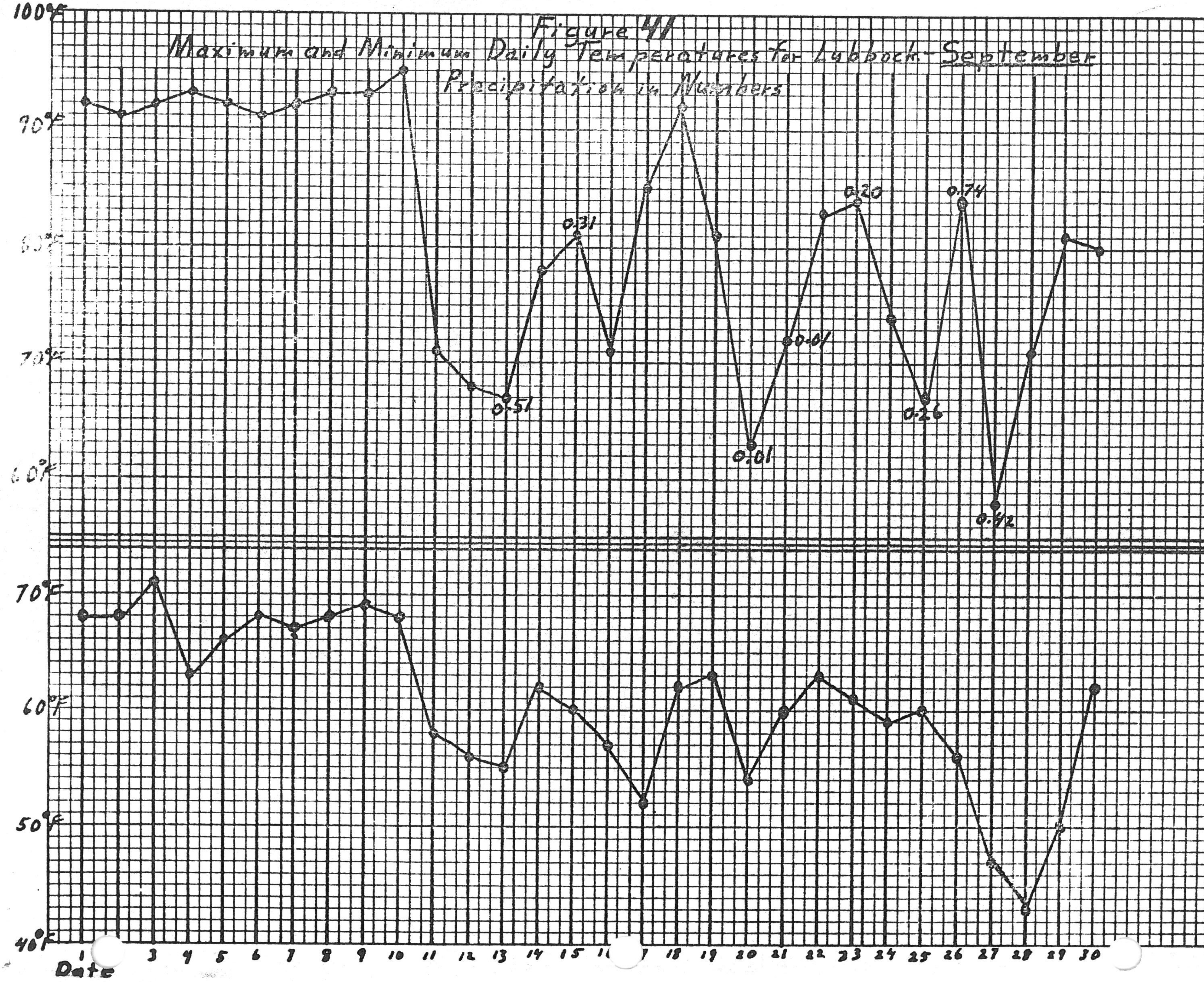


Figure 40
Maximum and Minimum Daily Temperatures for Lubbock
Precipitation in Numbers
August
60°F
70°F
80°F
80°F
90°F
100°F
Date
0.02
0.06
0.04
0.02
0.04

Figure 41

Maximum and Minimum Daily Temperatures for Lubbock - September

Precipitation in Numbers



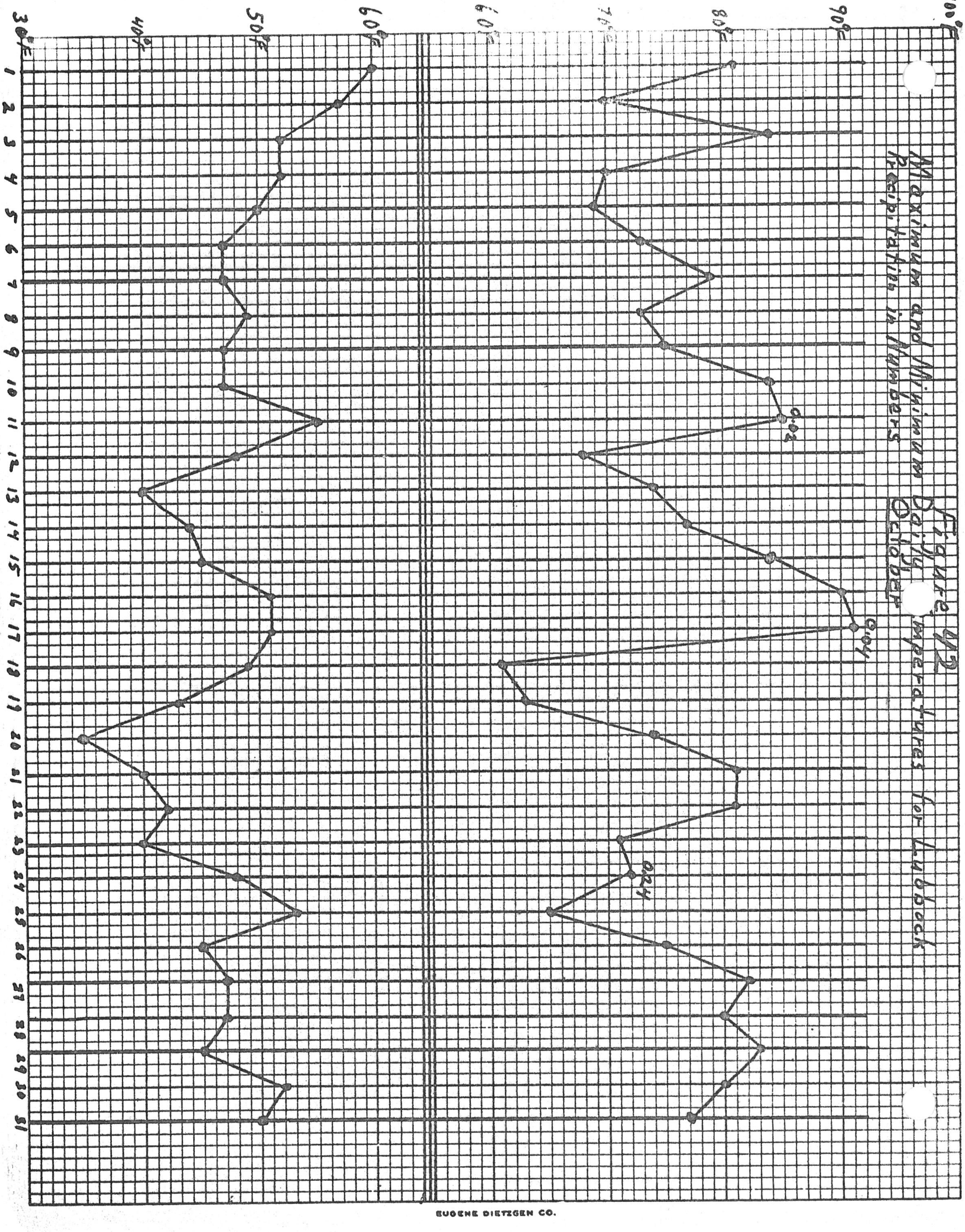


Figure 42
Maximum and Minimum Daily Temperatures for Lubbock
Precipitation in Numbers
October
30°F
40°F
50°F
60°F
60°F
70°F
80°F
90°F
100°F
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
0.02
0.04
0.24

The rapidity with which water temperatures change in the upper lake add to the stresses which water quality and chemical content already impose on fish there.

On the night of July 2, 1964, tests were made to determine daily dissolved oxygen fluctuations of the lake water. The tests were run on samples taken from a 2-foot depth with a Kemmerer sampler and fixed immediately (Table 9).

Examination of Table 9 reveals a 4.7 ppm drop in dissolved oxygen content from 8.33 p.m. to 6:30 a.m. Water temperatures changed 3 degrees. Wind and wave action occurred during the night. This kept surface D. O. readings higher than if tests had been made during a calm, warm night.

On July 2 at 7:52 p.m., the H_2S layer appeared at 16 feet. On July 3 at 7:20 a.m., tests of H_2S depths were made and the layer occurred at 14 feet in concentrations of 2.0 ppm. This indicates diurnal fluctuations of the H_2S level in the lake.

Table 9. Results of an All Night Dissolved Oxygen Sampling Program in the Upper Lake at Buffalo Springs Lake on July 2, 1964.

Time	Temperature	Dissolved Oxygen (D.O. in ppm)	Weather
8:33 p.m.	82° F.	10.7	Light breeze from the east, clear skies.
10:30 p.m.	81° F.	10.1	Calm and clear skies.
12:30 a.m.	80° F.	9.0	Moderate wind, light wave action, becoming cloudy.
2:30 a.m.	80° F.	7.9	Moderate wind, light wave action, light clouds.
4:30 a.m.	79° F.	6.3	Light clouds, water calm.
6:30 a.m.	79° F.	6.0	Light clouds, water calm.

These possible fluctuations should be checked very carefully, because if the layer shifts upward quickly during one night it could be a predominant factor in the deaths of large numbers of fish.

Fish Mortality

On April 9 a circuit of the shoreline of the lake revealed 107 dead or dying largemouth bass, 22 black bullheads, and 322 sunfish. Many other sunfish were observed but not counted. Regular counts of dead fish on the lake were not made; however, dead fish were seen repeatedly on visits to the lake. Buffalo Springs Lake employees picked up and hauled off all the larger fish each Friday.

Of the 107 largemouth bass seen, 90 fish were cut open and examined internally for parasites and other gross anomalies. Nothing was found except that several fish had rather large spleens. The sex ratio of dead bass examined was very nearly 50 per cent male to 50 per cent female. All larger fish which were opened for examination were returned to the water to sink and not be observed again.

An extensive autopsy was performed on a black bullhead on June 19. It was 225 mm long, weighed 396 grams, and was a ripe male. The fish had been under refrigeration one day prior to autopsy. Several streaks which appeared to be scratch marks occurred on the left side just posterior and ventral to the pectoral fin. These scratches were shallow, about 1 mm apart and the abraded area was 1½ inches long. Bright red blood was present in some areas. Some of the scratches penetrated the epidermis. The left pelvic fin had a circular abraded area at its base about 6 mm in diameter. The under surface of the jaw and the anterior portion of the belly were obviously red speckled. The red speckles were blood flecks diffused into the mucous layer, bright red and not clotted. Some areas appeared to have tiny openings beneath the red flecks. It was difficult to determine if the hemorrhage was through the walls of blood vessels or as a result of punctures in the blood vessels. It was concluded that the blood was seeping through the walls of the blood vessels in some areas.

The caudal fin had hardened (calcified) areas on some of the fin rays which appeared to be healed breaks.

Inside the mouth were the same type blood flecks, but actual penetrations of the skin could be seen here. Several anchor worms (Lernea sp.) were located just posterior to the vent. Upon incising the ventral abdominal wall, seeping of blood from vessels in all the mesenteries in the abdominal cavity was apparent. Numerous cestode or trematode parasites were in the mesenteries and stomach lining. The liver was yellowish. The gall bladder was about 1½ inches long, thin walled and contained clear fluid. Removal of the brain revealed the same type "bleeding" or seeping of blood from vessels in the brain tissue and the bleeding appeared to be concentrated in one area on the ventral surface near the center of the brain. The gills had some reddening but otherwise were normal.

Several specimens were dissected and examined carefully each time a netting survey was run in the field. The red flecks and bleeding symptoms predominated in most distressed fish. They also appeared on the fish used in the live caged fish test.

