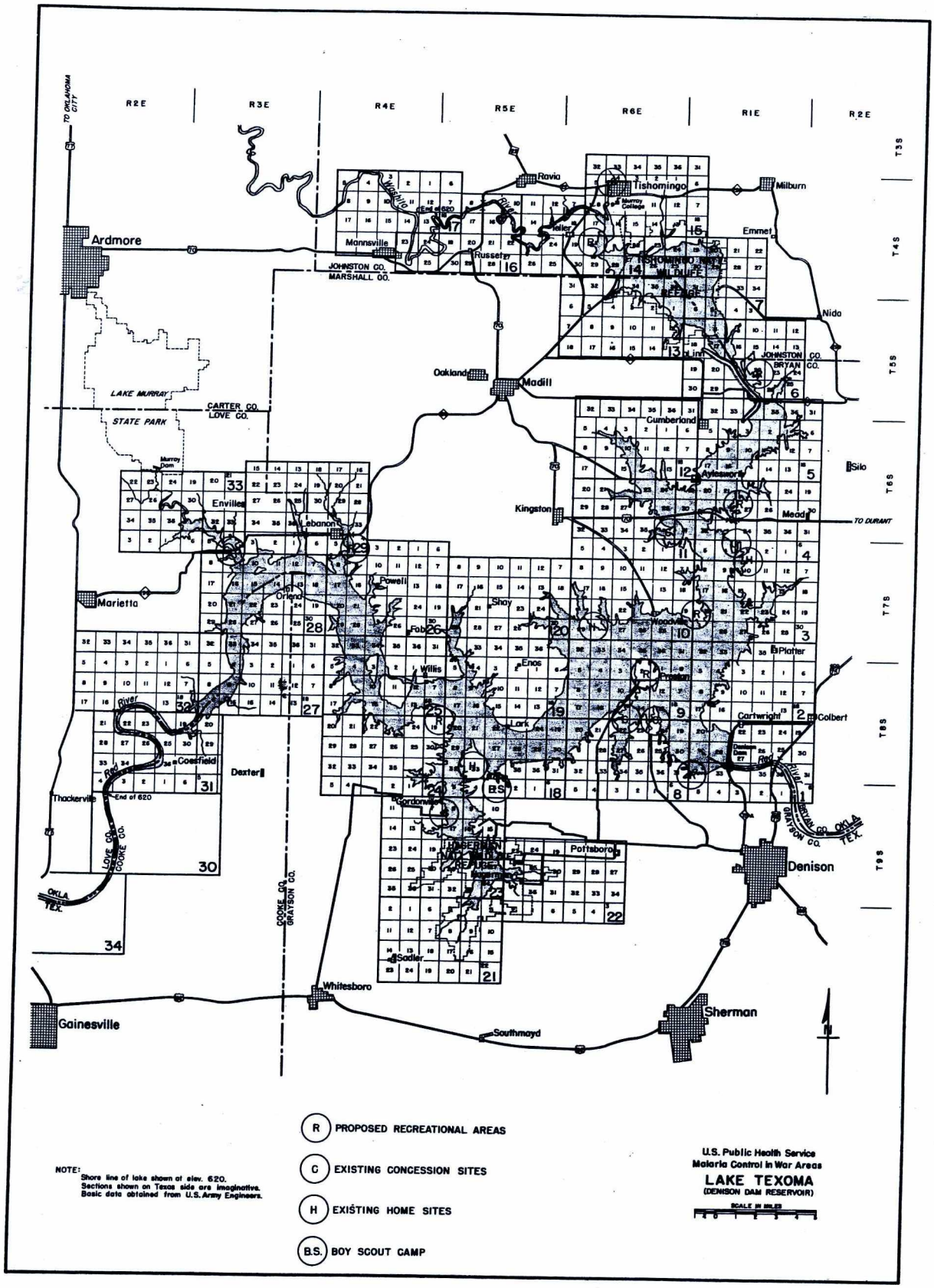


Figure 1

A Malaria Survey of the DENISON DAM RESERVOIR: LAKE TEXOMA

INTRODUCTION

Malaria has long been a familiar disease in certain parts of the Lower Red River Valley. Therefore, in 1944 some anxiety was manifested by several public health agencies with regard to the possible malaria hazard involved by the creation of Lake Texoma. Consequently, a preliminary *Anopheles* survey was made in a portion of the Lake Texoma area in September 1944 by the Oklahoma State Department of Health. The results of this survey further emphasized the need for an intensive malaria study of the entire reservoir area.

A conference to discuss the potential malaria hazard on Lake Texoma was held at the District Engineer Office in Denison, Texas, on March 24, 1945. Representatives of the following agencies attended this meeting: the Corps of Engineers, the U. S. Public Health Service, the Fish and Wildlife Service, the National Park Service, and the state health departments of Oklahoma and Texas.

At this conference the following decisions were reached: (1) that the Corps of Engineers would request the U. S. Public Health Service, office of Malaria Control in War Areas, to undertake an intensive malaria survey of the Lake Texoma area to be financed jointly by the Corps of Engineers and the Public Health Service; (2) that the state health departments of Oklahoma and Texas, and the health departments of the counties adjacent to the reservoir would assist with this survey; and (3) that a complete report would be submitted to the Corps of Engineers by the office of Malaria Control in War Areas at the termination of the study.

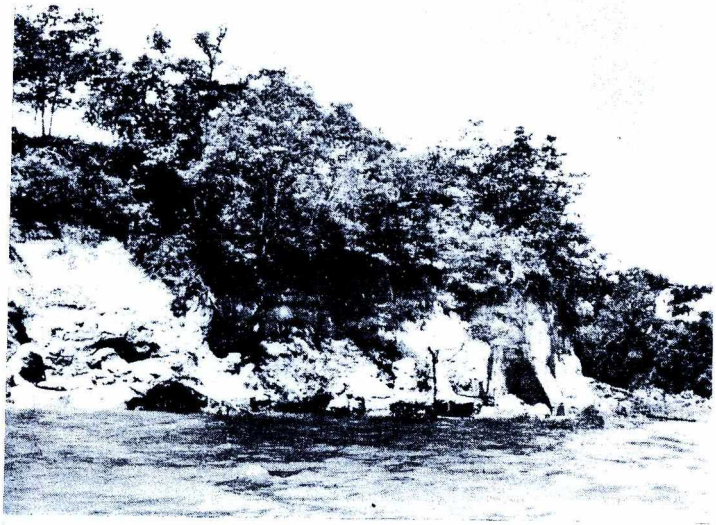
LOCATION AND PURPOSES OF THE WATER CONTROL PROJECT

Denison Dam is located on the Red River, approximately five miles northwest of Denison, Texas, just below the confluence of the Red and Washita rivers. The reservoir, Lake Texoma, with a maximum area of 145,500 acres at flood pool elevation (640),[1] and at normal pool elevation (617) an area of 95,000 acres, is one of the largest artificial lakes in the United States. At normal pool elevation the lake extends 44 miles up the Red River and 29 miles up the Washita River. Lake Texoma is located in Grayson and Cooke counties, Texas, and in Bryan, Marshall, Johnston, and Love counties, Oklahoma.

The Corps of Engineers began construction of the project in 1938, and regulated storage was started on October 31, 1943. The project was completed in 1944, and the normal pool elevation was reached in March 1945.

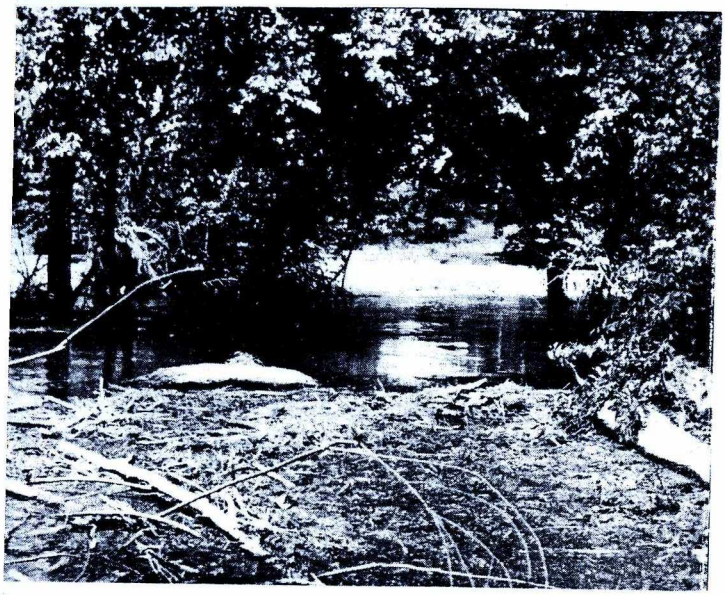
The Denison Dam project has been developed primarily for flood control and for the production of hydroelectric power. The rolled-fill earthen dam with the spillway crest at elevation 640 is approximately three miles long. According to the present plan of operation the storage capacity between elevations 617 and 640 is used for flood water and the water between elevations 617 and 590 is stored for use in hydroelectric production. However, it is expected that the water level of the reservoir will be maintained at the

1. All elevations are referred to mean sea-level datum.



(above) Figure 2. Steep shore line on Texas side of reservoir.

(center) Figure 3. Uncleared timber in Pennington Creek.



(below) Figure 4. Driftwood near Tishomingo, Oklahoma.

normal pool elevation of 617 during most of the year. Owing to the uniform distribution of rainfall throughout the year in this region, the volume of inflow is considered sufficient to produce the necessary hydroelectric power and at the same time to maintain a constant water-level at about 617. Secondary purposes for the reservoir include the development of certain areas for recreation and wildlife (Figure 1), by the National Park Service and the Fish and Wildlife Service.

PHYSICAL CHARACTERISTICS OF THE REGION

PHYSIOGRAPHY. The six counties adjoining the reservoir are within the Texas Coastal Plains Region and most of the land lies within a subdivision known as the Post Oak Belt. This belt is characterized as a very gently-rolling plain timbered principally with post oak on the uplands, and walnut, pecan, and willow along the streams. The sandy soil which predominates around the margin of the lake is lacking in organic fertility.

The length of the shore line of the reservoir at elevation 640 is approximately 1,250 miles. At normal pool elevation (617) the shore may be considered for the most part as sloping or steep (Figure 2) and only about 20 percent is flat. The classification of the slope of the shore at elevation 617 is as follows:

Steep	276 miles	32.5 percent
Sloping	415 miles	48.7 percent
Flat	160 miles	18.8 percent

Prior to impoundment most of the trees and other standing vegetation were cleared from the reservoir basin up to elevation 620; however, uncleared timber is still located in the following areas: Oklahoma - Zone 15[2] (Pennington Creek) (Figure 3); Texas - Zone 21 (Big Mineral Arm), Zone 26 (south of Orlena), and Zone 31.

The spring surcharge in 1945 stranded large quantities of flotage along the shore. The greatest deposition of logs

2. For explanation of Zones refer to Figure 1.

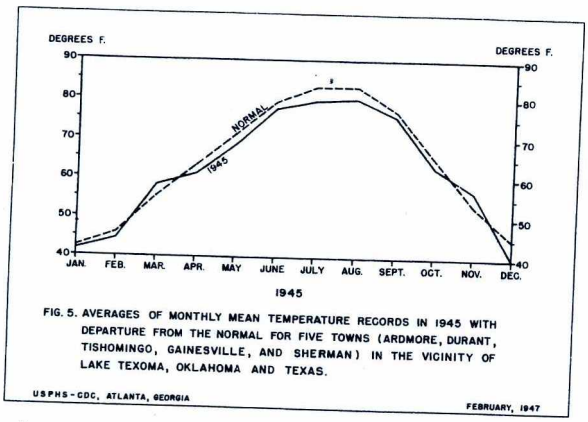


FIG. 5. AVERAGES OF MONTHLY MEAN TEMPERATURE RECORDS IN 1945 WITH DEPARTURE FROM THE NORMAL FOR FIVE TOWNS (ARDMORE, DURANT, TISHOMINGO, GAINESVILLE, AND SHERMAN) IN THE VICINITY OF LAKE TEXOMA, OKLAHOMA AND TEXAS.

and stumps occurred in Zones 7 and 14 near Tishomingo, Oklahoma (Figure 4). Most of this flotage resulted from uncleared areas.

