Botulism at the Bear River Refuge, Utah during the 1944 experimentation in water manipulation

by

G. H. Jensen
E. R. Quortrup
Charles C. Sperry
Cecil S. Williams

Submitted March 14, 1945.

CONTENTS

	Page No.
Summary and conclusions	1
Introduction	5
Climatological data	5
Biological data	9
Influence of water manipulation on botulism	12
Unit 1	13
Unit 2	22
Unit 3	38
Unit 4	48
Unit 5	53
Soil moisture and botulinus toxicity relationship	67
Bacterial populations	84
Toxicity tests	90
Recovery of botulism birds	92
Duck carcasses as a cause of botulism outbreaks	99
Appendix	101

ILLUSTRATIONS

Number	Tables	Page No.
1	Botulism summary	3
2	Wind records.	7
3	Duck sickness, Unit 1	16
4	Duck sickness, Unit 2	26
5	Duck sickness, Unit 3	43
6	Duck sickness, Unit 4	51
7	Duck sickness, Unit 5	58
8	Soil moisture contents and toxicity	73
9	Toxicity of liver samples after 2 weeks field incubation	76
10	Toxicity of liver samples in saturated and drying soils	76
11	Toxicity of liver samples after 2 and 11 weeks field incubation .	79
12	Bacterial plate counts, field station	85
13	Bacterial plate counts, depth and toxicity.	86
14	Recovery of botulism ducks in the laboratory	93
15	Recovery of botulism ducks in the hospital	95
16	Recovery of botulism ducks in the field	98
17	Comparison of field and laboratory data on recovery from botulism ..	98

Number	Figures	Page No.
1	Winds (bar graph)	8
2	Water levels, Unit 1	15
3	Sickness trends, Units 1 and 2	18

Number	Figures	Page No.
4	Location of sick birds in Unit 1	19
5	Approximate water levels, Unit 1	20
6	Water levels, Unit 2	24
7	Location of sick birds in Unit 2, August 1-9 .	29
8	Location of sick birds in Unit 2, August 10-16.	30
9	Location of sick birds in Unit 2, August 17-23.	31
10	Location of sick birds in Unit 2, August 24-31.	32
11	Location of sick birds in Unit 2, September 1-4	33
12	Location of sick birds in Unit 2, September 5-13	34
13	Location of sick birds in Unit 2, September 14-21	35
14	Location of sick birds in Unit 2, Sept.22-Oct.10	36
15	Approximate water levels, Unit 2 (an insert) . .	38
16	Water levels in Unit 3	41
17	Approximate water levels, Unit 3	42
18	Sickness trends, Units 3, 4 and 5	45
19	Distribution of sick birds in Unit 3	46
20	Water levels in Unit 4	49
21	Location of sick birds in Unit 4	54
22	Water levels, Unit 5	56
23	Approximate water levels, Unit 5	57
24	Distribution of sick birds in Unit 5, Aug. 1-31 .	59
25	Distribution of sick birds in Unit 5, Sept.1-10 .	61
26	Distribution of sick birds in Unit 5, Sept.11-14	62

Number	Figures	Page No.
27	Distribution of sick birds in Unit 5, Sept. 16-16	63
28	Distribution of sick birds in Unit 5, Sept. 18-20	64
29	Distribution of sick birds in Unit 5, Sept.21-Oct.10	65
30	Liver sample stations, Unit 4	68
31	Toxicity of liver samples by dates	74
32	Toxicity of liver samples by stations.	74
33	Toxicity and soil moisture by weight of soil . . .	77
34	Toxicity and soil moisture by saturation of soil .	77
35	Bacterial count from Unit 4 field stations	88

Botulism at the Bear River Refuge, Utah, during the 1944 experimentation in water manipulation.

This report is a summation of the research on duck sickness carried out at the Bear River Refuge during the summer and early fall of 1944. Included are the results of several inter-related experiments designed to obtain more concrete information on those questions which appeared most important to the control of the malady.

SUMMARY AND CONCLUSIONS

The following summary provides an index to the severity of sickness in the different units of the Refuge during 1943 and 1944. Conclusions are based on fringe observations and dike-side pickup of botulism birds (Table 1).

1. Everything considered it seems likely that 1944 was potentially a bad botulism year. Obviously, it would have been a more severe year had not the water manipulations been in effect. This would be true if for no other reason than that Units 1, 3, and 4 were dry for part of the sickness season.

2. Analysis of the data collected during 1944 gives added weight to the ideas suggested by the 1943 studies and to the premises on which the experimental program was founded.

3. Sickness was lowest in those units, the levels of which dropped consistently and fast enough to markedly reduce extensive refloodings. In Unit 4, which dropped at a rate of .53 inch per day, the average count of sick birds per trip over the unit during the drainage period was only 1.7 while the dike-side pickup of sick and dead was 4.2. Unit 1, which dropped at about the same rate (.55 inch per day), but in a different manner, experienced only one week of

higher sickness and one major flare, and the average daily count of sick on the fringe, before the unit went dry, was 25, average dike-side pickup of sick and dead being 1. Unit 3, where the level dropped at a rate of .41 inch per day and reached the borrow pits five days later than in Unit 1 and 15 days later than in Unit 4, had an average of 35 sick on the fringe, and a dikeside pickup of 15 per day during its drainage period. Compared to this, there was an average of 102 sick, per day in Unit 2, although the pickup along the dikes averaged only 4, over the same period. Unit 2 levels were high and more or less stable except for fluctuations caused by winds. In Unit 5 the per trip count of sick birds averaged 33 and the dikeside pickup was 5 per day during the period when Unit 3 levels were receding to the borrow pits. Unit 5 levels were maintained mostly against abrupt banks. Utilization of all units was appreciable except when water was confined to the borrow pits. Sickness in Unit 2 and 5 continued high after Units 1, 3 and 4 were dry. During the period Unit 4 was dry, the count of sick birds averaged 124 per day in Unit 5 and 206 in Unit 2. During the period Unit 1 was dry, the sick count in Unit 2 averaged 175 per day, and in Unit 5, 183. During the period Unit 3 was dry the count of sick in Unit 2 was 151 per day and in Unit 5, 160.

4. Sickness in a unit is not necessarily proportionate to the total unit bird population but rather to that part of the total which uses a critical area. Sickness, therefore, may be quite low with an extremely high bird population or very high with a small population for the unit as a whole.

5. Increase of sickness in every unit appeared to be correlated with reflocdings (due either to influxes or winds) and to increased local utilization.

6. Winds appeared to influence sickness trends in those units where levels were being lowered fast, only when of high velocity, because light winds

Table 1
BOTULISM SUMMARY
Fringe and Dikeside Appraisal
1943 and 1944

Unit	Fringe: Number of Counts		Fringe: Sick Count		Fringe: Dead Count		Fringe: Average sick per trip		Fringe: Average dead per trip		Dike: Dikeside pickup	
	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944
1	19	24	785	627	228	169	41	26	12	7	25	52
2	18	42	371	4943	130	1812	20	117	7	43	38	806
3	21	28	525	902	161	264	25	32	7	9	277	853
4	16	37	602	200	234	22	29	7	11	0.8	1009	545
5	21	38	410	3232	350	950	25	87	22	25	59	1111
Totals	95	169	2691	9904	1093	3217	140	269	59	85	1408	3367

failed to reflood the drier margins there, although they did reflood margins where levels were more stable. Winds must be regarded in the light of making toxin available rather than of aiding in its production. If toxin is not produced, or if produced and destroyed, winds of any velocity have no apparent influence on sickness trends. Also, winds which blow during the early part and toward the end of a sickness season have not the same effect as winds occurring in mid-season.

7. Dangerous sections, those in which the toxin appears to center under the present schedules were, in the main, the same as those located in 1948. These are obvious in the charts showing the distribution of sick birds in each unit.

8. The dangerous areas appear to be a) mucky areas at the mouths of channels where water enters the units.

b) exposed mucky areas along low banks and peninsulas, which are subject to exposure and reflooding --- either in marsh or lake bottom free of marsh vegetation.

c) shallow water areas in which a silting over of muddy may take place.

9. Maintenance of high, consistent levels (mostly against abrupt embankments) appears to reduce sickness in general, but does not prevent the development of a few potent areas where water enters the unit.

10. Drying of a unit after seeds have matured does not appear to reduce production of feeds the next year nor to lessen utilization of a unit after it is reflooded.

11. Reflooding of a lake bottom which was dry for twenty days or more did not result in high sickness in any of the three drained units this season.

Sickness during reflooding was of short duration on the fringe and passed almost unnoticed in the dike patrols along Units 1 and 3. Bikeside pickup on Unit 4, however, averaged 25 per day for the re-filling period of 17 days (in contrast with the 4 per day during the drainage and drying period) although the total of 596 victims was not indicative of an exceptionally high loss.

12. Laboratory data prove that antitoxin treatment and hospitalization of ducks made helpless or nearly so by botulism is effective, economical and practical as a high percentage of recovery follows such care. Both laboratory and field data indicate that hospitalization, with or without antitoxin treatment, of ducks mildly affected by botulism is not worthwhile from a standpoint of conservation or economy.

INTRODUCTION

The several schedules for handling of the water during the experiments in 1944 will be found in the report under the headings of individual units. Prior to a discussion of these and the sickness which developed under them, this year, it seems advisable to consider some climatological and biological data that apply in general to all units of the Refuge. For the sake of brevity, and to facilitate comparisons with similar data of the 1943 season, these data are presented for the most part in tabular form.

Climatological data

Air temperatures.

Comparisons of the minimum, maximum, and mean temperatures recorded at the weather station located at headquarters show that the 1944 botulism period averaged slightly colder than the same season of 1943.

Mean Monthly Temperatures

	Minimum		Maximum		Mean	
	1943	1944	1943	1944	1943	1944
August	60.2	51.7	90.7	91.4	76.1	71.5
September	50.9	46.2	84.0	82.1	66.2	57.2

Wind Movement

Two anemometers were in operation this season, one at the refuge headquarters and one on the outer dike between Units 4 and 5.

The anemometer at headquarters is low on the ground and close to buildings so is somewhat protected --- it recorded air movement totalling 100 miles or over in 24 hours on only five days each year in 1943 and 1944. However, the data from this instrument does permit a comparison of wind movements during the last 2 botulism seasons. Average miles of air movement per day

	1943	1944
August	62.1	51.7
September	32.4	39.7
Seasonal	47.2	45.7

The anemometer located on the outer dike was elevated about 12 feet above the ground level and connected to an automatic recorder. Since it is believed that this exposed machine gave a truer picture of winds in the field, detailed information obtained from it was used in evaluating other field data on botulism. Daily wind records, including direction, are given in tabular form (Table 2), and pictured by bar graph (Figure 1).

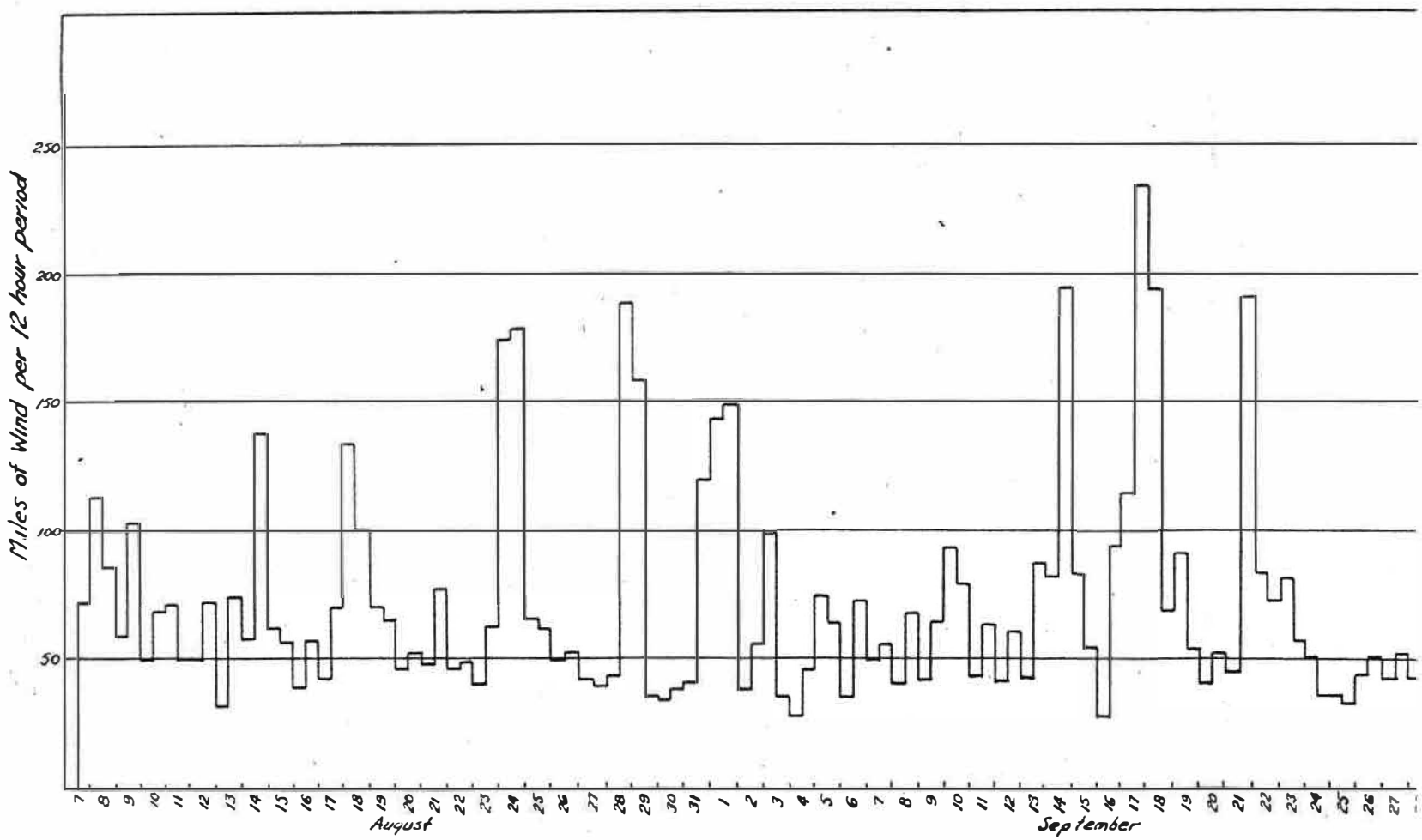
Table 2
Wind records at Bear River Refuge during the botulism season of 1944

Date	Wind - total miles in 24 hours	Direction in Units* 5	4	3	2	1
Aug. 7	71	S	SW	SW	C**	C
8	197	S	SW	SW	SW	SW
9	160	N	S	SW	SW	SW
10	114	N	N	SW	SW	SW
11	119	N	S	S	C	C
12	120	S	S	C	S	SE
13	104	N/S	N	S	S	-
14	192	N	N	C	N	NW
15	115	N	NE	SE	C	C
16	94	C	C	C	C	C
17	111	S	C	C	SW	SW
18	232	S	S	S	S	S
19	131	N	C	S	S	S
20	97	N	-	-	-	-
21	123	N	N	S	S	S
22	93	N	C	C	C	C
23	101	S	S	S	C	C
24	350	S	S	S	S	S
25	124	C	C	S	C	S
26	100	N	C	C	C	C
27	79	C	C	C	C	C
28	231	N	S	S	S	S
29	192	N	N	N	N	N
30	72	N	C	SE	SE	S
31	158	S	C	S	S	S
Sept. 1	290	N	NW	W	W	W
2	92	N	C	C	S	S
3	133	N	-	C	-	C
4	72	N	C	C	C	C

Date	Wind - total miles in 24 hours	Direction in Units 5	4	3	2	1
Sept. 5	137	W	W	W	W	W
6	106	N	C	S	S	SW
7	101	N	C	C	C	C
8	106	C	C	C	C	C
9	104	N	C	C	C	SW
10	169	N	N	N	NW	N
11	104	C	C	S	S	C
12	100	C	C	C	C	C
13	127	C	C	C	C	S
14	274	N	N	N	N	W
15	138	S	S	S	S	S
16	119	S	S	S	S	S
17	345	N	N	N	N	N
18	261	N	N	C	C	C
19	142	C	S/C	S	S	S
20	90	C	S	C	C	C
21	233	SW	SW	SW	SW	W
22	153	NW	NW	N	N	N
23	136	C	N	C	C	C
24	85	C	C	C	C	C
25	67	C	C	C	C	C
26	94	-	S	-	S	-
27	93	C	C	C	C	C
28	110	C	S	C	S	S
29	129	N	N	N	N	N
30	171	S	S	S	S	S
Oct. 1	152	E	E	C	E	SW
2	150	NW	NW	NW	C	C
3	64	C	C	C	C	C

*Direction of wind in the various units was recorded at the time water levels or other field observations were noted.
**C= calm

FIGURE 1



DAILY WIND IN MILES PER 12 HOUR PERIOD

Station on main dyke at O-Line, 1944.

Evaporation

The evaporation indicated by pan record was as follows:

	1943	1944
August	10.61	11.17 inches
September	7.40	7.03 inches
Total	18.01	18.20 inches

Unit 3, which was not to receive water and to be dried by evaporation and other natural factors, went dry on September 8. Levels of this unit lowered 15.6 inches in 38 days, a rate of .41 inches per day.

Precipitation

The 1944 season in Utah was reported to be the driest in 25 years. No precipitation occurred in August and only .42 inch in September. This fell on three days, but most of it (.38 inch) on the last day of the month.

	1943	1944
August	1.08	0
September	0	.42

Biological Data

Waterfowl Populations

The population of waterfowl on the Refuge this botulism season did not attain the enormous concentrations of 1943, but it was always ample on each unit even when near dry, to cause heavy utilization. At the beginning of the experimental period, (August 1) an estimate made from the fringe of each unit gave a figure of 271,000 ducks, while a similar estimate from the dikes totalled 75,000. In addition to the ducks, there were, of course, an abundance of avocets, stilts, phalaropes, godwits, ibis, and dowitchers along the fringe and thousands of

coots in both fringe and dike areas. Every species considered, the population during this season was about half that of 1943. The reduction was in the main attributable to the delayed flight of green-winged teal. While flocks of up to a thousand were frequently encountered in the marshes, the species did not approach the huge concentrations evident during late August of 1943.

Large concentrations of ducks were in evidence on individual units all during the botulism season. In Unit 1, the number visible from the fringe varied between 20,000 and 60,000 which was from 2 to 4 times as many as seen from the dikes. Even when the unit was nearly dry (September 2), there still were 20,000 ducks utilizing the remaining water area, although few were seen within one-fourth mile of the dikes. In fact, duck use of the borrow-pit water in Unit 1 was negligible all during the low-water period and did not change as reflooding of the unit began (September 25) although the number of ducks seen on the fringe increased at once. On September 27, an estimate of 36,000 was made. Species other than ducks also were abundant on the unit when it had water. On August 15, for example, the following were recorded: 8,000 godwits, 25,000 dowitchers, 2,000 ibis, and 30,000 coots.

Unit 2 started the botulism season with about 55,000 ducks visible from the fringe and 200 from the dikes. These numbers increased greatly as the season advanced. When other units became dry, Units 2 and 5 carried the load of ducks until refills took place. During mid-September 60,000 ducks could be seen from the dikes and the fringe appraisals indicated a duck population of 200,000. Some shifting in concentrations was apparent between units and from one section of a unit to another but almost every section was heavily utilized during the remaining days of September.

Unit 3 had a high duck population (76,000) on August 1. This increased to 100,000 pintails alone on the fringe and 35,000 along the dikes by August 11. On this day, an estimate of 150,000 shorebirds also was made for the fringe. These consisted of 70% phalarope (both); 15% avocets; 10%, dowitchers; and 5% stilts. The population was reduced somewhat, as the unit levels lowered, but even when the unit was reduced to a shallow puddle (September 2, see figure 17), there were still 100,000 ducks present. Only 500 to 1000 ducks used the borrow pit water during the "dry" period from September 8 to 29; but on Sept. 30 the southeast corner was flooded because of a broken spillbox and 30,000 ducks were attracted to the area. After the reflood (October 11) the population in the marsh area went as high as earlier in the season.

Unit 4 began the season with a duck population of about 30,000 mostly (95%) pintails. By August 10 the population had increased to 70,000 well scattered ducks and by the 14th to 100,000. An exodus occurred before August 16, however, as the estimate on that day was 15,000. There were 2,000 ducks still left on the unit on August 19 and about 500 continued to use the borrow-pit canals after the basin was dried completely on August 24. Reflooding started in mid-September and soon attracted large numbers of ducks -- September 19, 20,000, September 24, 51,000, and September 27, 68,500.

Unit 5 duck populations varied from 70,000 in early August to about 145,000 in mid-August, but these counts were made on the fringe as early season dikeside observations revealed only a few thousand coots and numerous duck broods. This unit apparently attracted the birds that left Unit 4 as that area was drained. As Unit 4 began to refill, the population in Unit 5 declined to about 80,000 on September 22. Later in September it began to build up again, reaching 200,000 on October 11.

Duck Feeds

The reduction of water levels in Units 1 and 4 during 1943 apparently did not lower production of pondweeds in those units this season. Production in Unit 4 appeared even greater than in 1943. So prolific were growths that as water levels went down it was difficult to determine the location of the real shore line. Because of this, the airboat was occasionally found to be riding entirely on exposed but still wet pondweeds.

Dead Muskrats

A high mortality was evident among muskrats during the 1944 season. This was general for all units, but reached greater proportions in Units 2 and 3. The cause is unknown, but the mortality occurred currently with sickness flareups among the ducks.

EXPERIMENT 1A
AN ATTEMPT TO CONTROL BOTULISM THROUGH WATER MANIPULATIONS

A program of experimental water handling aimed at controlling botulism was begun on the Bear River Refuge in 1943 and continued in 1944. It involved five different methods of handling the available water in the five units on the area. Several concepts arrived at from previous analyses of data from Unit 3 bearing on the relationships between water-levels and the trends in botulism led to the setting up of the program. One of these ideas was that sickness appeared less intense as long as the unit levels receded or went up steadily, but more serious when they became more or less static on the mucky lake-bottom. Other ideas which influenced the type of experimental program were 1) that high unit levels on abrupt shorelines tended to reduce sickness, 2) that those areas in which toxin seemed to be produced (tension zones) when moist lost their toxicity when dried out or when covered with water for a few days; and 3) that

extensive refloeding of the recently exposed lake-bottom by wind, rain, or additional inflow was conducive to increased sickness. The objectives of the program then were to test these concepts by actual field manipulations of unit water, and to more accurately locate where toxin was being produced and picked up by the birds.

Unit 1

Projected schedule. "Unit 1 is to be filled to level 4205.0 early in spring and maintained at that elevation until August 1, subject, however, to priorities granted to Units 5, 2, and 3 in the order named. Beginning August 1, the level is to be lowered 3 inches -- so as to change definitely the location of the water's edge -- and lowered at the rate of 0.3 inches a day for the following 10 days, the water released being spilled outside the dike area. Starting August 11, the water level will be rapidly dropped 2 inches and lowered at the rate of 0.3 inches a day for the succeeding 10 days. This will be repeated at intervals of 10 days until the unit is empty or until September 24". (Director's Order dated February 7, 1944.)

Purpose of Schedule. The schedule of Unit 1 was set up to compare with that of Unit 4 in which the rate of drop was about the same but the manner in which it was accomplished different. It was designed to get information on the question: "Can botulism be decreased by dropping levels away from tension zones and toxic spots that might become established if levels were more stabilized?"

Manipulation. Unit 1 began the experimental period on August 1 at level 4204.73. From that point on it dropped according to the procedure planned but at an average rate of .66 inch per day until September 4, at which time the unit was considered dry from the standpoint of fringe appraisal. There existed on that date only a narrow fringe of shallow water extending a short distance east

of the main spillbox on the D-line. Small pockets were also present in two other places separated from the main unit. One was at the mouth of the main lateral canal into the unit; the other the spillbox area of the Bear River Club dike.

Refuge management manipulation of water in Unit 1 closely followed the projected schedule (Figure 2). Between August 1 and September 4, the levels dropped 1.64 feet and the unit was dry. The accumulated drop projected for September 4, amounted to about 1.63 feet.

Sickness in Unit 1. Sickness in Unit 1 never reached serious proportions during the 1944 season. Only 627 sick and 169 dead were counted in 24 trips through the Unit (Table 3). This is an average of but 26 sick and 7 dead per trip. In comparison to other units, it ranked next to last in the total sickness produced, only Unit 4 having less sickness. In contrast, in 1943 Unit 1 produced more sickness than any of the other units, although sickness was low in all units during that season. The total figures do not permit comparison between sickness on Unit 1 during the 1943 and 1944 seasons. If, however, the data are reduced to average number of sick and dead counted per trip comparison can be made. This shows sickness during the 1944 season to be little more than half of what it was last year. The ratio is near 1:1.6.

In contrast with these fringe data, we find that dike-side information on botulism in Unit 1 is of value chiefly because of its negative quality. The D- and L-line dikes were traversed by car from 5 to 7 times each week during both of the last 2 botulism seasons and the total number of duck victims collected was only 52 in 1944 and 25 in 1943. We can, therefore, repeat, and with emphasis, our conclusion of 1943, namely, botulism losses in the eastern half of Unit 1 are not proportionately reflected along the dikes.