Other symptoms occurred also. Distressed fish appeared phlegmatic and unable to make coordinated actions. Sunfish were observed to endure muscle fibrillations. Schools of small black bullheads were observed swimming continually upward at a rate that only left them suspended in the water and others swam in continual circles. Saprolegnia sp. was present on most dead fish and some live fish. Some of the largemouth bass examined had thickened slime layers along the dorsal fin.

Distressed fish were collected and preserved by freezing in water and sent to the Federal Fish Pesticides Research Laboratories in Denver, and although test results indicated that pesticides were not the major cause of mortalities, they could conceivably have caused a few deaths. One largemouth bass (one tested) contained DDD - 3.56 ppm, DDT - 0.92 ppm, and DDE - 1.61 ppm, or a total of 6.09 ppm DDT and its metalolites. Twenty-four sunfish were tested and they contained an average of 1.49 ppm DDT and its metabolites.

Fish Population Study

In 10 months, from January 1 through October 31, 1964, 39,085 fishermen paid to fish at Buffalo Springs Lake at Lubbock. Seven hundred and fourteen people held season passes costing $20 per pass. It was estimated that during the 7 months of 1964 covered by this census, each holder of a season pass averaged 2 fishing trips a month to the lake, or 14 trips per person. This totals 9,996 visits by season pass holders. Fishing pressure by residents at the lake is not calculated although many residents fish regularly. Of these fishermen, 1,001 were interviewed. These 1,001 fishermen caught 3,915 fish totaling 1,107.25 pounds.

Total fisherman visits for the 7 months bracketed by the creel census was 45,177. Using the average number of fish per man (3.91) and average pounds of fish per man as computed from census data (1.11 pounds) as a basis for computation, 176,642 fish totaling 52,357 pounds were removed from this lake in the 7 months this creel census was in progress.

Buffalo Springs Lake has an area of 225 surface acres and if this figure is divided into the computed total poundage of fish caught by fishermen, a yield of 232.74 pounds of fish per acre is indicated.

Table 10 contains the total weight, number, species and per cent of fish caught by the 1,001 fishermen interviewed.

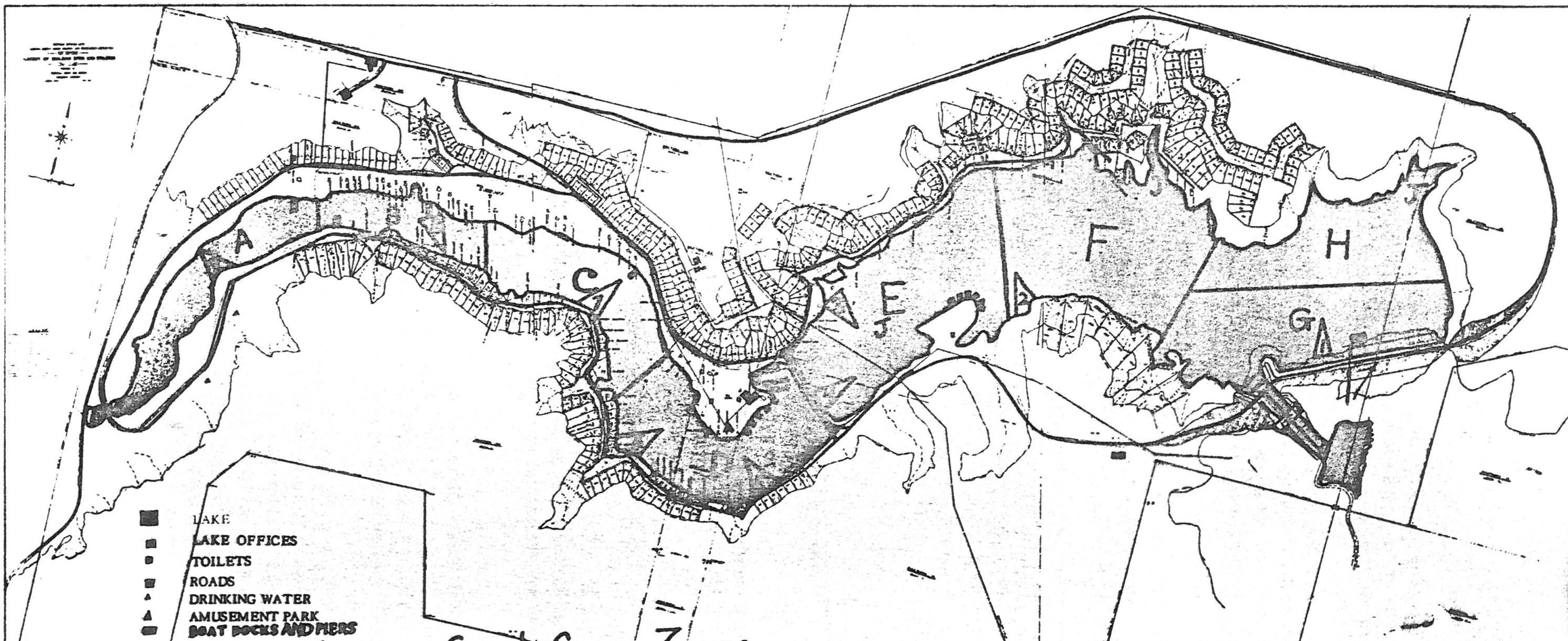
Table 10. Total Weight and Percentage of Fish Taken by Fishermen at Buffalo Springs Lake During 7 Months of a Continuing Creel Census in 1964.

Fish Species	Total Weight Grams	Total Weight Pounds	Number	Per Cent by Weight	Average Weight
Carp	6,536	14.41	3	1.30	4.80
Goldfish	675	1.49	1	0.13	1.49
Golden shiner	26	0.06	1	0.01	0.06
Channel catfish	25,601	56.44	26	5.09	2.17
Black bullhead	341,285	752.39	1,294	67.95	0.58
Largemouth bass	23,750	52.36	39	4.73	1.34
Sunfish sp.	102,731	226.48	2,536	20.46	0.09
White crappie	1,643	3.62	15	0.33	0.24
Total	502,247	1,107.25	3,915	100.00	

If the figures in Table 10 for per cent of fish taken by fishermen, by species and weight are applied to the computed 7 months total yield, the total weight of fish per species caught by fishermen should result. These figures are in Table 11.

Fishermen who were interviewed had fished an average of 4.43 hours per man and caught 1.11 fish or 0.25 pound of fish per man per hour. When data are separated into successful and unsuccessful fishermen, however, the successful fishermen caught 2.32 fish per hour or 0.52 pound of fish per hour.

For purposes of determining population distribution as revealed by creel and netting survey, the lake was divided into zones. These zones are shown as letters on the map in Figure 43. The numbers in the figure represent netting stations.



Letters (A→H) are in Creel Census Zones
Numbers (1→9) are Netting Stations

Figure 43

Table 11. Computed Total Weight of Fish Per Species Caught by Fisherman in 7 Months at Buffalo Springs Lake in 1964 (April through October).

Species	Per Cent	Total Weight
Carp	1.31	686.01
Goldfish	0.13	68.08
Golden shiner	0.01	5.23
Black bullhead	67.95	35,583.34
Channel catfish	5.09	2,665.48
Largemouth bass	4.73	2,476.96
Sunfish sp.	20.46	10,714.29
White crappie	0.32	167.57
Total	100.00	52,366.96

Tables 12 and 13 contain data concerning distribution of creel and net catch of all species by zone. Zones A, E, and G produced the most bass, and the only crappie recorded by regular census means were caught in G, where a covered, heated and lighted fishing pier is located. Depths are greater here than at any other locations, as can be seen by examining the contour map.

Table 12. Number and Per Cent of Each Species of Fish Taken in Each Zone by Fishermen as Shown by Creel Census Data in 1964.

Species	Zone, Number, and Per Cent								
	A	B	C	D	E	F	G	H	Total
Carp	3 100.00								3 100.00
Goldfish	1 100.00								1 100.00
Golden shiner					1 100.00				1 100.00
Channel catfish	9 34.61		2 7.69	2 7.70		7 26.92	5 19.23	1 3.85	26 100.00
Black bullhead	431 33.30	323 24.96	138 10.67	114 8.81	50 3.86	55 4.25	132 10.20	51 3.95	1,294 100.00
Largemouth bass	11 28.20		1 2.56	1 2.57	13 33.33	1 2.57	12 30.77		39 100.00
Sunfish sp.	102 4.02	274 10.80	170 6.71	527 20.78	282 11.12	122 4.81	929 36.63	130 5.13	2,536 100.00
White crappie							15 100.00		15 100.00
Total	557 14.22	597 15.25	311 7.95	644 16.44	346 8.84	185 4.73	1,093 27.92	182 4.65	3,915 100.00

Table 13. Number and Per Cent of Each Species of Fish Taken in Each Zone by Netting in Buffalo Springs Lake in 1964.

Species	Zone, Number and Per Cent A	B	C	D	E	F	G	H	Total
Carp	7 43.75	1 6.25	2 12.50	6 37.50					16 100.00
Goldfish	7 31.81	4 18.19	1 4.54	10 45.46					22 100.00
Carp-goldfish hybrid	12 41.37	1 3.45	5 17.24	6 20.69		4 13.08	1 3.45		29 100.00
Golden shiner	6 11.53	6 11.54	7 13.46	20 38.47	6 11.53	6 11.54	1 1.93		52 100.00
Channel catfish	9 31.03	1 3.45	3 10.34	3 10.35	7 24.14	6 20.69			29 100.00
Black bullhead	554 19.20	551 19.10	270 9.36	601 20.83	480 16.64	319 11.05	110 3.82		2,885 100.00
Largemouth bass	22 25.58		13 15.11	29 33.72	18 20.93	4 4.66			86 100.00
Sunfish sp.	618 11.31	593 10.85	1,107 20.27	1,426 26.10	708 12.96	791 14.48	220 4.03		5,463 100.00
White crappie	5 10.41	26 54.17	4 8.33	12 25.00		1 2.09			48 100.00
Total	1,240	1,183	1,412	2,113	1,219	1,131	332	0	8,630

Netting produced more white crappie in zones B and D. On one occasion a fisherman was observed catching a crappie in zone A. Lack of crappie and other fish in net No. 1 is probably due to its location. This net, a double unit, was set in water from 20 feet deep to 36 feet deep. It is attached at one end to a buoy which is about 180 feet from the shoreline and much of the net is suspended in open water where few fish are found.

Few fish of any description were taken in net No. 1 (Table 13). Another set, made at station 1 but tied off of the dam in water shelving from 4 feet to 24 feet in depth was made in July. Fish caught the same night in special net J and net No. 1 are listed in Table 14. These data clearly show why the large discrepancy exists between netting and fishing figures for zone G. Fishing in zone G is from the bank or fishing house instead of in open water where net No. 1 was set. Zone G is fished heavily year around because of convenience of access and comfort in the fishing house.

Black bullhead catch, by net and fishermen is rather evenly distributed over the lake. Fishermen caught more bullheads in zone A and netting produced more in zone D. Zone D, however, as shown in Figure 43, had two nets set in it as did zone E, which would account for some of the difference here (if not all). Fisherman catch was relatively small in zones E, F, and H. Zone E is used extensively by water skiers and zone F and H are inaccessible from the bank except by walking and climbing a bluff.

Table 14. Fish Taken in Net No. 1 and Special Net J in Zone G off the Dam in July 1964, in Buffalo Springs Lake.

Species	Number Kept	Number Returned	Total
Net No. 1			
Carp-goldfish hybrid	1	0	1
Black bullhead	2	2	4
Bluegill	34	103	137
Special Net J			
Channel catfish	1	0	1
Black bullhead	0	36	36
Largemouth bass	0	2	2
Redear sunfish	0	1	1
Bluegill	118	125	243

A floating net was set in the most northeast inlet in zone H at the letter J in Figure 43 in July. It produced very few fish, most of which were sunfish. Another net, set in zone F at the J in Figure 43, produced the fish listed in Table 15. As can be seen, adequate fish inhabit this inlet.

A comparison of Figures 44, 45, 46 and 47 reveals the similarities and differences in per cent of total fish caught by fishermen and the total fish netted in the zones in Figure 43 for several species of fish.