Willows are common in most of the inlets and are spreading rapidly into the upper reaches of the reservoir where large amounts of silt are being deposited.

Stands of aquatic vegetation favorable to anopheline breeding were not located in the reservoir proper. However, three ponds containing American lotus *(Nelumbo pentapetala)* were found in the following places: Oklahoma - Zone 14 (Section 22), Zone 15 (Section 10) (Figure 17); Texas - Zone 28 (Section 30).

CLIMATE

The climate of the region is mild. The average of the mean annual temperature records for five towns[3] in the vicinity of the lake where U. S. Weather Bureau Stations are located is 63.6° F. January, with a mean of 42.1° F., is the coldest month, while July and August, with an average of 83.2° F., are the hottest months. The maximum temperature ever recorded in the vicinity (Gainesville, Texas) was 114° F., and the lowest was -12° F. The daily temperature range in summer is about 10° F.

The average date of the last killing frost is March 23, and of the first killing frost November 10. The length of the growing season is approximately 231 days.

As shown in Figure 5, the year 1945 was cooler than normal. Only the months of March and November were above normal. The last killing frost in the spring was on April 5 and 6; the first killing frost in the fall occurred during the period of November 21-23, inclusive.

The average rainfall derived from the annual precipitation records for five towns[3] near the lake is approximately 37 inches. Normally, precipitation is quite evenly distributed throughout the year although April and May are usually the wettest months. While floods occur at irregular intervals, the average is about one flood a year. The extremes vary from five floods in one year (Red River, Colbert, Oklahoma, 1941) to no floods during a four-year period (Red River, Colbert, Oklahoma, 1909-12). Flood data given in Table 1 show that the greatest number of floods have occurred during the months of May and October.

The year 1945 was one of the wettest on record; the average rainfall according to the annual precipitation records for five towns[3] adjacent to the lake was 55.23 inches. Figure 6 shows that the heaviest precipitation in 1945 occurred during the months of February, March, June, and September.

The evaporation rate of about 61 inches a year indicates that the humidity is relatively low. The average annual relative humidity at Dallas, Texas, is 78 percent at 7:00 a. m., and 52 percent at noon.

The average annual wind velocity is about 10 m.p.h. The velocity is strikingly uniform throughout the year, the

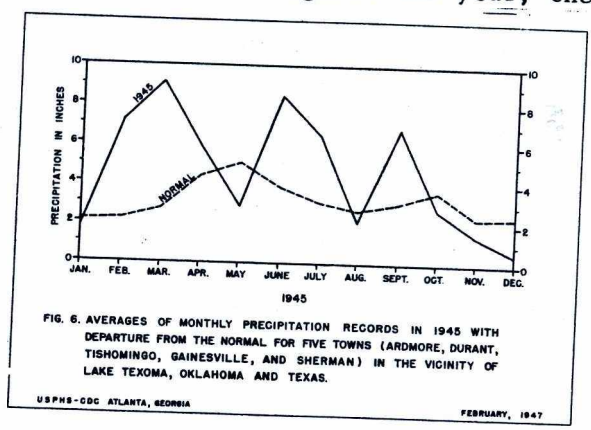


FIG. 6. AVERAGES OF MONTHLY PRECIPITATION RECORDS IN 1945 WITH DEPARTURE FROM THE NORMAL FOR FIVE TOWNS (ARDMORE, DURANT, TISHOMINGO, GAINESVILLE, AND SHERMAN) IN THE VICINITY OF LAKE TEXOMA, OKLAHOMA AND TEXAS.

3. Ardmore, Durant, Tishomingo, Gainesville, Sherman.

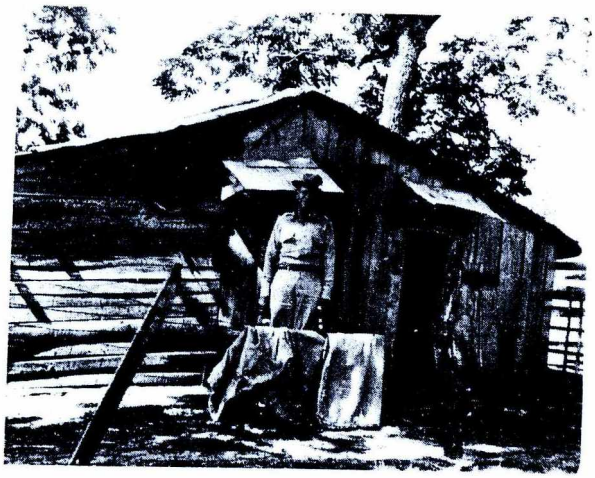


Figure 7. Stock barn as an example of a Natural Resting Place.

Table V

ESTIMATED VALUE OF PRINCIPAL AGRICULTURAL ENTERPRISES, GRAYSON COUNTY, TEXAS, 1945

FIELD CROPS AND LIVESTOCK	VALUE
Small Grain	$3,610,000
Cotton	1,650,000
Dairying	1,560,000
Corn	1,394,000
Peanuts	604,000
Beef	350,000
Poultry	124,000
Sheep	90,000
Grain Sorghum	60,000
Truck and Fruit	30,000
Hogs	20,000
Total	$9,492,000

BIOLOGICAL FACTORS

GENERAL CONSIDERATIONS. Although many species of *Anopheles* mosquitoes are capable of transmitting the human malaria parasites under laboratory conditions, only one species, *Anopheles quadrimaculatus* Say, is recognized as the important natural vector in the Southern and Eastern United States; therefore, in this survey primary consideration was given to *quadrimaculatus*.

The main objectives of the entomological survey made in 1945 were to determine first, the density of adult *quadrimaculatus*, and second, the location of the important breeding foci of this vector in the vicinity of Lake Texoma. Secondary objectives were to determine the prevalence and seasonal occurrence of all anopheline species. No consideration was given to culicine mosquitoes. The field work was initiated on May 1, and was terminated on November 23, 1945.

Figure 8. Barrel as an example of an artificial resting place.

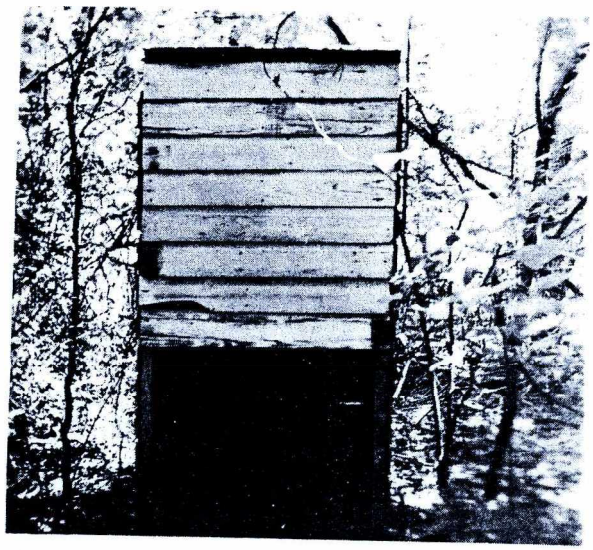


Figure 9. Privy-type house as an example of an artificial resting place.

Table VI

MALARIA MORBIDITY AND MORTALITY BASED ON PHYSICIANS' REPORTS FOR SIX COUNTIES ADJACENT TO LAKE TEXOMA, OKLAHOMA AND TEXAS, 1934 THROUGH 1943

Rates Per 100,000 Population

CO.	BRYAN		JOHNSTON		LOVE		MARSHALL		COOKE		GRAYSON		TOTAL	
Pop.*	38,138		15,960		11,433		12,384		24,909		69,499		172,323	
Year	Morb.	Mort.	Morb.	Mort.	Morb.	Mort.	Morb.	Mort.	Morb.	Mort.	Morb.	Mort.	Morb.	Mort.
1934	2.6	15.7	43.9	12.5	0.0	0.0	573.3	16.1	12.0	0.0	0.0	0.0	47.8	5.8
1935	687.0	18.4	488.7	12.5	8.7	8.7	710.6	0.0	4.0	0.0	335.3	5.8	384.7	8.1
1936	238.6	0.0	344.6	6.3	0.0	17.5	234.2	24.2	40.1	0.0	220.1	4.3	196.1	5.2
1937	81.3	7.9	162.9	0.0	0.0	0.0	177.6	0.0	216.8	0.0	217.3	0.0	164.8	1.7
1938	26.2	2.6	200.5	12.5	8.7	0.0	16.1	0.0	4.0	0.0	11.5	0.0	31.3	1.7
1939	31.5	5.2	382.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	44.7	1.2
1940	10.5	0.0	614.0	0.0	0.0	0.0	0.0	8.1	8.0	0.0	34.5	1.4	74.3	1.2
1941	2.6	2.6	902.3	6.3	0.0	0.0	0.0	8.1	0.0	0.0	21.6	1.4	92.4	2.3
1942	7.9	7.9	175.4	0.0	8.7	0.0	80.7	0.0	0.0	0.0	12.9	0.0	29.6	1.7
1943	0.0	2.6	125.3	0.0	0.0	0.0	8.1	0.0	24.1	0.0	80.6	0.0	48.2	0.6

* Population based on 1940 census.

The area included in this anopheline survey consisted of Lake Texoma proper and that territory radiating from the lake shore at contour 620 for approximately one mile. For convenience the territory was divided into zones numbered from 1 to 33 (Figure 10). These zone numbers correspond to the sheet numbers as used on the topographic maps of the Corps of Engineers. Because of the size of the lake, no attempt was made to gather detailed information along the entire shore. Rather, the aim was to obtain a clear picture of vector abundance in representative areas in all zones. Certain places, however, such as the proposed recreational areas and population centers near the lake, received special consideration. The entomological inspectors were encouraged to maintain a flexible inspection program, and modifications in the study were made in accordance with their findings. Thus additional stations were established when important foci were discovered.

Thirteen inspectors and boat operators were stationed at the following locations: Durant (2), Tishomingo (2), Madill (4), Marietta (1), Denison (2), and Whitesboro (2). Seven four-wheel-drive vehicles and six boats equipped with 5-horsepower outboard motors were used for transportation. The boat operators assisted in making inspections on land as well as in the water.

In order to determine *Anopheles* mosquito densities adult index stations which are designated as Natural Resting Places (NRP) (Figure 7) were selected within the area to be studied. These stations consisted primarily of barns,

Table VII

MALARIA BLOOD-SMEAR SURVEY TAKEN IN CERTAIN SCHOOLS OF SIX COUNTIES IN THE VICINITY OF LAKE TEXOMA, OKLAHOMA AND TEXAS, SEPTEMBER 1945

COUNTY	SLIDES EXAMINED	POSITIVE SLIDES OF *P. vivax*
Oklahoma		
Bryan	696	0
Carter	671	1
Love	874	2
Marshall	1,315	0
Texas		
Cooke	253	0
Grayson	888	0
Total	4,697	3