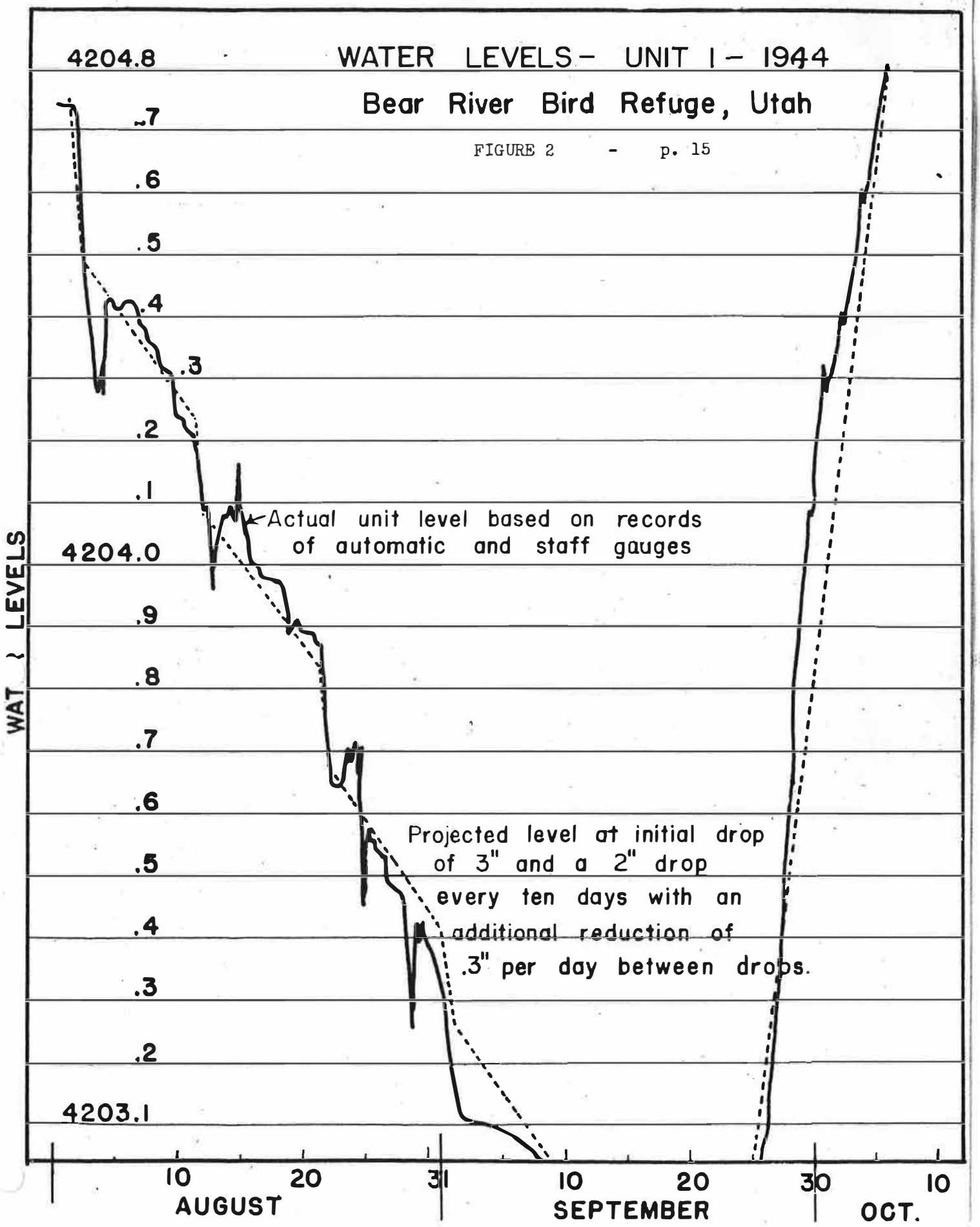

WATER LEVELS - UNIT I - 1944
Bear River Bird Refuge, Utah
FIGURE 2 - p. 15
4204.8
.7
.6
.5
.4
.3
.2
.1
4204.0
.9
.8
.7
.6
.5
.4
.3
.2
4203.1
WAT ~ LEVELS
Actual unit level based on records of automatic and staff gauges
Projected level at initial drop of 3" and a 2" drop every ten days with an additional reduction of .3" per day between drops.
10
20
31
10
20
30
10
AUGUST
SEPTEMBER
OCT.

TABLE 3 - DUCK SICKNESS APPRAISAL, UNIT 1 - 1944

Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup	Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup
Aug. 1	1	7	8	0	Sept. 7				0
2	-	-	-	-	8				0
3	6	14	19	0	9	Unit too dry			0
4	2	1	0	0	10	for use of			-
5	-	-	-	0	11	boat in			3
6	0	4	2	-	12	appraisal of			0
7	-	-	-	0	13	fringe conditions			1
8	15	6	21	0	14	Sept. 5 to 26			0
9	15	4	4	0	15				0
10	7	4	0	0	16				0
11	-	-	-	0	17				-
12	-	-	-	1	18				0
13	-	-	-	-	19				0
14	11	6	10	0	20				0
15	17	2	8	0	21				0
16	33	1	17	1	22				0
17	-	-	-	1	23				0
18	-	-	-	1	24				-
19	45	13	25	0	25				0
20	-	-	-	-	26				-
21	51	12	18	1	27	30	1	31	0
22	-	-	-	3	28	-	-	-	1
23	59	21	29	-	29	22	0	0	1
24	51	11	3	2	30				0
25	114	35	98	19	Sept. total	89	6	x	9
26	-	-	-	7	Oct. 1	-	-	-	-
27	-	-	-	2	2	30	-	8	0
28	24	14	0	2	3	-	-	-	-
29	293	7	12	2	4	-	-	-	0
30	-	-	-	1	5	21	1	0	-
31	-	-	-	0	6	-	-	-	-
Aug. total	480	162	x	43	7	-	-	-	-
Sept. 1	9	2	0	1	8	-	-	-	-
2	21	1	13	1	9	-	-	-	-
3	-	-	-	-	10	7	0	7	-
4	7	2	0	1	Oct. total	58	1	x	0
5	-	-	-	0	Season totals	627	169	x	52
6	-	-	-	0					

*Index of severity = The number of new dead added to the number of sick minus the number of sick recorded on the immediately previous trip made within 5 days.

The fringe count and dikeside pickup of botulism birds in Unit 1 indicate that sickness was not alarming. On only four days out of 24 trips did the number of such birds counted exceed 51 and on no day were more than 35 new dead recorded. The counts made show nine flareups, but all except one of these may be considered of little significa nce. The number of sick counted on any one day did not go above 35 until August 19, a day following the first strong wind which blew 232 miles in 24 hours. During the week following, sickness remained higher in the unit than during any other period. On August 25, it reached the peak, 114 sick and 55 dead. This also followed a high wind, one which blew 350 miles the previous day. From the peak of August 25, sickness fell off rapidly, with a slight increase on August 29 and another on September 2 (Figure 3). On both occasions the wind had blown hard the day preceding the upswing - 231 miles on August 28 and 290 miles on September 1. The windy days indicated are the only ones on which the wind blew over 200 miles. Prior to August 18 the air movement in 24 hours was over 150 miles only twice --- August 8 and 14. On both of these days a low flareup in sickness was recorded, but none on the day following.

The unit was dry from September 5 to 25, the only top soil showing noticeable moisture being a narrow zone bordering the borrow pits and spillbox puddles. Reflooding over this dry soil on September 25 was followed by a small flareup in sickness which dropped off until Oct. 2. On this day another slight increase was noted. Both September 30, and October 1 were windy days (171 and 152 miles, respectively.)

Location of sick birds in Unit 1 obviously was influenced by water levels and the position of the fringe (Figures 4 and 5). As the levels of the unit went down the sickness followed the fringe so that there occurred a more general distribution of sickness. Two areas stand out as concentration points, however.

FIGURE 5

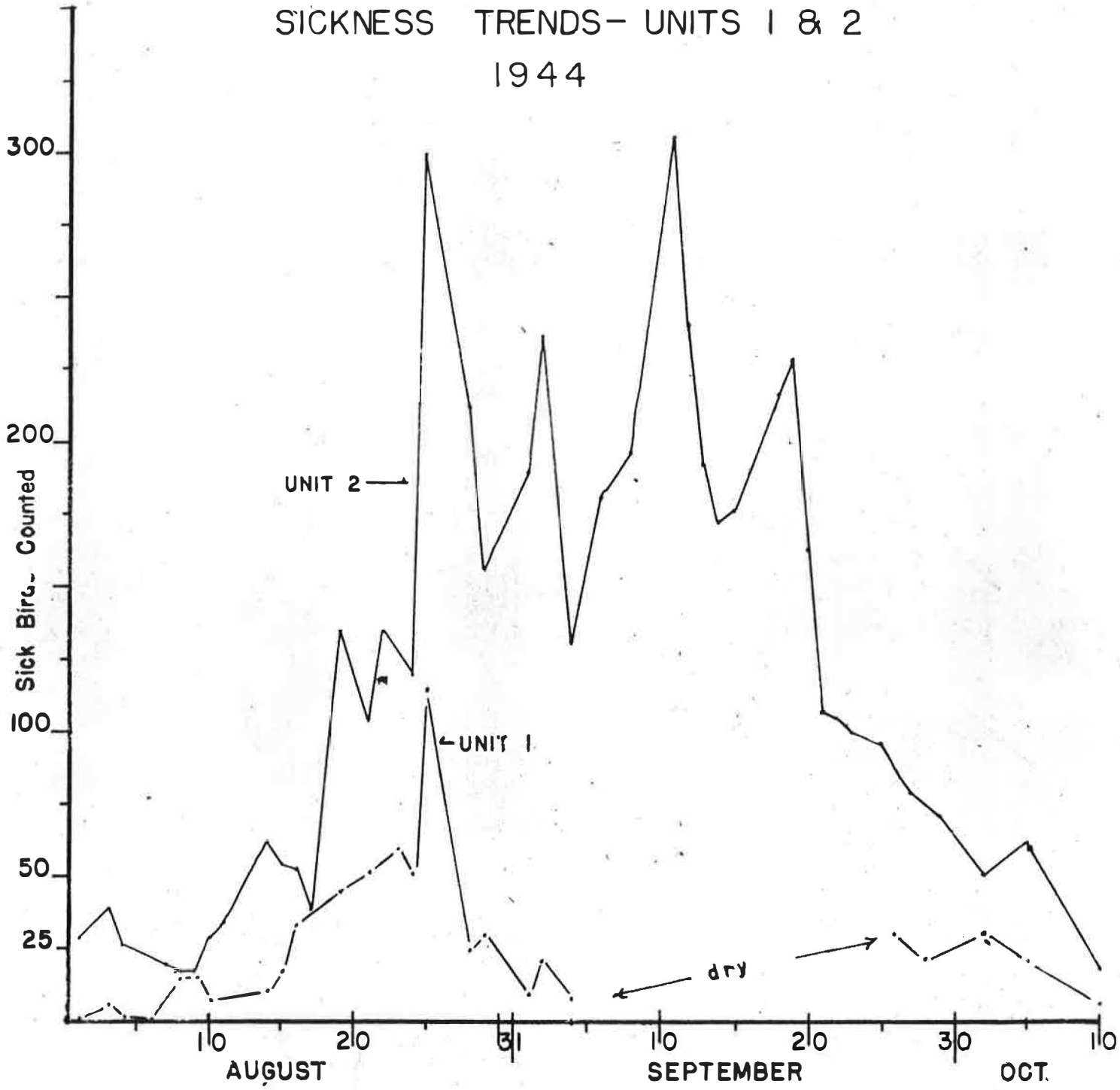

SICKNESS TRENDS- UNITS 1 & 2
1944
300
200
100
50
25
Sick Birds Counted
UNIT 2
UNIT 1
dry
1 0
2 0
3 1
1 0
2 0
3 0
1 0
AUGUST
SEPTEMBER
OCT.

FIGURE 5

APPROXIMATE WATER LEVELS — UNIT 1

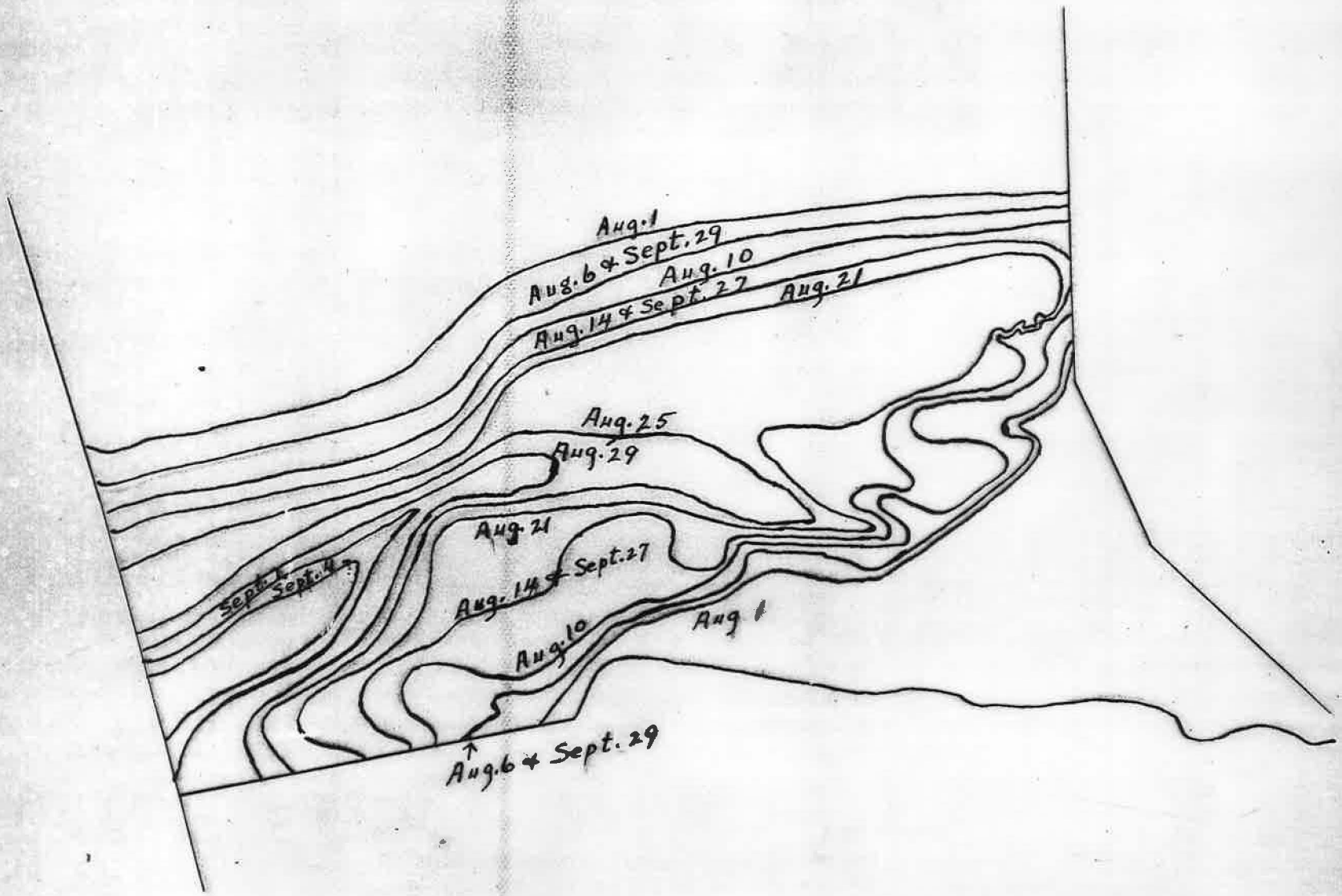
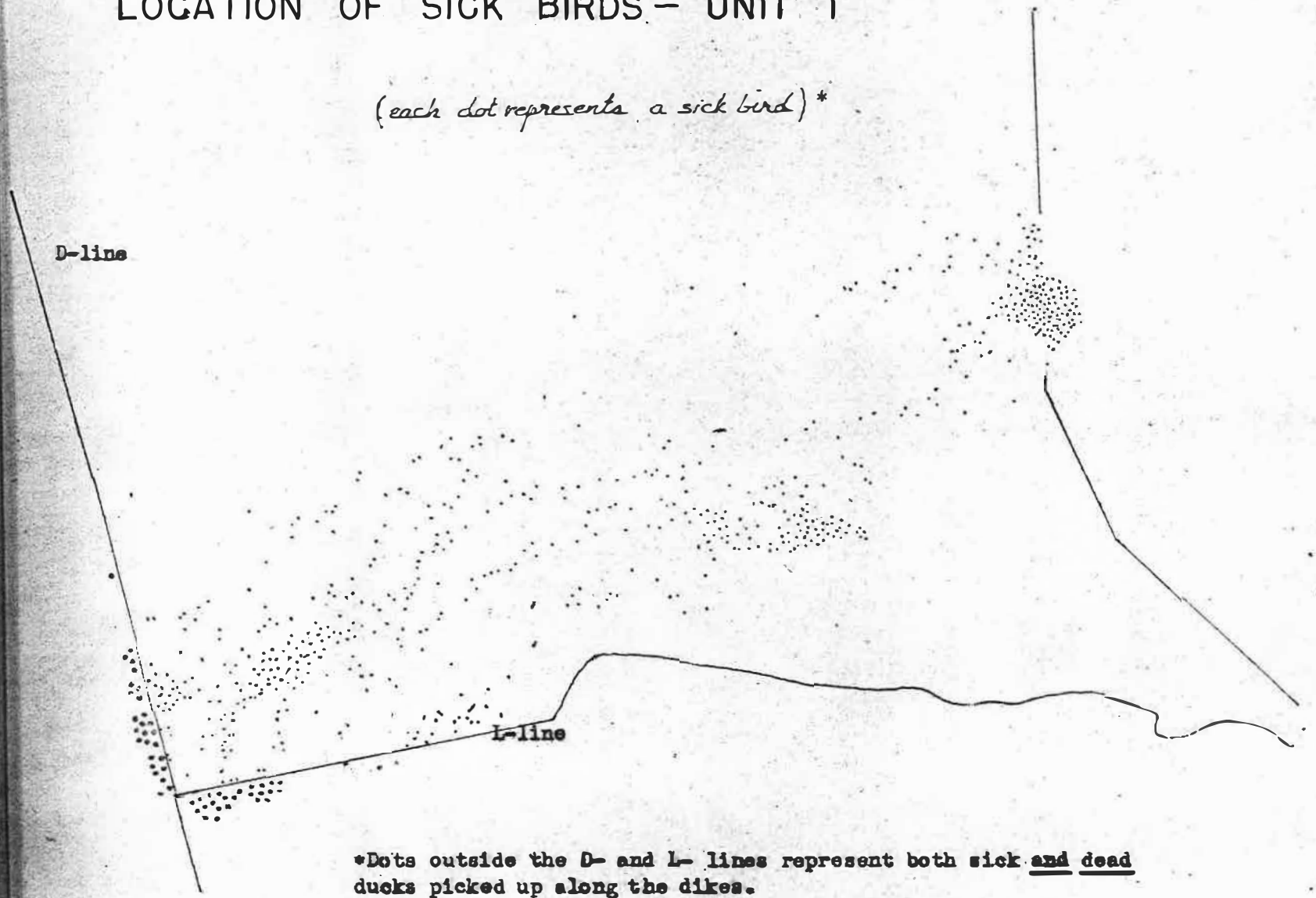


FIGURE 4

LOCATION OF SICK BIRDS — UNIT I

(each dot represents a sick bird)*



*Dots outside the D- and L- lines represent both sick and dead ducks picked up along the dikes.

These are the same two that were evident in the 1943 season (1) the spillbox area of the Bear River Club and (2) near the mouth of the main lateral canal. The first of these was a source of some inflow of water again this season but the flow into the canal area which was significant in 1943 was largely eliminated this season. Some seepage must certainly have occurred, however. Both areas were connected with the main body of water in the unit during the early part of the week of highest sickness beginning on August 19, but were separated when the peak came on August 25. Sickness on that day was entirely a mud flat proposition apparently arising from the reflooding caused by the high wind of August 24. The worst place along the fringe during that flareup was on the part extending north and east of the L-line spillbox. This area was removed from the marsh and not far from the dikes, so it is worthwhile to note that evidence of the peak flareup of the 25th was emphasized in the dikeside pickup of 19 duck botulism cases on that day. Seven additional victims were collected the next day -- 50 percent of the total Unit 1 dike collections for the season in those 2 days and no other one day yielded more than 3 birds.

From the appraisal of sickness conditions in Unit 1 it appeared evident that

1) sickness would have been considerably higher had it not been for the rapid drop in levels and the period of dryness which extended from September 5 to 25.

2) that the areas of greatest damage are in the vicinity of the spillbox of the Bear River Club dike and the mouth of the main lateral canal.

3) that sickness on mud flat areas of the unit occurred mainly where contours were such that stabilization took place for longer periods.

4) that under the 1944 water manipulation schedule, only the stronger winds (150 miles or more in 24 hours) seemed to influence sickness.

5) that, while sickness is seasonal in character, tending to build up to a peak from which it abruptly recedes, most of the sickness of the season comes from flareups.

6) that dike patrol data are worthless for appraising botulism results in the unit as a whole when water levels extend into the marsh area. Under such conditions, however, numbers of sick birds along the dikes are a positive indication of great sickness within the marsh.

Unit 2

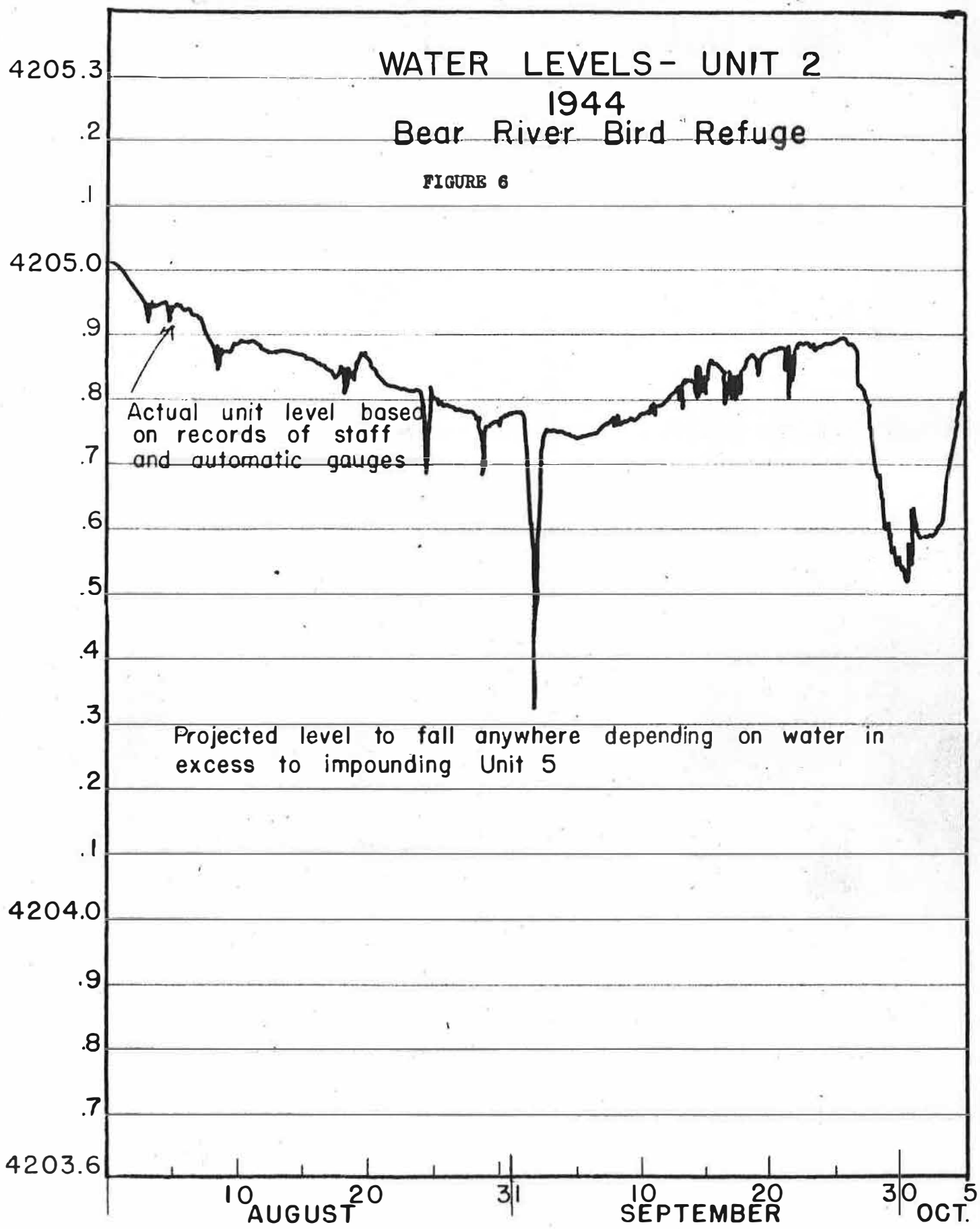
Projected schedule. "This unit is to be filled early in spring to 4205.3 and maintained as near this level as possible, subject to priorities given. After August 1, the unit is to receive all water in excess of maintaining Unit 5 at 4205.25 (except as indicated under Unit 4, page 6, and in paragraph C, page 2, on the refill, in which case Unit 4 has priority on refill over Unit 2); but it is desired that the level will not exceed 4205.3 at any time throughout the experimental season, August 1 to September 24. Therefore, should water in excess of the needs of Unit 5 be available by August 1, that water is to be passed into Unit 2 to attain the 4205.3 level. Water in excess of that need (except for refills), arriving at any time during the maintenance and experimental periods, should promptly be passed outside the unit". (Director's Order dated February 7, 1944) .

Purpose of Schedule: As stated in the 1943 report, the Unit schedule was designed to serve as a check on the severity of the botulism year. The unit has nearly always been a consistent and high producer of sickness and it was logical to believe that if it were not managed, i.e., a specific course for levels not set up, levels would be down and sickness would again be typical. Precipitation in

1943, however, was above normal and available water from Bear River, after other experimental priority, kept levels of Unit 2 up to what may be considered full impoundment. It never went below 4205.0 which is an infrequent occurrence. The results of 1943 served to show what maintenance of the higher levels in the unit would do. They were not an index to normal conditions. To prevent a repetition of such extremely high levels, the 1944 schedule put a maximum on the levels the unit could attain during the experimental period. This maximum, however, still was at a high level. If it could be attained and held, the results would give only a partial idea of what might happen at the normal lower levels. In other words the unit would not serve as a true index of sickness unless it followed a normal course which was lower than the maximum set up for it this year. It would only give somewhat of an idea.