Comparing bullhead-catch by fishermen to netting-catch in zone A, it is seen that fishermen caught more fish than were netted. This difference arises partly because of the excessive vegetation which built up from June through August and partly because a census was taken on May 16 following a 1.14-inch rain on May 15. Anglers caught 758 black bullhead on May 16. Most of these bullhead were caught in the upper end of the lake in zone A and B where fresh water and food were available for the fish. Fishermen lined the banks and harvested bullheads all night.

In zone C, more picnicking and less fishing is done. Zone D has the concession stand and playground on one side and residences and a steep bank on the other side, limiting fisherman access. Zone D also had two nets set in it. It is believed that differences between netting and creel are more a matter of fisherman preference of areas fished because of accessibility and convenience rather than because of inherent differences in sampling between netting and fishing.

The graphs concerning sunfish, channel catfish, and largemouth bass show considerable similarity and indicate that netting-catch and fisherman-catch coincide quite well with the exception of station 1 in zone G which has been explained previously.

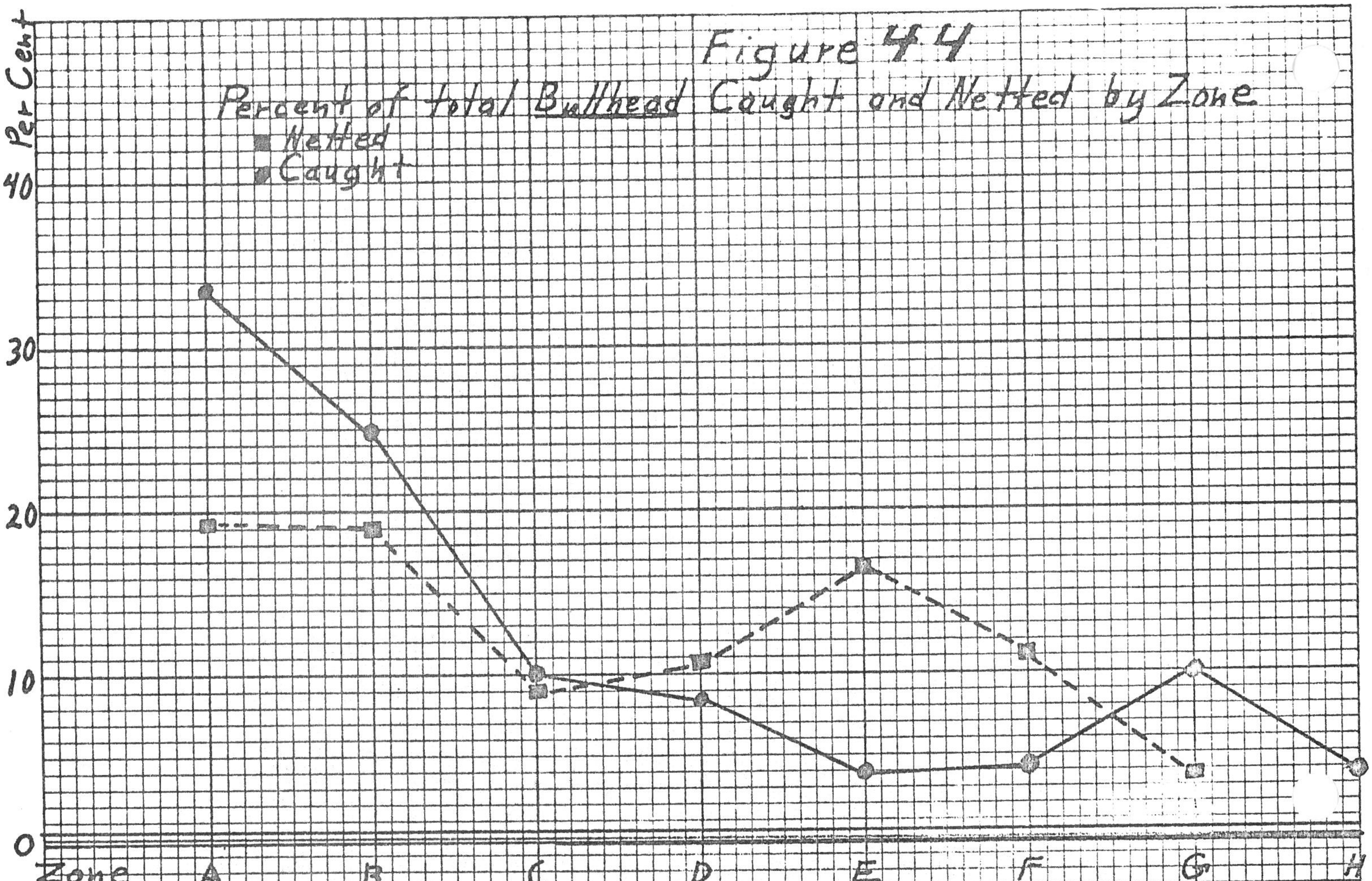


Figure 44
Percent of total Bullhead Caught and Netted by Zone
Netted
Caught
Per Cent
40
30
20
10
0
Zone
A
B
C
D
E
F
G
H

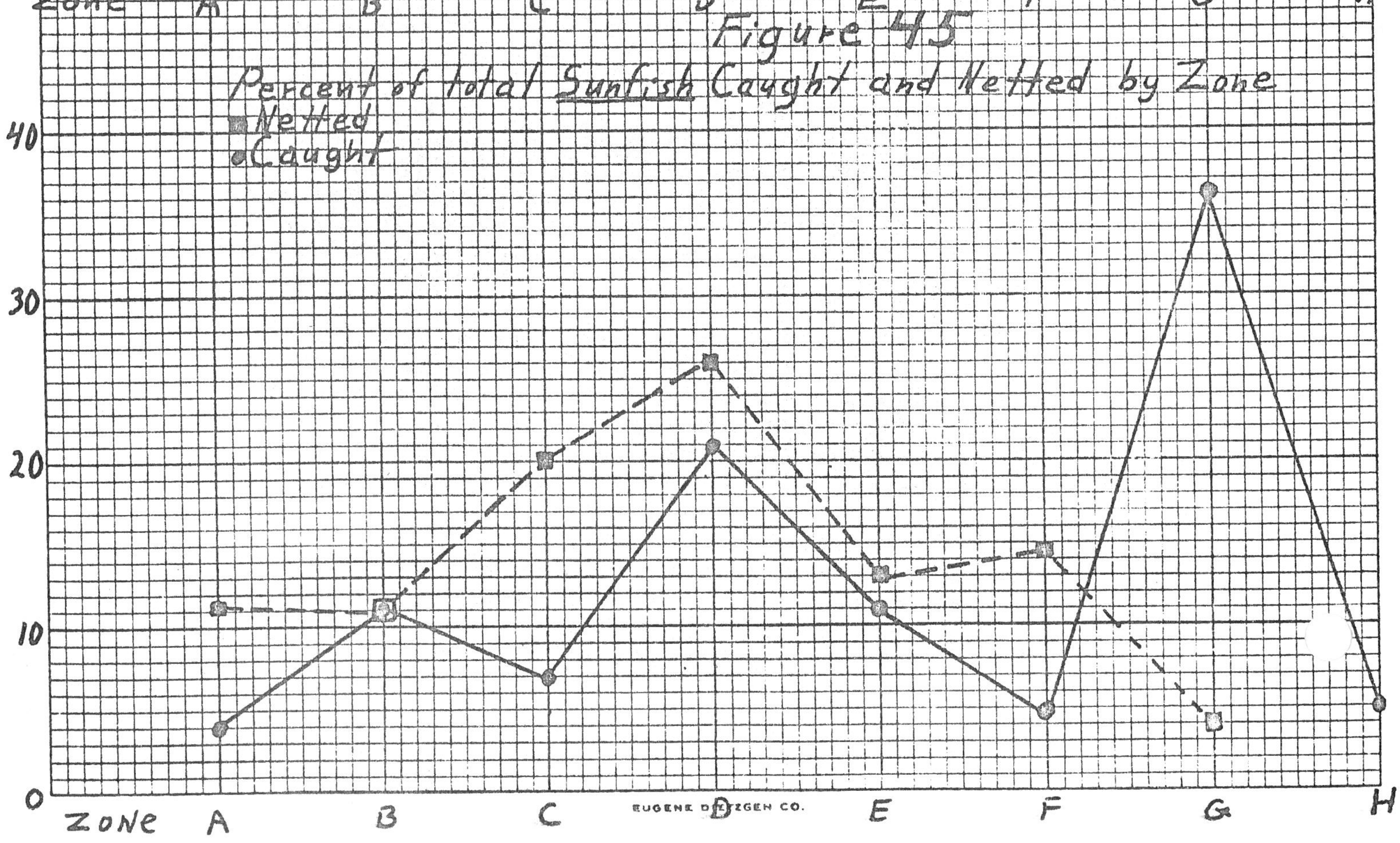


Figure 45
Percent of total Sunfish Caught and Netted by Zone
Netted
Caught
40
30
20
10
0
ZONE
A
B
C
D
E
F
G
H
EUGENE DIETZGEN CO.

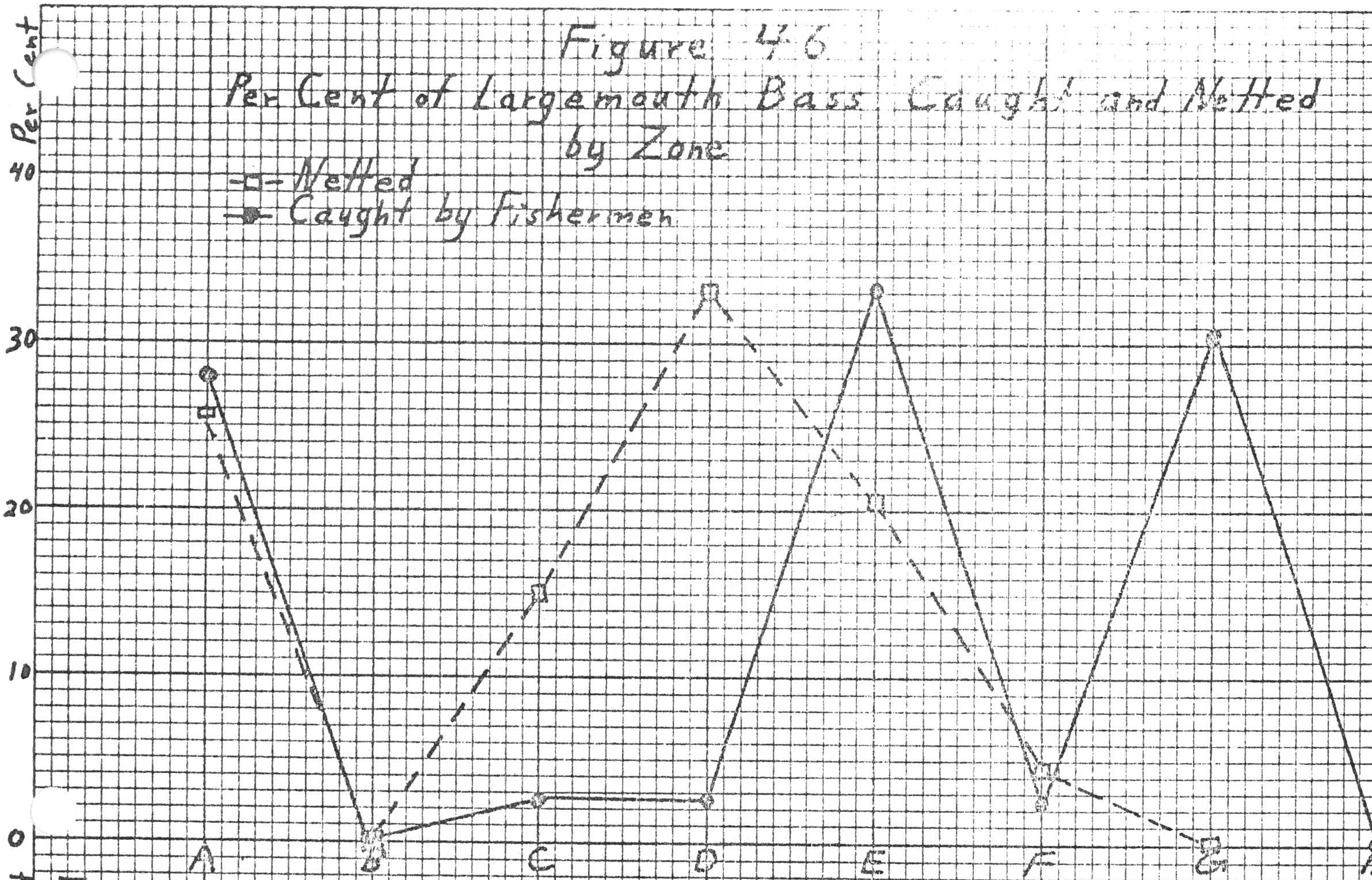


Figure 46
Per Cent of Largemouth Bass Caught and Netted by Zone
Netted
Caught by Fishermen
Per Cent
40
30
20
10
0
A
B
C
D
E
F
G
H
Zone