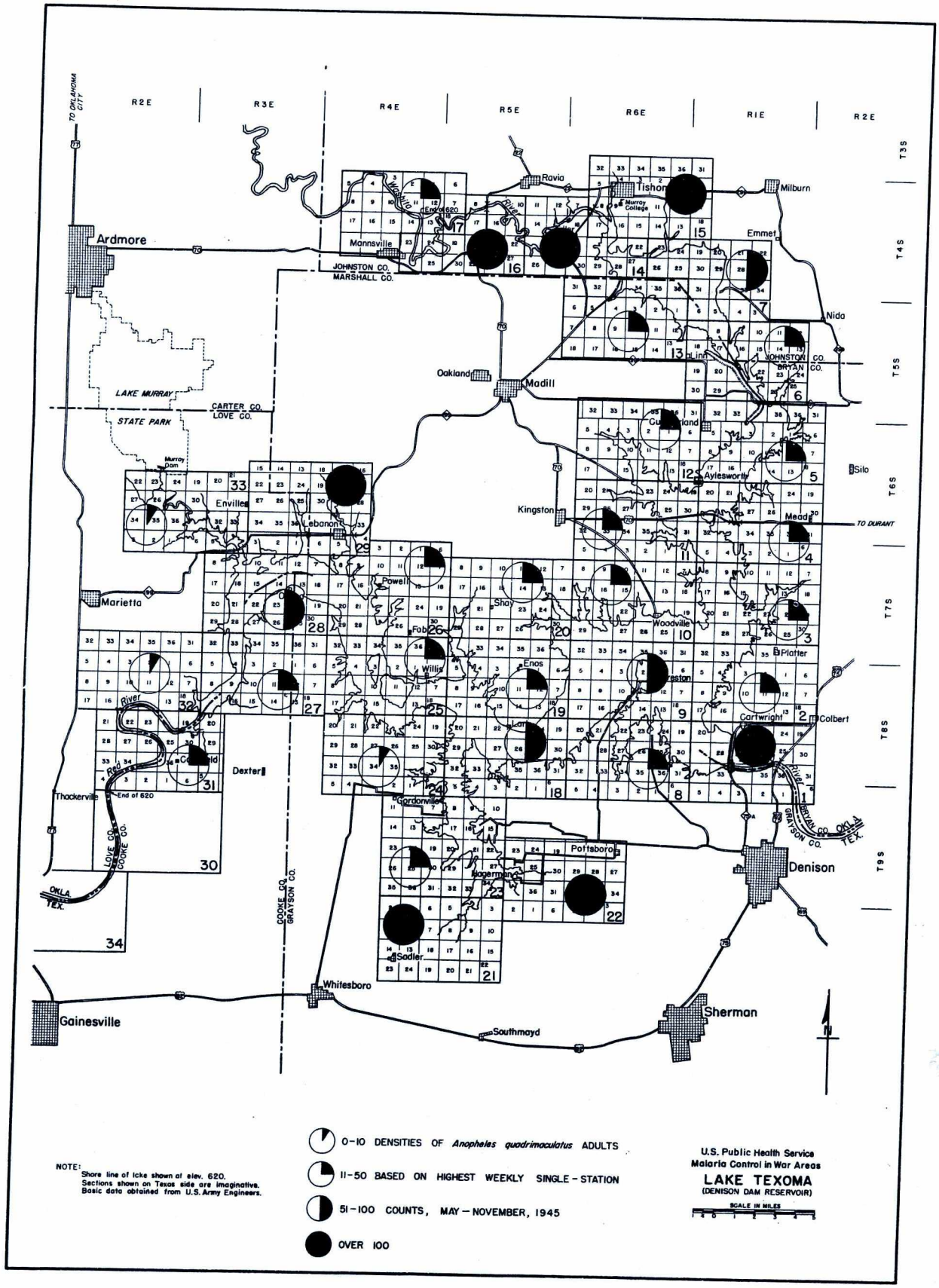


Figure 10

privies, sheds, culverts, and bridges. In the absence of a suitable NRP in a given locality an adult index station was set up consisting of a large barrel or a specially constructed, privy-type house and was designated as an Artificial Resting Place (ARP) (Figures 8 and 9). Observations at these stations were made at approximately weekly intervals and the adult *Anopheles* mosquitoes present were counted. A total of 676 adult resting stations was chosen, 405 of which were NRP's and 271 were ARP's. Of the total number, 479 stations were inspected regularly at weekly intervals. In setting up the stations emphasis was placed on those located within one-quarter mile of the shore line of the lake; these were designated as A-stations. Other stations were selected at one-quarter mile intervals within the one-mile zone immediately surrounding the lake and were designated as B-, C-, and D-stations, respectively. A few E-stations were located beyond the limit of the one-mile zone. With few exceptions, all anophelines found in a station were actually collected and counted.

To determine the actual breeding places of *quadrimaculatus*, larval stations were selected in the lake proper and in the watered areas within the one-mile zone. Inspections were made at two-week intervals, and a standard procedure of taking thirty dips at each station was followed.

DENSITY OF ADULT *ANOPHELES QUADRIMACULATUS*. The greatest densities of adult *quadrimaculatus* were found in Zones 1, 14, 15[4], 16, 21, 22, and 29 (Table VIII and Figure 10). In the above zones 27 stations yielded over 100 *quadrimaculatus* for a single inspection (Table IX). It should be stated that the office of Malaria Control in War Areas considers the density of ten female

Table VIII

DENSITY OF *ANOPHELES QUADRIMACULATUS* ADULTS BY ZONES BASED ON HIGHEST WEEKLY SINGLE-STATION OBSERVATIONS, LAKE TEXOMA, OKLAHOMA AND TEXAS, 1945.

ZONE	WEEK																												HIGHEST SINGLE STATION COUNT
	5/12	5/19	5/26	6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11	8/18	8/25	9/1	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/27	11/3	11/10	11/17	
Okla.																													
1	-	-	-	-	0	4	3	3	14	0	20	15	4	22	28	52	175	873	400	267	160	77	52	131	233	171	167	89	873
2	-	0	0	0	0	1	3	9	5	17	11	47	9	10	19	-	4	19	19	15	8	0	1	1	1	2	2	-	47
3	-	0	1	0	2	0	1	3	2	3	7	7	13	8	9	0	3	45	11	9	5	3	2	2	2	2	0	-	45
4	-	0	0	0	0	1	1	0	3	2	11	7	7	23	-	5	5	16	5	5	-	-	1	1	-	1	-	-	23
5	0	-	0	-	1	0	0	0	13	10	10	8	29	8	10	10	19	15	5	5	3	0	2	3	2	1	0	0	
6	0	-	-	0	0	0	0	1	5	2	4	-	3	-	2	2	5	4	7	22	2	-	0	1	0	0	0	0	29
7	0	0	0	0	0	0	0	19	22	28	6	22	65	25	49	30	36	25	58	26	21	44	78	36	25	9	3	2	65
10	0	0	-	0	2	1	1	8	3	2	7	15	24	11	23	25	19	19	7	4	2	-	0	3	0	1	2	0	78
11	0	0	-	0	0	0	0	0	4	1	0	12	3	5	0	7	10	31	4	2	0	2	0	0	0	0	0	0	25
12	0	-	0	-	1	0	0	4	10	5	3	-	11	29	17	12	10	-	3	-	-	1	0	4	5	6	14	0	31
13	0	-	0	-	0	1	4	0	5	1	17	-	9	38	21	16	6	3	38	22	-	2	3	4	2	1	2	-	29
14	1	-	2	0	0	1	3	42	26	18	45	95	76	210	180	102	67	105	121	47	31	12	6	6	5	4	0	2	38
15	0	0	1	1	1	1	3	25	34	35	39	108	131	183	286	149	201	143	37	62	52	23	15	15	6	3	3	8	210
16	1	3	3	6	13	13	13	26	183	544	428	596	714	1700	1451	1892	2750	2306	764	1027	506	41	49	40	9	8	10	9	286
17	1	0	0	1	2	0	1	3	5	2	12	39	25	22	21	39	36	46	46	25	22	6	2	3	0	5	9	2	2750
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85	15	0	44	12	8	0	0	0	0	0	46
19	0	0	0	0	0	0	0	1	1	3	19	22	7	4	40	10	7	13	9	1	6	2	4	2	1	1	0	0	85
20	1	0	0	0	0	0	3	2	2	3	8	7	12	17	6	3	7	1	5	7	3	1	11	3	0	2	1	0	
25	0	0	0	0	0	0	1	0	2	1	13	5	21	45	43	24	17	0	3	7	5	5	2	1	4	1	1	0	40
26	0	0	0	0	0	0	0	2	6	2	4	5	3	16	18	8	14	1	70	5	3	3	3	0	0	0	0	0	17
27	0	0	0	0	0	0	0	1	0	2	15	22	17	10	5	10	25	9	7	6	-	12	40	4	2	0	0	-	45
28	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	-	70
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	-	40
31	0	0	0	0	0	0	0	6	1	3	14	26	32	40	104	49	69	33	23	28	3	2	2	1	0	1	1	0	8
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	-	104
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0	0	-	-	0	0	0	0	0	-	0
																													8
Texas																													0
1	0	0	0	0	0	0	0	0	0	0	-	13	60	42	26	8	27	51	47	5	7	-	4	1	0	0	1	-	
8	0	0	0	0	1	1	0	0	0	0	2	7	10	13	3	3	6	10	1	2	1	2	5	0	0	0	0	-	60
9	0	0	0	0	0	0	0	3	3	0	0	14	45	71	13	59	5	3	4	4	2	1	0	1	0	1	0	-	13
18	0	-	0	0	0	0	0	4	4	1	5	2	4	7	1	3	3	4	2	4	3	0	1	0	0	0	10	4	71
21	-	0	0	0	0	0	3	6	6	13	155	291	143	52	65	24	186	67	55	11	15	12	20	12	13	11	8	0	10
22	-	1	0	0	3	1	0	3	16	9	55	202	253	261	154	166	166	108	8	45	4	4	5	7	1	1	0	-	291
23	0	0	0	0	0	0	0	1	1	6	6	11	33	10	17	14	20	13	26	14	3	5	1	3	0	9	1	0	261
24	-	0	0	0	0	0	1	0	0	0	0	-	1	2	-	1	5	2	2	4	-	5	-	1	1	-	0	0	33
25	-	0	0	0	0	-	-	0	-	0	0	0	2	-	-	2	2	1	1	8	-	1	0	-	0	0	0	-	5
26	-	-	-	0	0	0	0	0	-	0	10	1	2	4	3	0	4	1	0	2	-	-	-	0	0	-	0	0	
27	0	-	0	0	0	0	0	0	0	0	0	1	4	1	5	1	-	5	1	-	2	-	0	0	0	-	0	0	8
28	0	0	0	0	0	0	6	0	-	0	11	54	12	3	8	12	3	17	2	4	-	-	0	1	0	0	0	0	10
31	0	-	0	0	0	0	0	0	0	-	4	2	2	-	-	18	-	-	4	-	2	-	-	0	-	0	-	0	5
High Sta.	1	3	3	6	13	13	13	42	183	544	428	596	714	1700	1451	1892	2750	2306	764	1027	506	77	78	131	233	171	167	89	54
																													18
																													2750

4. A mosquito control project was in operation at Tishomingo, Oklahoma, July 3 - October 9, 1945, and undoubtedly reduced the quadrimaculatus *population in this area.*

Table IX

NUMBER OF STATIONS HAVING HEAVY DENSITIES OF *ANOPHELES QUADRIMACULATUS* ADULTS BASED ON WEEKLY INSPECTIONS, 1945

STATE	ZONE	ADULT STATIONS	STATIONS HAVING OVER 100 *QUADS.*	
		Total No.	No.	Percent
Oklahoma	1	24	10	41.0
Oklahoma	16	19	7	38.9
Oklahoma	15	16	4	25.0
Texas	21	21	2	9.5
Oklahoma	14	24	2	8.3
Texas	22	15	1	6.6
Oklahoma	29	32	1	3.1

quadrimaculatus per station for three consecutive weeks as the threshold of sanitary significance. The highest single station count[5] of the survey was 2,750 *quadrimaculatus*, collected in Station 16-C (Figure 7), Zone 16, on August 31, 1945.

The greatest densities of *quadrimaculatus* were found beyond the quarter-mile zone adjoining the lake (Table X). The maximum station counts within the quarter-mile zones from the lake were as follows: A, 333; B, 400; C, 2,750; D, 873; and E, 160. The finding of the highest adult *quadrimaculatus* densities in the C and D quarter-mile zones (½-1 mile from lake shore) indicates that the principal breeding areas were located outside the lake proper.