Manipulation. This summer was one of the driest in twenty-five years, yet it soon became evident that there was sufficient water over and above the needs of Unit 5 to maintain Unit 2 at a high level. The unit began the experimental season (August 1) at 4205.01, almost .1 foot lower than the lowest point attained in 1943 (Figure 6). From 4205.01 it slowly dropped to a low of 4204.75 on September 4 where it remained until an upward trend began about September 8. This trend continued until September 25, at which date flow into Unit 2 was largely stopped and water was spilled into Unit 1 so that repairs to pipe lines crossing the main channel of Unit 2 could be made. Levels dropped about .4 foot by October 1 and then started up again reaching 4204.8 by October 5.

Sickness in Unit 2. The first sick ducks of the 1944 season were picked up in Unit 2 on July 14 by Assistant Refuge Manager Mark Nelson and officially set the beginning of a sickness season that extended into early October. Botulism


WATER LEVELS- UNIT 2
1944
Bear River Bird Refuge
FIGURE 6
4205.3
.2
.1
4205.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
4204.0
.9
.8
.7
4203.6
Actual unit level based on records of staff and automatic gauges
Projected level to fall anywhere depending on water in excess to impounding Unit 5
10
20
31
10
20
30
5
AUGUST
SEPTEMBER
OCT.

in Unit 2 in late July and the first few days of August was regarded then as rather severe. However, this impression was due to the number of dead rather than to the number of sick (Table 4). It was the only period during which the new dead exceeded the sick on the counts. The toxin produced at that time must certainly have been more potent or available in greater quantity than later. The proportion of sick to dead become noticeably greater as the season advanced. Toward the end of the season (early October) fringe counts listed very few dead.

The 1944 level of Unit 2 exposed more fringe and muck banks than was the case in 1943. At 4205.5 level the Unit may be regarded as fully impounded, all natural channels in the lower marshes being submerged. At 4205.0 these banks are only partially exposed and mud flats are in evidence along the L-line, although these flats are mainly of alkaline clay. Below 4205.0 the mucky areas bordering banks and islands of alkali bulrush begin to show and the lower the levels go the greater is the extent of the fringe over mucky lake-bottom. The lowest level attained by the Unit during the experimental period was 4204.73 and it was evident that at this level the fringe was still mostly within the alkali bulrush patches on higher contour levels. In the lower marshes only a few of the islands of emergent vegetation and mud banks were exposed. Even here (near the mouths of the river channels) the levels were not low enough to permit much drying of the exposed soils. Shallowly exposed areas were kept wet or moist at all times. Wind action was a factor in this.

Under the levels varying from 4205.0 to 4204.73, there was considerable stabilization of fringe followed by reflooding. Almost any high wind except from directly north would reflood some portion. The number of sick counted on trips through the unit was 4943, the dead, 1812. These figures were appreciably higher

TABLE 4 - DUCK SICKNESS APPRAISAL, UNIT 2 - 1944

Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup	Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup
Aug. 1	28	72	100	0	Sept. 7	-	-	-	8
2	-	-	-	0	8	196	57	73	6
3	38	101	111	5	9	-	-	-	0
4	25	73	81	1	10	-	-	-	-
5	-	-	-	0	11	304	70	178	66
6	-	-	-	-	12	240	102	38	24
7	19	20	13	0	13	192	52	4	10
8	17	13	11	0	14	172	70	50	88
9	17	4	4	0	15	176	56	60	206
10	28	18	29	4	16	-	-	-	28
11	34	24	30	0	17	-	-	-	-
12	-	-	-	1	18	218	29	69	94
13	-	-	-	-	19	227	57	68	30
14	62	45	73	0	20	162	48	0	9
15	54	23	15	10	21	21	106	42	40
16	52	14	12	1	22	104	20	18	28
17	37	31	18	0	23	99	8	13	7
18	-	-	-	0	24	-	-	-	-
19	134	48	145	3	25	95	1	0	12
20	-	-	-	-	26	-	-	-	-
21	104	63	33	0	27	38	0	0	20
22	134	40	70	0	28	-	-	-	2
23	70	27	0	1	29	71	8	1	13
24	119	23	77	0	30	-	-	-	-
25	298	141	320	9	Sept. total	3174	851	x	733
26	-	-	-	8	Oct. 1	-	-	-	-
27	-	-	-	-	2	30	0	0	3
28	212	135	49	9	3	-	-	-	0
29	156	32	0	1	4	-	-	-	-
30	-	-	-	8	5	62	7	19	-
31	-	-	-	9	6	-	-	-	-
Aug. total	1639	952	x	70	7	-	-	-	-
Sept. 1	189	50	83	7	8	-	-	-	-
2	236	67	114	12	9	-	-	-	-
3	-	-	-	-	10	18	2	0	-
4	131	61	0	17	Oct. total	150	9	x	3
5	-	-	-	0	Season totals	4943	1812	x	306
6	130	43	97	2					

*Index of severity = the number of new dead added to the number of sick minus the number of sick recorded on the immediately previous trip made within five days.

than in any other unit. In fact, they were higher than in all other units combined. However, a better comparison between the sickness of last season (1943) and this year can be had by using the average numbers of sick and dead counted per trip through the unit (Table 1). Travel through the unit was of course over the same route each time. The average number of sick counted per trip in 1943 was 20; in 1944, 117. The average number of new dead per trip amounted to 7 in 1943; 43 in 1944. It is evident that the severity of sickness as evidenced by this unit was 6 times greater in 1944 than in 1943. In 1943 Unit 2 produced the least amount of sickness of all the units; and in 1944, the most.

Although, as previously stated, a few sick birds were in evidence in the Unit as early as July 14, the higher peaks of sickness did not show until in mid-August and September (Figure 3). On only one trip through the Unit between August 19 and September 22 did the count of sick birds go below the hundred mark. Beginning September 23, the sickness dropped off rapidly.

It seems evident from the sickness trends shown in the unit that sickness was dependent in the main on some development which followed a normal curve beginning in late July, reached a high in early September and almost terminated by early October. Increases and decreases during the period seemed dependent on the interplay of other factors such as strong winds, feeding habits of birds and water flow. If the sickness indices were charted, they would show sickness as divisible into eight major peaks. These are shown in the following tabulation:

Date of Peaks	Number of Birds Counted: Sick	Av. per trip	Dead	Av. per trip	Dikeside Pickup: Total	Av.
August 1-9	145	24	285	31	6	0.9
Aug. 10-16	230	46	124	18	16	2.7
Aug. 17-23	479	95	209	41	4	0.7
Aug. 24-31	785	196	336	84	44	6.3
Sept. 1-4	556	185	178	59	36	12.0
Sept. 5-13	1112	272	329	65	121	15.1
Sept. 14-21	1059	178	302	50	494	49.1
Sept. 22- Oct.10	577	72	51	6	85	9.4
Total	4943	117	1812	43	806	13.6

The reason behind these peaks can at present be only surmised, but it seemed apparent in the field that they were correlated in some manner with winds and water influences in reflooding moist fringes and alkali bulrush islands. It is difficult to disregard these apparent influences. High winds preceded all the major flareups, i.e., August 19, 25, September 2, 5, 11, 15, and 19. However, it was apparent that sickness increases did not always follow winds of high velocity. The direction and duration of the winds seemed important as did also the time. High winds following still higher winds of a few days previous would not reflood additional lands.

The upswing in levels due to influx of water began the second week in September and it is felt that the increased sickness between September 8 and 22 was due in part at least to the subsequent reflooding of the previously exposed area. There occurred also an increased utilization of Unit 2 as well as Unit 5, when Units 1 and 3 went dry. The reflooding of Unit 4 in mid-September equalized somewhat the distribution of birds. When Unit 1 was again reflooded beginning on September 25, utilization of Unit 2 also dropped off.

The locations of sick birds in Unit 2 during each of the peak periods are shown on thin maps included herein. (Figures 7 to 14). Interpretation of these data is facilitated by using each chart as an overlay on a Unit 2 outline map

FIGURE 7

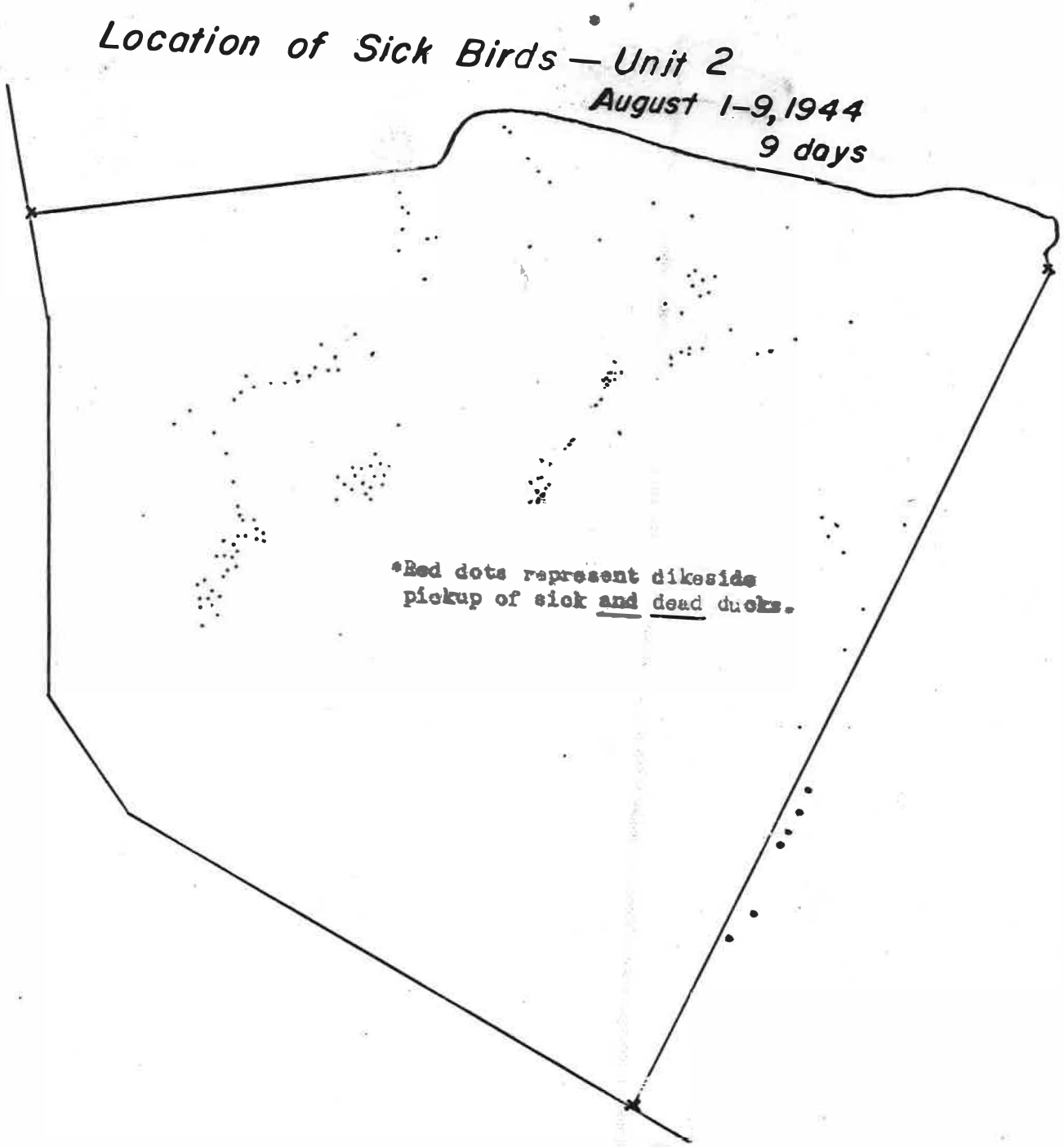
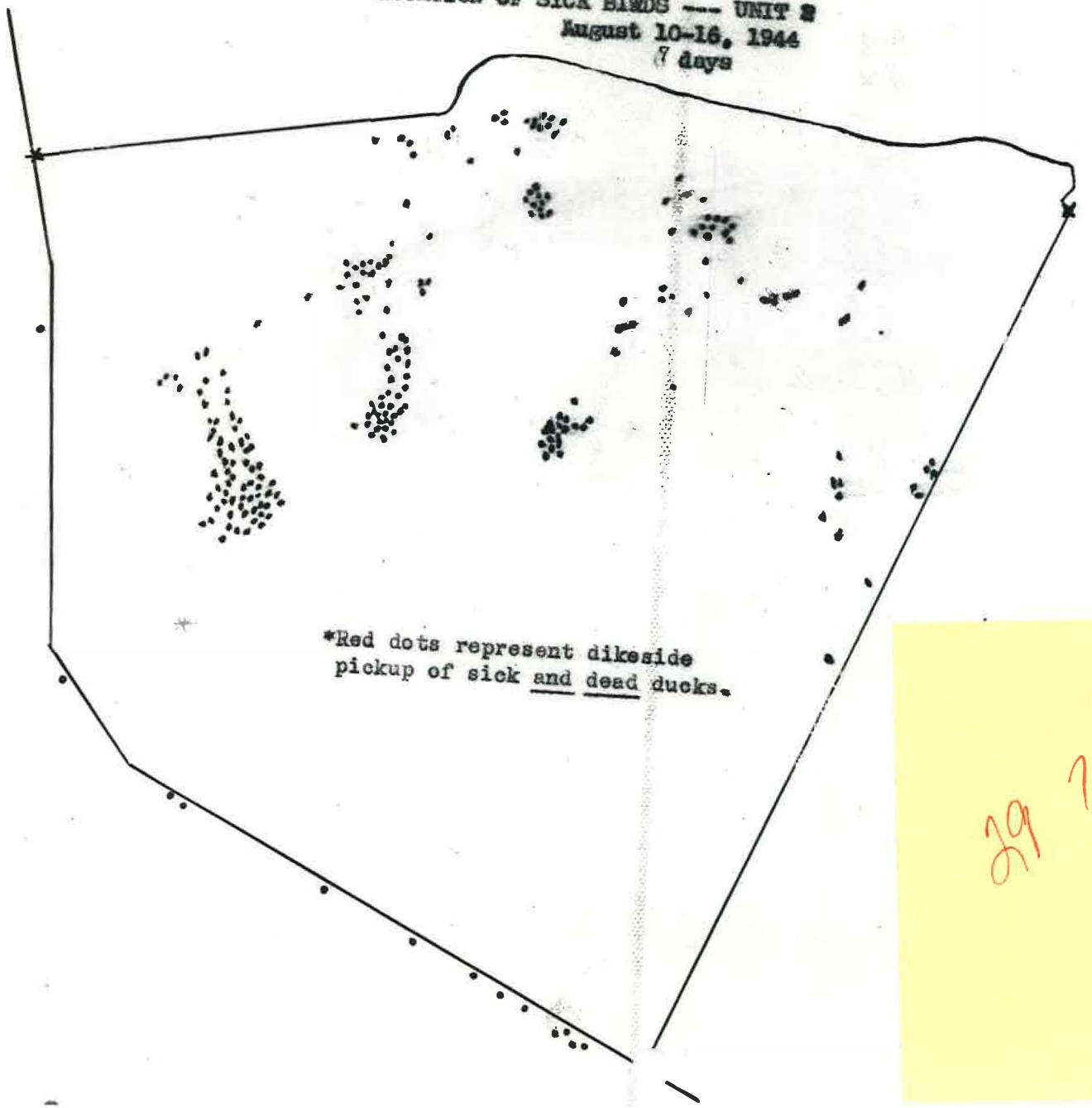

Location of Sick Birds — Unit 2
August 1-9, 1944
9 days
*Red dots represent dikeside pickup of sick and dead ducks.

FIGURE 8

LOCATION OF SICK BIRDS* --- UNIT 2
August 10-16, 1944
7 days



*Red dots represent dikeside pickup of sick and dead ducks.

29 ?

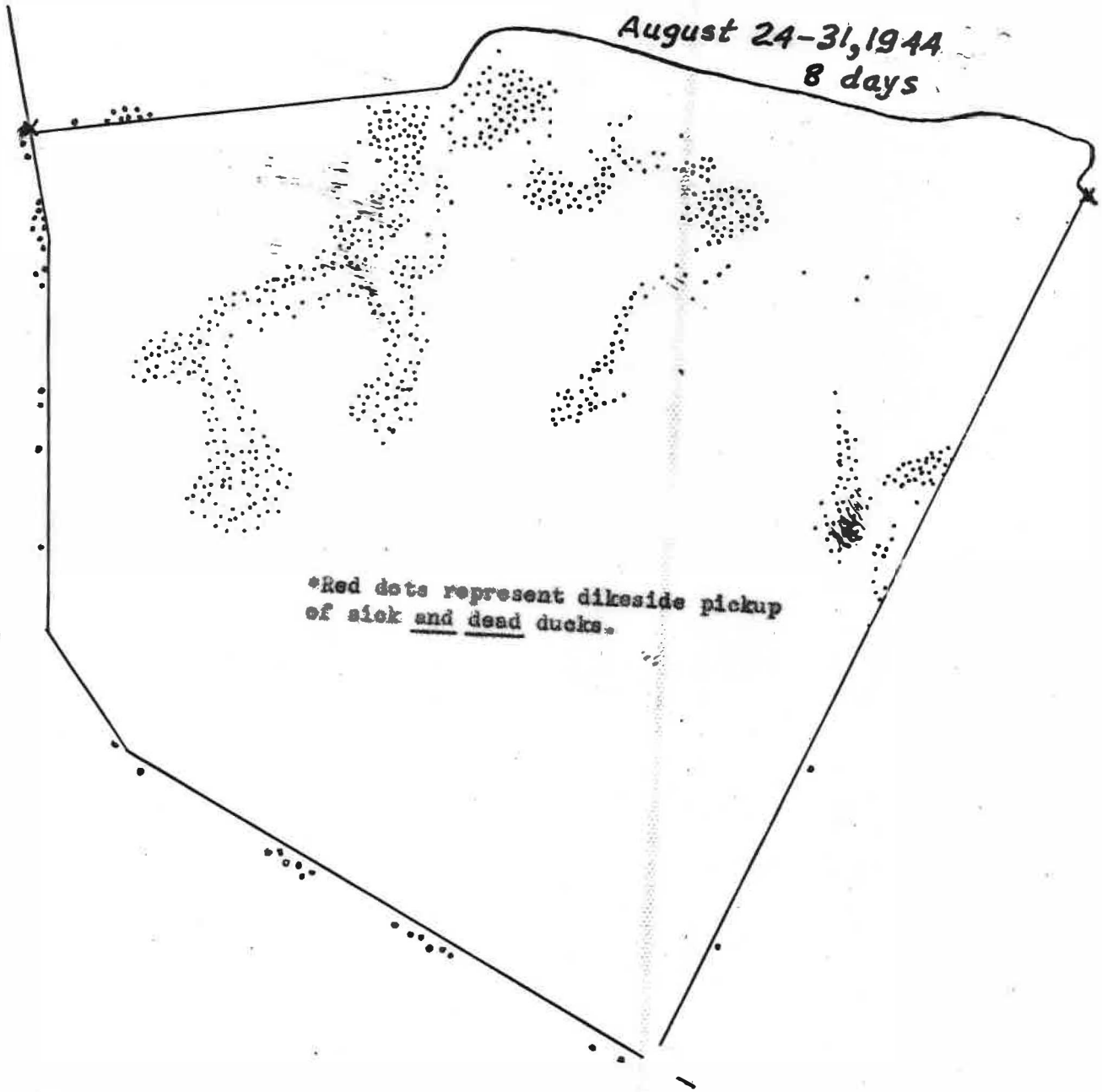
FIGURE 9

LOCATION OF SICK BIRDS--UNIT 2
August 17-23, 1944
7 days

*Red dots represent dikeside pickup of sick and dead ducks.

FIGURE 10

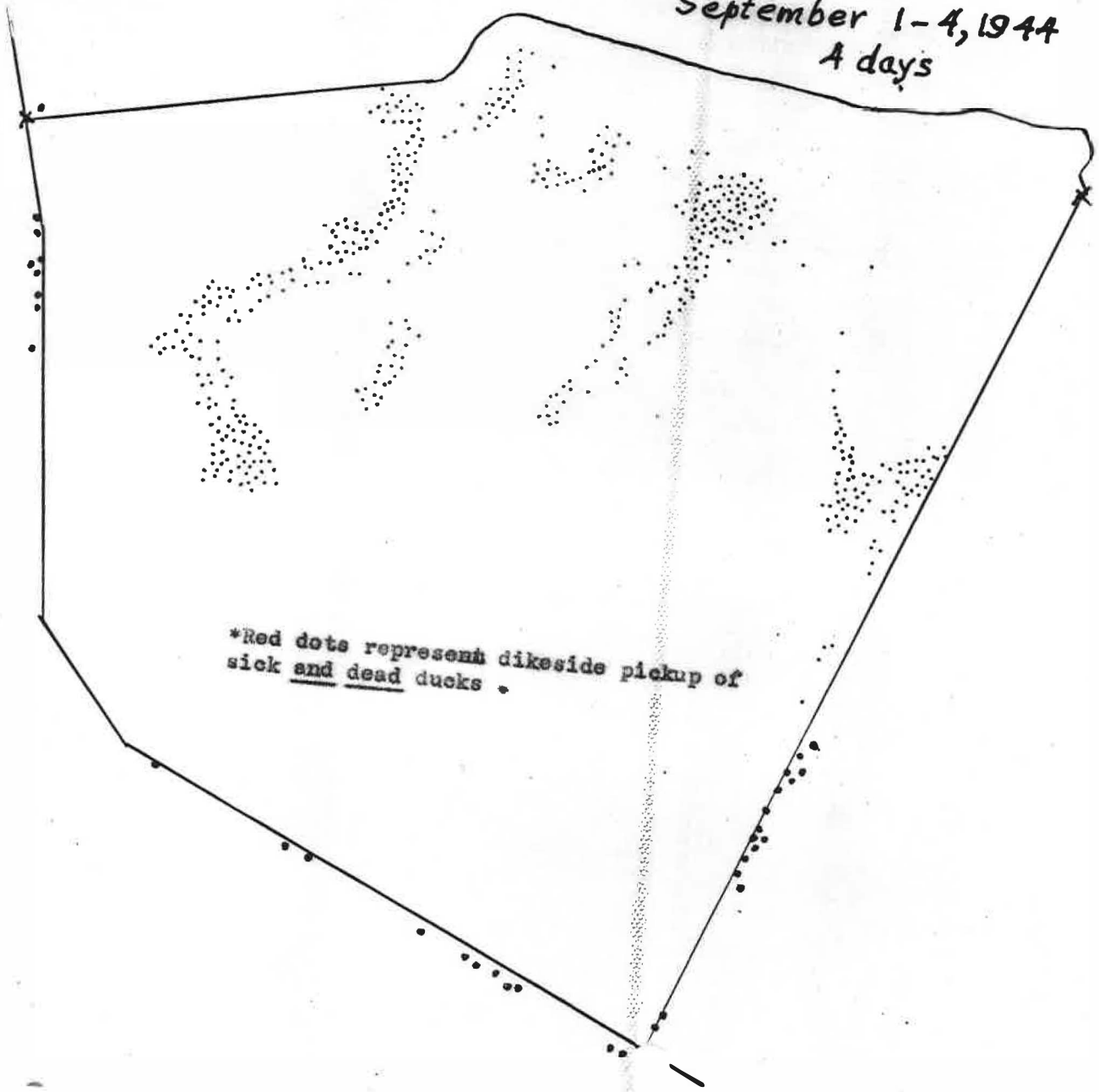
Location of Sick Birds* — Unit 2



*Red dots represent dikeside pickup of sick and dead ducks.

FIGURE 11

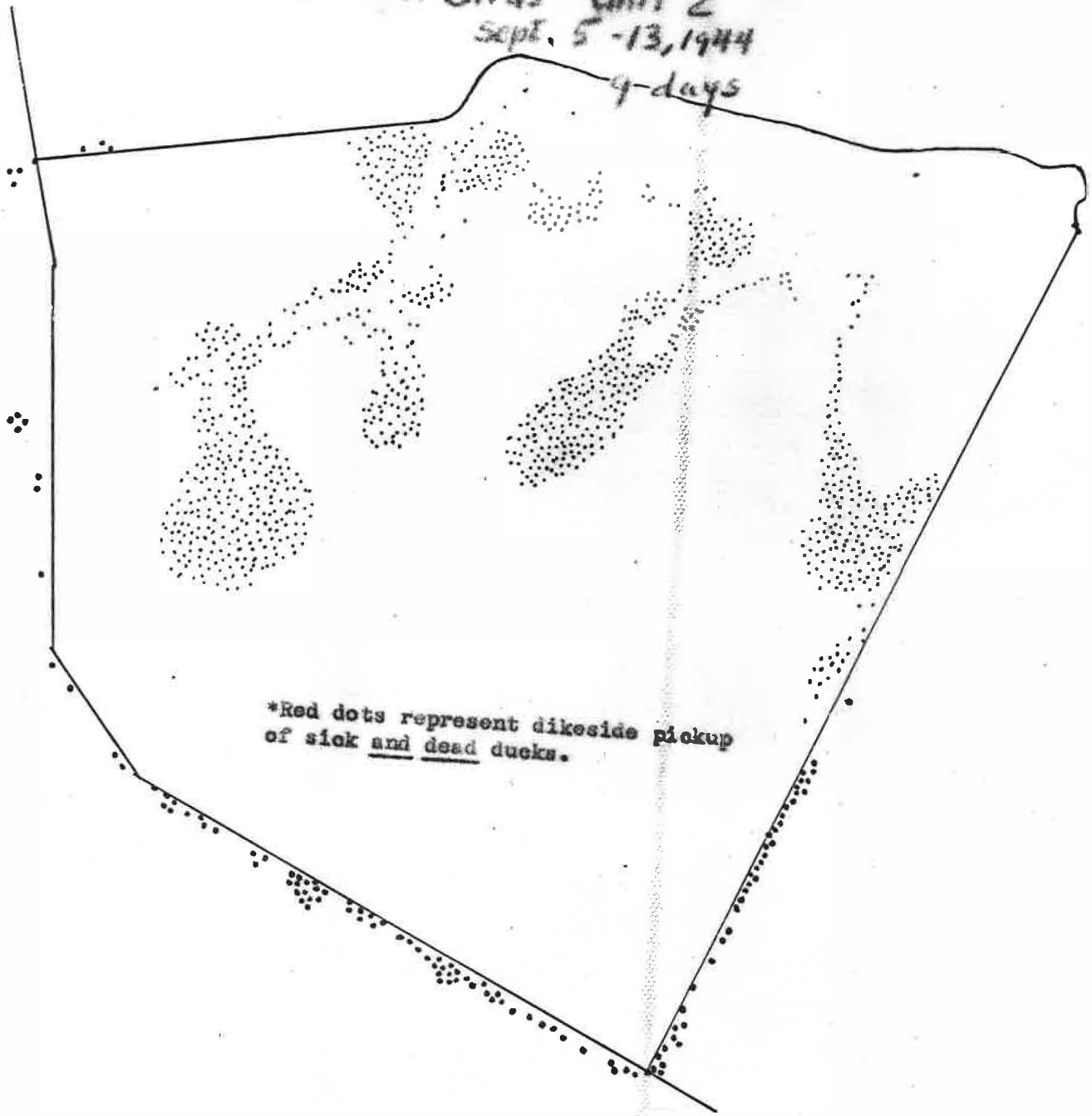
Location of Sick Birds—Unit 2*
September 1-4, 1944
4 days



*Red dots represent dikeside pickup of sick and dead ducks.