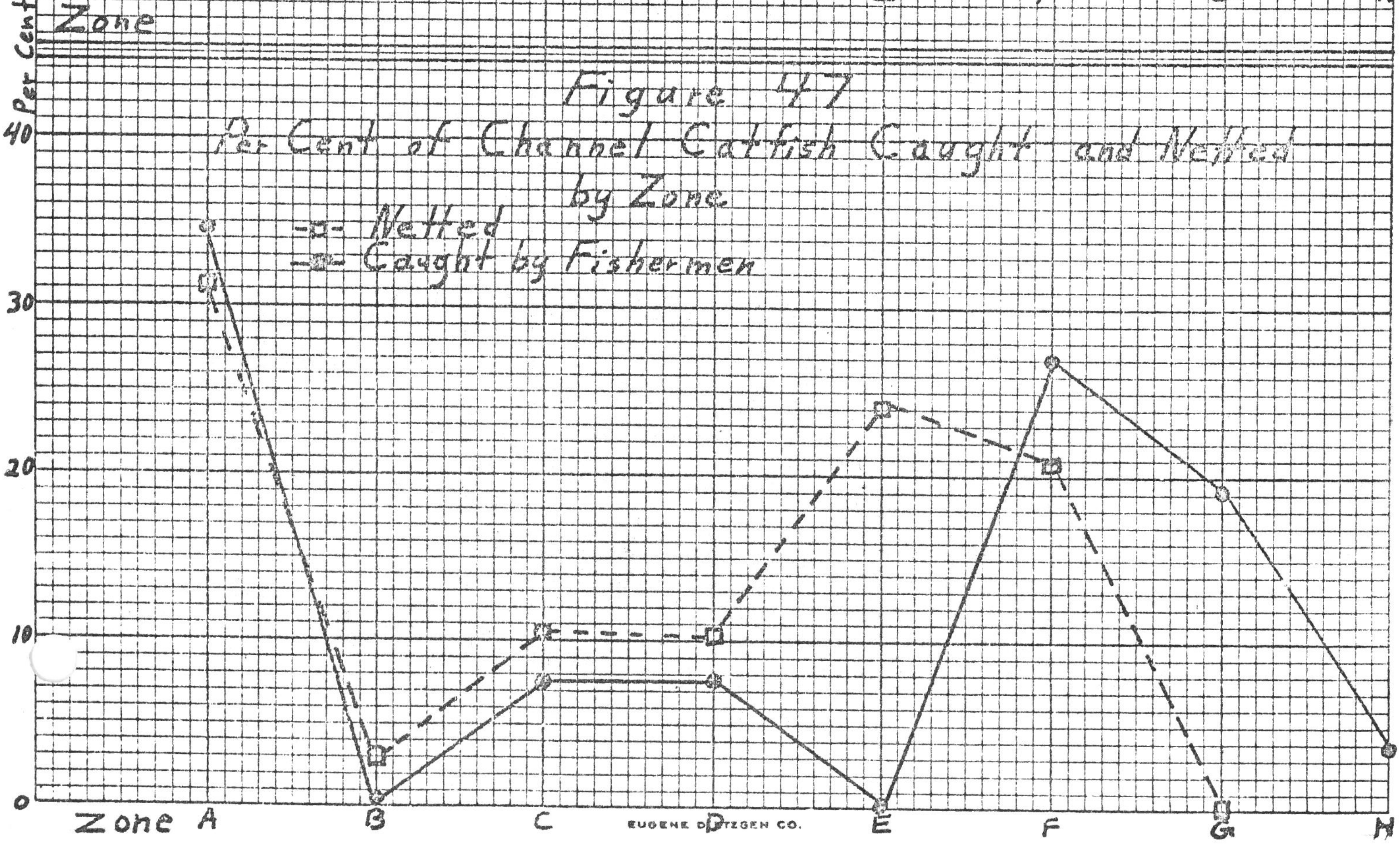


Figure 47
Per Cent of Channel Catfish Caught and Netted by Zone
Netted
Caught by Fishermen
Per Cent
40
30
20
10
0
Zone A
B
C
D
E
F
G
H
EUGENE DIETZGEN CO.

Table 15. Special Net J in Zone F in July 1964, in Buffalo Springs Lake

Species	Number Kept	Number Returned	Total
Carp	1	0	1
Goldfish	1	0	1
Carp-goldfish hybrid	1	0	1
Black bullhead	34	0	34
Largemouth bass	2	0	2
Bluegill	133	0	133

Channel catfish catch in zone E by nets was considerably above fisherman catch (Figure 47). This is because both netting stations are in areas where fishermen have difficulty gaining access and skiing is almost continuous in the summer. This seems to indicate, however, that skiing disturbs fishermen more than it disturbs fish.

A really significant trend indicated by this method of study is that the netting figures and creel census figures coincide very closely for areas on the lake, as well as for total catch and precentage catch. This indicates that netting surveys with the methods and nets used in Region I coincide closely with what the angler can expect to catch in a heavily fished lake such as Buffalo Springs Lake at Lubbock. It is realized that this statement is based on a short-term study; however, the trend should be either substantiated or refuted on this lake as study progresses.

Figures 48, 49, 50 and 51 illustrate this point quite well. Not only does species percentage of total catch coincide for the year (Figure 48), but by the month (Figure 51). Even more unusual and probably coincidental is the comparison of total fish per month by netting and fishing (Figure 49). Ten units of net were consistently set in the lake. Monthly numbers of fishermen who paid entrance varied, but many fishermen are unsuccessful. How many practiced, successful fishermen fished each month is not known. More fishermen were present in June than in May, and still fishermen caught less fish and nets caught less fish (Figure 49 and Table 16).

Table 16. Total Paid Fishermen for 10 Months in 1964 at Buffalo Springs Lake.

Jan.	Feb.	March	April	May	June	July	August	September	October
575	683	2,646	4,236	7,843	8,289	5,482	5,020	2,463	1,848

Figure 50 shows desirable and undesirable fish by percentages as represented by netting and creel census. Two columns for desirable and undesirable are shown since many people caught and retained both bullheads and sunfish. The description of bullheads as desirable or undesirable is purely a matter of personal preference.

The average weight of all the bullheads caught by fishermen for the year was 0.58 pound and this size bullhead, when divested of head, entrails, and fins, leaves a small amount of useable meat. Although fishermen today do not need to supply fish for the table (it would be much cheaper to buy the fish) it is much more enjoyable to catch larger fish, and quantity of edible flesh does have some bearing on the appeal of a fish to the fisherman.

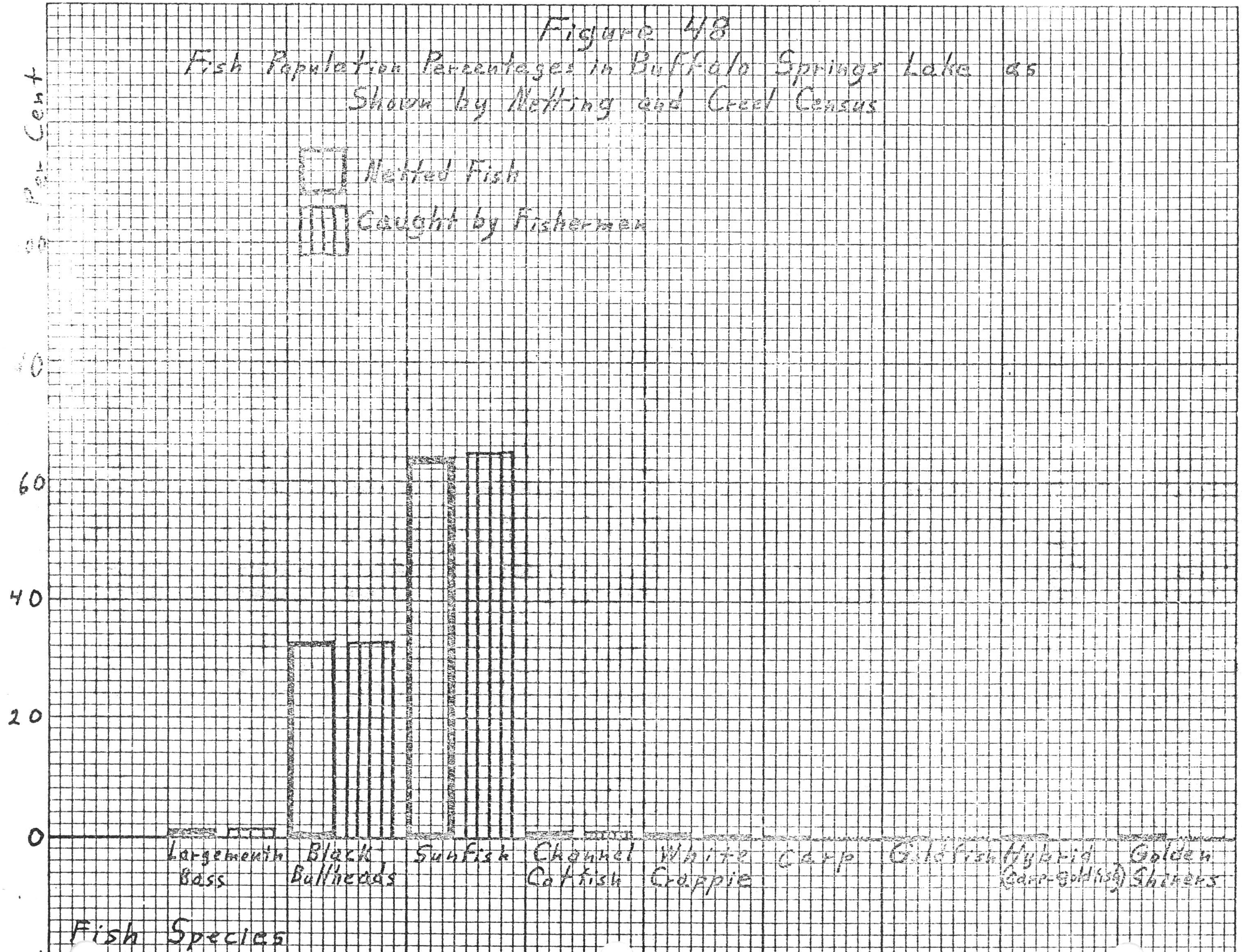


Figure 48
Fish Population Percentages in Buffalo Springs Lake as
Shown by Netting and Creel Census
Netted Fish
Caught by Fishermen
Per Cent
80
60
40
20
0
Largemouth Bass
Black Bullheads
Sunfish
Channel Catfish
White Crappie
Carp
Goldfish
Hybrid (Carp-Goldfish)
Golden Shiners
Fish Species