Table X

HIGHEST SINGLE STATION COUNTS OF *ANOPHELES QUADRIMACULATUS* ADULTS IN QUARTER-MILES (A, B, C, D, E) DISTANCES FROM LAKE TEXOMA, OKLAHOMA AND TEXAS, 1945

STATE	ZONE	DISTANCE IN MILES					STATE	ZONE	DISTANCE IN MILES				
		0-1/4	1/4-1/2	1/2-3/4	3/4-1	Over 1			0-1/4	1/4-1/2	1/2-3/4	3/4-1	Over 1
		A	B	C	D	E			A	B	C	D	E
Okla.	1	56	400	54	873	160	Okla.	27	40	---	22	5	0
"	2	47	3	11	1	19	"	28	8	---	---	---	---
"	3	13	5	2	10	45	"	29	104	18	36	1	---
"	4	23	3	7	11	16	"	31	0	0	0	---	---
"	5	29	3	2	10	15	"	32	3	---	8	---	---
"	6	22	3	1	1	3	"	33	0	0	0	0	---
"	7	78	---*	---	0	---	Texas	1	6	29	35	19	60
"	10	25	4	8	19	1	"	8	13	11	13	---	---
"	11	12	3	0	0	31	"	9	71	21	---	---	---
"	12	29	14	0	0	---	"	18	10	4	4	---	---
"	13	38	38	8	8	3	"	21	291	42	186	2	---
"	14	58	210	180	23	---	"	22	24	25	261	22	---
"	15	113	12	286	239	---	"	23	36	26	---	4	---
"	16	333	182	2,750	76	13	"	24	5	3	5	1	4
"	17	22	65	46	6	---	"	25	8	2	1	---	---
"	18	6	85	---	---	---	"	26	10	---	---	---	---
"	19	40	19	5	---	---	"	27	2	---	---	1	5
"	20	17	4	1	2	5	"	28	54	17	---	---	---
"	25	45	---	---	0	---	"	31	18	18	3	---	---
"	26	70	---	2	0	1							

* No station present.

5. *A single station count refers to the number of* Anopheles *mosquitoes counted and recorded for any given station on any one date.*

LOCATION OF *ANOPHELES QUADRIMACULATUS* BREEDING FOCI. The location of the most important breeding places for the larvae of *quadrimaculatus* in zones having the highest adult counts were as follows:

Zone 1 - Bryan County, Oklahoma (Section 27). This area which is located adjacent to the Denison Dam contains approximately eighty acres of potential mosquito breeding habitat (Figure 11). All data gathered indicate that the malaria mosquito-breeding problem has become more acute in this area because of the proximity of Lake Texoma. A continuous water supply from one of the toe drains (Figure 12) has created much of the problem. As shown in Figure 11 the water flows southeastward and eventually becomes impounded in Swamps C and E. Swamp D is formed by seepage water. The series of three swamps is studded with timber standing in water ranging from a few inches to about three feet in depth (Figure 13). In addition to the timbered areas, Pond A and Marsh B are located nearby.

Zone 15 - Johnston County, Oklahoma (Sections 4, 8, 9, 16). The Pennington Creek inlet which contains about 30 acres of uncleared timber is an important breeding place.

Zone 16 - Johnston County, Oklahoma (Section 16). The extremely high production of malaria mosquitoes in this section is due to two swamps of about 80 acres in extent (Figure 14).

Zone 21 - Grayson County, Texas. The chief source of breeding is 300 acres of uncleared timber in the Big Mineral Creek inlet. This breeding area is within the Hagerman National Wildlife Refuge.

Zone 14 - Johnston County, Oklahoma (Sections 7, 12). The highest larval counts in this zone were found in the Rock Creek and Sandy Creek inlets which contained a moderate amount of flotage.

Zone 22 - Grayson County, Texas (Sections 25, 30). The principal breeding places consist of a one-acre cattail pond in Section 30, and a creek inlet in Section 25 which contains a large quantity of flotage. This breeding area is within the Hagerman National Wildlife Refuge.

Zone 29 - Marshall County, Oklahoma (Section 5). The most important breeding place is an inlet about ¾ of a mile south of Lebanon, Oklahoma, where willows and flotage are abundant.

It should be emphasized that while a significant amount of *quadrimaculatus* breeding did occur in certain limited areas within the reservoir proper, the results of the 1945 larval survey, together with data from adult index stations, demonstrate that areas outside the lake proper constitute the primary source of breeding, although in Zone 1 the heavy production was due indirectly to the presence of the dam. Breeding in the lake during 1945 occurred principally in the inlets containing uncleared timber and flotage.

PREVALENCE AND SEASONAL DISTRIBUTION OF ANOPHELES. Of the 89,804 specimens of *Anopheles* adults collected during the survey, 65.5 percent was *quadrimaculatus*, 32.4 percent *punctipennis*, and 1.8 percent *pseudopunctipennis*. *Anopheles crucians* and *barberi* were found in extremely small numbers.

A study of the seasonal distribution of anophelines in the vicinity of Lake Texoma reveals that *punctipennis* appears earlier in the spring and breeds later in the fall than *quadrimaculatus* (Figure 15). Significant[6] densities of female *quadrimaculatus* adults were found for a period of six months (June 5 - December 7), and densities of over 100 at a single station observation for a period of four months (July 5 - November 7). *Quadrimaculatus* reached the peak of its abundance during the latter part of August and the first part of September. *Pseudopunctipennis* adults were not found before August 4 and became most numerous in October.

SPECIAL ENTOMOLOGICAL SURVEYS. Entomological studies of lesser extent were made in the vicinity of Lake Texoma during 1944 by the Oklahoma State Health Department, and constitute the only sig-

6. Ten or more specimens at a single-station observation.

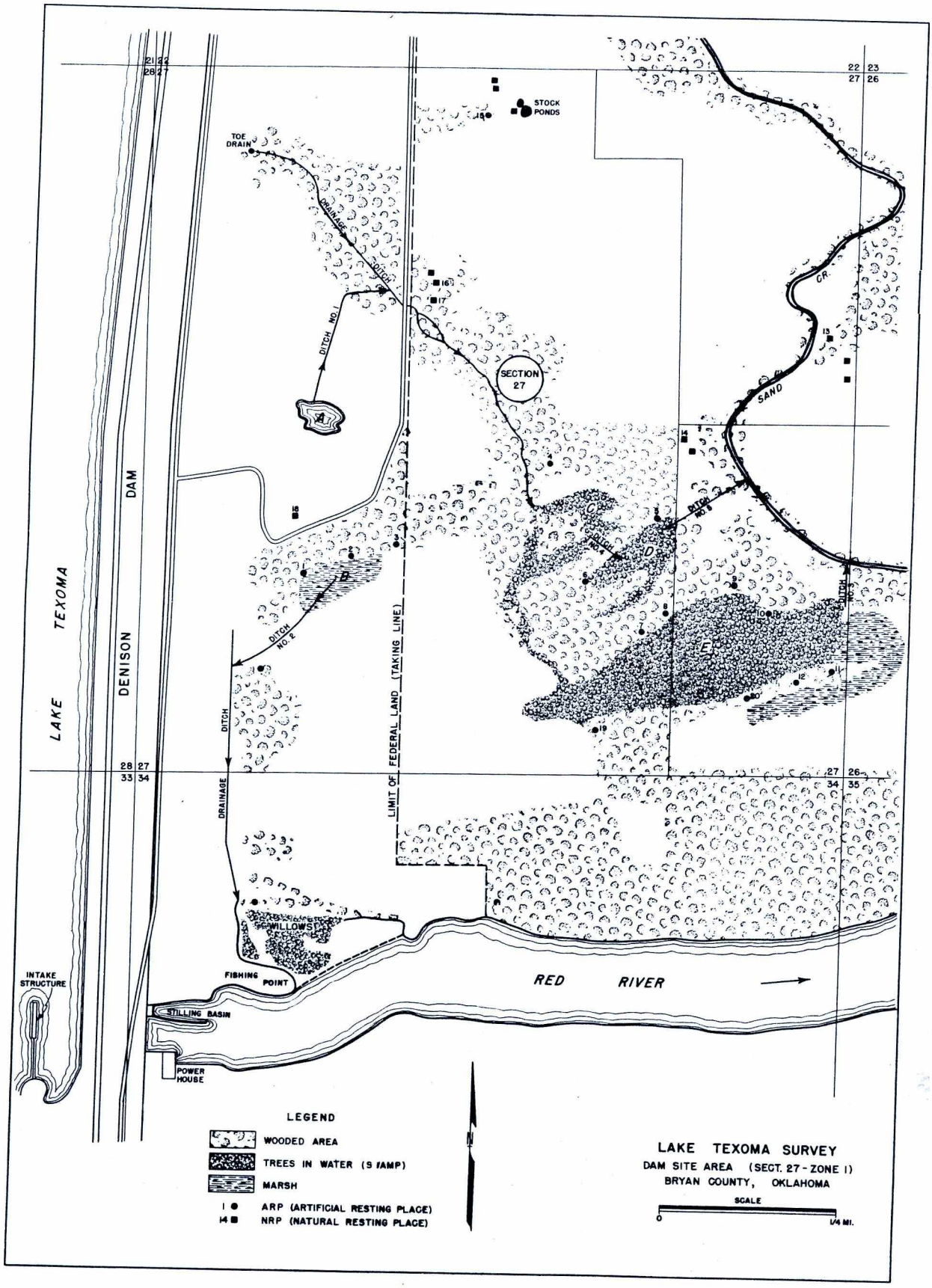


Figure 11

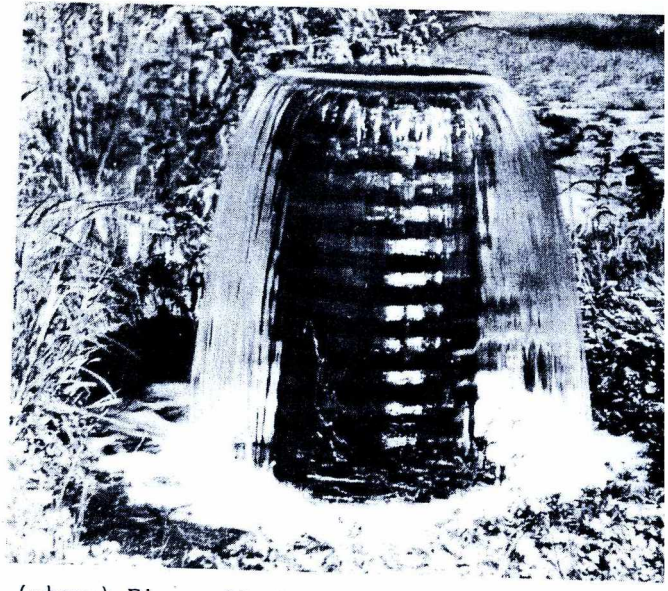
nificant data on *Anopheles* prevalence collected prior to 1945.

At Powell, Oklahoma, five adult *Anopheles* index stations were visited weekly from May into October 1944. At these five stations, the highest single-station counts of *quadrimaculatus* for the season were: 363, 139, 68, 16, and 6. In 1945 the highest weekly single-station counts for five stations near Powell were: 70[7], 6, 5, 3, and 3. While these data for the two years are not considered comparable, it is felt that a significant difference in the *Anopheles* population is indicated. It is to be emphasized that the greater *Anopheles* population in 1944 was undoubtedly due to the high breeding potential of the lake margin where the rising water level during the 1944 mosquito breeding season gradually advanced into marginal vegetation and at the same time carried large quantities of flotage (Figure 16) which together produced an almost ideal malaria-mosquito breeding habitat. During the 1945 season a spring surcharge stranded much of the flotage before the mosquito breeding began and following the subsequent recession to the normal pool elevation a clean shore line unsuitable to *Anopheles* production resulted.

Further substantiation is given to the foregoing discussion in the fact that during a special survey in September 1944, large numbers of *Anopheles* larvae, 98.3 percent of which were *quadrimaculatus*, were found along the margin of the lake between the dam site and the Cumberland Oil Field levees, a distance of approximately 20 miles, while on a special survey over the same area in September 1945 no larvae were located.