FIGURE 12

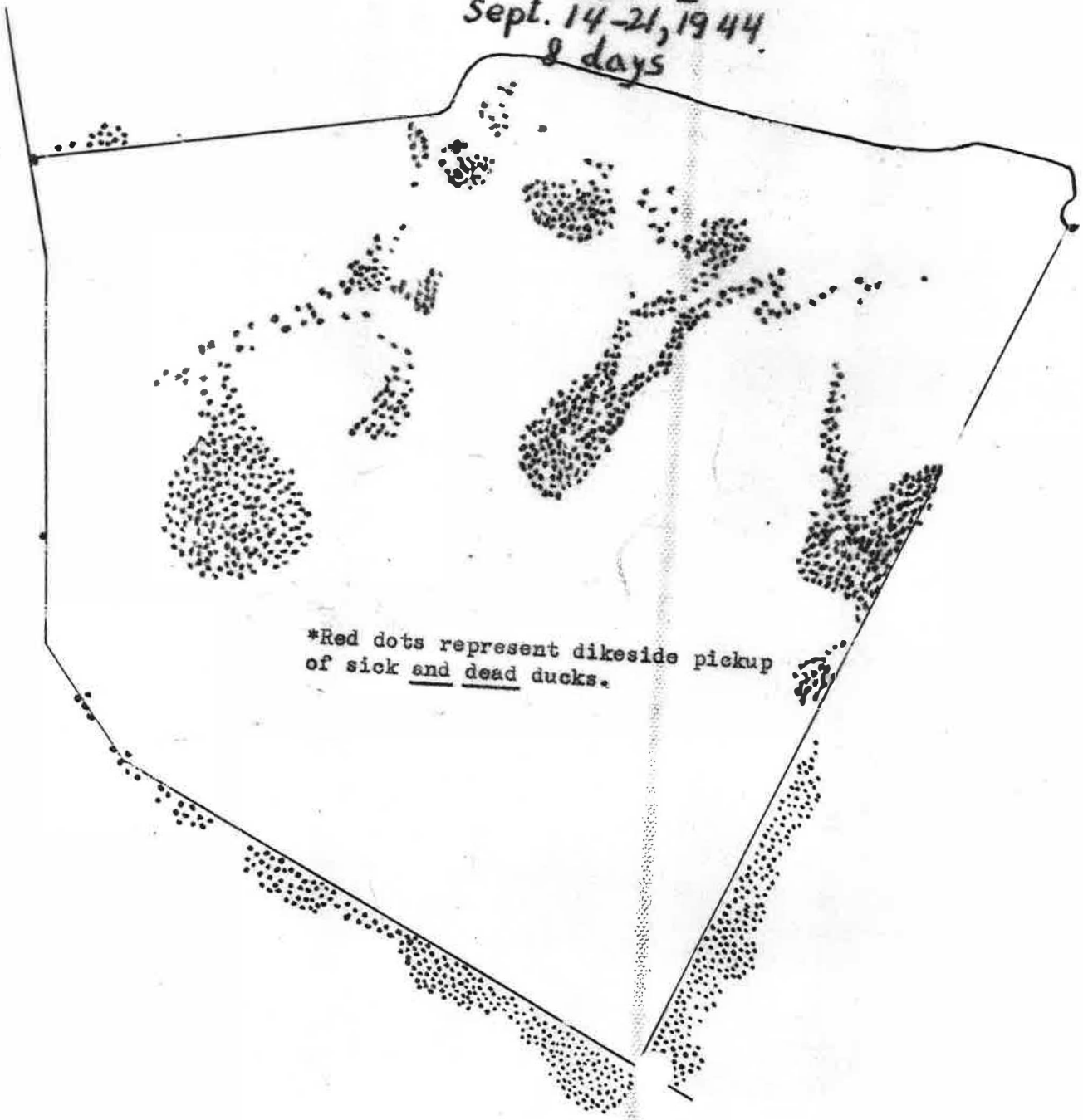
Location of Sick Birds - Unit 2
Sept. 5-13, 1944
9-days



*Red dots represent dikeside pickup of sick and dead ducks.

FIGURE 15

Location of Sick Birds - Unit 2
Sept. 14-21, 1944
8 days



*Red dots represent dikeside pickup of sick and dead ducks.

showing approximate water levels at high, low, and intermediate stages (Figure 15). Thus it is evident that sickness was pretty general in the marsh. The worst locations, however, appeared to be the overflow areas near the mouths of the main channels, the Rock Island area, and the Far Channel. Sickness was up in the latter area from the start, but did drop off on the north and west banks after the first week in September. In the Rock Island area, the source of sickness seemed to be the overflow area near the mouths of the adjacent channels. Sickness increased there along with the increase at other Channel areas to the east. This shift became evident on September 4 and apparently coincided with the increased flow which started the unit levels upward.

Three other locations were important. Two were alkali bulrush stands on the border of the fringe, the east sides in water, the west not. One could bank on finding sick birds at any time during the season on the east side. The other location was near the mouth of the lateral canal off the L-line. At this place, the muck was deep and, exposed in small islands which were frequented by avocets, stilts, and dowitchers. No flow was observed in the channel but water movement from the east frequently inundated the small islands. Most of the sick birds found in this location were dowitchers, although other species, particularly greenwinged teal and avocets, were encountered.

The upper channels were comparatively free of sick birds. It seemed apparent that botulism victims found there moved up from the lower areas; the further up a channel one went, the fewer the sick birds likely to be seen.

Dike-side observations and pick-up data clearly indicate that toxin was obtained in the interior of the unit rather than in deep water adjacent to the dikes or along the dike fringes. Two outstanding factors lead to such a conclusion, namely,

FIGURE 15

APPROXIMATE WATER LEVELS- UNIT 2, 1944

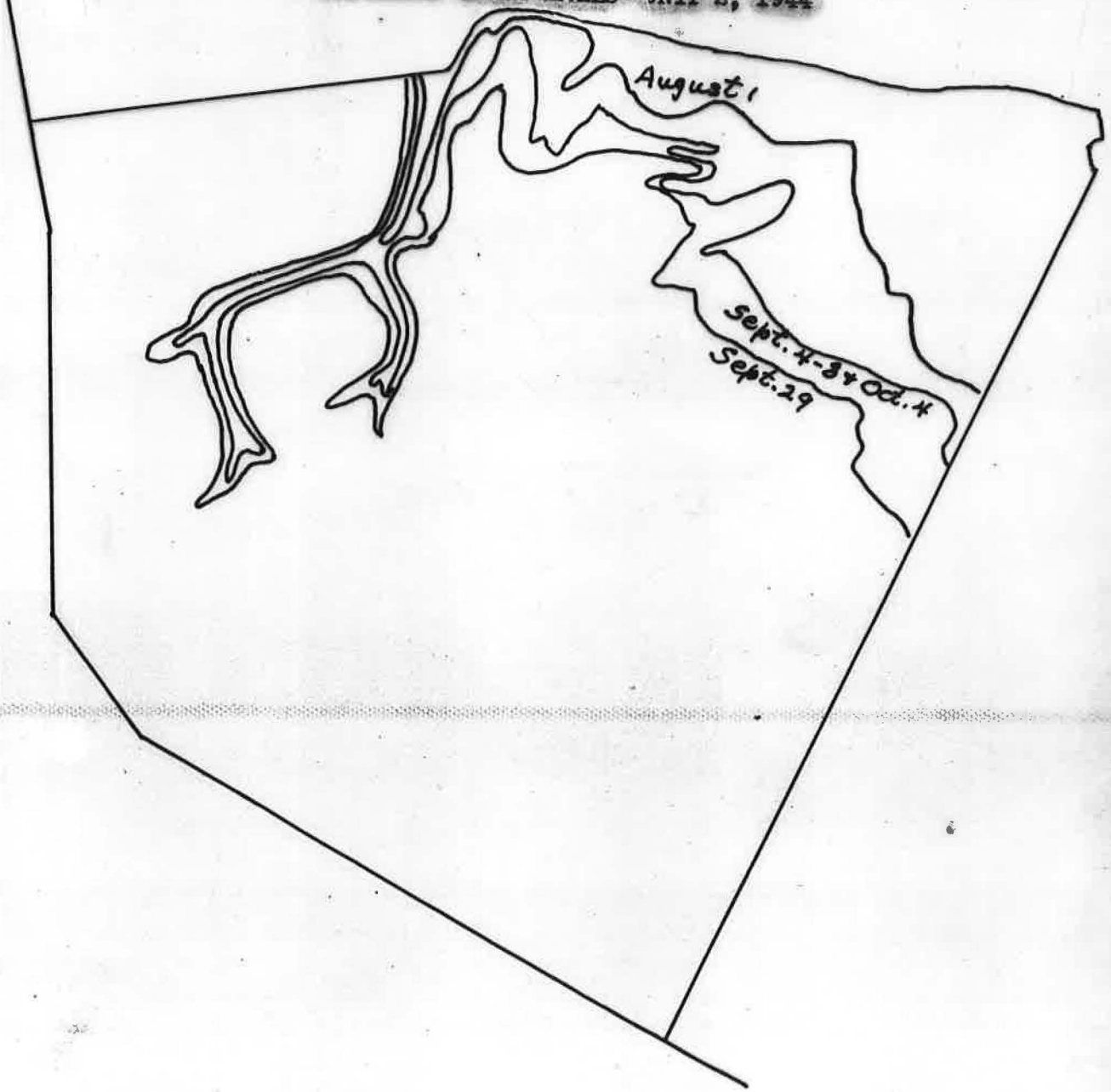


Figure 15 is an underlay for Figures 7 to 14.

FIGURE 16

APPROXIMATE WATER LEVELS- UNIT 2, 1944

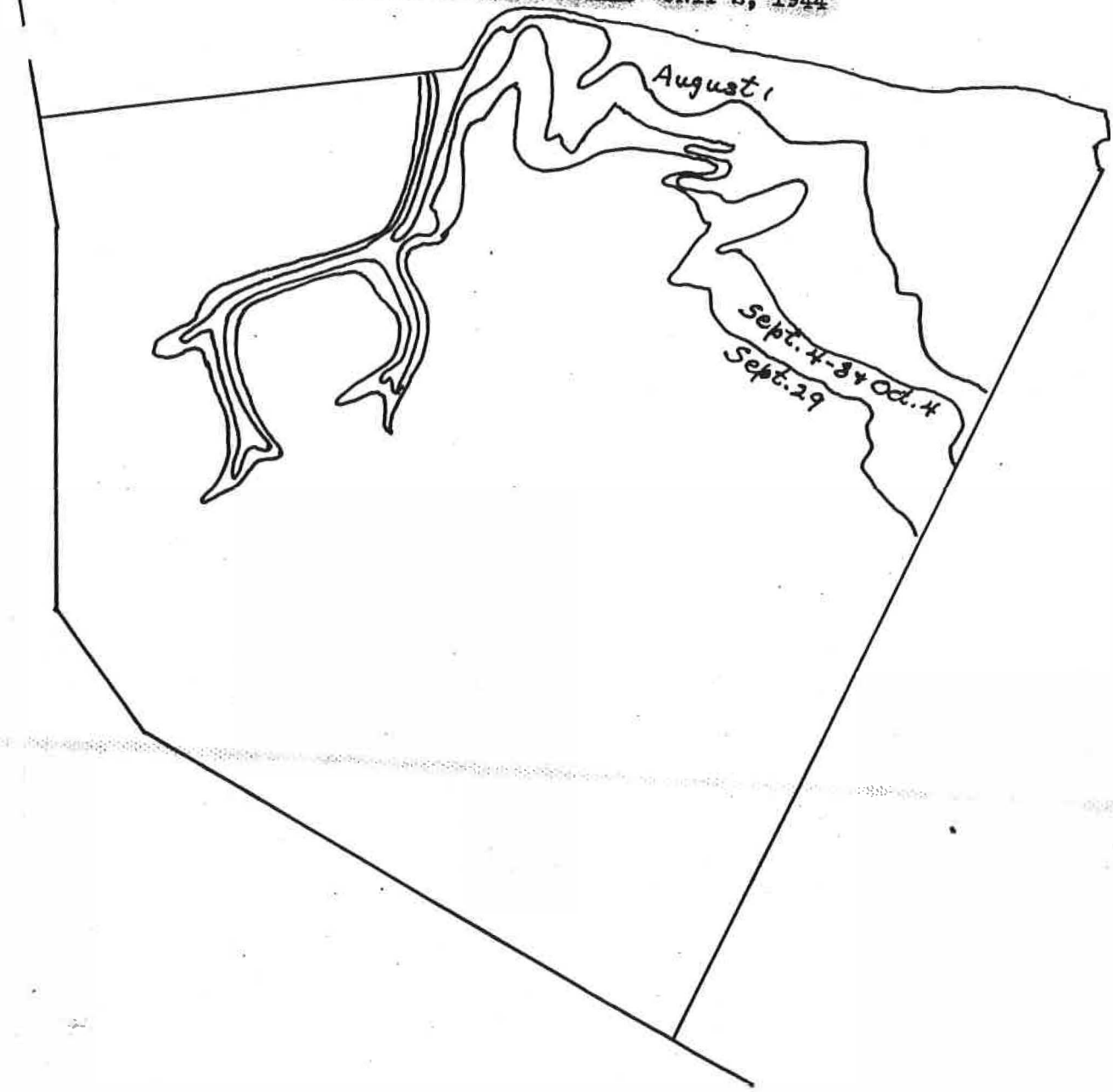


Figure 15 is an underlay for Figures 7 to 14.

1. A great majority of the dikeside collections in Unit 2 were carcasses of ducks --- not sick birds (691 dead and 115 sick) and many of them clearly were several days old.

2. Dike-side pickups in Unit 2 were light through August and early September but after September 10 every strong wind from the north or northwest washed many carcasses up on the southeastern dikes and it was following such winds only that large collections of dike—side carcasses could be made.

Unit 3

Projected schedule. "Unit 3 is to be filled early in spring to 4205.0 and, if water is available, maintained at that elevation until August 1, subject to priorities which have been given to Units 5 and 2. Beginning August 1, no more water will be permitted to enter Unit 3 until refilling is undertaken from the river. It is essential that accidental spilling of water from the river into the unit be prevented; consequently, it is essential that boards be placed in the major spillway at headquarters, August 1, and sandbagged if that is found necessary. Further, water from this unit is not to be used to help to refill Unit 4 at the time of experimental reflooding of that unit. The lowering in water levels is to be effected entirely by evaporation and transpiration; this phase of the experiment is to terminate when the unit becomes dry or, if this is not accomplished by September 24, refilling will be undertaken on that date if water is available. This unit will be refilled as rapidly as the available water will permit, subject to the priorities given Units 4 and 1 on the refill." (Director's Order dated February 7, 1944).

Purpose of Schedule: The schedule of Unit 3 was designed to learn the amount of sickness which would follow consistent reduction of levels in the unit by evaporation and other natural factors. It was felt that the constant

trend down at the evaporation rate might be sufficient to retard development of toxin and duck usage on exposed fringes.

Manipulation: Unit 3 began the experimental period, August 1, at level 4204.45 and lowered at the average rate of .41 inch per day until it was dry (4203.14) on September 8. The rate of lowering was more rapid than the evaporation indicated by either the pan records of this season or by the average pan records of previous years (Figure 16). Location of the fringe became more involved as the levels receded (Figure 17). During the lowering period, strong south winds caused refloodings on August 8, 18, 24, 28, and September 1. The wind of August 28 caused reflooding for only a short time for it shifted to a northerly direction with little change in velocity. Refilling the unit began October 30. A few days earlier some water flowed into the unit from Unit 4 through a broken spillbox but water did not get out of the borrow pits until October 3.

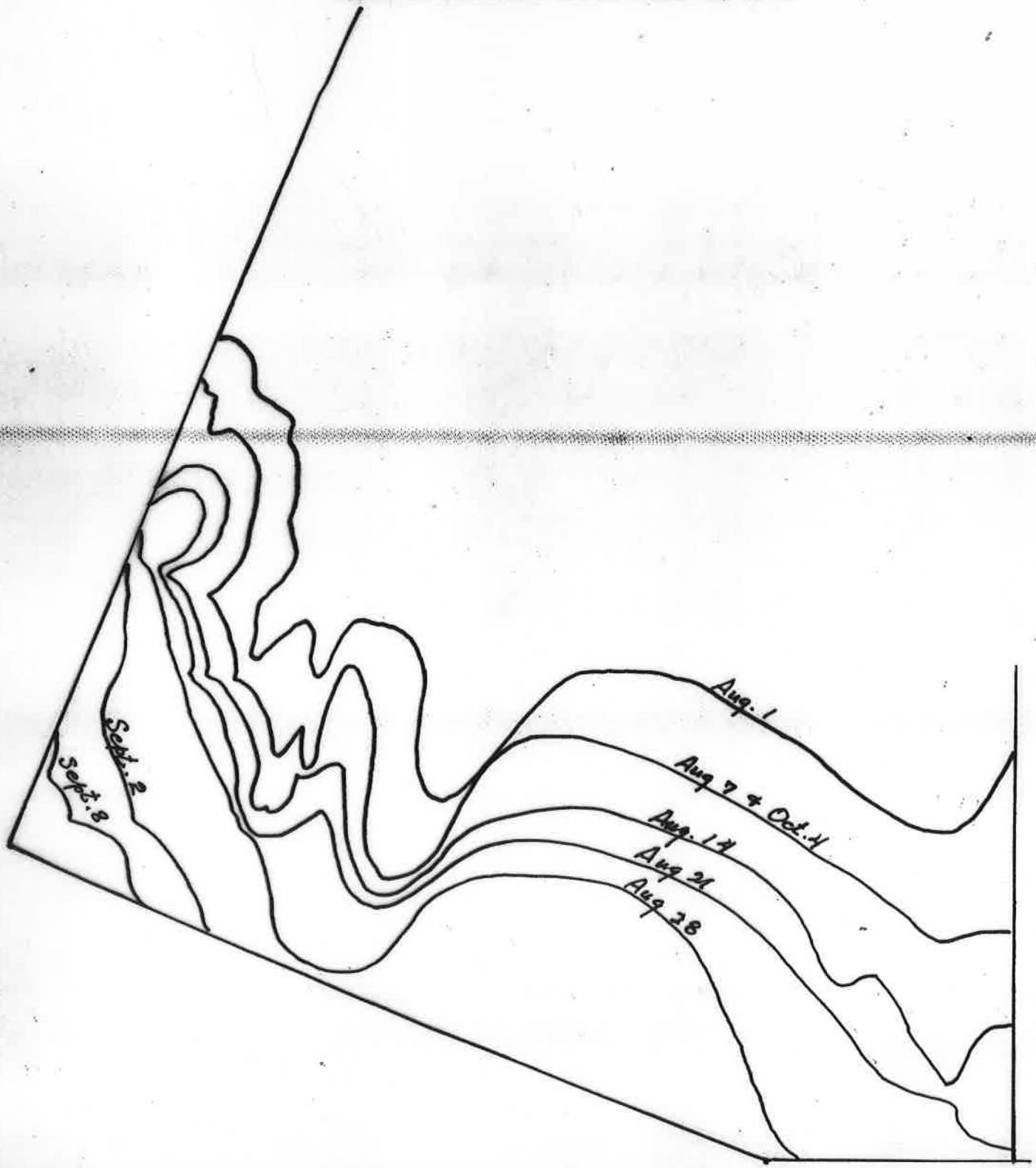
Sickness in Unit 3. Twenty-eight inspections of the unit were made over the fringe during the botulism period. The count of sick birds on these trips totalled 902, of dead birds, 264 (Table 5). The average numbers per trip were 32 sick and 9 dead. Compared to these, 1943 showed averages of 25 sick and 7 dead (Table 1).

Beginning with August 1, when the first botulism duck was seen in Unit 3, the dikes were patrolled 54 times and 853 botulism duck victims were collected -- 3 times as many as were picked up in 1943 (277) with essentially the same effort.

Sickness in the unit was apparent in early August, but not until August 19 did the count go above 50 sick birds. On that day, a noticeable flareup

FIGURE 17

APPROXIMATE WATER LEVELS—JULY 3, 1944



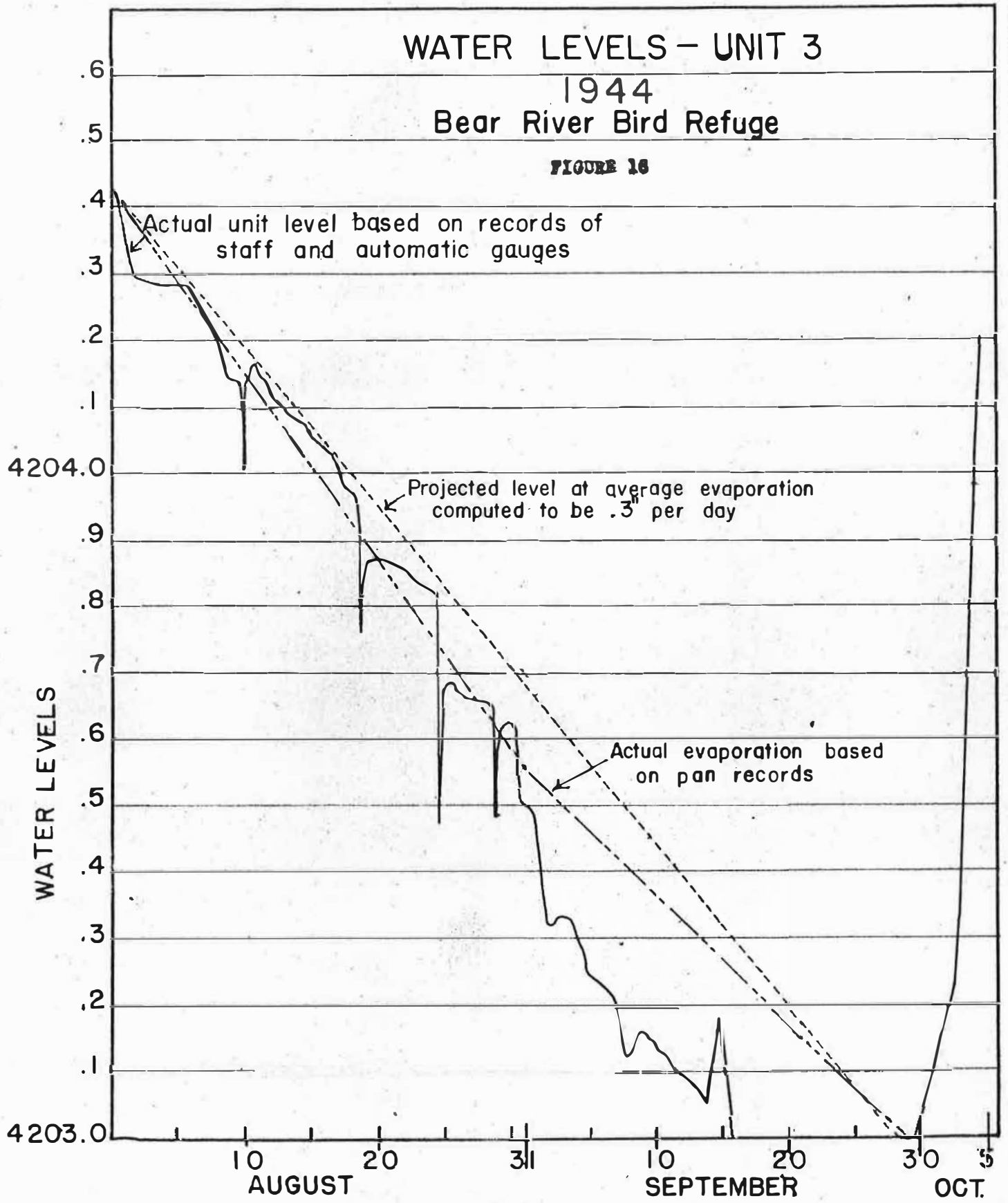

WATER LEVELS – UNIT 3
1944
Bear River Bird Refuge
Actual unit level based on records of staff and automatic gauges
Projected level at average evaporation computed to be .3" per day
Actual evaporation based on pan records
WATER LEVELS
.6
.5
.4
.3
.2
.1
4204.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
4203.0
10
20
31
10
20
30
5
AUGUST
SEPTEMBER
OCT.