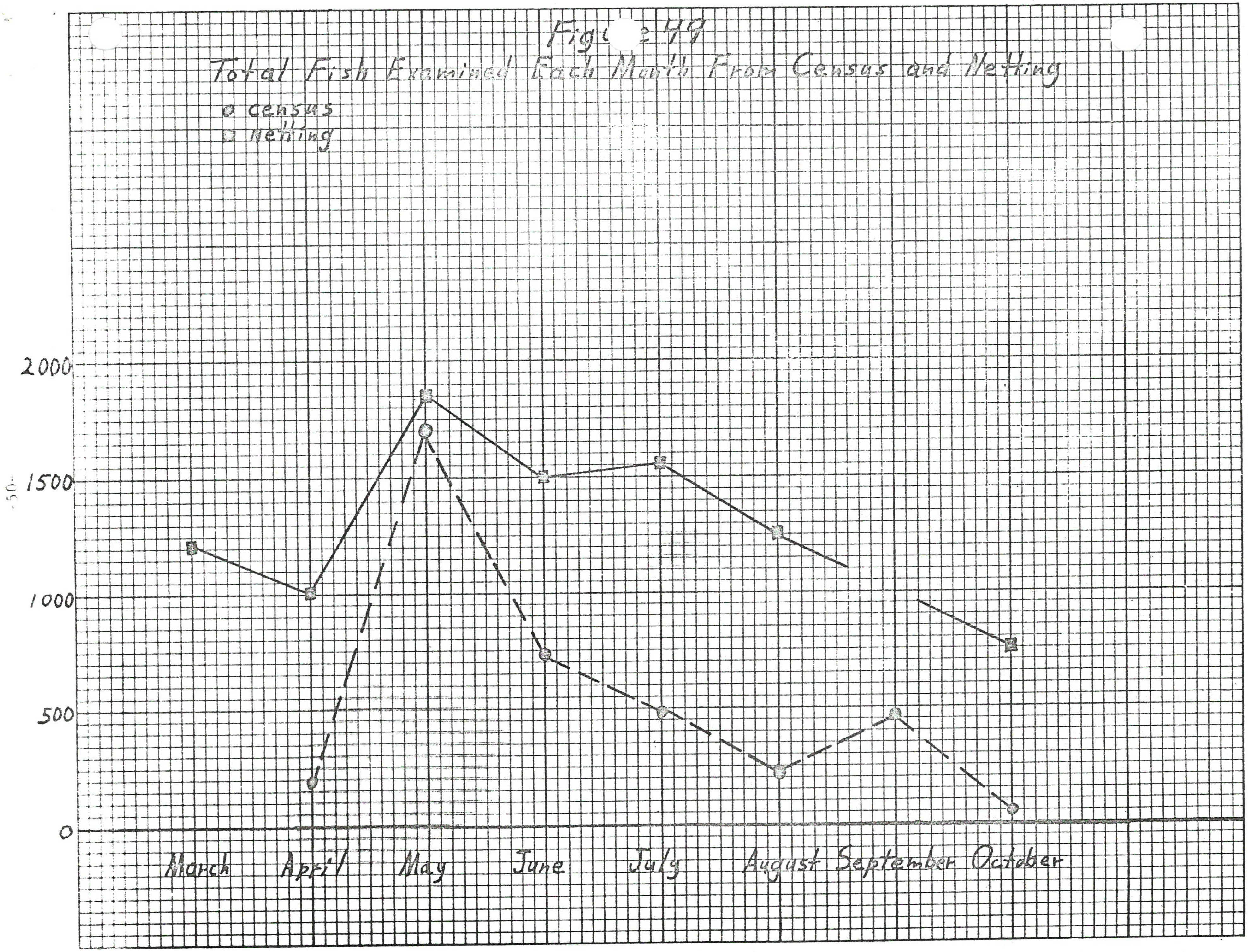


Figure 49
Total Fish Examined Each Month From Census and Netting
Census
Netting
2000
1500
1000
500
0
March
April
May
June
July
August
September
October

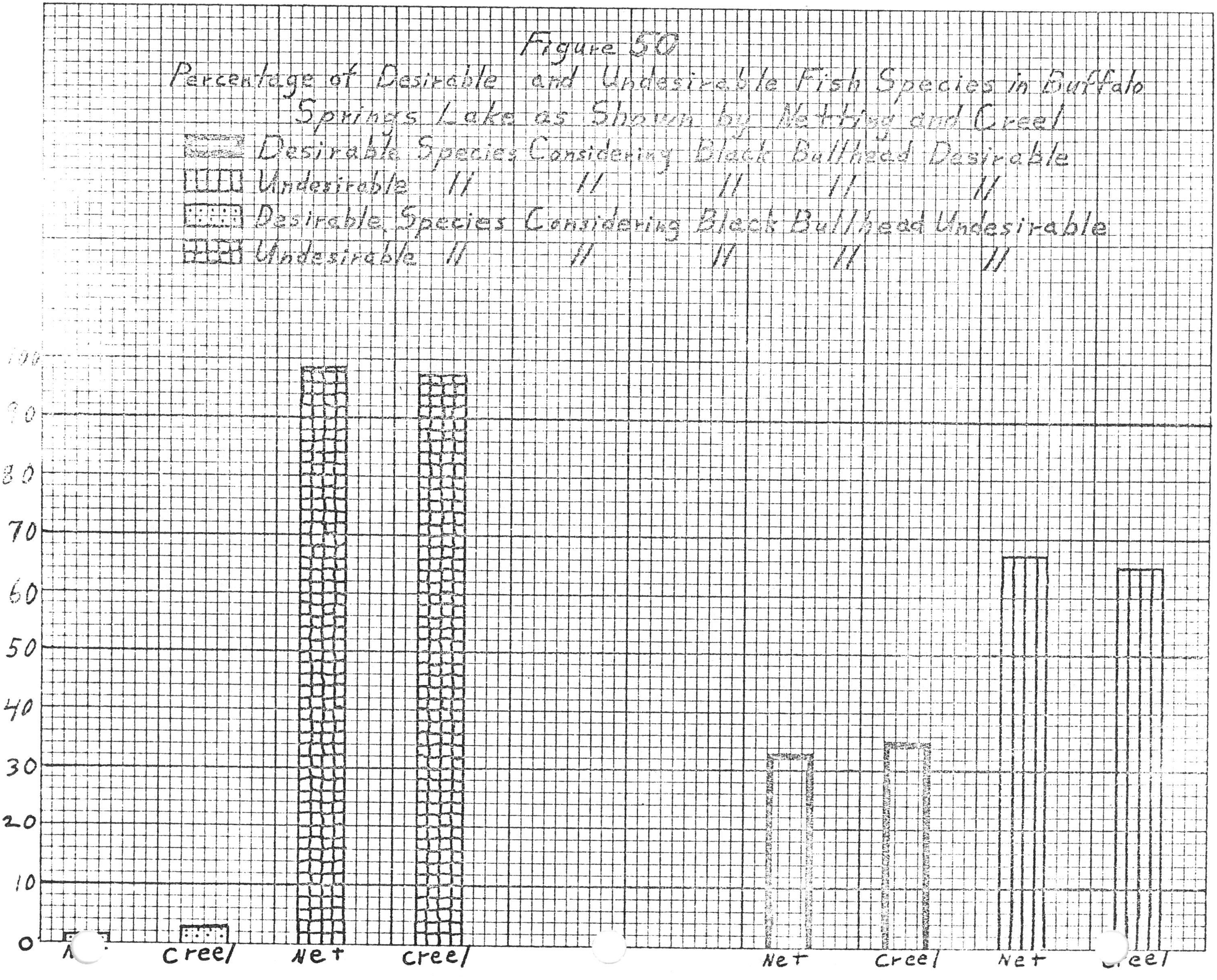


Figure 50
Percentage of Desirable and Undesirable Fish Species in Buffalo Springs Lake as Shown by Netting and Creel
Desirable Species Considering Black Bullhead Desirable
Undesirable " " " " "
Desirable Species Considering Black Bullhead Undesirable
Undesirable " " " " "
100
90
80
70
60
50
40
30
20
10
0
Creel
Net
Creel
Net
Creel
Net

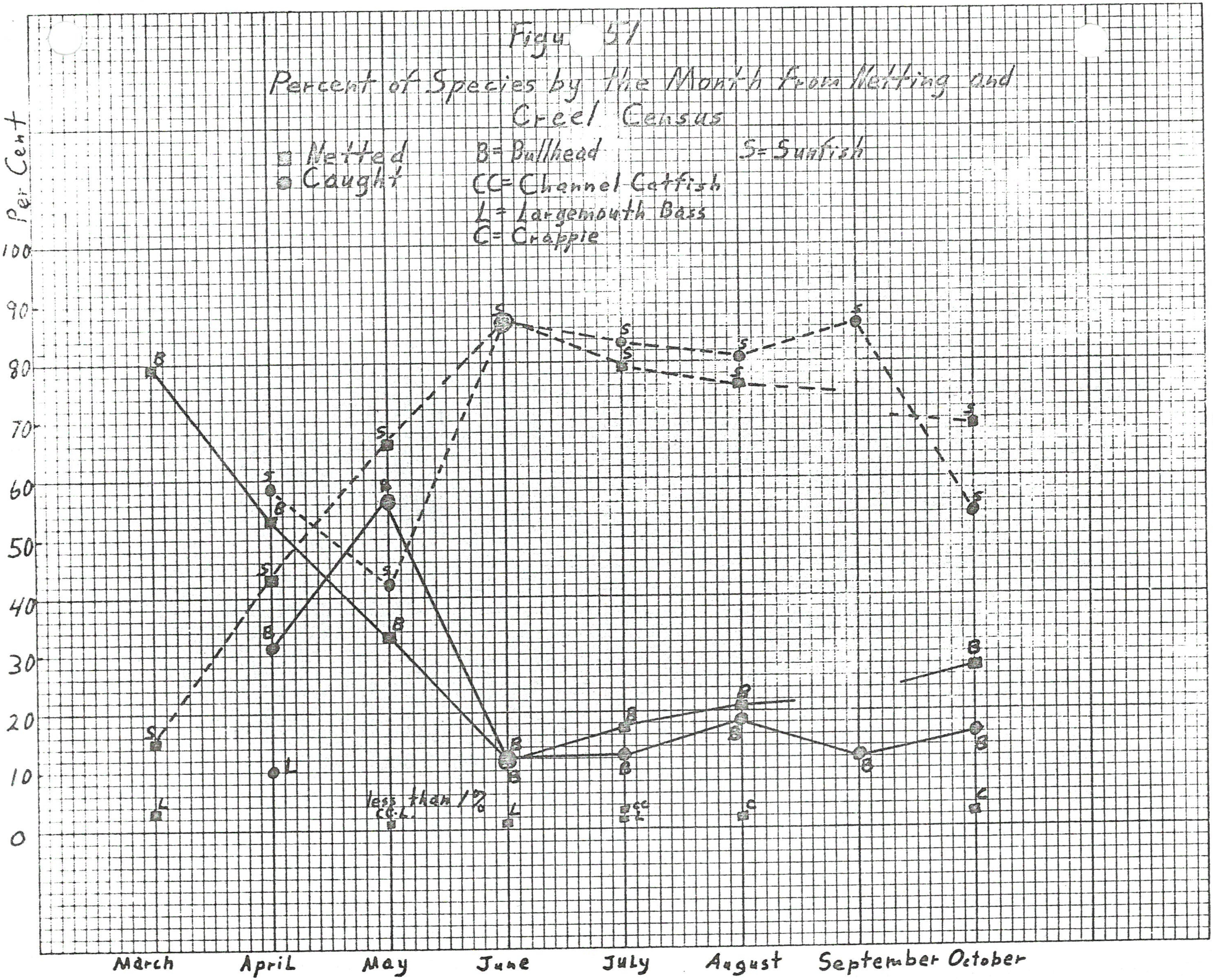


Figure 57
Percent of Species by the Month from Netting and Creel Census
Netted
Caught
B= Bullhead
CC= Channel Catfish
L= Largemouth Bass
C= Crappie
S= Sunfish
Per Cent
0
10
20
30
40
50
60
70
80
90
100
March
April
May
June
July
August
September
October
less than 1%
CC.L.

The average weight for all the bullheads netted which were retained and weighed was 0.49 pound. This somewhat smaller average weight could be expected as many fishermen released the smaller bullheads they caught.

Sunfish caught averaged 0.09 pound, and netted bluegill which were retained averaged 0.11 pound.

The average size largemouth bass caught by fishermen was 1.34 pounds and netted was 1.48 pounds.

The average size of channel catfish caught by fishermen was 2.17 pounds and by netting was 4.28 pounds. Only 9 channel catfish were retained from netting and they were retained because they were dead in the nets when taken.

The average size crappie caught by fishermen was 0.24 pound and by netting was 0.19 pound.

All the netting versus fishing data available, this year indicate a close parallel between netting samples and average creel of fishermen on the lake. Considering this, netting reconnaissance (on this lake or others having a similar fish population and fishing pressures) is a good index to relative fish population in the lake and the success fishermen might expect.

Records were kept of the baits used by successful fishermen. Table 17 contains these data.

Table 17. Baits and Number of Carloads of Successful Fishermen Using Each Kind of Bait, Correlated to Species Caught.