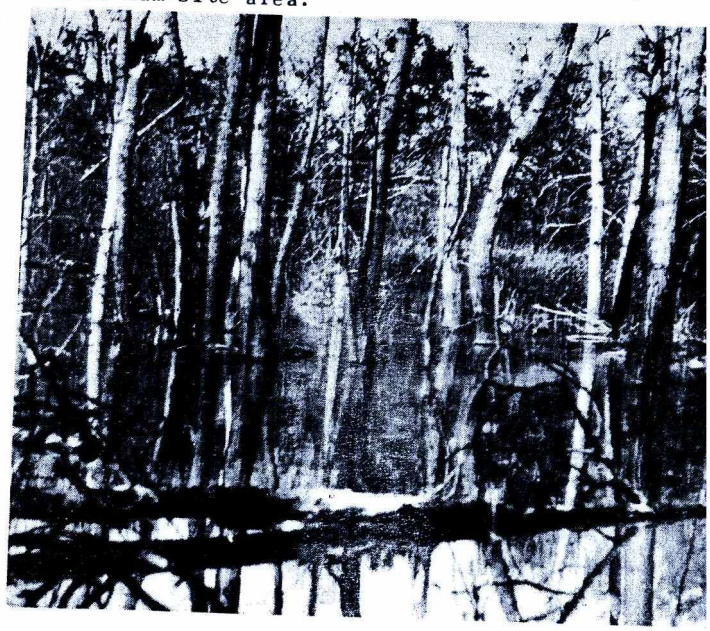
BIOLOGICAL FACTORS AFFECTING *ANOPHELES* PRODUCTION. At present only a few aquatic plants conducive to anopheline production have become established in relatively small areas within the lake itself. Several indigenous species which will probably become established in the reservoir have been found in the vicinity of Lake Texoma. The following is a list

7. This count of 70 was made in the same station as the 363-count of 1944; however, the other four stations in 1945 were not in the same locations as those in 1944.



(above) Figure 12. Toe drain outlet in dam-site area.

(center) Figure 13. Standing timber in swamp E of dam-site area.



(below) Figure 14, Swamp near highest NRP, Zone 16.

of those plants which have been noted in the Lake Texoma region:

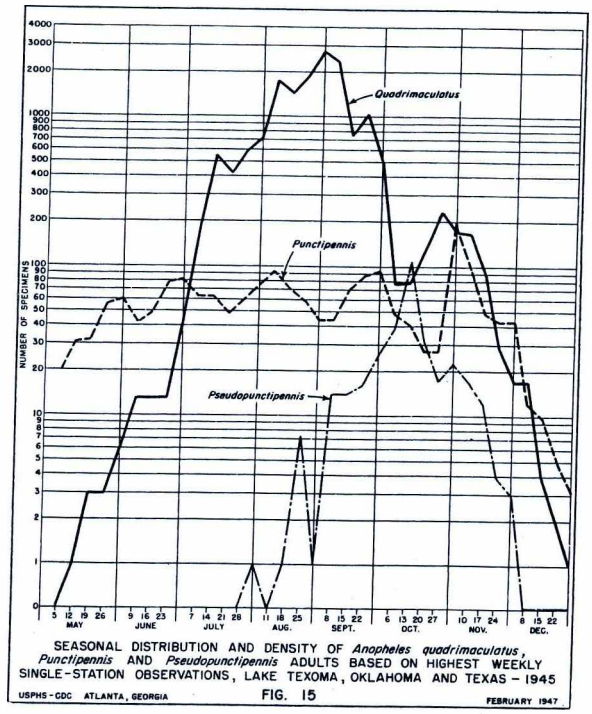
Stonewort	*Chara*
*Cattail	*Typha latifolia*
Arrowhead	*Sagittaria*
Water plantain	*Alisma plantago-aquatica*
*Duckweed	*Spirodela polyrhiza*
*Willow	*Salix*
*Smartweed	*Polygonum coccineum*
Water lily	*Nymphaea tuberosa*
Lotus	*Nelumbo pentapetala*
*Water primrose	*Jussiaea diffusa, decurrens*
*Water milfoil	*Myriophyllum*
Water pennywort	*Hydrocotyle ranunculoides*

* Occur within Lake Texoma

The top-minnow, *Gambusia affinis*, is common in the region and has become well-established within the reservoir. It should be emphasized that in some locations where the top-minnow was very abundant, *Anopheles* larvae were also taken in large numbers which seems to indicate that these fish in some situations are not too important a factor in limiting malaria-mosquito larvae production.

RECREATION AND WILDLIFE AREAS

In 1941 Congress authorized the National Park Service of the Department of the Interior to make a survey of the Lake Texoma area. As a result, a report on the "Recreational Resources of the Denison Dam and Reservoir Project" was published. This work contains a detailed master plan on recreational development. A considerable number of recreational areas was proposed (Figure 1). In 1946 the National Park Service prepared a modified master plan. This plan calls for the development of recreational areas in approximately the same locations as outlined in the original master plan, but on a less extensive scale. Even though a completely organized program has not become a reality, already thousands of people have been attracted to the lake where they have



SEASONAL DISTRIBUTION AND DENSITY OF *Anopheles quadrimaculatus*, *Punctipennis* AND *Pseudopunctipennis* ADULTS BASED ON HIGHEST WEEKLY SINGLE-STATION OBSERVATIONS, LAKE TEXOMA, OKLAHOMA AND TEXAS - 1945

USPHS - CDC ATLANTA, GEORGIA FIG. 15 FEBRUARY 1947

1945	HIGHEST STATION COUNT PER INSPECTION		
WEEK ENDING:	QUAD.	PUNCT.	PSEUDOP.
May 1	0	20	0
12	1	31	0
19	3	32	0
26	3	56	0
June 2	6	60	0
9	13	42	0
16	13	49	0
23	13	77	0
30	42	81	0
July 7	183	63	0
14	544	63	0
21	428	48	0
28	596	60	0
Aug. 4	714	74	1
11	1,700	94	0
18	1,451	72	1
25	1,892	60	7
Sept. 1	2,750	44	1
8	2,306	44	14
15	764	70	14
22	1,027	86	16
29	506	92	25
Oct. 6	77	48	39
13	78	41	109
20	131	27	32
27	233	27	17
Nov. 3	171	189	22
10	167	97	17
17	89	48	12

participated in various types of outdoor recreation, including fishing, hunting, boating, and picnicking.

In general, the modified master plan calls for the following types of recreational developments: Recreational areas proper, concession sites (without over-night facilities), home sites (land developed and leased for use as home building sites), and a site for a Boy Scout camp. It is considered that these developments, with two possible exceptions, are satisfactorily located from a malaria control standpoint. The location of recreational sites near the towns of Lebanon and Tishomingo, Oklahoma, where large populations of *quadrimaculatus* have been found, is considered inadvisable unless the necessary malaria control measures are taken.

An investigation of the Lake Texoma area was made by the Fish and Wildlife Service in 1942, and two sites were selected and have been developed for wildlife refuges. The Hagerman National Wildlife Refuge consists of a 10,500-acre reserve on the Big Mineral Arm in Texas, while the 13,500-acre Tishomingo National Wildlife Refuge is located in Oklahoma. The location of these two refuges appears satisfactory from a malaria control standpoint. Although the western limit of the Oklahoma refuge lies within one mile of the town of Tishomingo, the present potential malaria-mosquito breeding areas are located at a safe distance from the town.

PREDICTION OF MALARIA HAZARD

A conclusion regarding the malaria hazard in the Lake Texoma area must be based upon such findings as are discussed in the foregoing sections of this report. These findings may be briefly summarized as follows:

1. Most of the lake shore is not favorable for malaria mosquito production. Uncleared inlets present the greatest problem.

2. Aquatic plants, with the exception of willows, have not invaded the lake to any considerable extent.

Figure 16. Flotage in Lake Texoma prior to High Surcharge in 1945.

3. The present water-level operation of the reservoir, particularly the spring surcharge, will tend to keep mosquito breeding and aquatic plant growth in the reservoir to a minimum. Should there be a rise in the water-level in the summer that puts the water into the marginal vegetation, the water should be lowered from the vegetation in less than two weeks.

4. The human population within malaria mosquito flight-range of the reservoir is sparse. Tishomingo, Oklahoma, is the principal town on the lake shore.

5. Epidemiological information based on recent surveys indicates that malaria is present in the Lake Texoma area but it is of low endemicity.

6. Recent entomological data demonstrate that *Anopheles quadrimaculatus*, the principal vector of malaria in the South, is common around the entire margin of the lake, and extremely heavy populations are found in a few localized areas, especially in swampy areas adjacent to the lake located in Zones 1 and 16.

7. The two most important areas from a malaria standpoint, i. e., where heavy densities of malaria mosquitoes occur near large human populations, are the dam site, where a large number of fishermen[8] gather, and the town of Tishomingo, Oklahoma.

It is concluded from the foregoing facts that although only a minor malaria hazard is present at this time a high potential malaria hazard does exist in the Lake Texoma region. The final section of this report contains recommendations concerning the malaria control measures considered necessary to prevent a serious malaria problem from arising.

RECOMMENDATIONS FOR MALARIA CONTROL

These recommendations are designed to provide malaria control in the territory adjacent to all significant centers of population and planned developments with housing facilities; the proposed program is not devised to provide complete mosquito control on Lake Texoma. A careful study of the entomological records in relation to human population centers formed the basis for all recommendations.

The proposed program includes: (1) clearing, (2) drainage, (3) water-level management, (4) larviciding, (5) removal of secondary growth (willows, etc.), (6) flotage and drift removal, (7) aquatic plant control, (8) location and development of wildlife, recreational, and leased areas, and (9) the establishment of a malaria control unit.

CLEARING. It has long been recognized that the clearing of the site of an artificial lake is of paramount importance in preventing *Anopheles* production. All timber and underbrush should be removed up to elevation 620 (taking into account the effects of the backwater curve) in the following areas: (1) in the Pennington Creek inlet near Tishomingo, Oklahoma (Figure 17), (2) within malaria mosquito flight-range of the town of Lebanon, Oklahoma. It is further recommended that in these two areas the trees and underbrush be cut at least six inches below the water surface at the normal summer operating level of the reservoir. The work should also include the removal and disposal of all logs, brush, and other debris already felled and in the water between the low-water elevation and elevation 620. Timber along the lake shore which is killed due to intermittent inundation should be removed periodically.

In the past, heavy production of *quadrimaculatus* mosquitoes has usually occurred on artificial lakes where the timber and underbrush were not completely removed. It is, therefore, recommended that developments with housing facilities be located beyond malaria mosquito flight-range of uncleared timber areas on Lake Texoma. If it appears desirable from other standpoints to locate housing sites within malaria mosquito flight-

8. A survey made in July 1945 shows that over 10,000 people gathered at the fishing site below the dam during a ten-day period. Many of these people were present during the evening, a time when the malaria mosquito becomes active.