FIGURE 16

TABLE 5 - DUCK SICKNESS APPRAISAL, UNIT 3 - 1944

Date	Fringe Count sick	Fringe Count new dead	Index of severity*	Dikeside pickup	Date	Fringe Count sick	Fringe Count new dead	Index of severity*	Dikeside pickup
Aug. 1	2	14	16	0	Sept. 7	-	-	-	15
2	-	-	-	-	8	3	3	-	4
3	8	22	28	1	9				4
4	9	5	6	2	10				-
5	-	-	-	0	11	Unit too dry			4
6	-	-	-	-	12				7
7	14	11	16	0	13	for use of			4
8	13	10	9	0	14				0
9	17	1	5	0	15	boat in			8
10	15	11	9	0	16				0
11	10	4	0	0	17	appraisal			-
12	-	-	-	0	18				0
13	-	-	-	-	19	of fringe			0
14	17	3	10	7	20				0
15	23	4	10	13	21	conditions			2
16	23	5	5	5	22				1
17	11	2	0	31	23				0
18	-	-	-	21	24	Sept. 9 to Oct. 4			0
19	78	10	77	30	25				0
20	-	-	-	-	26				-
21	63	10	0	80	27				0
22	98	4	39	46	28				0
23	37	8	0	62	29				2
24	19	6	0	69	30				0
25	129	41	151	65	Sept. total	176	55	x	183
26	-	-	-	44	Oct. 1				-
27	-	-	-	-	2				5
28	58	19	0	78	3				0
29	47	6	0	58	4				0
30	32	11	0	32	5	40	2	42	-
31	-	-	-	21	6	-	-	-	-
Aug. total	683	207	x	665-	7	-	-	-	-
Sept. 1	19	1	0	28	8	-	-	-	-
2	120	32	133	36	9	-	-	-	-
3	-	-	-	-	10	3	0	0	-
4	24	10	0	29	Oct. total	43	2	x	5
5	-	-	-	9	season totals	902	264	x	863
6	10	9	0	10					

*Index of severity = The number of new dead added to the number of sick minus the number of sick recorded on the immediately previous trip made within 5 days.

Page 42 (Figure 17) placed between pp. 45 and 46

took place following a strong south wind (Figure 18). Three other flareups occurred later, August 22, 25, and September 2. The first, a minor increase, could not be associated with any happening in the field. The latter two, however, were associated with very strong winds of the days immediately preceding them. In the first instance, a south wind blew 232 miles on August 24, and sickness on the fringe jumped from 25 sick and dead on that day to 170 on the following day. The flareup on September 1, gives even a better example of the influence winds may play in duck sickness. On August 30, a collection of all the sick and dead on Unit 3, including a dike-side pickup of 32, was made. No inspection of the fringe was made on the following day, but only 21 sick and dead ducks were collected in a complete coverage of the Unit 3 dikes. Comparable effort along the dikes the next day (September 1) yielded 28 botulism victims and the fringe count totalled only 19 sick and 1 dead. All that day a south wind, the strongest of the season, blew and the fringe sickness jumped to 120 sick and 32 dead; and the dike-side pickup doubled to 56. During the last major flareup Unit 3 held borrow pit water only except for a small area in the southwest corner (Figure 17) and the duck population did not exceed 1000.

The fringe sickness recorded on the peak days of these four flareups, i.e., on August 19, 22, 25, and September 1, amounted to 47 percent of all such sickness in the unit for the season. Total sickness in the 12 days embraced by these 4 flareups was 82 percent of the unit sickness as indicated by dike-side collections although the 12 days represented less than 20 percent of the botulism season.

The distribution of sick birds noted in Unit 3 implicates the western part of the area as the chief source of sickness (Figure 19). Three main concentration points were apparent: (1) on a muck flat peninsula east of the vegetation

FIGURE 18

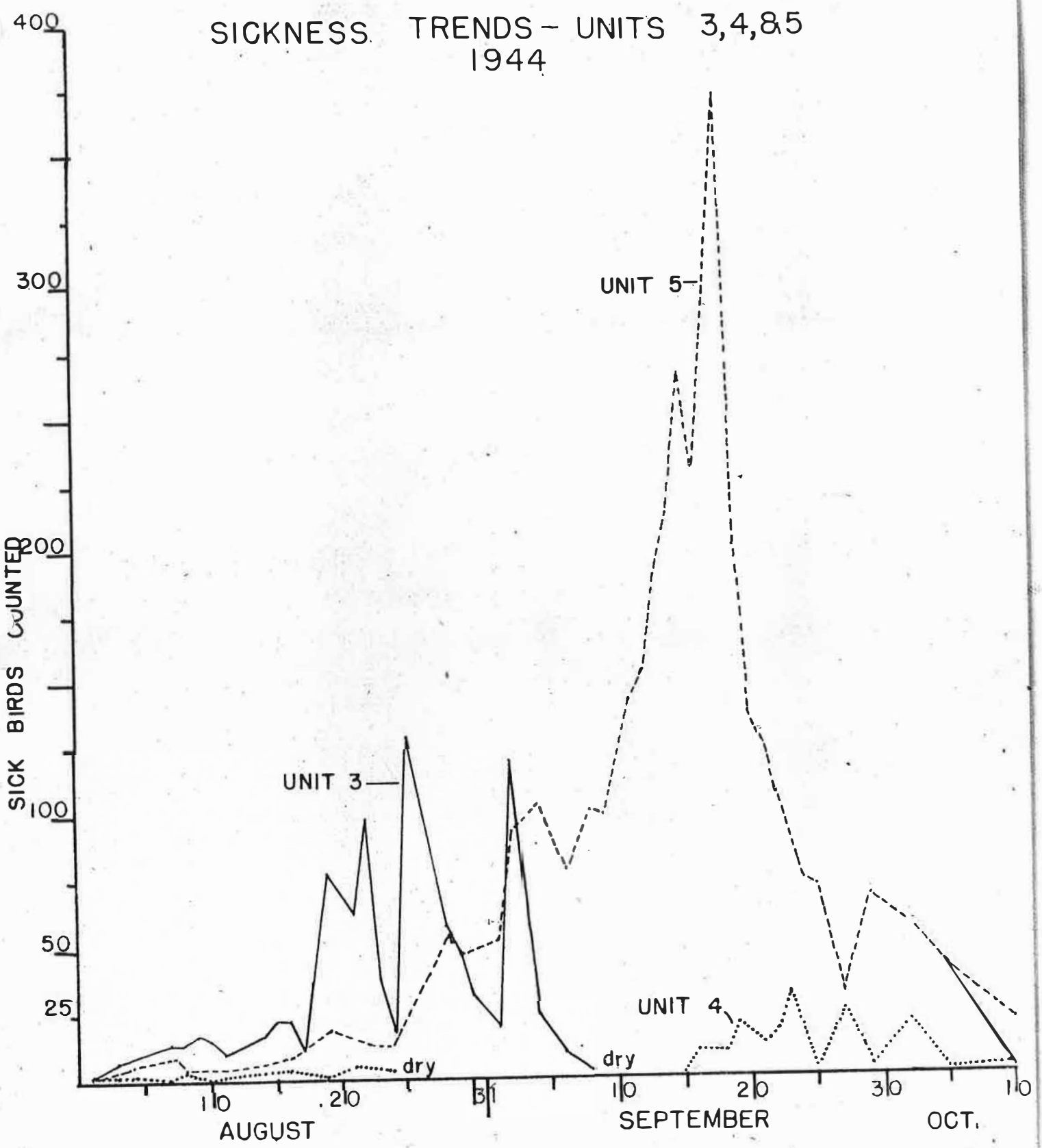
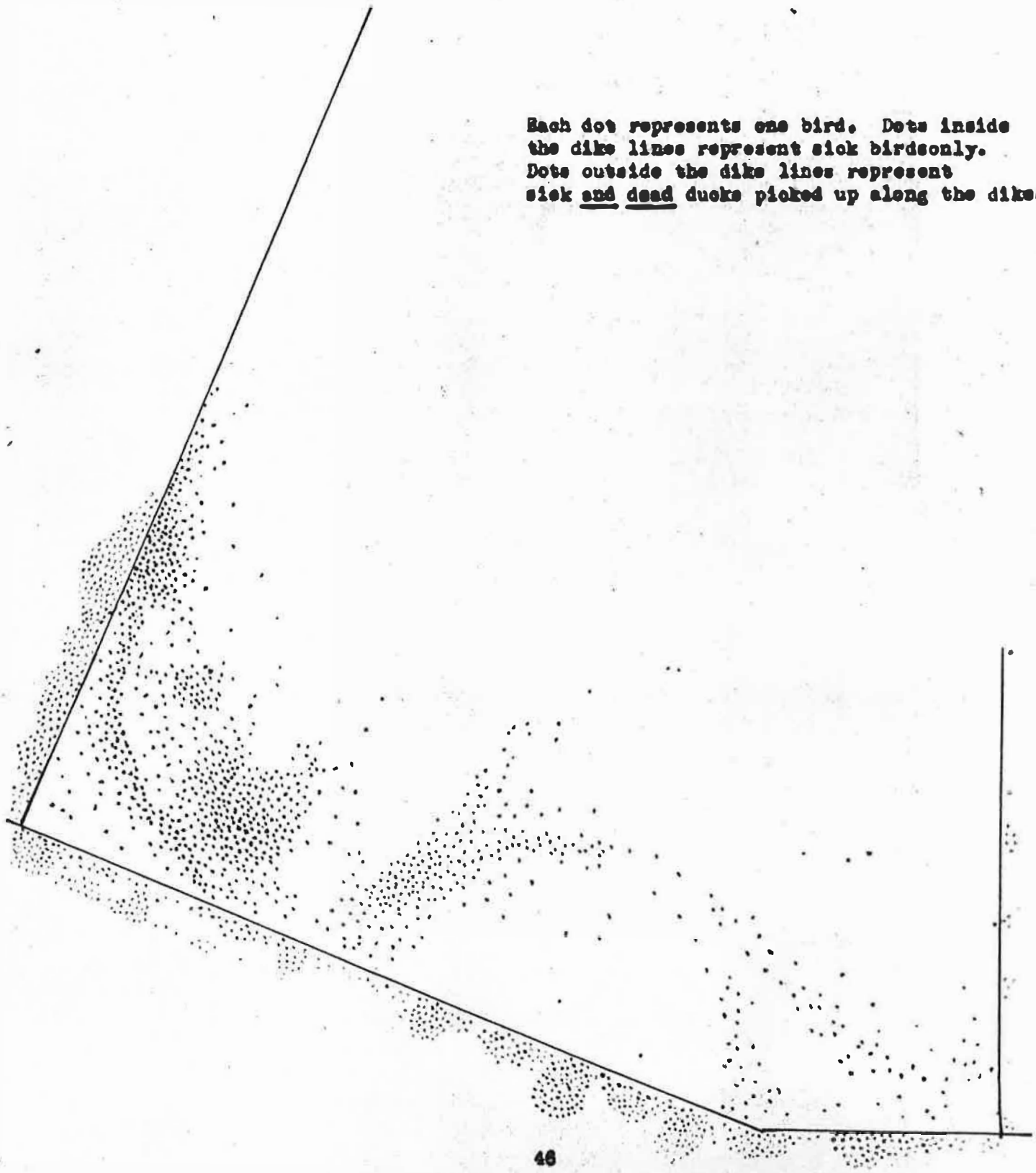

SICKNESS TRENDS - UNITS 3,4,&5
1944
SICK BIRDS COUNTED
400
300
200
100
50
25
UNIT 5
UNIT 3
UNIT 4
dry
dry
1 0
2 0
3 1
1 0
2 0
3 0
1 0
AUGUST
SEPTEMBER
OCT.

FIGURE 19

DISTRIBUTION OF SICK BIRDS— UNIT 3, 1944



2) the section south and west of the point of vegetation, and 3) in the bulrush island areas along and east of the H-line. It seemed obvious that the areas where levels receded slowest were the worst. Tension zones remained moist there longer and when these were flooded extensively, sickness increased markedly.

The data obtained on the fringe of this unit during 1944, offer evidence that the rate of level-lowering was sufficiently fast to prevent all but the stronger winds from reflooding extensive areas. They also indicate that when such winds do occur sickness increases can be expected. How large these may be apparently depends not so much on how many birds are frequenting the unit as a whole but on how many of them feed in the dangerous areas and on how long the reflooding remains.

The Unit 3 dike-side data of 1944 indicate that botulism was 3 times as serious as in 1943. Dike patrols during both seasons confirm the following conclusions:

1. Strong south winds usually are promptly followed by a substantial increase in the number of botulism victims along the dikes.

2. Dike-side increases in the number of botulism cases rise suddenly (flareup) but take several days to subside.

3. Evidence of increased sickness on the back side of Unit 3 is seen apparent along the dikes except when confined to the marshy northwest region.

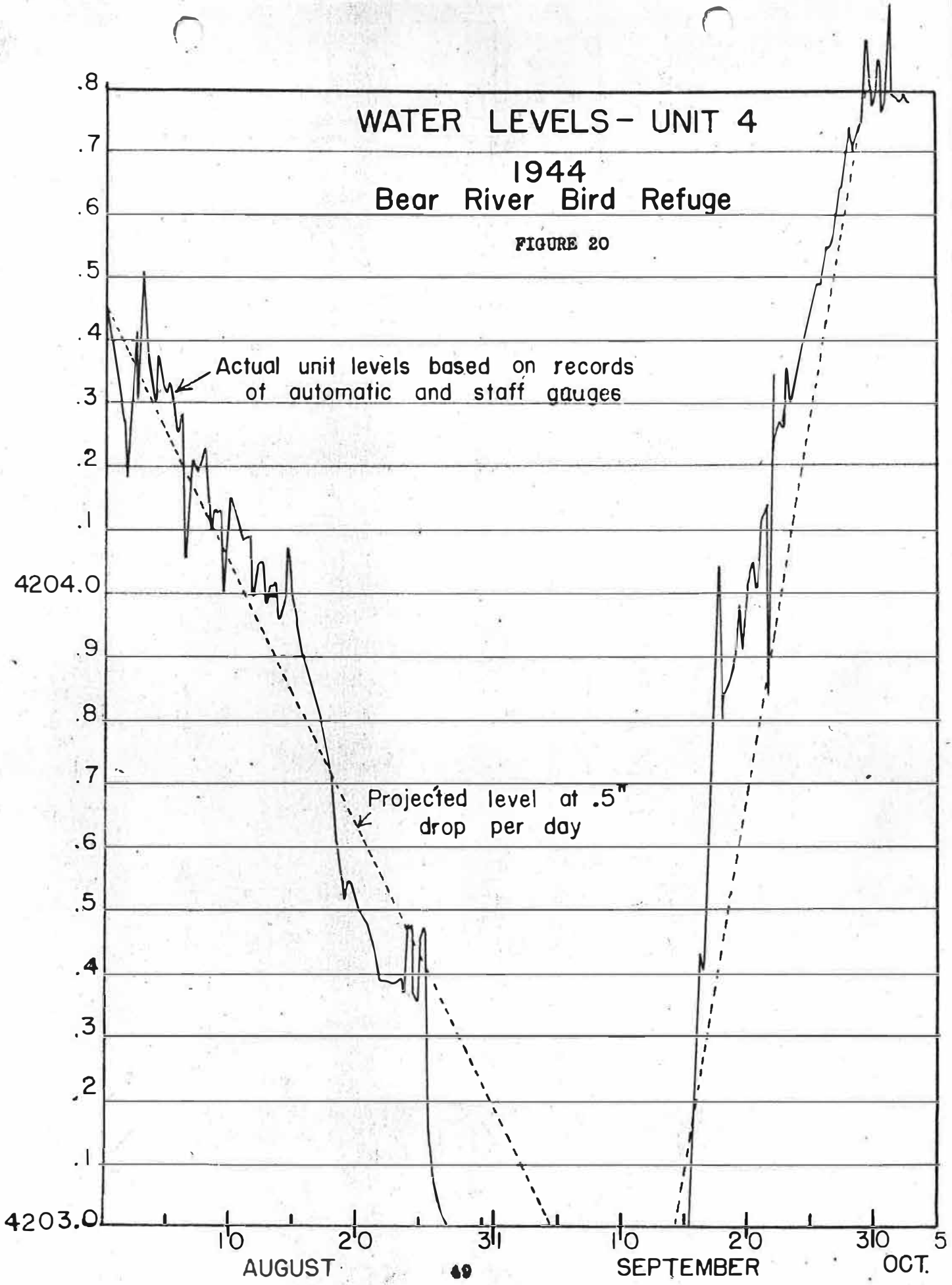
4. Botulism in Unit 3 seems definitely correlated with the outer fringe and is influenced but little by conditions along the dikes or in adjacent open water.

Unit 4

Projected schedule. "This unit is to be filled to elevation 4205.0 early in the spring. It is to be held as near that level as possible until August 1, priotity of water for maintenance in the several units being 5, 2, 3, and 1 in that order. Beginning August 1, no more water is to enter the unit — even though it may be available — until after the unit has dried. Beginning August 1, the water level will be reduced at the rate of 0.5 inch a day (including the loss from evaporation) until the unit is dry. Water released is to be spilled on the outside. It is possible that the unit may be dry late in August and the unit can, therefore, be used as an experimental one to test the effects of reflooding and stabilized fringe during the botulism season provided water is available at that time. Unit 4 is to have first priority of the use of available refill water, and water surplus to the needs of Unit 5 may be used for this purpose in accordance with written instructions furnished by the botulism committee as much in advance as possible". (Director's Order dated February 7, 1944).

Purpose of Schedule: Unit 3 and Unit 4 schedules were aimed at testing different rates of a continual drop in water levels on duck sickness. When the schedules were set up, it was thought Unit 3, which was to be reduced by evaporation alone, would lower at the rate of about .3 inch per day (average pan evaporation); whereas, Unit 4 was intended to go down about .2 inch per day faster by means of a constant water spill.

Manipulation: Unit 4 manipulation approached its projected schedule very closely, dropping at the average rate of .53 inch per day from its initial level of 4204.45 on August 1 (Figure 20). It dried to the borrow pits by August 22. Two days later a spillbox broke between Unit 3 and 4 flooding a small dry section


WATER LEVELS - UNIT 4
1944
Bear River Bird Refuge
FIGURE 20
Actual unit levels based on records of automatic and staff gauges
Projected level at .5" drop per day
.8
.7
.6
.5
.4
.3
.2
.1
4204.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
4203.0
1 0
2 0
3 1
1 0
2 0
3 0
5
AUGUST
SEPTEMBER
OCT.

in the southeast corner. This inflow evaporated within a few days and the unit remained dry until September 16 on which the refill was started at about 10:00 A.M. The refill was fast, the unit attaining the full level (4204.84) on September 29.

The experimental stabilization of levels to try producing some sickness was not attempted because by the time water needed for such an experiment was available, the period earmarked for experimentation was drawing to a close. Since Unit 4 had to be filled before Units 1 and 3, time was not available to experiment and get water to hunting levels in those units with the amount of water then in sight. It was determined advisable to forego the stabilization experiment and in doing so get a test of the refloeding of a lake bottom completely dry for nearly a month (August 22 to September 15).

Sickness in Unit 4. During the period in which Unit 4 was dropping at about .5 inch per day, practically no sickness developed on the fringe. Only 24 sick and 5 dead were observed on the fringe from August 1 until the unit went dry (Table 6). When the unit began to be refilled on September 15, some sickness was apparent but throughout the remainder of the season, only 176 sick birds were counted in 14 inspections of the fringe.

Many dike patrols were made around 3 sides of Unit 4 during late July and early August before the first botulism birds were seen there on August 9. The initial dikeside pickup from this unit was made the following day, but total collections were only 50 while the basin was being drained to the borrow pits (August 22). During the dry period (August 22 - September 15), when there was water in the borrow pits only, the dikeside pickup averaged 4 ducks per day -- the same as during the latter half of the drainage period.

TABLE 6 - DUCK SICKNESS APPRAISAL, UNIT 4 - 1944

Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup	Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup
Aug. 1	1	4	5	0	Sept. 7				3
2	-	-	-	-	8	Unit too dry-			6
3	1	0	0	0	9				5
4	1	0	0	0	10	for use of boat			-
5	-	-	-	0	11	in appraisal of			10
6	-	-	-	-	12	fringe conditions			6
7	0	0	0	0	13	Aug. 25 to Sept. 14			1
8	3	0	3	0	14				6
9	2	0	0	0	15	1	0	1	1
10	0	0	0	2	16	10	1	10	1
11	1	0	1	2	17	-	-	-	-
12	-	-	-	1	18	10	0	0	42
13	-	-	-	-	19	20	0	10	31
14	3	0	2	0	20	16	6	1	55
15	0	0	0	0	21	13	2	0	38
16	3	1	4	7	22	16	1	4	28
17	-	-	-	9	23	31	2	17	83
18	-	-	-	14	24	-	-	-	-
19	1	0	0	4	25	4	0	0	28
20	-	-	-	-	26	-	-	-	-
21	8	0	4	11	27	25	6	27	27
22	-	-	-	7	28	-	-	-	18
23	-	-	-	3	29	4	0	0	14
24	3	0	0	9	30	-	-	-	10
25				7	Sept. total	150	17	x	424
26	Unit near			11	Oct. 1	-	-	-	-
27				-	2	20	0	16	23
28	dry; no			7	3	-	-	-	-
29				0	4	-	-	-	-
30	Fringe counts made.			3	5	2	0	0	-
31				1	6	-	-	-	-
					7	-	-	-	-
Aug. total	24	5	x	98					
Sept. 1				3	8	-	-	-	-
2				5	9	-	-	-	-
3				-	10	4	0	2	-
4				0	Oct. total	26	0	x	23
5				3	Season				
6				2	totals	200	22		545

*Index of severity = The number of new dead added to the number of sick minus the number of sick recorded on the immediately previous trip made within 5 days.

Thus the 1944 season was a repeat of 1943 in that under the conditions of the first drop down Unit 4 had no appreciable sickness either on the fringe or along the dikes. It is logical to wonder why sickness did not go highhr in Unit 4. Winds, of course, blew across Unit 4 as well as in Unit 3 where so much of the sickness was thought to be correlated with wind action. Several factors probably contributed to the difference. The rate of drop in Unit 4 was appreciably faster than in Unit 3 and it would take a stronger wind to reflood exposed lake bottom of the same dryness. In addition, only one of the strong winds affecting Unit 3, that of August 18, occurred while Unit 4 was being drained and at that time the water was low, being well within the protection of the B-line dike.

The refill that began on September 15 was promptly followed by a marked increase in botulism along the dikes -- 1 case on the 16th and 42 cases on the 18th. This increase, while not alarming, definitely was more than the greater bird usage alone would justify because the population stepup was from about 500 to 10,000. After the initial flare, dikeside pickup dropped about 25 percent and then fluctuated little except for a peak collection of 83 botulism ducks on September 23 -- probably the result of a high wind from the southwest on the 21st. Total dikeside pickup during the refilling was 396 sick and dead ducks -- an average of 23.3 per day. This was close to the 1943 average of 26 but the 1943 refloeding was halted for a stabilization experiment and later continued, so that twice as many days elapsed between initial refloeding and complete filling as in 1944 and total botulism losses were much greater - 946 as compared to 396. Bear River field data in general, however, indicate that 1944 conditions were more favorable to botulism production than were those of 1943. We conclude,

therefore, that the minor losses in Unit 4 this year may be due to the longer period of drying of the exposed lake bottom. For in 1943 the unit was reflooded before the lake bottom dried out while this year the reflooding was over lake bottom entirely dried for 25 days.

Distribution of sick birds on Unit 4 is fairly well scattered and shows no concentration points (Figure 21). However, more records are in evidence to the east side than to the west. It seemed evident as the appraisals were being made that little toxin was available on the fringe and that it was likely the sick birds observed along the dikes were getting their toxin in the same general area. Some of the more active sick ducks collected along the northern half of the F-line were fringe birds from the shoal northwest corner of Unit 5 that crossed the dike into the protecting deep water of the Unit 4 borrow pit.

Unit 5

Projected schedule. "Unit 5 is to be used to test the botulism trend in a completely impounded area and is to be filled early in spring to elevation 4205.25 and maintained at that level until September 24. This unit is to have first priority of water use, with a view of maintaining a level at elevation contour 4205.25 throughout the entire season from the time of filling to September 24". (Director's Order dated February 7, 1944).