Bait	Species and Number of Carloads of Successful Fishermen Using Those Baits: Black Bullhead	Channel Catfish	Largemouth Bass	Sunfish	Crappie	Goldfish	Carp
Worms	135	6	6	109		1	2
Shrimp	28	7	1	21			
Minnows	18	3	9	14	8		
Artificials	0	1	11	8			
Stink bait	1	4		1			
Cut bait	7	1		5			

The major purposes of the population study were to determine population proportions, geographic locations of fish population concentrations, forage production, reproduction success of game fish, and growth of the offspring.

No reproduction was recorded, forage production is low, and the fish population is evenly distributed throughout the lake around the shoreline. Table 18 gives data concerning the total fish taken by netting. Weight figures are omitted because many fish were returned to the water after marking and were not weighed. Those that were marked by punching were not weighed or measured as no means of identifying individuals were available. After tagging began in August, weight and length of each specimen tagged were taken and recorded.

Table 18. Total Netted Fish From Buffalo Springs Lake from March Through October 1964.

Species	Number	Per Cent
Carp	17	0.18
Goldfish	22	0.24
Carp-goldfish hybrid	30	0.33
Golden shiner	52	0.58
1/ Channel catfish	31	0.34
2/ Black bullhead	2,988	32.85
1/ White bass	1	0.01
1/ Largemouth bass	88	0.96
2/ Green sunfish	1	0.02
2/ Redear sunfish	3	0.03
Bluegill	5,812	63.89
2/ Longear sunfish	3	0.04
1/ White crappie	48	0.53
Total	9,096	100.00

1/ Desirable fish.
2/ Optional desirable or undesirable.

Desirable 3,163 per cent 34.77 (considering bullhead desirable) (also sunfish other than bluegill)

Undesirable 5,933 per cent 65.23

Desirable 168 per cent 1.84 (considering bullhead undesirable) (also sunfish other than bluegill)

Undesirable 8,928 per cent 98.16

Game fish (largemouth bass, channel catfish, white bass, and crappie) represent 1.84 per cent of the population by netting and 2.04 per cent of the population as shown by creel census. Less desirable but utilizable bullheads and sunfish comprised 96.83 per cent of the fish population. Carp, goldfish, carp-goldfish hybrids, and golden shiners, all undesirable, comprised 1.33 per cent of the population.

There is an equal distribution of total fish population in the lake (Figure 52). However, this total population is 96.83 per cent bullheads and sunfish. These fish appear to have reached an equilibrium in zones netted and have less than 10 per cent variation between zones in population proportions or densities, judging from total catch per zone by nets (or creel). The two nets in zone D and E cause an introduced error in total numbers of fish for comparison of fish density in these zones. Net No. 3 was set out in the lake in 12 to 18 feet of water. It usually produced less fish by number than net No. 4, which is a shoreline set. The deep end of net No. 4 was often submerged into the toxic zone as evidenced by dead fish. Contours show the water depth to be 20 feet deep within 200 feet of the shoreline. Because of the location and nature of these two nets, they are nearly equal to a single sampling unit in better locations in other zones.

Both nets in zone D were set in good locations for fishing and produced good catches. The per cent of fish caught in this zone is biased on the high side.

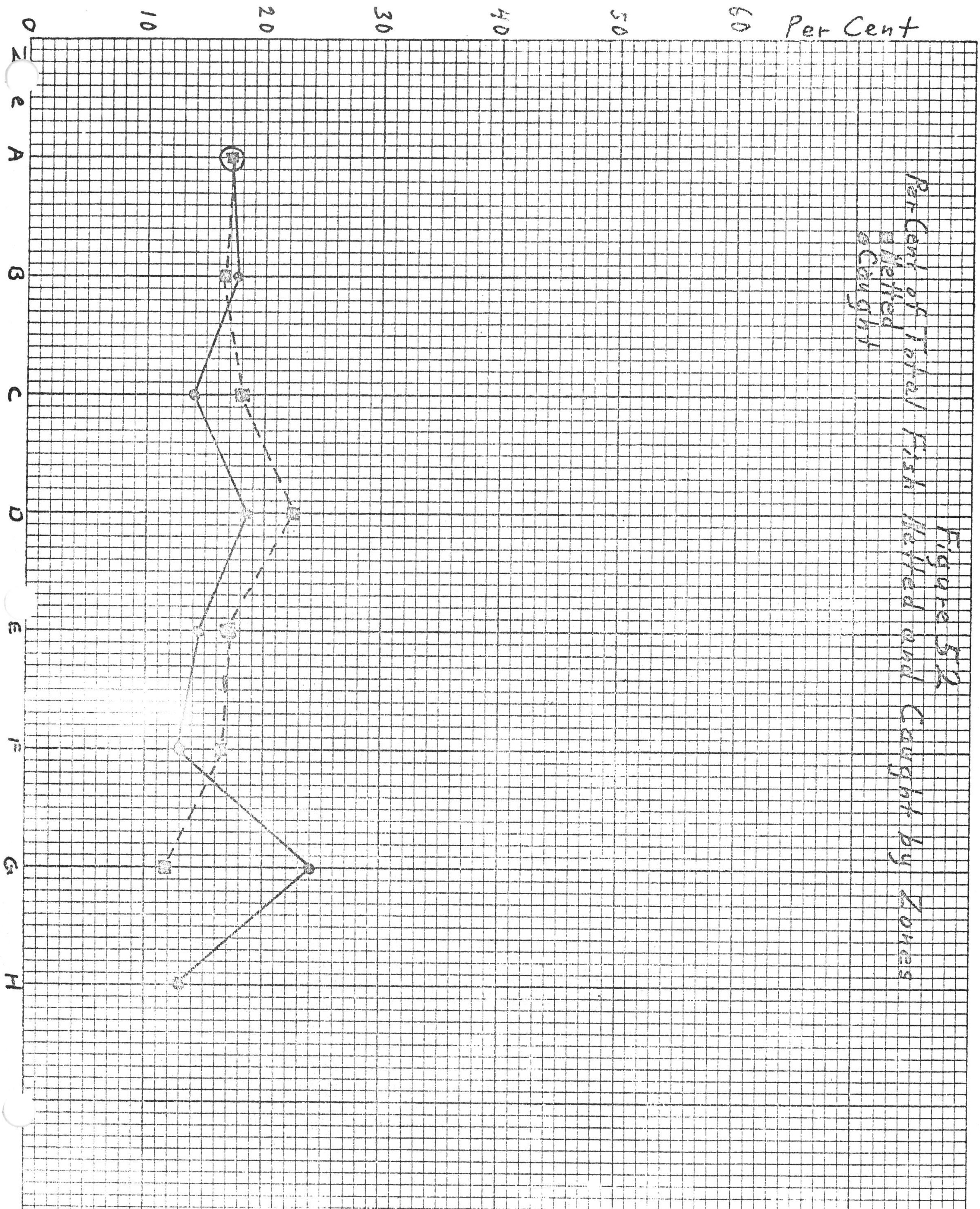


Figure 52
Per Cent of Total Fish Netted and Caught by Zones

The situation at net No. 1 has been explained. If net No. 1 had been set from the shore as the other nets were set, very likely it would have produced much different data. The different set would have conformed more to fisherman-catch and netting in other zones. This net did indicate, as did No. 3, that fewer fish are found away from the shore and cover.

Net location Nos. 2, 3 and 4 were not fished in July. They were replaced as indicated by the letter J in Figure 43. A floating net was set in zone H to determine if crappie occurred in the shallow water area above numerous tree stumps and snags in the most northeast inlet in the lake. Few fish were taken, no crappie, and a bottom set was not attempted.

Net J in zone F produced game fish, sunfish, and bullheads in similar proportions to those of other sets.

Net J in zone E was set in 28 feet of water, well into the toxic zone (the upper level of which was approximately 18 feet deep at the time), away from the shore to determine if fish were found there at all. Two sunfish were taken. One was dead and the other was very sick. These sets were not repeated as time and lack of personnel to carry out the scheduled work was critical. The failure to set net Nos. 2, 3 and 4 in July also accounts for some of the variation in population sampling indicated in Figure 52.

Considering all variations in sampling, bullheads and sunfish are evenly distributed around the lake.

Largemouth bass, channel catfish, and crappie do not seem to be evenly distributed as illustrated by creel census and netting.

Figures 44, 45, 46 and 47, containing data for largemouth bass, channel catfish, bullheads, and sunfish, are good illustrations of the zones and percentages of fish distribution as shown by netting and creel.

So few channel catfish and largemouth bass were caught by fishermen or with nets that the value of the distribution pattern is doubtful. The significance of the data is that fisherman and netting catch indicate the same type and percentage of fish population.

Monthly data for each net were kept and percentages calculated. Figure 49 contains the figures for total fish caught by fishermen and examined by census takers. The significant factor here is the general shape of the curve. Netting data alone are available for March. A small decline occurred in total fish caught in April compared to March. In April there was only one creel census taken which accounts in part for the small number of fish taken. In May, both creel and nets showed a substantial increase in total numbers of fish taken. A more or less gradual decline in number of fish caught occurred throughout the months of June, July, August, September, and October. This decline may be attributed to several factors.

The graphs of temperature gradient and depth of occurrence of the toxic zone show the zone to be receding in the fall. This increased the area available for fish life and the fish population spread into the new area. As temperatures became homogeneous, the zone disappeared. During this time netting produced fewer and fewer fish, and total catch as shown by creel census declined. In netting, the same number of nets were set each month. Small creel, however, is explainable partially on the basis of declining numbers of fishermen as shown by gate count. Total number of fishermen interviewed for June was 172, July - 114, August - 57, September - 66, and October - 42. Regretfully, there was no netting in September to determine if the few additional people interviewed that month caused the increase in number of fish caught, or if fish were simply more active and netting catch might have paralleled the increase.

The general curve, however, for creel and netting indicates greater activity and larger populations producing better fishing in April, May and June than for the following months. Average weight for fish taken in these months are listed in Tables 19, 20 and 21.

Table 19. Average Weight of Fish Taken by Netting by Month in Buffalo Springs Lake in 1964.

Species	Months and Averages						
	March	April	May	June	July	Aug.	Sept.
Largemouth bass	1.60	1.54		1.09	1.79	0.87	2.26
Channel catfish		4.40	5.06		2.64	3.92	6.39
Black bullhead	0.50	0.54	0.61	0.46	0.47	0.44	1 fish
Bluegill	0.09	0.09	0.09	0.08	0.09	0.08	0.09

Table 20. Average Weight of Fish Taken by Fishermen by the Month in Buffalo Springs Lake in 1964.

Species	Months and Averages						
	April	May	June	July	Aug.	Sept.	Oct.
Largemouth bass	1.20	1.41	1.26	1.81	1.60	0.99	
Channel catfish		2.58	5.50	1.22	4.85 (1 fish)	0.27	
Black bullhead	0.54	0.66	0.36	0.26	0.44	0.22	0.55 (8 fish)
Bluegill	0.07	0.10	0.09	0.09	0.09	0.07	0.08

Table 21. Average Weight of Black Bullheads in Buffalo Springs Lake from a Combined Total of Fisherman Catch and Netting.

Species	Months and Averages							
	March	April	May	June	July	Aug.	Sept.	Oct.
Black bullhead	0.50	0.54	0.63	0.41	0.365	0.44	0.22	0.55 (8 fish)

The general size of bullheads collected or caught in March, April, and May were larger than those caught or netted in June, July and August (Tables 19, 20 and averages in Table 21). This trend indicates that the larger bullheads in Buffalo Springs Lake were cropped during the spring months either by fishermen or by fish kills. The die-off did not appear to be size-selective, although this aspect was not investigated.

Sunfish weights remain very close to the same. This indicates an overabundant population and removal of fish by fishermen cannot be selective for large fish. The larger fish are very much the same maximum size attainable, because of available food, space, and environmental conditions.

Channel catfish and largemouth bass were present as adults only (bullheads and sunfish had tremendous numbers of young), and no reproduction was evidenced for game fish by seining, visual observation, fisherman catch or netting.

Forage

Table 22 contains the combined data for all seining collections in Buffalo Springs Lake in 1964, excepting 1 seine drag on March 28 with a 40-foot seine. In this haul rough calculations indicated that 714 pounds of small (2 to 3.5 inches) black bullheads were taken. An average of 8.5 pounds of fish per shovel for 3 scoop shovels full of fish was established. Altogether, 84 scoops of fish were loaded and hauled away. Each scoop-full contained an average of 360 fish, indicating that 30,240 fish were taken in the 1 seine haul. The fish had an average weight of 10.71 grams or 0.024 pound each.