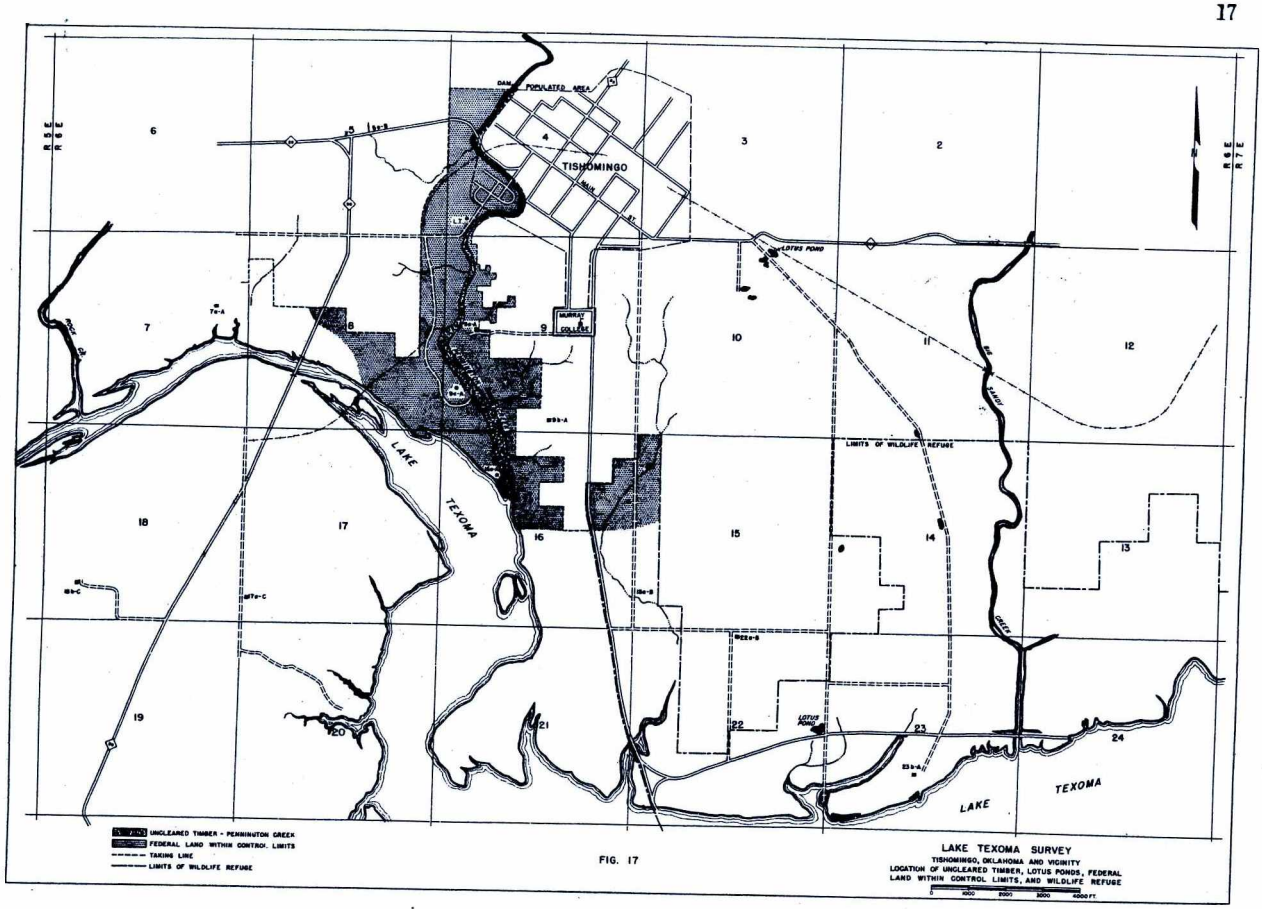


FIG. 17

range of uncleared timbered areas, then the timber and underbrush should be removed.

These recommendations include the removal of 35 acres of standing timber at an estimated cost of $300 per acre, a total of $10,500. This operation should be carried out as soon as possible since the removal of the timber will reduce the cost and increase the efficiency of larvicidal operations.

DRAINAGE. It is recommended that the following breeding places be permanently eliminated by drainage: (1) the pond and series of swamps which lie immediately east of the dam (Zone 1 - Section 27, Oklahoma). This important breeding focus should be drained as soon as possible. On projects 2, 3, 4, and 5 (Figure 13), it may be necessary to construct a series of small ditches leading into the main outlet ditch; (2) the small pond on the Preston Bend Peninsula (Zone 9 - Section 2, Texas) (Figure 18).

Any residual pools in the zone of the flood-control pool (617 to 640) which lie within malaria mosquito flight-range of Tishomingo and Lebanon, Oklahoma, or any planned areas with housing facilities, should be drained if such pools are located.

These recommendations include the removal of 3,500 cubic yards of earth at an estimated cost of $1.25 per yard, a total cost of $4,375.

WATER-LEVEL MANAGEMENT. Proper water-level management is recognized as one of the most successful and efficient methods of mosquito and plant control on artificial lakes. In view of the fact that on Lake Texoma the proposed operation of the reservoir necessitates a constant-level pool at elevation 617 throughout most of the year, except at times of flood when the storage volume between elevations 617 and 640 will be used, the following recommendations are made: (1) a high surcharge (above

Figure 18. Stock pond, Preston Bend Peninsula, Zone 9.

elevation 620) should be obtained in the spring in order to strand flotage at as high an elevation as possible and to insure a clean shore line during the malaria-mosquito breeding season; (2) a sharp drop in water-level should follow the surcharge to strand flotage; (3) the water level should be held as near elevation 620.0 in the spring as possible to inhibit marginal growth. The water level should be dropped to elevation 618.0 at the beginning of the malaria mosquito breeding season, to be followed by a gradual recession during the season; (4) following summer floods the water elevation should be brought back to an elevation which presents a clean shore as soon as possible after the flood crest has been reached.

Aquatic plant growth may be a problem in Lake Texoma; however the small amount of water fluctuation which will inevitably occur (Figure 19) during the summer months may be sufficient to inhibit plant growth.

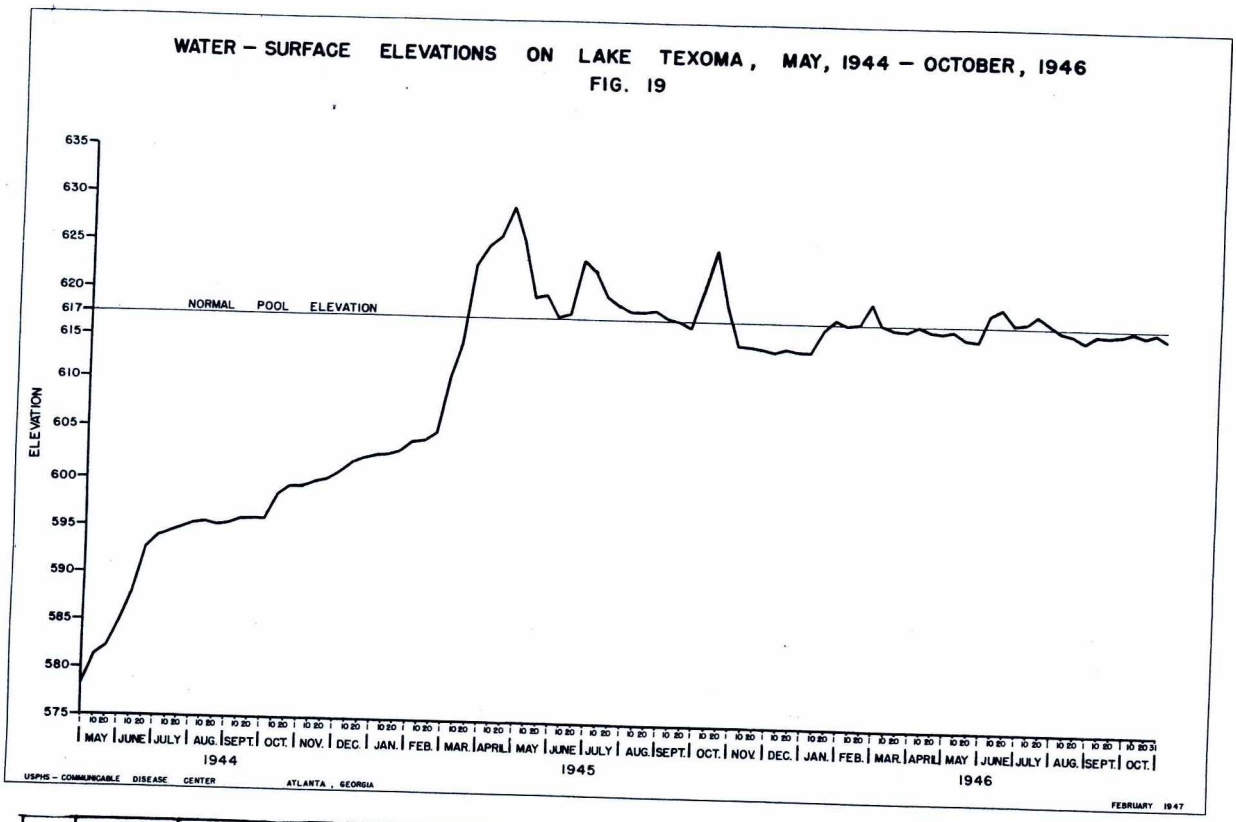
A study of the 1945 pool elevations (Figure 19) shows that peaks occurred during April, June, and October. These correspond with the periods of heavy precipitation (Figure 6). The highest elevation recorded was 629.04 on April 18, 1945. During 1946 the water level of the reservoir presented a more normal picture than in 1945 (Figure 19) in that precipitation was more normal and the pool elevations fluctuated around 617.

LARVICIDING. Even though an artificial lake is well-prepared and maintained, it is generally necessary to control mosquitoes on certain sections of the impoundage by the use of larvicides. The proposed larvicidal operations for Lake Texoma are restricted to *quadrimaculatus* breeding areas within mosquito flight-range of towns, centers of populations, and recreational or leased areas with housing facilities. Larviciding of the following areas is recommended: (1) within one mile of the town of Tishomingo, Oklahoma, and Murray College, it being understood that the Corps of Engineers will not be expected to larvicide those breeding areas near Tishomingo not on Federal property (Figure 17); (2) within one mile of the town of Lebanon, Oklahoma; (3) it will be necessary to control mosquito breeding in the territory immediately east of the dam (Zone 1 - Section 27, Oklahoma) by the use of larvicides until more permanent control is effected; (4) in the event it is found impractical to eliminate the stock pond on the Preston Bend Peninsula (Zone 9 - Section 2), mosquito breeding should be controlled by the use of larvicides.

Even though the entomological records for 1945 do not indicate the need for extensive larvicidal operations, future entomological studies should be made to determine whether larviciding should be extended to control mosquito breeding near recreational and leased areas with housing facilities.

Oil (Diesel No. 2) or paris green are the two larvicides generally employed on artificial lakes. Oil, although more costly, is also effective against many species of culicine mosquitoes. Where possible, it is recommended that oil be employed and that it be applied by a water-oil unit operating from a shallow-draft boat. This type of equipment is favored for use on artificial lakes because a heavy stream of oil and water is particularly effective in breaking up mats of flotage commonly found on impoundages, thereby resulting

WATER – SURFACE ELEVATIONS ON LAKE TEXOMA, MAY, 1944 – OCTOBER, 1946
FIG. 19



1944	POOL ELEVATION	1944	POOL ELEVATION	1945	POOL ELEVATION	1945	POOL ELEVATION	1946	POOL ELEVATION	1946	POOL ELEVATION
		July		January		July		January		July	
		1	593.97	1	602.73	1	622.48	1	614.30	1	617.44
		10	594.36	10	602.96	10	619.31	10	616.28	10	618.23
		20	594.71	20	603.37	20	618.99	20	617.26	20	617.35
		August		February		August		February		August	
		1	595.32	1	604.19	1	617.76	1	616.77	1	616.65
		10	595.46	10	604.49	10	617.70	10	616.78	10	616.16
		20	595.18	20	605.35	20	617.97	20	619.18	20	615.62
		September		March		September		March		September	
		1	595.43	1	610.24	1	617.17	1	616.94	1	616.28
		10	595.73	10	614.55	10	616.79	10	616.46	10	616.21
		20	595.76	20	622.90	20	616.09	20	616.26	20	616.24
		October		April		October		April		October	
		1	595.74	1	624.95	1	620.44	1	616.75	1	616.60
		10	598.53	10	625.79	10	624.94	10	616.28	10	616.23
					(629.04 (April 18)						
		20	599.33	20	628.93	20	618.51	20	616.12	20	616.58
May		November		May		November		May			
1	578.16	1	599.44	1	625.61	1	614.85	1	616.33		
10	581.37	10	599.73	10	619.04	10	614.75	10	615.64		
20	582.20	20	600.02	20	619.39	20	614.55	20	615.35		
June		December		June		December		June			
1	585.9	1	600.95	1	617.09	1	614.32	1	618.26		
10	587.58	10	601.99	10	617.40	10	614.54	10	618.93		
20	592.55	20	602.54	20	623.56	20	614.45	20	617.20		

is more efficient control. Water-oil larviciding is not feasible for large acreages of shallow breeding places, especially uncleared areas; these require other larvicidal methods, such as airplane dusting with paris green.

In view of the considerable savings which may be effected by the use of DDT larvicides, especially as compared to oil, consideration of its use, with adequate precautions against overdosing, is recommended. While the economic advantage of DDT larvicides over paris green larvicides may not be considerable, it should be pointed out that the former kills all types of mosquito larvae, whereas paris green kills essentially only anopheline larvae.

Available entomological data for the Lake Texoma area reveal that the malaria-mosquito breeding season extends from May to October. It will, therefore, be necessary to make approximately 20 larvicidal treatments each year. If it becomes necessary in the interest of flood control to raise and hold the water at elevations above 620 during the mosquito breeding season, larvicidal operations should be extended into temporarily critical areas as determined by entomological data.