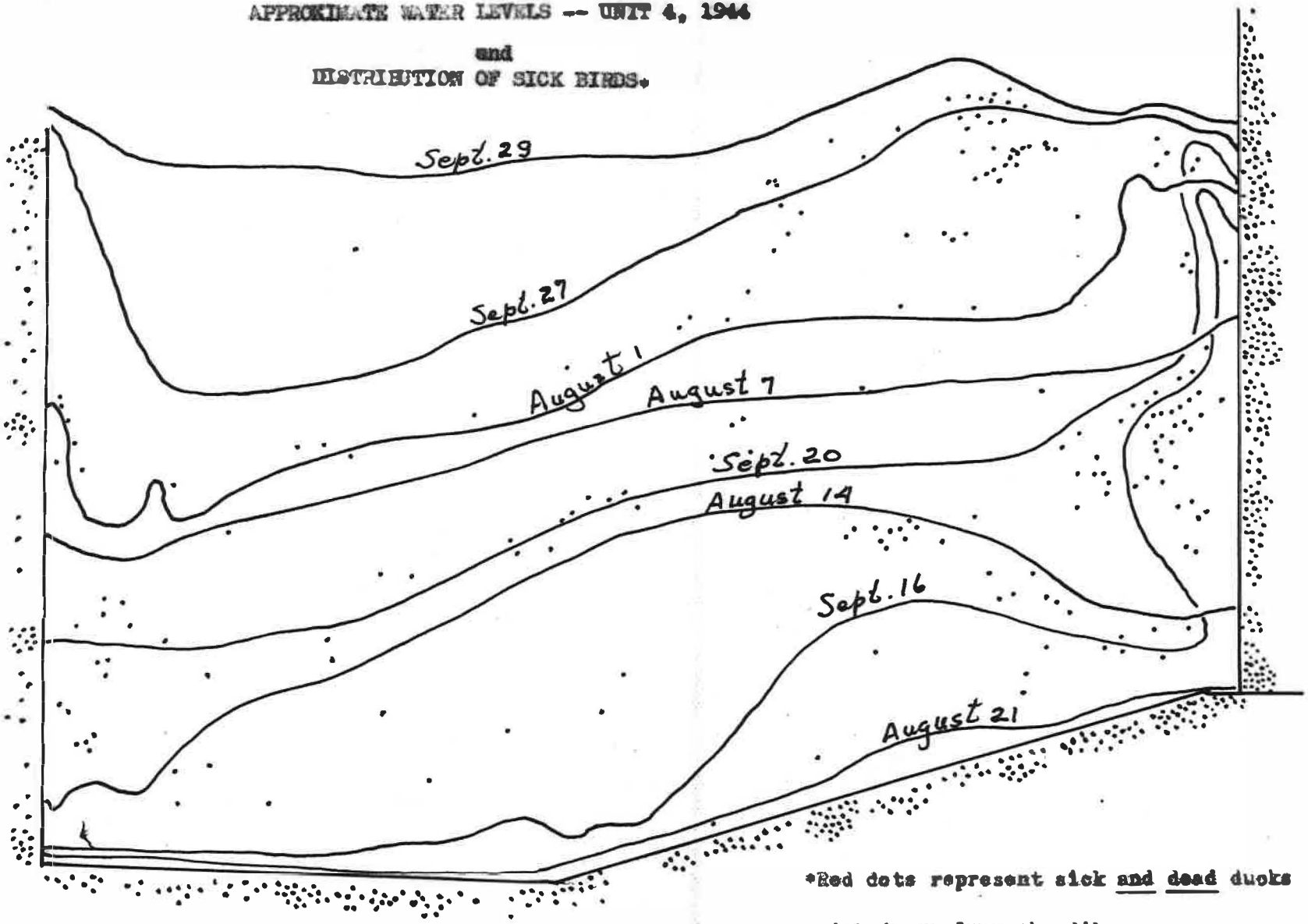
Purpose of Schedule. The schedule for handling water in Unit 5 was aimed at learning what sickness would occur in the unit when the water's edge remained consistently on abrupt banks and there would be no reflooding of extensive flats. The level was stipulated to be lower this year to reduce the flooding of lands north of the main unit that occurred last year and made appraisal of sickness and location of the source of toxicity very difficult.

FIGURE 21

APPROXIMATE WATER LEVELS -- UNIT 4, 1944

and

DISTRIBUTION OF SICK BIRDS.*



*Red dots represent sick and dead ducks picked up along the dikes.

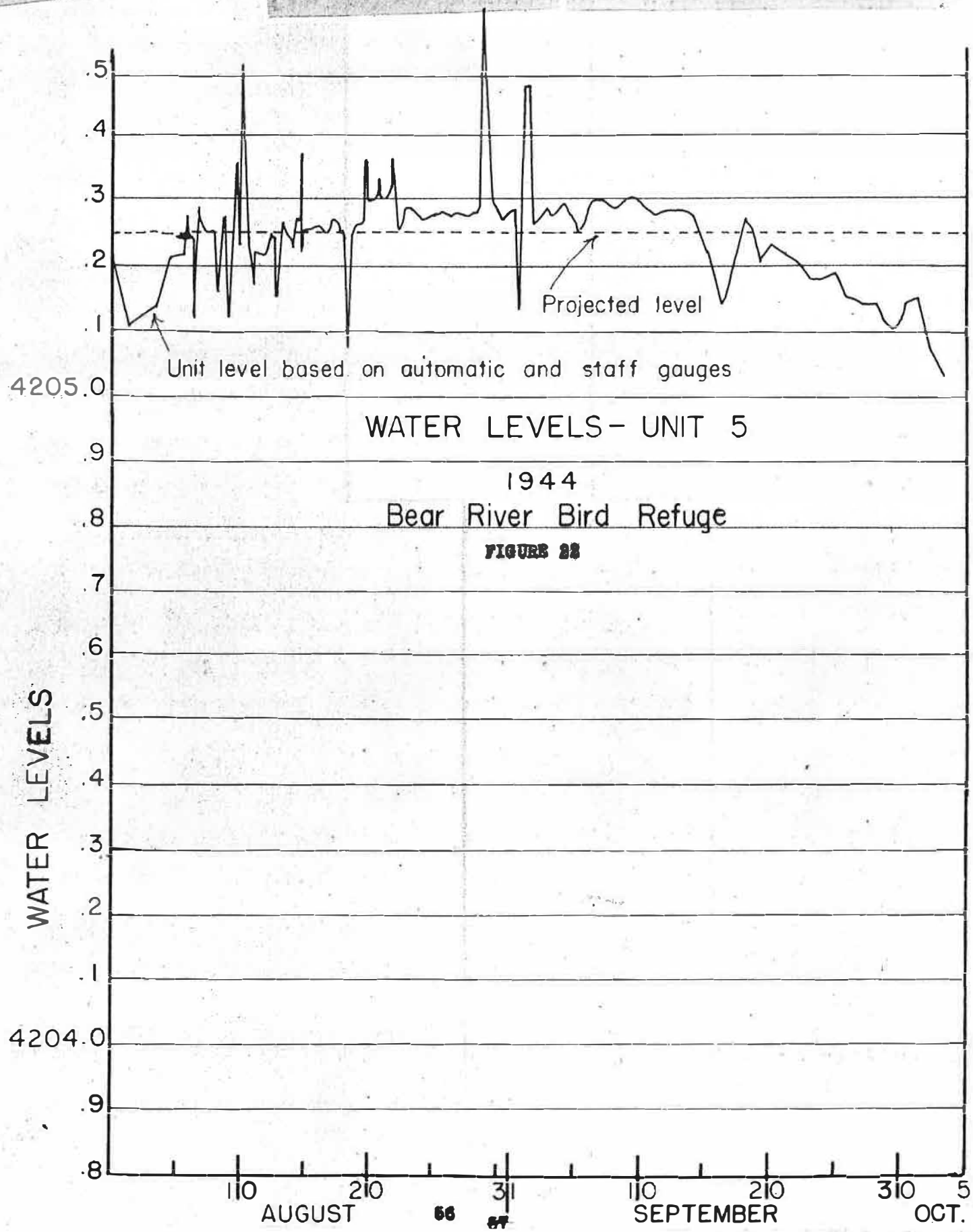
Manipulation. The levels of Unit 5 stood at 4205.21 at the start of the experimental period (Figure 22). Except for variation in readings caused by winds the unit fluctuated between 4205.21 and 4205.30 until September 15 when the filling of Unit 4 helped to reduce Unit 5 levels. After that date the levels slowly dropped to 4205.14 at the end of September. On October 4, the level stood at 4205.03 and water was flowing into Unit 4.

Under the levels holding this year during the experimental period, there were only a few small places of mud exposed south of the north channel bank across the unit. These were narrow and continually moist or flooded. To the north the area of flooding was limited to the three-way canal area and north of the old channels east of Reeder's Canal (Figure 23). Water in this latter area was evidently coming south across the Bear River Silts from the Knudson Marsh area.

Sickness in Unit 5. In appraising the sickness on the fringe of Unit 5, 37 inspections were made between August 1 and October 11. On these inspections 3232 sick and 950 dead birds were counted, an average per trip of 87 sick and 25 dead (Table 7). Compared to these figures, sickness in Unit 5 during 1943 was low. The average numbers of sick and dead birds counted per day that season were 23 sick 8 dead (Table 1).

Unit 5 dikes received cursory to searching attention almost daily after mid-July but 24 inspections were made before the first dike-side botulism cases were noted on August 18. From that day until October 4 there were 41 additional dike patrols made and 1111 botulism duck victims collected -- 19 times as many (59) as were gathered by similar work along the same dikes in the 1943 season.

During the first month of the experimental period (August), only 190 sick and 123 dead were counted in 13 trips across the unit, while 26 dike-side patrols yielded but 30 botulism cases (Figure 24).



WATER LEVELS- UNIT 5

1944

Bear River Bird Refuge

FIGURE 22

TABLE 7 - DUCK SICKNESS APPRAISAL, UNIT 5 - 1944

Date	Fringe count sick	Fringe count new dead	Index of Severity*	Dikeside pickup	Date	Fringe count sick	Fringe count new dead	Index of severity*	Dikeside pickup
Aug. 1	1	1	2	0	Sept. 7	7	-	-	29
2	-	-	-	-	8	102	35	58	26
3	2	3	4	0	9	100	27	25	15
4	6	3	7	0	10	-	-	-	-
5	-	-	-	0	11	144	32	76	46
6	-	-	-	-	12	154	41	51	18
7	9	4	7	0	13	190	49	85	22
8	4	9	4	0	14	213	41	64	12
9	-	-	-	0	15	266	55	108	59
10	-	-	-	0	16	231	73	38	20
11	5	9	10	0	17	-	-	-	-
12	-	-	-	0	18	372	54	195	136
13	-	-	-	-	19	202	144	0	179
14	7	7	9	0	20	138	31	0	110
15	-	-	-	0	21	126	24	12	58
16	9	8	10	0	22	107	26	7	27
17	-	-	-	0	23	-	-	-	38
18	-	-	-	3	24	75	14	0	-
19	17	18	26	0	25	73	5	3	37
20	-	-	-	-	26	-	-	-	-
21	-	-	-	3	27	32	17	0	16
22	14	13	16	2	28	-	-	-	11
23	-	-	-	3	29	68	3	39	8
24	14	1	1	0	30	-	-	-	0
25	-	-	-	0	Sept. total	2923	825	x	1066
26	-	-	-	2	Oct. 1	-	-	-	-
27	-	-	-	-	2	57	1	0	15
28	34	40	50	5	3	-	-	-	0
29	48	7	1	2	4	-	-	-	0
30	-	-	-	3	5	41	1	0	-
31	-	-	-	5	6	-	-	-	-
Aug. total	190	123	x	30	7	-	-	-	-
Sept. 1	33	18	23	1	8	-	-	-	-
2	94	29	70	9	9	-	-	-	-
3	-	-	-	-	10	21	0	0	-
4	104	47	57	53	Oct. total	119	2	x	15
5	-	-	-	13	Season				
6	79	60	35	113	totals	3232	960		1111

*Index of severity = The number of new dead added to the number of sick minus the number of sick recorded on the immediately previous trip made within 5 days.

FIGURE 23

APPROXIMATE WATER LEVELS— UNIT 5, AUGUST 1 - OCTOBER 4,1944

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
VEGETATION TYPE MAP - UNIT 5
BEAR RIVER MIGRATORY WATERFOWL REFUGE
BOX ELDER COUNTY, UTAH
PREPARED IN DIVISION OF WILDLIFE RESEARCH
APRIL - 1941

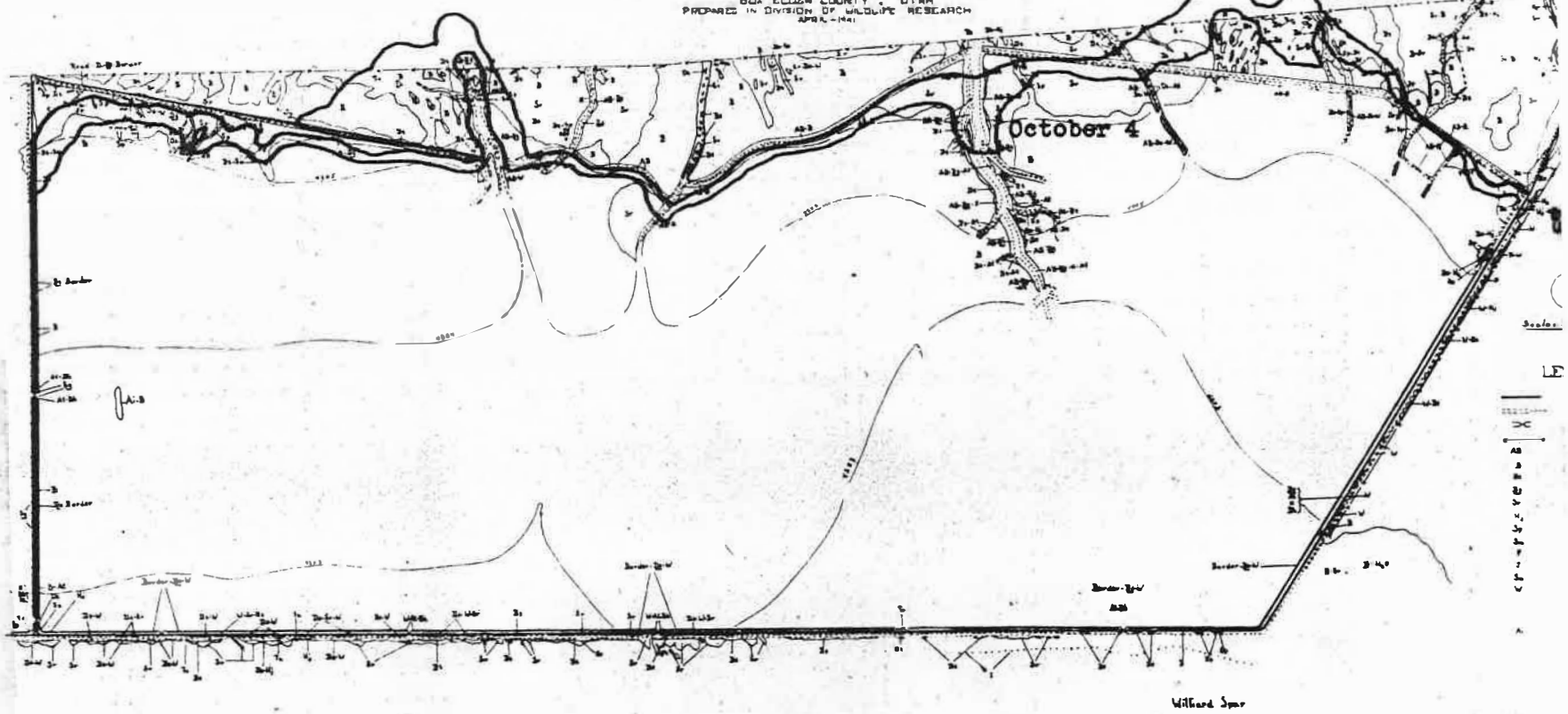
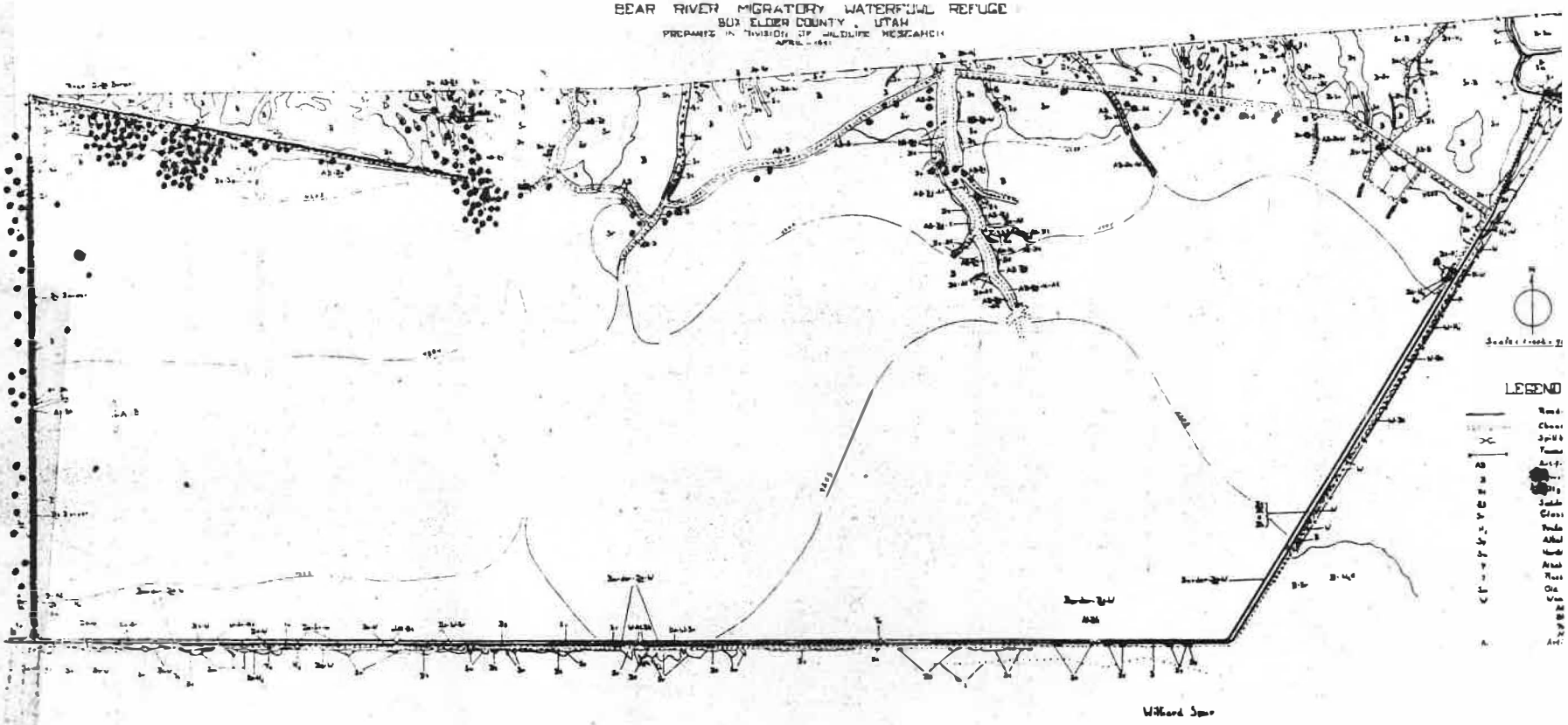


FIGURE 24

DISTRIBUTION OF SICK BIRDS--UNIT 5, AUGUST 1-31,1944
(13 census trips)

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
VEGETATION TYPE MAP - UNIT 5
BEAR RIVER MIGRATORY WATERFOWL REFUGE
BOX ELDER COUNTY, UTAH
PREPARED IN DIVISION OF WILDLIFE RESEARCH
APRIL - 1941



Fringe sickness began to go up a little on August 19, following a wind of the previous day (when the first dike-side cases were recorded) but did not go above a count of 50 sick until August 28 and the daily dike pickup never exceeded 5 during the entire month. Fringe sickness may have increased following the wind of August 24 and the higher count recorded on the 28th could logically have been a hold over as no fringe inspections of the unit were made between the 24th and 28th. A dike patrol was made on the 26th, however, and only 2 botulism victims collected -- the same as on the 29th following the pickup of 5 on the 28th.

September brought increased sickness and one flareup followed another so closely that the number of sick observed on the fringe was high nearly every day. However, there definitely were five major flareups there on September 2, 11, 13, 15, and 18 but with data now at hand, no conclusions as to causes of these can be drawn.

Increased sickness, usually pronounced, was noted along the dikes at the same time or within 24 hours following each of the 5 major fringe flareups. Only on the one occurring September 15 was the dike-side increase negligible (18 to 22 pickup) for the collection increased from 3 to 7 times on each of the other 4 flares. Likewise the decrease was rapid in 4 of the 5 cases as the following day's pickup was only one-fourth to one-half that of the peak. The extreme flareup on September 18, however, (20 to 136) resulted in a dike-side collection of 179 botulism cases on the 19th and 110 on the 20th before the flare died down.

Fringe sickness was almost entirely restricted to definite locations on the west side of the unit. Utilization was lower here than toward the east. The areas pointed as most dangerous are obvious when Figures 26 to 29 are examined. They are the mouths of the channels through which water entered the unit. Why

FIGURE 25

DISTRIBUTION OF SICK BIRDS--UNIT 5, SEPTEMBER 1-10,1944

(6 census trips)

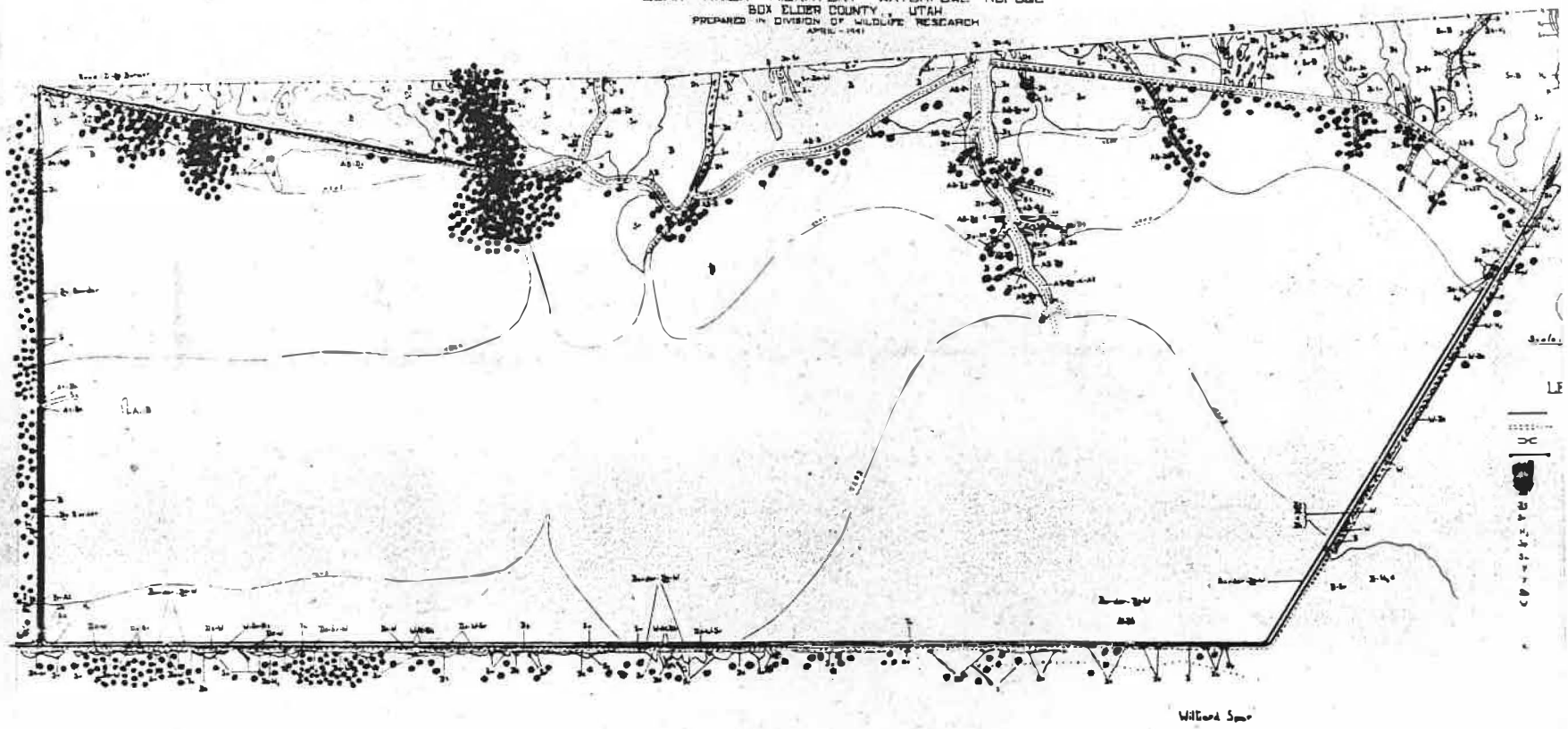


FIGURE 26

DISTRIBUTION OF SICK BIRDS-- UNIT 5, SEPTEMBER 11-14,1944
(4 census trips)

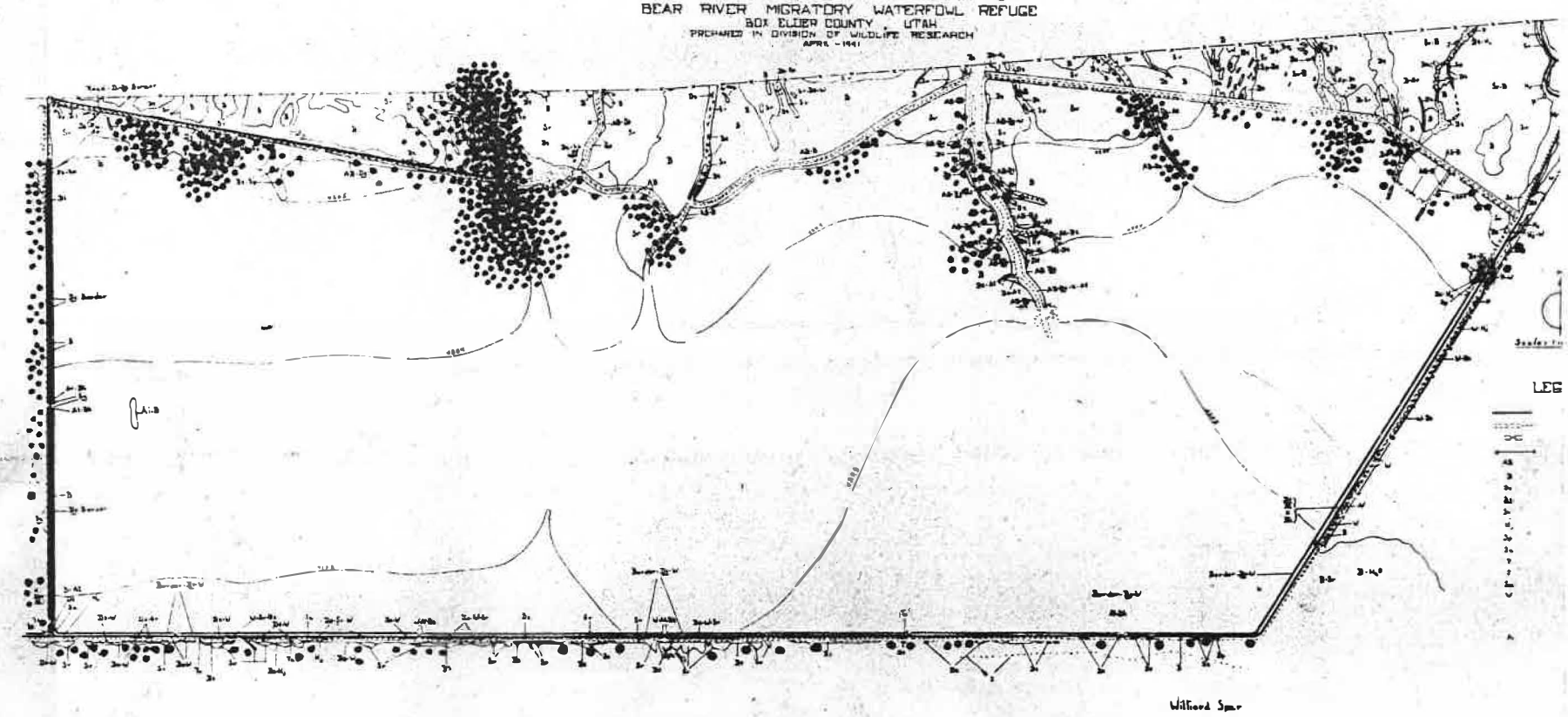


FIGURE 27

DISTRIBUTION OF SICK BIRDS-- UNIT 5, SEPTEMBER 15-16, 1944
(2 census trips)