Table 22. Combined Data From all Seining in Buffalo Springs Lake, 1964.

Species	Months and Numbers and Per Cent						
	May	June	July	Aug.	Oct.	Total	Per Cent
Carp							
Goldfish							
Carp-goldfish hybrid							
Golden shiner	31	19	72	1	40	163	3.14
Red shiner	62	54	15	37	210	378	7.29
Plains minnow	34	7		3	33	77	1.48
Bullhead minnow				1		1	0.02
Fathead minnow	87	24	124	582	206	1,023	19.72
Channel catfish							
Bullhead catfish	1,003	125	402	8	10	1,548	29.85
Plains killifish					1	1	0.01
Mosquitofish			1		10	11	0.22
White bass							
Largemouth bass	3		1			4	0.07
Green sunfish	157	26	87	61	43	374	7.21
Redear sunfish	1					1	0.02
Bluegill	370	247	358	186	94	1,255	24.20
Orangespotted sunfish	45	114	50	32	56	297	5.72
Longear sunfish	10	31	9	1		51	0.99
White crappie			1			1	0.02
Hybrid (sunfish)				2		2	0.04
Total	1,803	647	1,120	914	703	5,187	100.00

Forage (bait) species, including mosquitofish in this category, comprise 31.88 per cent of the seinable fish population (Table 22). Bullhead catfish comprise 29.85 per cent and sunfish 38.18 per cent, of which 24.20 per cent are bluegills. Therefore, the largemouth bass, channel catfish and other carnivorous game species must survive, grow, and prosper on 31.88 per cent of the seinable population. They must do this in competition with black bullheads and sunfish for insect and planktonic foods. The spines of young bullheads and the spines, wariness, and swiftness of young sunfish make them less available as forage than minnows the same size. Sunfish and bullheads rapidly grow too large to be readily eaten by small game fish. The available food presents additional obstacles to the growth of young game fish to adult size and limits the population of adult game fish which the lake can support.

In order to compare ratios of adult sunfish and bullheads with immature fish of these species we may eliminate the population which are not captured by nets. This gives us a population of young fish which can be compared to adult netted species. When this is done we compare golden shiner, bullheads, largemouth bass, sunfish, and white crappie. Figure 53 contains these data. It is believed that this lake alone, because of its unique fish population, shows close similarities between creel, netting, and seining data. This facet of sampling could well be utilized and should be tested on various lakes to determine relationships between young and adult populations in order to determine what effect fishing pressure, predation, and adverse environmental conditions have on the developing fish population.

Sunfish were overabundant in all areas seined. In May no sunfish fry were noticed, but in June numerous sunfish fry and a few minnow fry were captured. In July, sunfish fry and minnow fry were very numerous. At no time were fry or fingerling of largemouth bass, channel catfish, white bass, or crappie taken. Fingerling of these game species were not taken in seines or nets and no fish of these species were observed which could have been produced in the current year. Several small channel catfish were reported taken by fishermen, and some were checked at the census station. However, those checked were large enough to have been stocked in 1963. For these reasons it is believed that game species had not successfully spawned in Buffalo Springs Lake in 1964.

Very few insects, young or mature, were ever taken by seine. This was true in all areas of the lake which were seined. Even when seining in dense vegetation with a 1/32-inch mesh, 4-foot seine no insects were taken. There was always an abundance of sunfish and bullheads which thoroughly cleaned the lake of insects. This is concluded because sunfish and bullhead stomachs contained more insects than stomachs of any other fish taken (Table 23). Because of the abundant sample of sunfish and bullheads, and the lack of specimens of other fish due to the tagging program, stomachs were accumulated instead of being reported by the month and the volume of information from food analysis is small.

Food analysis of largemouth bass stomachs revealed that they were taking black bullheads as forage. One specimen examined had its stomach wall punctured by the pectoral spines of the two bullheads it had consumed. Apparently, the fish was in good health until suffocated by the gill net. The lesions through the stomach wall appeared to be healing.

The "minnow" to "other fish" percentages shifted considerably by the month as seining data show in Tables 24, 25, 26, 27 and 28. These data were collected under varying circumstances. The number of total seine hauls, areas where seined, and time of day the seining occurred varied.

Table 23. Food Taken by Predacious Species of Fish at Buffalo Springs Lake in 1964. Compiled from Data Taken During 8 Months Surveys.

Species	No. Examined	No. Empty	Algae	Insect Larvae	Crustacea	Crayfish	Vegetation	Insects	Fish
Channel catfish	4	3							1
Black bullhead	118	61	37	18	11	1	17		6
Largemouth bass	7	4							3
Sunfish (mixed)	98	54	7	15	23		17	3	2

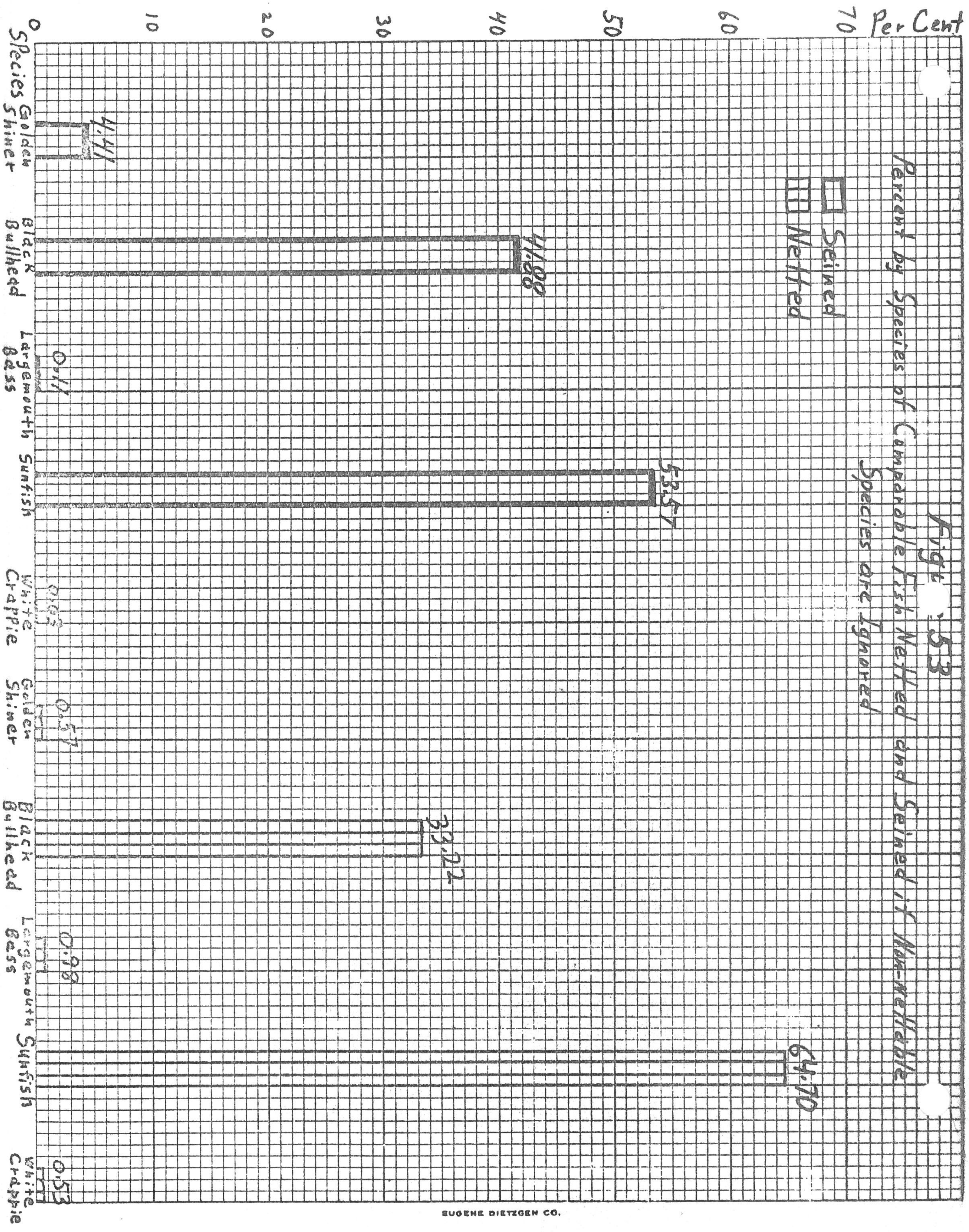


Fig. 53
Percent by Species of Comparable Fish Netted and Seined if Non-Nettable Species are Ignored

Table 24. Seining Data From Buffalo Springs Lake - May 1964.

Species	Number of Fish	Per Cent
Golden shiner	31	1.71
Red shiner	62	3.44
Plains minnow	34	1.89
Fathead minnow	87	4.82
Black bullhead	1,003	55.63
Largemouth bass	3	0.17
Green sunfish	157	8.71
Redear sunfish	1	0.05
Bluegill	370	20.52
Orangespotted sunfish	45	2.50
Longear sunfish	10	0.56
Total	1,803	100.00

Minnows 11.86 per cent
Other 88.14 per cent

Table 25. Seining Data From Buffalo Springs Lake - June 1964.

Species	Number of Fish	Per Cent
Golden shiner	19	2.93
Red shiner	54	8.35
Plains minnow	7	1.08
Fathead minnow	24	3.71
Black bullhead	125	19.32
Green sunfish	26	4.02
Bluegill	247	38.17
Orangespotted sunfish	114	17.62
Longear sunfish	31	4.80
Total	647	100.00

Minnows 16.07 per cent
Other 83.93 per cent

Table 26. Seining Data From Buffalo Springs Lake - July 1964.

Species	Number of Fish	Per cent
Golden shiner	72	6.42
Red shiner	15	1.34
Fathead minnow	124	11.07
Black bullhead	402	35.90
Mosquitofish	1	0.09
Largemouth bass	1	0.09
Green sunfish	87	7.76
Bluegill	358	31.97
Orangespotted sunfish	50	4.46
Longear sunfish	9	0.81
White crappie	1	0.09
Total	1,120	100.00

Minnows 18.92 per cent
Other 81.08 per cent

Table 27. Seining Data From Buffalo Springs Lake - August 1964.

Species	Number of Fish	Per Cent
Golden shiner	1	0.10
Red shiner	37	4.05
Plains minnow	3	0.33
Bullhead minnow	1	0.11
Fathead minnow	582	63.68
Black bullhead	8	0.87
Green sunfish	61	6.68
Bluegill	186	20.35
Orangespotted sunfish	32	3.50
Longear sunfish	1	0.11
Hybrid (sunfish)	2	0.22
Total	914	100.00

Minnows 68.27 per cent
Other 31.73 per cent

Table 28. Seining Data From Buffalo Springs Lake - October 1964.

Species	Number of Fish	Per Cent
Golden shiner	40	5.68
Red shiner	210	29.88
Plains minnow	33	4.69
Fathead minnow	206	29.30
Black bullhead	10	1.43
Plains killifish	1	0.14
Mosquitofish	10	1.42
Green sunfish	43	6.12
Bluegill	94	13.37
Orangespotted sunfish	56	7.97
Total	703	100.00

Minnows 71.11 per cent
Other 28.89 per cent

Regardless of these variations, the data shown have value. The large increase in "minnow" percentages compared to "other" occurring in August and October is attributable to the maturing of minnow fry to a stage identifiable in the field. Bullheads and sunfish fry had become large enough to evade seining in the clear waters of the lake. Also, the lowering and subsequent disappearance of the toxic zone allowed the sunfish and bullheads to broaden their habitat range, having the effect of reducing their numbers in seine collections.

All areas which were seined produced "forage" species. Abundance varied depending on the area, but not to such an extent that special significance should be applied.

Condition indexes ("K" factors) were computed for all fish retained and autopsied. So few game fish were retained that monthly variations are insignificant, and the accumulated average "K" factors obtained for all species retained are shown in Table 29. They may be misleading for some species because only distressed or dead fish were retained to be sutopsied. These fish may or may not have been in poor condition when netted as healthy fish are sometimes suffocated or injured in the nets. "K" factors obtained do not represent an unbiased sample of the netted fish, but bullheads and sunfish were so similar in size despite the method of collection that the "K" factors for these species are considered valid. The average "K" factor for bullheads taken in April was based on 3 fish which were very emaciated, and is not included.