It is estimated that about 90 acres will require treatment by power equipment and about 70 acres by hand. The annual cost of the larvicidal operations will be approximately $12,750.

REMOVAL OF SECONDARY GROWTH. Although there is a large acreage on Lake Texoma covered with willows and underbrush, the amount of mosquito breeding in these areas in 1945 was not large. It is recommended, however, that willows and underbrush be removed in the following areas: (1) in the vicinity of Tishomingo, Oklahoma, (2) near Lebanon, Oklahoma, (3) near the dam site. It may be possible to mow these areas or even burn them off. These methods have proven practical and economical and should be done in the fall.

The estimated cost of removing thirty acres of secondary growth in the areas described above at $50 per acre will be approximately $1,500.

FLOTAGE AND DRIFT REMOVAL. Flotage generally found at the edges of newly-formed artificial lakes tends to create favorable habitats for *quadrimaculatus* mosquitoes. In order to decrease future malaria control costs it is recommended that: (1) a high surcharge be provided in the spring to strand this objectionable material (this operation is by far the easiest, quickest, and cheapest method for removing flotage); (2) an inspection be made of the special control areas near the towns of Tishomingo and Lebanon, Oklahoma, to determine if it will be necessary to remove driftwood by manual or mechanical methods in order to facilitate larvicidal operations; (3) an inspection be made where large concentrations of driftwood occur on the shore. It is believed that many such accumulations can be burned at a small cost, and thereby obviate the possible shifting of the driftwood by high water and wind into control areas, thus necessitating its removal at a greater expense.

The estimated cost of this operation will be approximately $1,000.

AQUATIC PLANT CONTROL. Plants which are undesirable from a malaria control standpoint should be controlled within the reservoir. The early determination of the presence of such plants and the instituting of steps toward their control will greatly reduce the cost of removal, as well as the cost of mosquito control.

There is a good possibility that the more recently developed methods for the chemical control of plants will be useful on Lake Texoma and it is suggested, in view of economy, that the use of these methods be investigated.

American lotus has been located in ponds in Zone 15 (Section 10) and Zone 14 (Section 22) in Oklahoma, and in Zone 28 (Section 30) in Texas. It is recommended that these plants be controlled as soon as possible to aid in preventing their introduction into the lake.

The cost of removing this aquatic plant from three acres comprising these ponds will be about $300.

DEVELOPMENT OF RECREATIONAL AND LEASED AREAS. It is highly desirable that a careful study be made of the terrain and of available entomological records before locating any housing facilities on the margin of the lake.

If the following procedures are carried out, it is believed that suitable recreational areas can be selected at minimum disease hazard and mosquito control cost.

1. All recreational and leased areas with housing facilities should be located more than two miles from Wildlife Refuges which provide favorable breeding habitats for the *quadrimaculatus* mosquitoes.

2. No recreational or leased area with housing facilities should be located southeast of Ravia, Oklahoma, in Zone 16, because of the hazardous population of *quadrimaculatus* mosquitoes found there. These areas should be located where mosquito breeding has proven light, or where the potentiality for breeding is low.

3. The use of these areas will be increased by provision of water supply and sewage facilities installed in accordance with the standards of respective state health departments and by construction of all-weather roads leading into each area; and will be selected for their natural attractiveness.

While the cost of proper planning will be negligible, time spent on this phase of the program will greatly increase the usefulness of the lake from many standpoints and will result in lowering annual mosquito control costs.

RESTRICTION ON USE OF LAND. In the territory adjacent to wildlife areas and sections of the shore line where heavy mosquito production is taking place and where it is planned not to recommend the control of mosquitoes, it is recommended that consideration be given to permitting the owner or lessee the normal use of the land for timbering, farming, grazing, or other normal uses during the mosquito breeding season. The restriction included in this recommendation should prohibit the night occupancy of existing dwellings or the construction of new dwell-

Table XI

LOCATION AND EXTENT OF PROPOSED MALARIA CONTROL PROGRAM ON LAKE TEXOMA, 1946

	OKLAHOMA			TEXAS		MISC.	TOTALS
	TISHOMINGO	LEBANON	BELOW DAM	PRESTON BEND	ZONE 28		
Clearing	32 acres	3 acres	---	---	---	---	35 acres
Drainage	---	---	2,500 cu. yd.	200 cu. yd.	---	800 cu. yd.	3,500 cu. yd.
Power	30 acres	5 acres	---	---	---	45 acres	80 acres
Larviciding Hand	5 acres	5 acres	10 acres	---	---	50 acres	70 acres
Willow Control	15 acres	4 acres	11 acres	---	---	---	30 acres
Driftwood Removal	11 miles	---	---	---	---	---	11 miles
Aquatic Plant Control	2 acres	---	---	---	1 acre	---	3 acres

ings for human occupancy within the mosquito flight-range zone. The restriction on the use of the land should prohibit the use of tents for night occupants during the mosquito breeding season.

ESTABLISHMENT OF A MALARIA CONTROL UNIT. The success of the proposed malaria control program for Lake Texoma will depend largely on the selection of well-qualified personnel to direct the operational and entomological phases of the program.

It is recommended that a small, full-time malaria unit be organized to supervise all malaria control operations on the reservoir.

The key professional personnel would consist of an engineer and an entomologist who, together with the necessary sub-professional personnel, would carry on the control program. The primary duties of the engineer would be to plan and direct control operations, purchase equipment and supplies, and employ and and train the necessary operational per-

Table XII

COST ESTIMATE OF MALARIA CONTROL ON LAKE TEXOMA, 1946

ITEM	UNITS	UNIT COSTS	ESTIMATED COST	TOTALS
Non Recurrent Costs				
Clearing	35 acres	$300.00	$10,500.00	
Drainage	3,500 cu.yd.	1.25	4,375.00	
Driftwood Removal	11 miles	90.00	990.00	
			$15,865.00	
Equipment				
Water-oil Unit	1	$600.00	$ 600.00	
Hand Sprayers	12	15.00	180.00	
Hip Boots	19	6.00	114.00	
50-gal. Drums	15	4.50	67.50	
			$ 961.50	
				$16,826.50
Recurrent Costs (Per Annum)				
Larviciding (20 applications)				
Power	80 acres	3.00	$12,150.00	
Hand	70 acres	5.25		
Willow control	30 acres	50.00	1,500.00	
Aquatic plant control	3 acres	100.00	300.00	
			$13,950.00	
Supervision				
Engineer	1	3,400.00	$ 3,400.00	
Entomologist	1	3,400.00	3,400.00	
Inspectors	2	2,400.00	4,800.00	
Contingency Fund			700.00	
			$12,300.00	$26,250.00
Total Estimated Cost (First Year)				$43,076.50

sonnel. The entomologist would plan the inspection program, determine the need for control in the vicinity of all housing developments and centers of population, and check on the efficiency of control operations. In addition he would employ, train, and supervise all entomological inspectors to assist in this work.

Before the control program is inaugurated, two entomological inspectors should be employed, together with one foreman and five laborers, for larvicidal operations. The state health departments can assist in the training of the professional personnel.

By carefully planning both the entomological inspection and operational phases of the program the small crew could be employed to advantage on a full-time basis. For example, the entomological inspectors and the larvicidal foreman and crew can be employed during the winter season to remove driftwood and secondary growth, and to drain residual pools. This more permanent work will be reflected in reduced larvicidal costs in future years.

MODIFICATION OF RECOMMENDATIONS. The recommendations included in this report are based primarily on the entomological data for 1945, together with other available data and on the assumption that a water level schedule favorable for malaria control will be maintained. It is a well-known fact that the incidence of malaria and the prevalence of mosquitoes vary from year to year and it is therefore dangerous to draw conclusions from one year's study. Among the factors having a direct influence on the mosquito population are: (1) climatological conditions, (2) modifications in operating schedules, and (3) the effects caused by the falling of dead timber in the reservoir. It is certain that a modification of these recommendations will be necessary in the light of more complete information on the above mentioned factors.

SUMMARY OF COST ESTIMATES

A summary (Tables XI - XII) shows the location, extent, and cost of the proposed malaria control program.

9. Indicates the appearance of the first brood for the season.

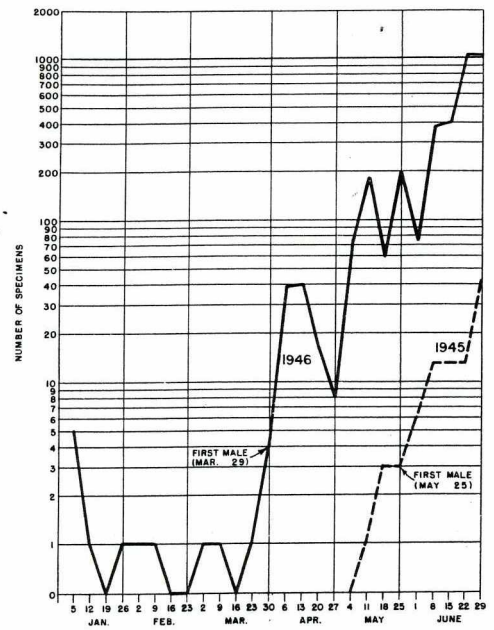
MALARIA CONTROL ON LAKE TEXOMA DURING 1946

WINTER AND SPRING ACTIVITIES BY THE U. S. PUBLIC HEALTH SERVICE. The U. S. Public Health Service continued with the entomological studies in the region of Lake Texoma until the Corps of Engineers initiated a malaria control program in June 1946. The primary purpose of the entomological studies made between January and June 1946 was to determine *quadrimaculatus* densities during the winter and spring in the vicinity of the lake. For this special investigation, weekly inspections were made in the area east of the dam site (Zone 1 - Section 27, Bryan County, Oklahoma). *Quadrimaculatus* females were found during each weekly inspection, except in four instances between January 1 and April 1; the highest single-station observation for the period was five *quadrimaculatus* which were found on January 5, 1946.

The beginning of the *quadrimaculatus* breeding season in the Lake Texoma region was very early in 1946. The first *quadrimaculatus* larvae were found on March 27, and the first *quadrimaculatus* males[9] on March 29. A significant density of the vector (10 or more specimens in a single station) was found in a station on April 1, over 100 were found on May 6, and over 1,000 on June 19, 1946. These records show that the *quadrimaculatus* breeding season was about two months earlier than in 1945 (Figure 20). Correlated with this early breeding season, the 1946 mean temperatures for the first four months of the year were above normal and were higher than the 1945 temperatures for the corresponding period (Figure 21). A temperature of 90° F. was recorded in localities around Lake Texoma on March 30-31.

MALARIA CONTROL PROGRAM BY THE CORPS OF ENGINEERS. Pursuant to recommendations made by the U. S. Public Health Service, the Corps of Engineers organized a malaria control unit on Lake Texoma during the summer of 1946. The unit was

FIG. 20



EARLY SEASONAL DISTRIBUTION AND DENSITY OF *Anopheles quadrimaculatus* ADULTS IN 1945 AND 1946, BASED ON HIGHEST WEEKLY SINGLE STATION OBSERVATION LAKE TEXOMA, OKLAHOMA AND TEXAS

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comprised of the following personnel: an engineer, an entomologist, two entomological inspectors, two foremen, and four laborers (the engineer, one foreman, and two of the laborers were part-time employees on the program). The 1946 program consisted of two phases, viz., entomological and engineering.

Entomological Inspection. The objectives of the entomological program were to determine (1) *quadrimaculatus* densities and to locate breeding places of the vector in the vicinity of human population centers and proposed developments on Lake Texoma, and (2) the effectiveness of the malaria control operations.

Weekly inspections were made in the two control zones, viz., the dam-site area (Zone 1), and Tishomingo, Oklahoma (Zone 15). Semi-monthly inspections were made near other centers of human population and proposed development areas which included: (1) Home-site areas, (2) concession sites, (3) Boy Scout camp, (4) private camps, (5) small towns near the lake shore, (6) recreational areas, and (7) wildlife refuges.