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
VEGETATION TYPE MAP - UNIT 5
BEAR RIVER MIGRATORY WATERFOWL REFUGE
BOX ELDER COUNTY, UTAH
PREPARED IN DIVISION OF WILDLIFE RESEARCH
APRIL-1941

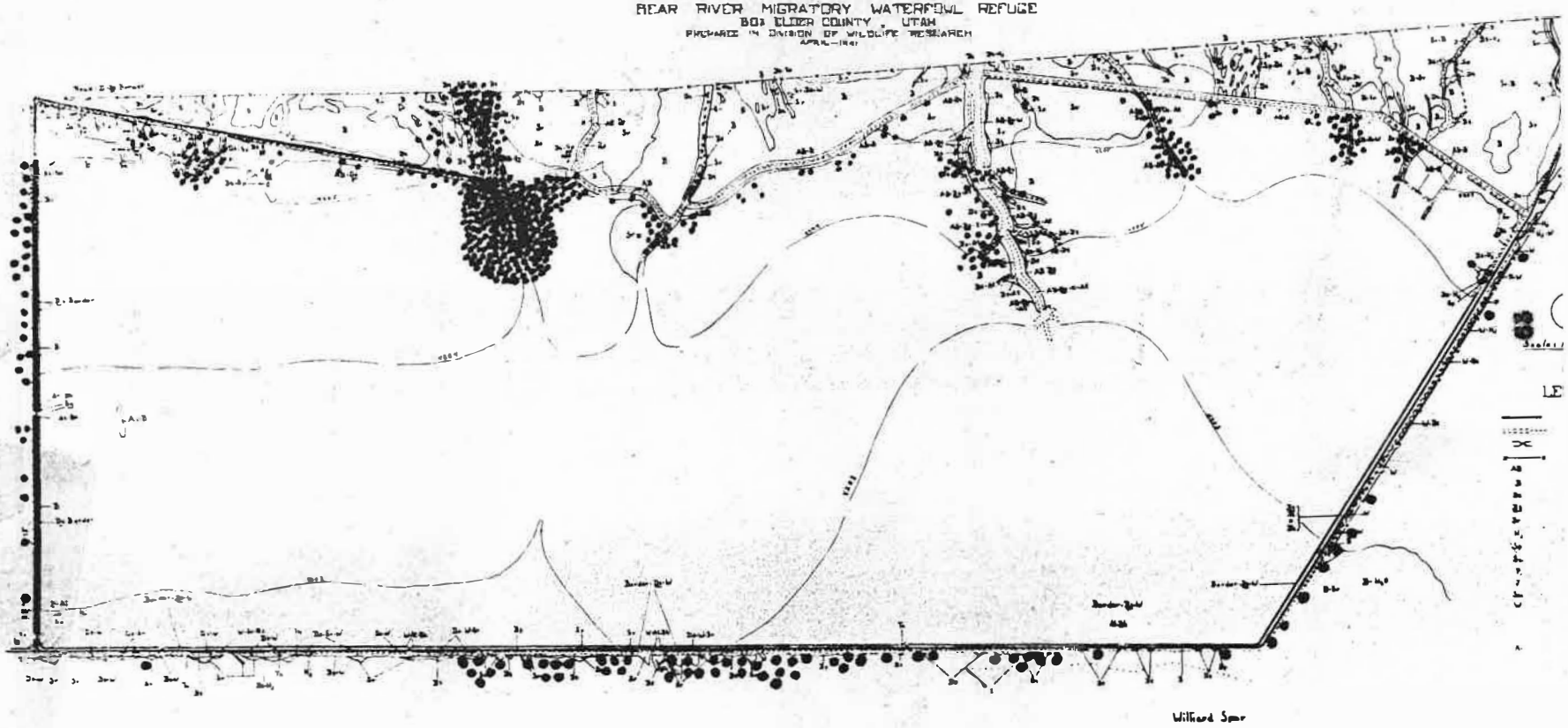


FIGURE 28

DISTRIBUTION OF SICK BIRDS--UNIT 5, September 18-20,1944
(3 census trips)

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
VEGETATION TYPE MAP - UNIT 5
BEAR RIVER MIGRATORY WATERFOWL REFUGE
BOX ELDER COUNTY, UTAH
PREPARED IN DIVISION OF WILDLIFE RESEARCH
APRIL - 1941

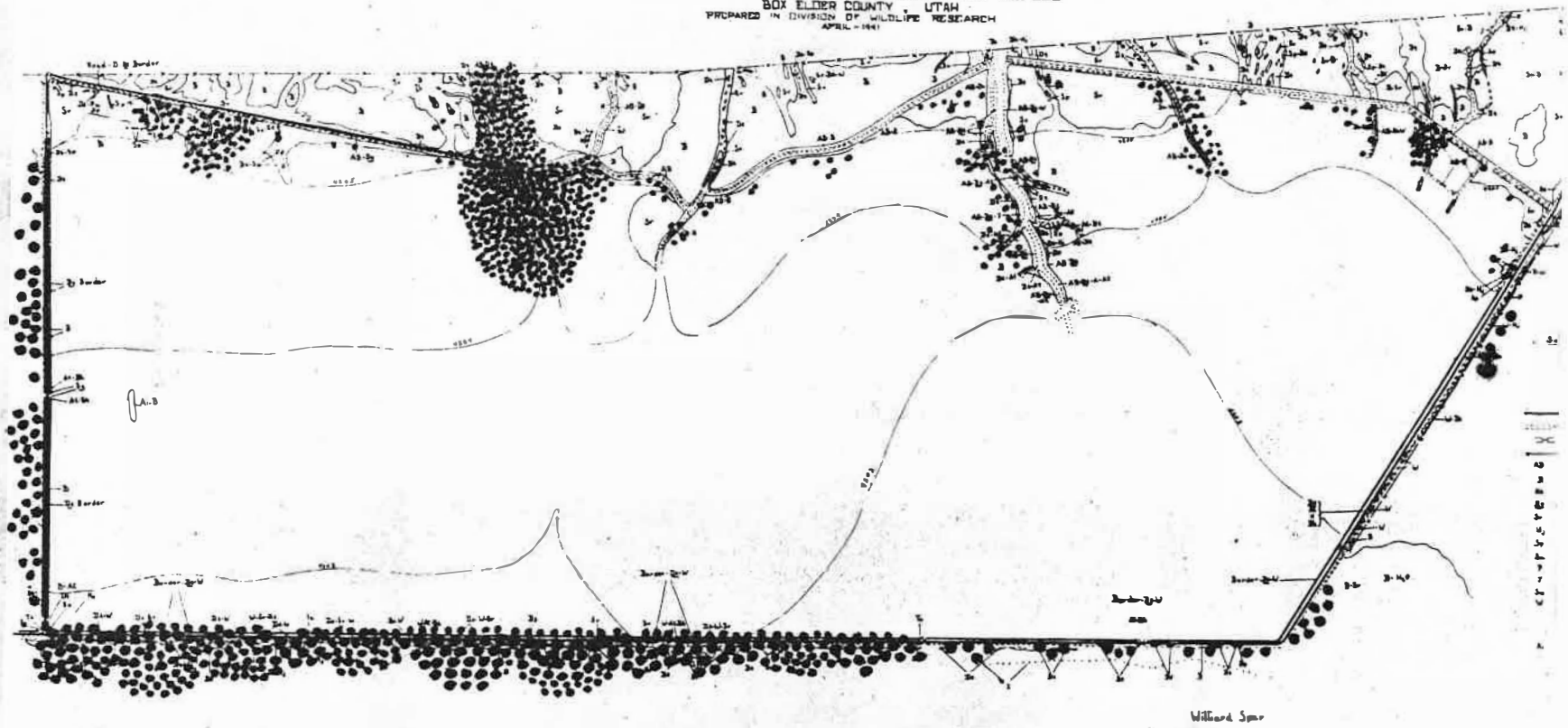
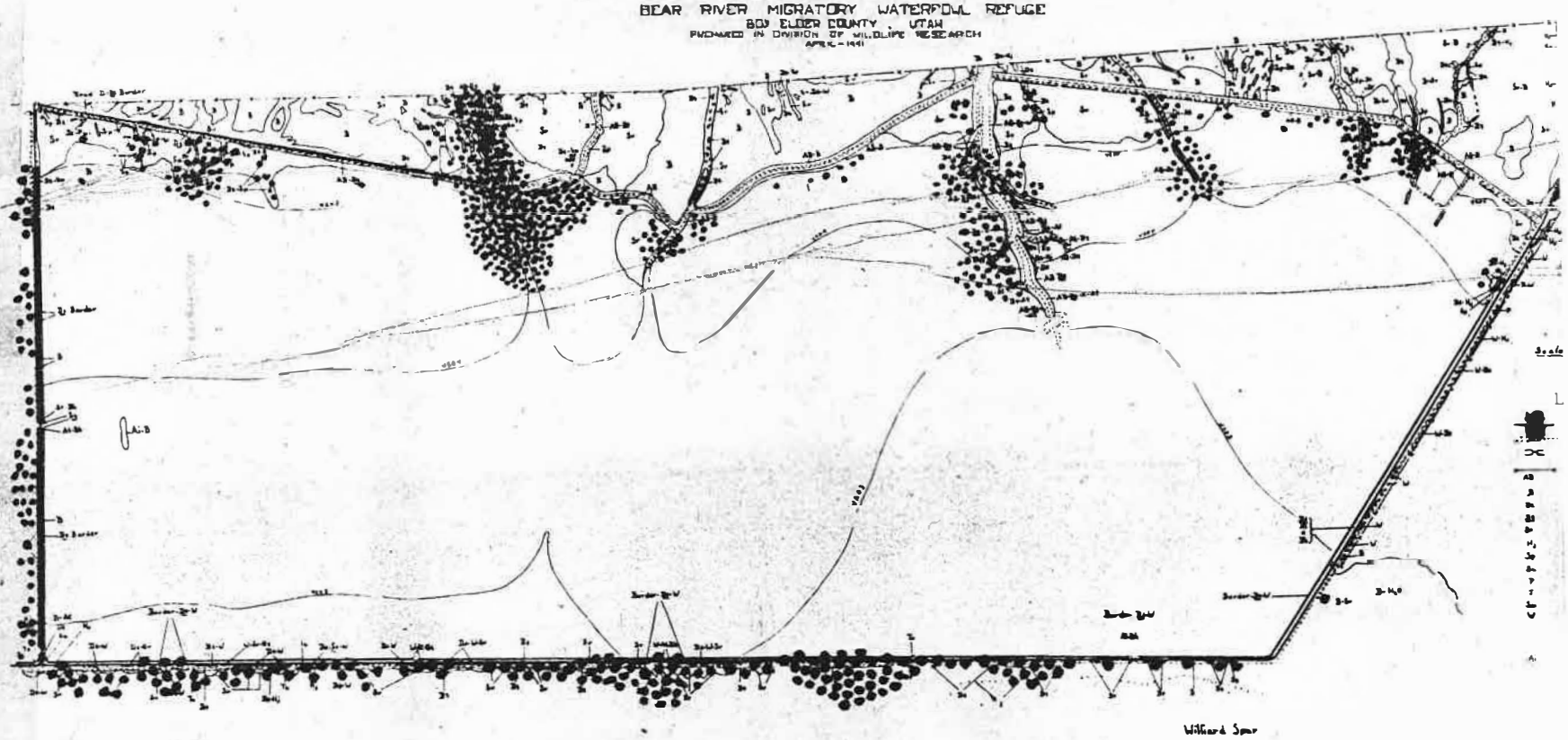


FIGURE 19

DISTRIBUTION OF SICK BIRDS-- UNIT 5, SEPTEMBER 21- OCTOBER 10,1944

(9 census trips)



these locations were centers of sickness will be a moot question until detailed investigations of them can be made and experiments carried out. Toxicity tests made in the locations indicate further studies should point toward investigating the habitats which develop in the spill areas. The lower levels of this year created more exposure of muck in marsh areas. This might well be a factor in the higher sickness.

Sickness on other parts of the fringe was never high at any time. A few sick were to be found daily scattered across the unit from east to west until the 5 way was reached and then the count always took a decided jump. Minor concentration points for sick birds east of the 5-way were along Readers' Channel and the small overflows to the east. The latter were immediately south of the area apparently being kept flooded by water from the Bear River Silts land. Whether there was also a flow into the main unit through the old channels is not known. The channels provided only a limited amount of marsh, but sickness was more evident there than on the extensive shorelines.

Dike-side sickness in Unit 5 during August was light (3 percent) but occurred only along the F-line while during September both the F-line and the D-line were repeatedly lined with botulism ducks, chiefly carcasses. Only 8 percent of the total pickup on Unit 5 dikes was made on the eastern third of the area.

THE RELATION OF SOIL MOISTURE TO BOTULINUS TOXICITY IN LIVER SAMPLES

INCUBATED IN THE FIELD, 1944

by

Jensen and Quortrup

In order to more fully understand the relation of soil moisture to the production and storage of botulinus toxin, this experiment was designed. Because the east side of Unit 4 produced numerous sick birds in 1943 and because the water level in this unit was to drop .5 inches per day in 1944, the east side of this unit was selected for this study. A transect was established starting in the southeast corner. It ran a straight course through the unit from there across to the southern tip of the artificial island; thence across the three-way lateral canal into the open water to the north. This ground has a gradient from around 4203 feet elevation in the southeast corner to an elevation around 4205 feet at the north. This coupled with the plan of reducing the water level on each successive day would give a gradient from relative dryness to complete saturation with water. Twenty-four stations were established along this transect at intervals of about 130 yards. Each station consisted of 2 stakes 35 feet apart. Figure 30/gives graphically the location and water level relationships of the 24 stations.

on page 69

Methods

At each of these stations liver samples were planted in the soil at a depth of 1 1/2 to 2 inches and allowed to incubate for 2 weeks, after which they were removed and tested for toxicity according to approved methods using mice subjected to intraperitoneal inoculations. This necessitated planting liver at the 2 4 stations on August 2 and

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
VEGETATION TYPE MAP UNIT 4
BEAR RIVER MIGRATORY WATERFOWL REFUGE
BOX ELDER CO., UTAH
PREPARED IN THE DIVISION OF WILDLIFE RESEARCH
APRIL, 1941

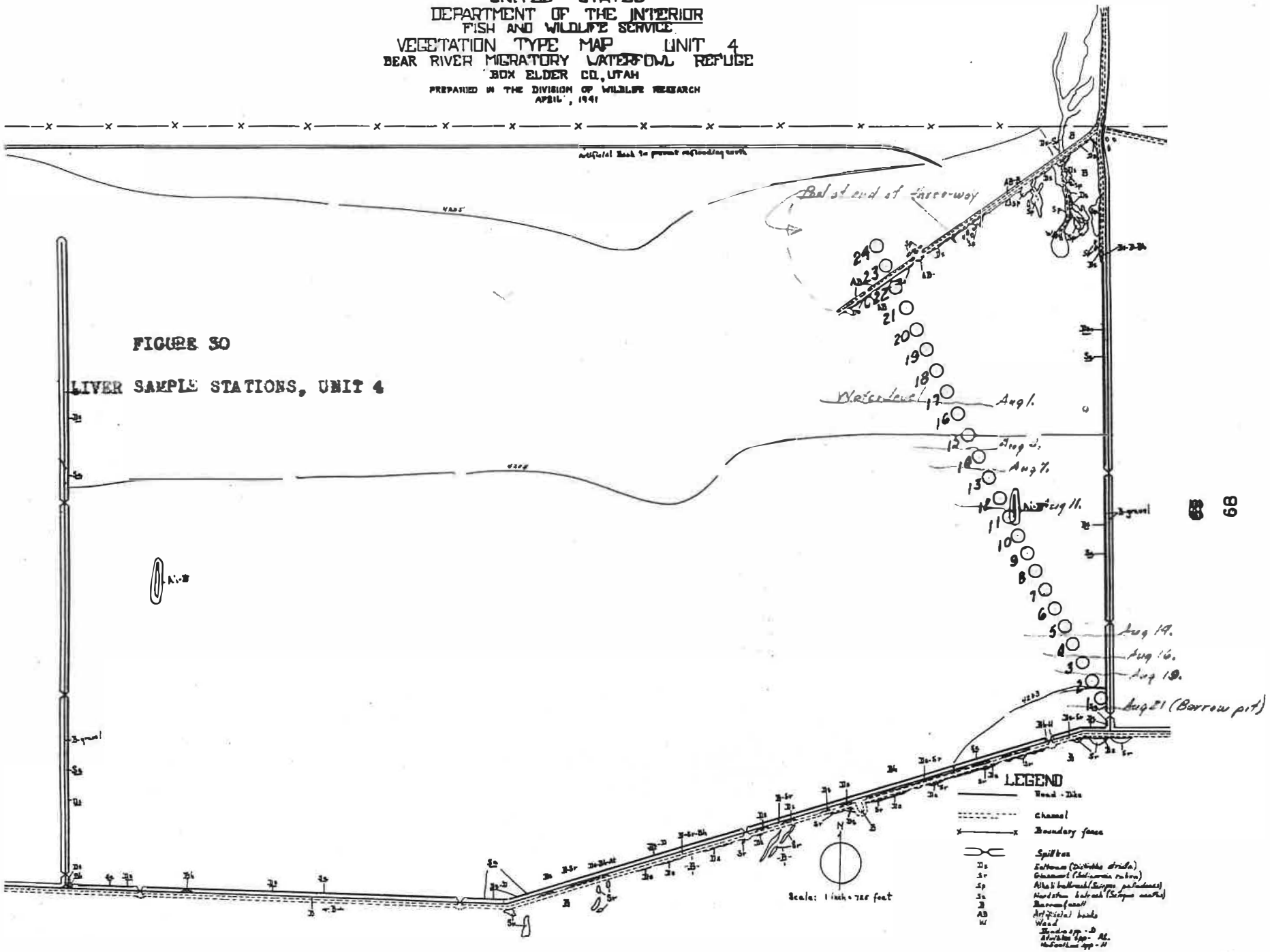


FIGURE 30

LIVER SAMPLE STATIONS, UNIT 4

each successive week thereafter. The first samples were taken from the field on August 16 and subsequent samples on each successive week thereafter. At each time the transect was visited from August 2 to October 10, soil samples were collected at each liver plant where the soil was exposed. These samples were to be used in determining the per cent of moisture by weight and also the per cent of saturation of each sample.

In order to determine whether, if toxin was produced, it would be stored throughout the season and to learn of the rate of liver decomposition, three of the twenty-four stations were selected representing the maximum, minimum and median of soil elevations. These stations were numbers 2, 12, 17. At these stations, in addition to the liver plantings mentioned above, nine pieces of liver were planted in the soil at a depth of 1 1/2 to 2 inches and after 2 weeks incubation one sample was taken from each of the three stations on each successive week throughout the experimental period and tested for toxicity. Samples were not planted in groups of nine at all stations because it was felt that the media might be used up before the time of sampling arrived.

These three stations were also used to study bacterial populations. At each of these three stations at weekly intervals five samples were taken and plate counts made of each sample. ~~This will be considered in a separate discussion to be submitted by Dr. Quortrup after the study has been completed.~~

A vegetation transect was made along the 24 stations and yield estimates were obtained at 5 stations. Five samples were taken at each station by screening the vegetation from the soil and water from an area of one square foot.

The liver was purchased fresh from the meat market. While fresh, it was cut up into 10 gram pieces, placed in a cheese cloth container and sterilized under 15 pounds of steam for 30 minutes. They were then stored in the ice box until used in the field. When these samples were placed in the field they were in a more or less dry state. After being placed in the field the sample would take or lose moisture according to the amount that was present in the soil. After these samples had incubated in the field they were collected and placed in sterile bottles, taken to the laboratory and made up to a standard volume of 40 ml. The cheese cloth container was loosened and after diffusion and settling had taken place the supernatant liquid was used in the toxicity tests. These tests were performed by inoculating intraperitoneally 1/2 ml. of this liquid checked against 1/2 ml. of botulinus antitoxin (75 units). Those samples which killed mice when not protected with antitoxin but failed to kill when mice were protected with antitoxin were considered toxic because of botulinus toxin. Those samples that killed mice both unprotected and protected with antitoxin, were considered toxic but not because of botulinus toxin. There is a possibility that some deaths in the non-botulinus group were from botulinus toxin. Those samples which failed to kill mice were considered negative.

The soil samples were collected in seamless tin cans, the volume of which was 182 ml. The samples were taken to the laboratory and weighed after which they were allowed to air dry. Their dry weight was then determined. With these measurements it was possible to calculate the percent of moisture by dry weight and the per cent saturation for each sample.

Results

At the time this experiment was started the surface water ranged from 12 inches deep at station 1 to 1/2 inch deep at station 17. Stations 18 to 22 were in a drying state at this time. Stations 23 and 24 were never without free surface water throughout the experiment. The free water receded from station 17 at the rate of .5 inch per day and by August 22 the free surface water was gone from all stations except 23 and 24. There was no reflooding because of wind at any station except station 22 which was located on the edge of the three-way lateral canal. Refilling of the unit commenced on September 15 and flooded station 1 to 12 by September 20. All stations were covered with water by September 27. This refill was gradual and constant and covered each station only after the water had deepened sufficiently to do so. Reflooding and subsequent draining followed by reflooding did not occur.

Sago pondweed was dominant in the stations from 1 to 15. In the deeper stations *P. pusillus* was frequent. At station 16 widgeon grass became dominant and continued so approaching the feather edge. *Cladophora* assumed local dominance because of drifts and heavy growth. Yields were as follows:

Station 4	16.0 gr/sq.ft.	*P. pectinatus*
Station 7	12.5 gr/sq.ft.	*P. pectinatus*
Station 10	12.4 gr/sq.ft.	*P. pectinatus*
Station 12	15.3 gr/sq.ft.	*P. pectinatus*
Station 20	5.4 gr/sq.ft.	*R. maritima*

The stations from approximately 15 down are on a more organic soil with water deep enough to allow a fairly good growth of pondweed. The remaining stations have more clayey soil with shallower water and

are vegetated with widegon grass. These areas are less productive.

Table 8 shows soil moisture per cent by weight and liver extract toxicity by date and station for the 216 samples. Red markings indicate botulinus toxicity, green markings indicate toxicity but not botulinus toxicity, while no color markings are those samples which were non-toxic. The numerals inside the squares opposite dates and stations indicate at the time of sampling the per cent moisture by weight of the soil in which the liver was planted. The numerals in the margins to the right and bottom of the page indicate totals by station and date respectively according to the color schedule above.

It is observed that out of a total of 216 samples 33 were botulinus toxic, 51 were toxic not from botulism while 132 were non-toxic. These represent 15, 24, and 61 per cent, respectively, of the total number of samples. It is seen that the toxic samples were grouped somewhat around the top center of the table with a slight shift to the right. The general trend of soil moisture is likewise so disposed. This appears to be the case both for botulinus and non-botulinus toxicity. Non-toxic samples are greatest in that portion of the table represented by extremes of soil moisture--dryness and free surface water.

Figure 31 shows that botulinus toxicity was at the highest point during the period of August 30 to September 13 while non-botulinus toxicity was at the peak sooner (August 23 to September 6) and started dropping off a week sooner. During the stages of reflooding at the close of the experiment, non-botulinus toxicity increased. The non-toxic data would be the inverse of the combined toxicity data with the total number of samples for each date equaling 24.

Table 18 Shows soil moisture content per cent by dry weight of the soil and liver extract toxicity by date and station for the 216 samples. (Squares with numerals indicate per cent moisture by dry weight; squares with no numerals indicate periods when [redacted] free water was over the surface; red indicates botulinus toxicity; green indicates non-botulinus toxicity; no color indicates non-toxicity.)