Table 29. Average "K" Factor of Fish Taken From Buffalo Springs Lake by the Month in 1964.

	March	April	May	June	July	August	October
Carp		2.9	2.9	3.4	2.6	2.9	3.1
Goldfish			5.0		4.4	4.9	
Carp-goldfish hybrid	3.9		3.4		3.5	4.1	3.6
Golden shiner	2.0	1.9	2.0				
Channel catfish		2.2	2.0		2.0	1.9	2.1
Black bullhead	2.3		2.3	2.3	2.2	2.2	2.1
White bass						3.7	
Largemouth bass	3.0	2.7		2.7	3.3	2.5	3.5
Bluegill	3.8	4.2	4.0	4.4	4.1	3.7	3.6
White crappie					3.0	2.9	3.3

Tagging Program

A tagging program was planned for several reasons. One reason was to determine growth rates of fish tagged, another was to record movements of tagged fish. A third reason was to attempt to determine population density if sufficient data were obtained. Table 30 contains marking data. The marking was accomplished with a paper punch by methods previously described until tags were made available in August. All fish were punched (or tagged) and released at the site of capture.

The marking system allowed determination of movements and number of recaptures. Table 30 reveals that movements were random and recaptures varied in location. Fish recaptured were not remarked with the site of recapture. Marks appeared to be sufficiently permanent.

Sunfish were observed to be less capable of surviving the hardship of being netted and marked than were black bullheads. Fewer sunfish were recaptured and it is believed that their frailty partially accounted for this. Tagging with jaw and button tags was begun in August. One tagged crappie, listed in Table 29, was caught by a fisherman and destroyed before measurements and sex could be determined. Sunfish, because of their numbers, size, and frailty are being marked by punching instead of tagging as the study continues.

Possibilities of attempting to determine total population of nettable size species by the Peterson method have been considered. At present, however, insufficient data are available to produce accurate enumerations of the total population.

Table 30. Marked Fish Which Were Recaptured, Where Marked, Where Recaptured and Date of Recapture in Buffalo Springs Lake - 1964.

Netted Fish	No.	Net Where Marked	Net Where Recovered	Month When Recovered
Channel catfish	1	9	4	October
	1	9	9	July
Black bullhead	1	5	4	October
	1	1	1	July
	1	1	J in zone G	July
	1	2	7	June
	1	7	7	June
	1	Not recorded	7	May
	1	Not recorded	8	May
	1	7	9	May
	1	7	1	April
	3	2	3	April
	2	2	4	April
	1	5	J in zone H	April
Largemouth bass	1	Seined (lower lake)	3	June
Sunfish sp.	1	2	7	October
	2	3	4	October
	1	1	J in zone G	July
	1	2	9	May
	1	3	3	April
Fisherman-caught Fish			**Zone Where Recovered**	
Black bullhead	1	5	A	
	1	3	B	
	2	1	B	
	1	4	B	
	1	1	D	
White crappie	1	6 (#A 8596)	G (Crappie House)	October

There have been 7,320 fish marked (Table 31), of which 345 were tagged. Fish loss from natural die-off is undetermined and was so large that any attempt to determine total population by mark and recovery this year would be quite inaccurate. The study is continuing.

Summary

Figures 5 and 54 illustrate, when considered together, the productive and non-productive areas in Buffalo Springs Lake.

All the area below 15 feet in depth which is occupied by the toxic zone is unproductive water. Not only is that area unproductive but it becomes lethal to fish when toxic layers occur from 15 feet downward. The area below 15 feet in depth is subject to toxic gases without warning, particularly during the spring months when temperatures favor bacterial action. Also, accumulated materials carried in during cold weather provide abundant fuel for bacterial action. Warming of the lake water to temperatures suitable for fish spawning also introduces temperatures suitable for bacterial action. Accelerated bacterial action occurs and toxic gases and zones are produced.

The open water area in the lower lake is used by skiers daily and, as demonstrated by net Nos. 1 and 3, is relatively unused by fish.

In the upper lake, the sago pondweed (Figure 2) occupies much of the shelving zone along the shoreline thus making feeding by predator fish on forage species difficult. When Figures 54 and 2 are considered together it is readily seen that, between the toxic zone and the sago pondweed, little "living zone" for game fish remains.

This is in addition to the relatively poor average water quality which makes the toxic zone possible and produces stresses which keep the fish population at a low level of health. These stresses are: dissolved toxic gases, large fluctuations of dissolved oxygen, dense fish population, and rapid changes in water temperature and quality during periods of high water.

The dense population of sunfish and bullheads make reproduction by game fish extremely difficult. They limit forage production for game species and compete for available food. They almost insure that no survival would occur if game fish should successfully spawn, without the additional stresses mentioned above.

Table 31. Total Number of Fish Marked and Tagged in Buffalo Springs Lake in 1964.

Fish	Total Marked	Tagged and Weighed
Carp	5	
Goldfish	11	
Carp-goldfish hybrid	17	
Golden shiner	45	
Channel catfish	27	6
Black bullhead	2,775	311
White bass	1	1
Largemouth bass	68	5
Green sunfish	1	
Redear sunfish	2	
Bluegill	4,322	
Longear sunfish	3	
White crappie	43	22
Total	7,320	345

Recommendations:

1. General cleanup of the watershed to produce better water quality is needed.

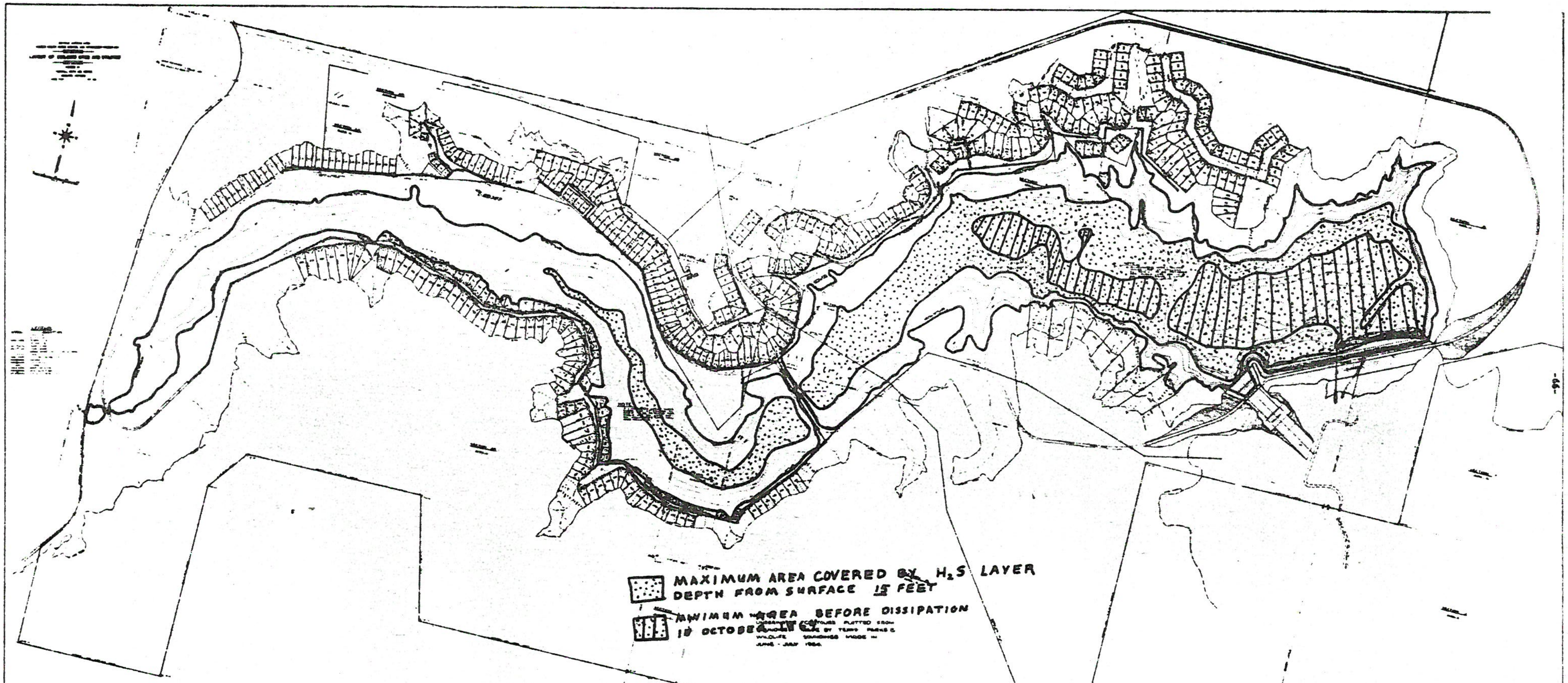

MAXIMUM AREA COVERED BY H_2S LAYER
DEPTH FROM SURFACE 15 FEET
MINIMUM AREA BEFORE DISSIPATION
18 OCTOBER

Figure 54

2. The thermal stratification should be broken up to prevent formation of the toxic zone.

Some suggested methods of breaking up the thermal stratification are presented for consideration.

Outflow from the lake could be drained from the bottom instead of over the spillway. This would aid in ridding the reservoir of built up impurities which settle out in the lower lake basin and it would tend to lower the level of thermal stratification.

Piercing or cutting the old dam beneath the bridge which separates the upper and lower lake would allow watershed run-off and normal flow to flush out the upper lake. This would prevent the stagnant pool below the 12-foot depth which it now accumulates. Removing the stagnant water would prevent or retard thermal stratification and formation of a toxic layer in the upper lake.

Several methods of eliminating thermal stratification have been experimentally tried by others. Their success has been limited because of expense. Water has been pumped from the bottom to the surface (and the reverse) of small lakes thus eliminating stratification. Compressed air has been piped to the bottom of lakes and allowed to rise and form convection currents to mix cooler bottom water with surface water. This air has been allowed to rise freely or enclosed by large collapsible sleeves of plastic which act similarly to the air powered filters of aquaria which set up currents of water in tubes by allowing air to rise and cause the flow of water with the rising bubbles.

A suggested alternate would be to construct auxiliary canals along the lake shore and feed inflow into the bottom of the lake. This flow could be channeled to suitable locations by pipes allowing the fresh water to flow into the lake bottom. This would prevent thermal layeration during the summer by convection currents set up as the warmer (less dense) water flowed upward. Winter usage would provide varying conditions depending on weather. This method might be beneficial by preventing stagnant conditions which presently allow bacterial action to form toxic substances in bottom waters.

Experimental manipulation of the upper lake before piercing the old dam might aid in evaluation of the alternate method suggested. Because of the depth and contour of the upper lake it should be treated first as it is smaller and is the area where the most productive water is found. Experiments to establish the benefit of this method could be done by pumping surface water to the bottom in the deeper areas in the upper lake. If this proved beneficial the cost of an auxiliary canal along the lake feeding inflow into the bottom water might be justified.

3. Accelerated control measures should be applied to the sago pondweed, beginning earlier and removing decaying weeds more quickly.

4. The bullhead and bluegill population needs reducing to lessen competition with game species. When these things are done the game fishery should be greatly improved in Buffalo Springs Lake.

CHECKLIST OF SPECIES TAKEN AT BUFFALO SPRINGS LAKE
1964

Common Name	Scientific Name
Carp	*Cyprinus carpio*
Goldfish	*Carassius auratus*
Carp-goldfish hybrid	
Golden shiner	*Notemigonus crysoleucas*
Red shiner	*Notropis lutrensis*
Plains minnow	*Hybognathus placita*
Bullhead minnow	*Pimephales vigilax*
Fathead minnow	*Pimephales promelas*
Channel catfish	*Ictalurus punctatus*
Black bullhead	*Ictalurus melas*
Plains killifish	*Fundulus kansae*
Mosquitofish	*Gambusia affinis*
White bass	*Roccus chrysops*
Largemouth bass	*Micropterus salmoides*
Green sunfish	*Lepomis cyanellus*
Redear sunfish	*Lepomis microlophus*
Bluegill	*Lepomis macrochirus*
Orangespotted sunfish	*Lepomis humilis*
Longear sunfish	*Lepomis megalotis*
White crappie	*Pomoxis annularis*

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Project co-leader
Date August 9, 1965

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