1946		1945	
WEEK ENDING	HIGHEST STA. COUNT (*Quad.*)	WEEK ENDING	HIGHEST STA. COUNT (*Quad.*)
Jan. 5	5	May 5	0
12	1	12	1
19	0	19	3
26	1	26	3
Feb. 2	1	June 2	6
9	1	9	13
16	0	16	13
23	0	23	13
		30	42
Mar. 2	1		
9	1		
16	0		
23	1		
30	4		
Apr. 6	39		
13	40		
20	16		
27	8		
May 4	75		
11	183		
18	59		
25	197		
June 1	74		
8	380		
15	400		
22	1,048		
29	1,046		

The results of the 1946 entomological study support the 1945 findings in that the heaviest densities of the vector were found in Zones 1, 15, and 16 (Table XIII). Significant densities of *quadrimaculatus* were found also in Zones 3, 7, 8, 9, 21, 22, and 29. Of the latter, Zones 3, 9, and 29 are of particular interest from a malaria standpoint because of the presence of the Sand Point Home Site in Zone 3, Concession Site No. 2 in Zone 9, and the town of Lebanon, Oklahoma, in Zone 29.

Important breeding places discovered in 1946 included an old stock pond located

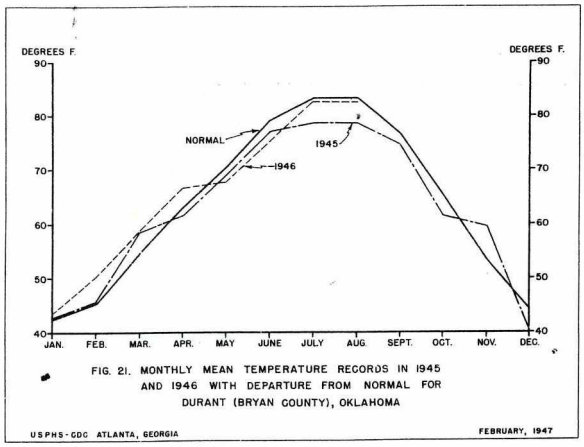

FIG. 21. MONTHLY MEAN TEMPERATURE RECORDS IN 1945 AND 1946 WITH DEPARTURE FROM NORMAL FOR DURANT (BRYAN COUNTY), OKLAHOMA

on Government property on the Preston Bend Peninsula, Zone 9, and some ponds in Borrow Area D and Disposal Area I near the dam site in Zone 1.

Malaria Control Operations. Dam-site area - It should be stressed that extremely high production of *quadrimaculatus* occurred in the area below the dam before control operations were started. For example, on July 19, 1946, six collecting stations located around the margin of Swamp E (Figure 11) contained an average of 1,025 *quadrimaculatus* per station, with a single-station count of 2,220.

A drainage project was started in the dam-site area (Section 27) on July 22 and was terminated on August 12, 1946. During this period approximately 80 acres of potential breeding places were eliminated by excavating five ditches (Figure 11). The effectiveness of the drainage project is revealed by a study of the *quadrimaculatus* populations in the area during the summer months (Figure 22). It will be noted that a striking reduction of the vector occurred following the week ending August 17. Although the drainage project when completed was very satisfactory, silting in the ditches later caused incomplete drainage. A limited amount of mosquito breeding occurred in Swamp D after completion of the project; this breeding can be remedied by lowering drainage ditch No. 5 about one foot. Also, drainage ditch No. 2 should be deepened to eliminate standing water in the ditch itself. Pond A and an adjacent marshy area were not completely drained by drainage ditch No. 1, but subsequently these mosquito breeding habitats were partially eliminated by filling. A more extensive drainage system here, or completion of the filling operations will completely eliminate this breeding area.

Late in the season *quadrimaculatus* larvae were found in various habitats, such as ditches, ponds, etc., within one-half mile of the Denison Dam. The finding of these larvae prompted the inauguration of a larviciding program, which was continued from September 10 until October 22. Weekly applications of oil (Diesel No. 2) by hand sprayers on about four acres of potential mosquito breeding places kept the vector under control.

Tishomingo, Oklahoma - Before the control program was started in Zone 15, *quadrimaculatus* was breeding in moderate to heavy numbers. On July 15, over 100 *quadrimaculatus* (63 females) were found in a single station.

MONTHLY TEMPERATURE RECORDS FOR DURANT, OKLAHOMA, 1945 AND 1946

MONTH	1945 MEAN	1946 MEAN	NORMAL
Jan.	42.8	43.4	42.3
Feb.	45.9	50.3	45.5
Mar.	58.4	58.8	54.8
Apr.	61.5	66.9	63.0
May	69.0	67.9	70.4
June	77.0	75.6	79.0
July	78.8	82.5	83.1
Aug.	78.5	82.3	83.3
Sept.	74.4		76.6
Oct.	61.4		65.1
Nov.	59.5		53.4
Dec.	40.5		44.1

Table XIII

DENSITY OF *ANOPHELES QUADRIMACULATUS* ADULTS BY ZONES
BASED ON HIGHEST WEEKLY SINGLE-STATION OBSERVATIONS,
LAKE TEXOMA, OKLAHOMA AND TEXAS, 1946

ZONE	WEEK ENDING																					HIGH COUNT
	6/22	6/29	7/6	7/13	7/20	7/27	8/3	8/10	8/17	8/24	8/31	9/7	9/14	9/21	9/28	10/5	10/12	10/19	10/26	11/2	11/9	
1	1,048	1,046	1,037	1,707	2,220	2,134	1,446	1,091	358	90	76	35	52	73	66	94	41	11	52	106	15	2,220
3									1		11		3		14		17		4		0	17
4							1		0		1		2		2		6		4		4	6
5							0		0		0		2		8		1		3		3	8
6							1		3		0		1		2		1		1		0	3
7						20		11		10		9		16		8		3		6		20
8						3		3		2		3		22		3		7		11		22
9					17	21		3		4		1		12		4		9		28		28
10							0		0		0	0	1		3		3		1		2	3
11							2		0		0		0		2		4		0		0	4
12							0		0		0		0									0
15	9	8	23	30	119	39	37	23	16	15	12	15	11	30	22	18	15	18	-11	18	6	119
16								874						735								874
18	1	2		6		6			0		0		0		1		4		3			6
21													47		27		21		8			47
22													73		35		24		16			73
23							5		1	0	0		0	1	3	0	3	1	2	5	0	5
24												0		1		0		0		7	0	7
25										0		0				4		1		0		4
28									1			1		1		0		4		3	4	4
29		00	21	46	22	37	23		9	8		6		9		2		3		1		46
33									0	1		0		0		0		2		0		2
HIGH STA.	1,048	1,046	1,037	1,707	2,220	2,134	1,446	1,091	358	90	76	35	73	735	66	94	41	18	52	106	15	2,220

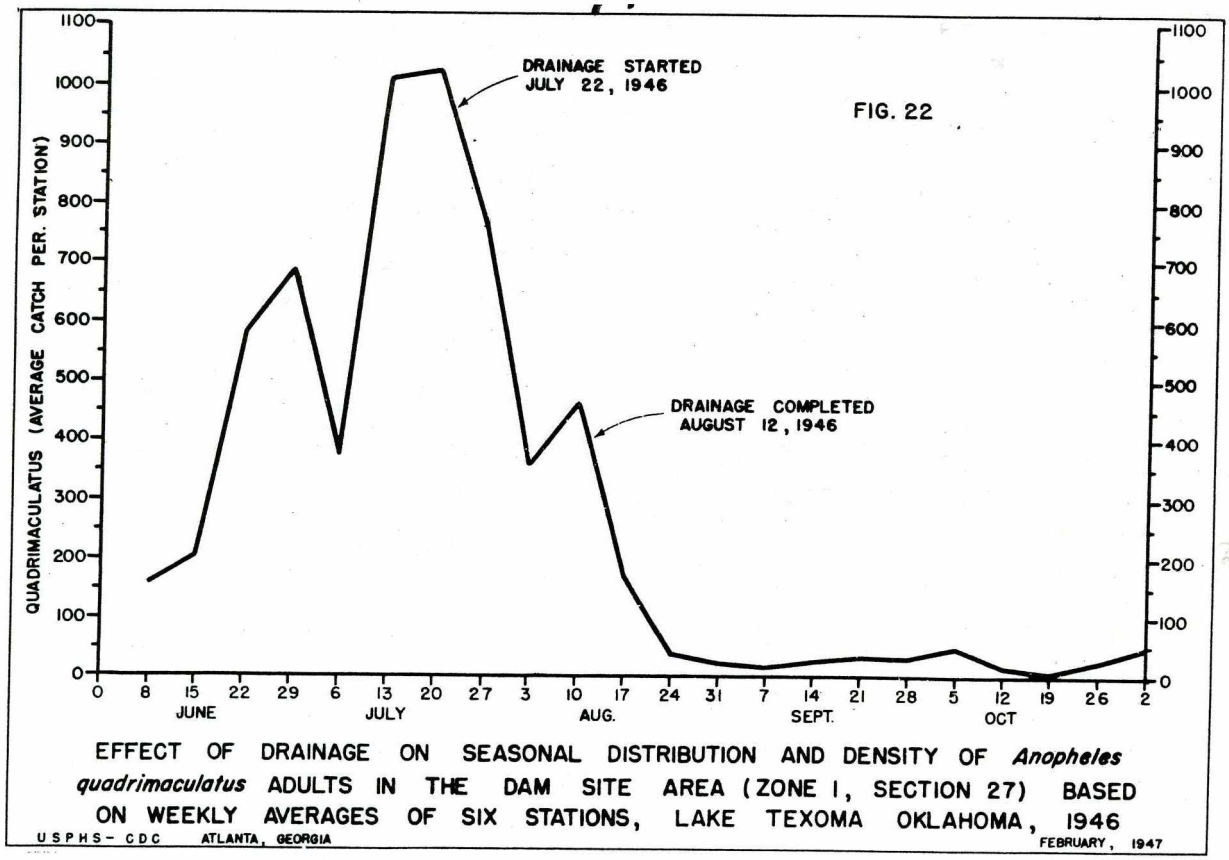

FIG. 22

EFFECT OF DRAINAGE ON SEASONAL DISTRIBUTION AND DENSITY OF *Anopheles quadrimaculatus* ADULTS IN THE DAM SITE AREA (ZONE 1, SECTION 27) BASED ON WEEKLY AVERAGES OF SIX STATIONS, LAKE TEXOMA OKLAHOMA, 1946

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* See tabulation page 27.

The control program was started on July 29 and was terminated on November 1. Approximately 28 acres - 15 by power and 13 by hand - were treated each week with oil. The power spraying was done by means of a water-oil unit which operated in the Pennington Creek inlet. Ponds located on Government property and in the vicinity of the town of Tishomingo were treated by means of hand sprayers.

The results of the larviciding at Tishomingo were quite satisfactory. The entomological records reveal that at no time after control was started were more than 10 female *quadrimaculatus* found in any resting place in Zone 15 for a period of three consecutive weeks.

A summary (Table XIV) showing the cost of the malaria control program on Lake Texoma for 1946 follows:

Table XIV

COST OF MALARIA CONTROL ON LAKE TEXOMA, OKLAHOMA AND TEXAS, 1946, CORPS OF ENGINEERS

ITEM	UNITS	UNIT COSTS	TOTALS
Drainage	2,447 cu. yd.	$ 0.29	$ 708.44
Filling	5,400 cu. yd.	0.09	463.00
Larviciding (14 applications)			
Power	15 acres	3.76	789.60
Hand	13 acres	5.14	935.48
Supervision			
Engineer (1 month)	1	377.00	377.00
Entomologist (4 months)	1	283.00	1,132.00
Inspectors (5 months)	2	200.00	2,000.00
Total Cost			$6,405.52

WEEK ENDING	QUADRIMACULATUS (Ave. of 6 Stations)
June 8	159
15	202
22	583
29	688
July 6	377
13	1,012
20	1,025
27	768
Aug. 3	368
10	463
17	169
24	38
31	22
Sept. 7	15
14	24
21	30
28	29
Oct. 5	46
12	12
19	3
26	22
Nov. 2	47

APPENDIX

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Bryan County, Oklahoma
Carter County, Oklahoma
Marshall County, Oklahoma