Station	Aug 2	Aug 9	Aug 16	Aug 23	Aug 30	Sept 6	Sept 13	Sept 20	Sept 27	Oct 3	Oct 10	Total	Total
1				98	95	59	58					5	3
2				77	63	56	47					2	3
3				72	61	43	59					3	1
4				77	88	43	29					4	5
5			72	54	49	44	32					3	6
6			58	49	39	34	33					4	5
7			78	60	51	23	36					2	5
8			83	51	50	36	38					3	5
9			70	52	50	37	27					3	1
10			91	34	25	19	19					2	4
11			30	33	45	28	18					0	7
12			74	57	34	34	27					3	5
13			65	39	40	36	16	15				5	4
14			43	29	29	13	18	13				1	6
15		49	34	19	12	9	15	4				0	6
16		43	38	20	13	14	8	13				1	7
17		31	12	9	10	8	5	5				1	7
18	29	20	11	6	7	4	1	5				0	9
19	29	14	19	7	8	3	5	1				0	9
20	34	17	6	4	9	1	3	4				1	7
21	39	22	9	6	6	1	1	2				1	7
22	33	26	45	26	34	19	27	40				3	4
23												1	8
24												1	8
Total			2	4	6	7	7	3	1	2	1	31	132
Total			19	8	9	7	12	19	19	22	17	132	216

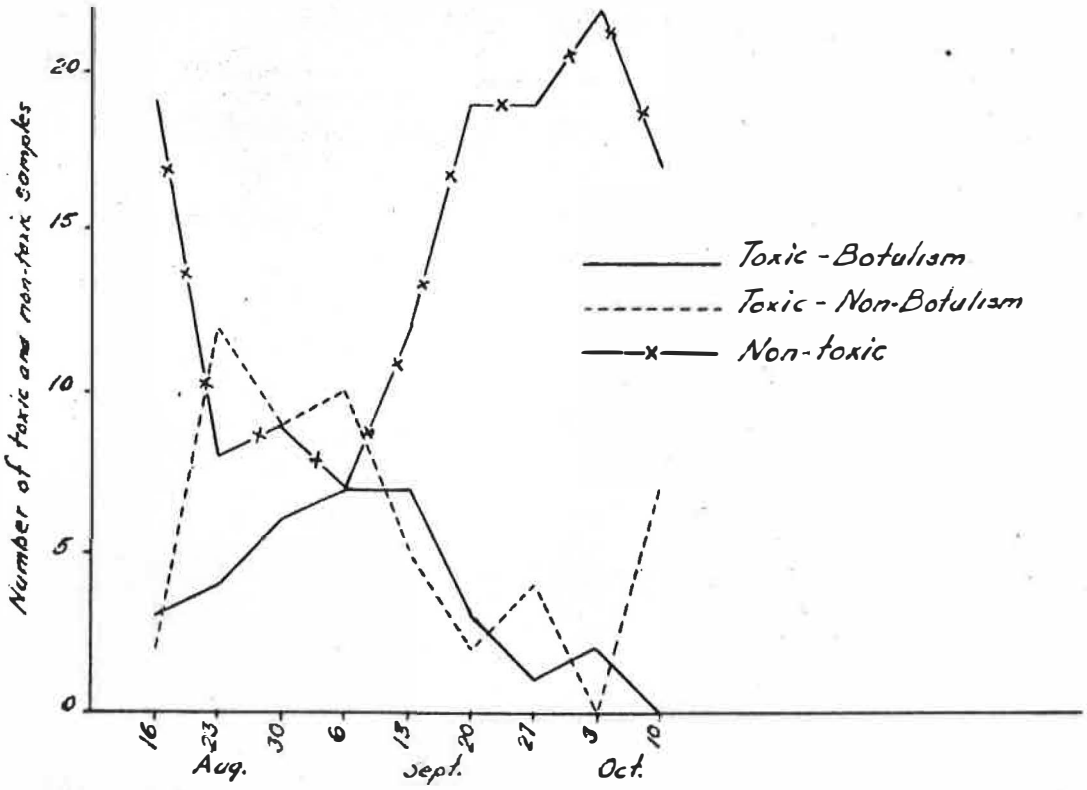


Figure 1. Shows the number of samples toxic from botulism, toxic but not botulism and non-toxic by dates.

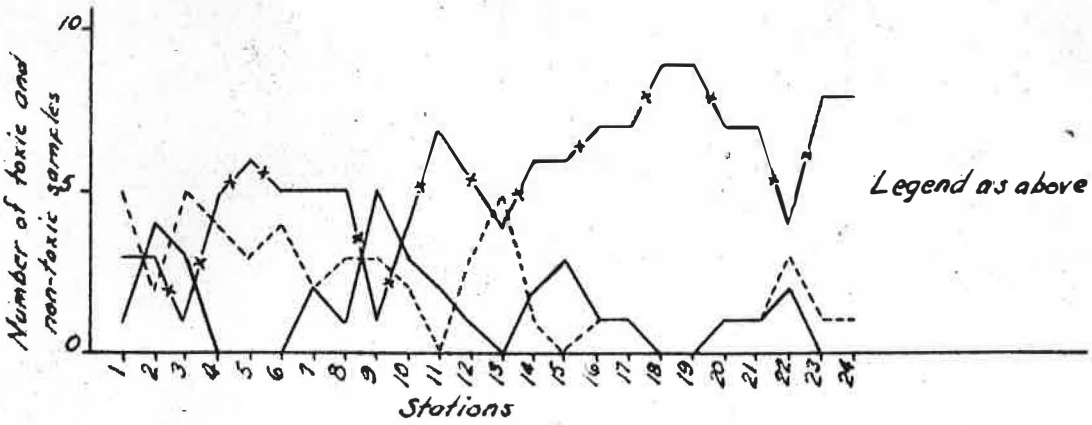


Figure 2. Shows the number of samples toxic from botulism, toxic but not botulism and non-toxic for the twenty-four stations.

Figure 2 shows by station the number of samples botulinus toxic, the number of samples non-botulinus toxic, and the number of samples non-toxic. Station 9 produced the greatest number of toxic samples due to botulism with 4, 5, 6, 13, 18, 19, 23, and 24 producing no botulinus toxicity. Stations 1, 3, 9, and 13 produced the highest toxicity not due to botulinus toxin, while 11, 16, 18, and 19 produced no toxicity of this type. Non-toxic samples would be characterized by the inverse of the above toxicity data with the total number of samples for any one station being nine.

Table 2 shows by frequency groups with intervals of ten the number of toxic samples obtained which were toxic from botulism, toxic but not from botulism, and non-toxic with their totals from liver extract after the liver had been incubated in the field for 2 weeks. One hundred sixteen samples are represented and these are segregated by moisture in per cent by dry weight and by moisture in per cent saturation. This table represents those samples which were below the point of complete saturation. Out of a total of 116 samples, 27 were botulinus toxic, 38 were non-botulinus toxic and 51 were non-toxic. This represents 23, 33, and 44 per cent, respectively, of the total number of samples. Figures 3 and 4 give a graphical picture of the toxicity data from Table 2. Figure 3 represents the data based on soil moisture in per cent dry weight, while Figure 4 represents the data based on soil moisture in per cent saturation of the soil. Based on soil moisture in per cent by dry weight the toxicity was spread over a broad base with an ill defined course. Botulinus toxicity was highest from 15 to 35 per cent moisture groups and lowest at the 75 to 85 per cent moisture groups. When the curve is based

Table 2. Shows botulinus toxicity, non-botulinus toxicity and non-toxicity by frequency grouping for 112 liver extract samples from liver incubated in the field for two weeks.

Per cent	Toxicity				Non-toxicity		Totals	
	Botulinus		Non-botulinus					
	% by weight	% saturation	% by weight	% saturation	% by weight	% saturation	% by weight	% saturation
91-99.9	1	–	1	–	1	–	3	–
81-90	0	2	1	2	1	1	2	5
71-80	0	2	3	1	3	1	6	4
61-70	2	4	2	8	0	7	4	19
51-60	3	8	7	12	1	3	11	23
41-50	2	5	6	9	4	9	12	23
31-40	6	2	8	3	4	6	18	11
21-30	4	2	4	1	3	7	11	10
11-20	6	1	4	1	9	11	19	13
0-10	3	1	2	1	25	6	30	8
Total	27	27	38	38	51	51	116	116

Table 3. Shows the comparison between saturated and drying soils with regard to botulinus toxicity, non-botulinus toxicity and non-toxicity in liver extract samples from liver incubated in the field for two weeks.

Per cent Saturation		Toxicity		Non-toxicity	Totals
		Botulinus	Non-botulinus		
100	Flooded	0	2	20	22
	Reflooded	6	11	61	78
Sub total		6	13	81	100
Below 100		27	38	51	116
Total		33	51	132	216

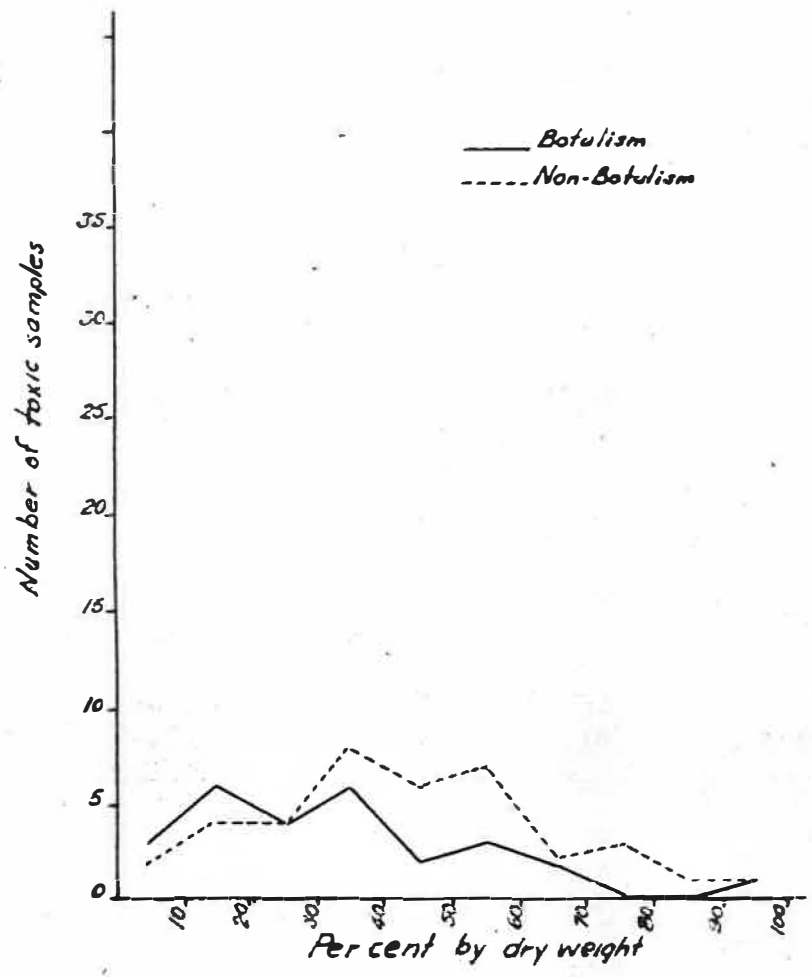


Figure 3. Shows correlation and distribution of botulinus and non-botulinus toxicity based on soil moisture in per cent dry weight of the soil.

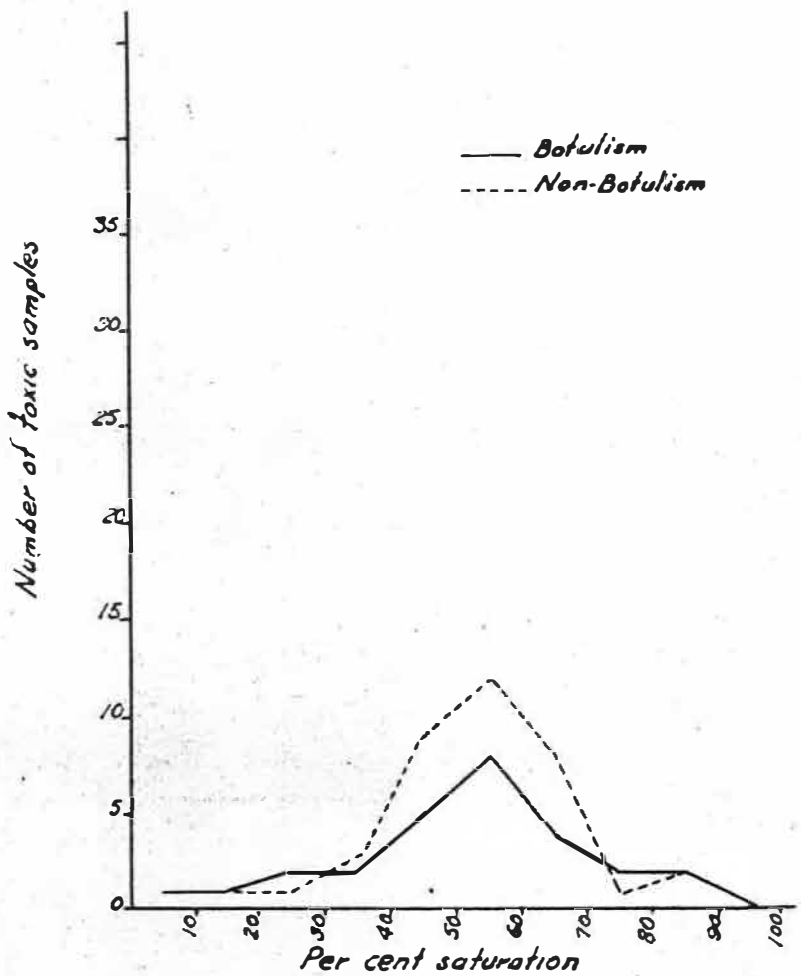


Figure 4. Shows correlation and distribution of botulinus and non-botulinus toxicity based on soil moisture in per cent saturation of the soil.

on soil moisture in per cent saturation the curve becomes more clearly defined with the high point for both types of toxicity being centered at the 55 per cent point. It is also observed that both types of toxicity are correlated. Increases and decreases in one curve are compensated for by near corresponding changes in the other curve.

In Table 10 the samples are grouped into two classifications. Those samples that were taken when soils did not have free surface water, and thus were in some state of dryness, form one group. In this group the number of samples observed was 116 (54 per cent) out of a total of 216. The other group consists of those samples which were characterized by free surface water at the time of sampling. This group is subdivided into those which were flooded initially and those that became reflooded after being in some state of dryness. This group contained 100 (46 per cent) out of a total of 216 samples. It is seen that out of 22 flooded samples that no botulinus toxicity was produced and only 2 samples were toxic from other causes. Reflooded soils produced 6 and 11 toxic samples from botulism and from other causes respectively. In comparing the totals, those samples which were from soils completely saturated were less productive of toxic samples of both types than the samples from the soils which had dried to some extent, with botulinus toxicity being 6 and 27, and non-botulinus toxicity being 13 and 38, respectively. Computations reveal the following: Out of 33 botulinus toxic samples, 27 (82 per cent) were from soils in a drying condition while only 6 (18 per cent) were from soils that were covered by free surface water. Of the 51 non-botulinus toxic samples 38 (75 per cent) were from soils in a drying condition while 13 (25 per cent) were from soils covered with free water. Corresponding figures for non-toxic samples showed 61 per cent of 132 samples from saturated soils and 39 per cent from drying soils.

The liver samples that were incubated in the field successively from 2 to 11 weeks at station 2x, 12x, and 17x produced 6 samples of liver extract which were toxic because of botulism, six which were toxic but not from botulism, and 15 which were non-toxic. The total number of samples was 27 (Table 11). Moisture conditions of the soil would be very similar to those obtained at stations 2, 12, and 17. It is seen that the botulinus toxicity occurred in the more frequently moist soils and non-botulinus toxicity was highest in soils at the drier stations.

Table 11 shows the number of toxic and non-toxic liver extract samples from liver incubated in the field for 2 to 11 weeks.

	Toxicity		Non-	
Station	Botulinus	Non-botulinus	toxicity	Totals
2X	4	0	5	9
12X	2	3	4	9
17X	–	3	6	9
	6	6	15	27

Discussion

Moisture holding capacity of a soil is dependent upon the physical characteristics of the soil. A clay soil having its particles more finely divided contains more air space than a sandy soil with its larger soil particles. A clay soil is thus lighter than a sandy soil and is heavy only in the sense that it is more difficult to till. In these submerged soils, buoyancy of the soil particles by water would tend to increase the pore space, so that the weight of volume

of soil would increase as free water is removed, i.e., the soil becomes more compact as water recedes. It remains in this condition until the forces of winter and spring water change the consistency back to the lighter pre-existing condition. In soils which have water over them at all times, no change in the condition of the submerged soil is experienced.

Moisture holding capacity of the liver may not be the same as that of the soil in which it was planted. Because of the physical character of the liver, it is possible to produce toxin at a certain moisture content whereas the same moisture content in the soil would not produce toxin, and vice versa. While no measurements were made between liver sample moistures and soil moisture, there would surely be a high degree of correlation because the degree to which the dry liver would take on moisture would be dependent upon the amount of moisture in the soil. Thus, the moisture content of the soil would be an index upon which we could base judgment.

The moisture content of the soils gave a gradient from wetness to dryness with respect to position and time. This does not apply rigidly. Some soils were moistened by sub-irrigation and slight local elevations produced conditions conducive to dryness. This would cause aberrant samples so far as the soil moisture gradient was concerned. Local differences in soil type as well as matted aquatic plants lying over the surface caused differences in soil moisture at some stations.

The stations themselves were inconsistant with regard to producing toxic and non-toxic samples. Individual records from stations reveal no trends, and it is only after the whole of the data was regrouped in an objective manner that certain correlation with soil moisture was indicated. In order to cut down variation between samples of the same

station, it would be advantageous to group the weekly samples in a more confined area. There is a minimum where grouping would tend to confound the results from individual samples; however, it was far from being approached in the present experiment.

No explanation is given for the correlation between botulinus and non-botulinus toxicity based upon the observations of this experiment.

Within the limitations of the data, reflooding of moist soil seems to play a significant part in producing botulism. Williams et al. has alluded to this condition in past reports. The bulk of the toxic samples, botulinus and non-botulinus, were grouped in the drying soils around the 50-60 per cent saturation interval. These would be soils without free surface water and in no way would they be used by feeding waterfowl. It would be only after these soils were reflooded that feeding ducks would frequent them and be exposed to the toxin. E. R. Quortrup has demonstrated that soils exposed for three days produced more botulinus toxic samples than soils exposed for ten or in excess of ten days. Samples from flooded soils with depth of 8 inches to 10 inches and 1/4 inch to 1/2 inch were also less toxic than the 3 day exposed group.

We might argue that field applications of these findings could produce botulism as follows: If at the Bear River Refuge we have water with a stabilized level there is an area of varying moistness from the water's edge back to the dry land sometimes referred to as the tension zone. A high percentage of our toxicity would be produced in this moist area and would continue to be produced if we maintained these stable conditions. The toxin would continually be made available to ducks with each reflooding. Toxin is being produced and destroyed in this moist area. If we would keep the shore line in a state of change toward lower

or higher levels we would reduce to a minimum the availability of toxin. When reflooding is undertaken it should be rapid with a considerable increase in depth. This would place the feeding area of puddle ducks on dry ground where toxin would be more nearly destroyed and that which was still present would be diluted to impotency. These remarks are based on 27 samples which were toxic from botulism and before definite conclusions can be given increased data should be had.

Insufficiency of data precludes discussion of the samples incubated from 2 to 11 weeks.

Summary

1. Soil moisture content with regard to botulinus toxicity has been studied by establishing a transect of 24 stations across Unit 4, Bear River Refuge. Liver was planted in the surface soil and incubated, after which it was examined for botulinus toxicity. Non-botulinus toxicity was also given consideration in the analysis.

2. Soil samples and moisture determinations were made in order that correlations between soil moisture and toxicity might be established.

3. Out of a total of 216 liver extract samples from the liver plants, 33 were botulinus toxic, 51 were non-botulinus toxic, and 132 were non-toxic.

4. Of these 33 botulinus toxic samples, 27 (82 per cent) were from soils in a drying condition while only 6 (18 per cent) were from soils that were covered by free surface water. Of the 51 non-botulinus toxic samples 38 (75 per cent) were from soils in a drying condition while 13 (25 per cent) were from soils covered with free water.

5. Of the toxic samples in the group of drying soils, the toxicity was centered around the midpoint of the 50-50 per cent saturation interval. This was true for botulinus and non-botulinus toxicity.

6. This would tend to give credence to the observations made by several workers that reflooding is one of our important factors in botulism outbreaks.

BACTERIAL POPULATIONS

E. R. Quortrup

In conjunction with the liver plant studies bacterial plate counts were made from stations 2, 12, and 17 in order to obtain additional data in regard to the relation of bacterial cycles to toxin production.

Five separate mud samples were collected in sterile vials from each station. Upon arrival in the laboratory, the mud samples were thoroughly shaken with equal volumes of sterile water to make a uniform suspension. One ml. of each sample was diluted according to standard methods and plated out on nutrient agar and incubated aerobically for 48 hours. The dilution used was 1:10,000 or 1:100,000 according to circumstances.

Tabulations of bacterial counts are made in Chart I showing individual counts and average counts from each station.

In Chart II the average bacterial counts are shown from each station progressively through the season together with concomitant water depth and toxicity due to botulism. It is noted in this chart that the highest average bacterial population exists at the drier levels and that the lowest bacterial counts were made at the station having the most moisture, based on an average for the entire period. Based on these three stations only, the frequency of toxic samples are inversely proportional to bacterial abundance and in direct proportion to moisture. Toxicity tests are considered from both plots at each station, that is, those that were furnished with liver samples at the beginning of the season as well as from those that were renewed at bi-weekly intervals. Thus we have at station 2 a total of 7 toxic samples and an average of 6,462,666 bacteria per ml.; at station 12, 3 toxic samples and 40,927,444 bacteria; and at

BACTERIAL PLATE COUNTS
Field Station, Bear River Refuge 1944

Chart 1 (TABLE 12)

Station	Aug. 16	Aug. 23	Aug. 30	Sept. 6	Sept. 13	Sept. 20	Sept. 27	Oct. 3	Oct. 10
	15,600,000	200,000	970,000	2,310,000	27,950,000	840,000	2,260,000	240,000	50,000
2	19,100,000	5,300,000	810,000	2,520,000	27,700,000	3,740,000	330,000	50,000	10,000
	17,200,000	2,500,000	670,000	5,200,000	33,600,000	1,540,000	420,000	90,000	90,000
	16,300,000	3,100,000	720,000	6,420,000	38,150,000	2,180,000	330,000	250,000	70,000
		700,000	3,390,000	2,060,000	26,750,000	1,680,000	220,000	100,000	60,000
Average	17,050,000	2,360,000	1,312,000	3,702,000	30,830,000	1,996,000	712,000	146,000	56,000
	31,400,000	800,000	440,000	4,540,000	2,430,000	60,000	410,000	140,000	140,000
	407,000,000	100,000	1,700,000	4,380,000	34,300,000	6,440,000	2,750,000	270,000	110,000
12	481,000,000	1,400,000	820,000	6,220,000	5,240,000	2,360,000	3,320,000	160,000	230,000
	442,200,000	1,700,000	1,750,000	5,100,000	2,380,000	1,420,000	840,000	180,000	80,000
		800,000	1,060,000		34,300,000	4,080,000	330,000	260,000	60,000
Average	340,000,000	960,000	1,154,000	5,772,000	15,730,000	2,872,000	1,530,000	205,000	124,000
	561,000,000	100,000	560,000	6,820,000	1,820,000	120,000	1,980,000	2,340,000	90,000
	481,800,000	6,600,000	320,000	4,520,000	1,540,000	1,820,000	1,120,000	520,000	320,000
	514,800,000	300,000	1,520,000	920,000	68,500,000	1,870,000	720,000	450,000	200,000
	607,200,000	3,300,000	350,000	3,892,000	52,500,000	730,000	1,520,000	1,720,000	1,510,000
		4,700,000	720,000	3,960,000	59,000,000	650,000	2,740,000	2,080,000	320,000
Average	541,200,000	3,000,000	694,000	4,022,400	36,672,000	1,038,000	1,616,000	1,425,000	488,000

(TABLE 13)

Chart 2

BACTERIAL PLATE COUNTS CORRELATED WITH DEPTH AND TOXICITY

Date	Station 2			Station 12			Station 17			Toxic samples
	Bacterial count	Depth	Toxicity	Bacterial count	Depth	Toxicity	Bacterial count	Depth	Toxicity	All plots
Aug. 16	17,050,000	3	-	340,000,000	M	+	541,200,000	D	-	3
Aug. 23	2,360,000	W	-	960,000	M	-	3,000,000	D	-	4
Aug. 30	1,312,000	M	-	1,154,000	D	-	694,000	D	-	6
Sept. 6	3,702,000	M	+	5,772,000	D	+	4,022,400	D	+	7
Sept. 13	30,830,000	M	+	15,730,000	D	-	36,672,000	D	-	7
Sept. 20	1,996,000	8	+	2,872,000	1½	-	1,038,000	D	-	3
Sept. 27	712,000	15	+	1,530,000	8	-	1,616,000	2	-	1
Oct. 3	146,000	15	+	205,000	8	+	1,425,000	2	-	2
Oct. 10	56,000	20	-	124,000	13	-	488,000	7	-	0
Average	6,462,666			40,927,444			60,572,777			

In this chart toxic samples are considered from the liver plots but mud samples for bacterial plate counts were taken a few feet from the plots.

Legend: Water depth in inches: M - moist: W - wet: D - dry.

station 17, only one toxic sample but an average of 60,572,777. This checks with previous laboratory tests showing that certain bacteria destroy botulinus toxin. It is admitted that we do not have a sufficient number of toxic samples to draw definite conclusions, but the trend is revealed.

In Chart III the total toxicity curve from all regular stations is plotted against the bacterial population from stations 2, 12, and 17. It appears that bacterial populations follow each other rather closely at all three stations seasonally irrespective of water levels, although the higher counts generally were encountered in the drier areas. It is not known what the bacterial populations were prior to August 16 when the experiment was started but it is believed that they were high as evidenced by the initial high count. This would be expected as coincident with maximum summer temperatures.

The toxicity curve is low at the beginning of the experiment coinciding with a high bacterial count. At the time when the bacterial curve shows an abrupt drop the number of toxic samples begin to increase until another bacterial peak occurs when the toxicity curve again begins to drop. There is evidently a correlation between bacterial populations and toxin production which may be better understood by continued experimentation on a larger scale as the present data are inadequate to warrant final conclusions.

More important than bacterial counts would probably be intensive species determination, which is not practicable under the present manpower set up. A limited number of bacteria have been isolated for study as to their antagonistic or symbiotic action on C. botulinum, but

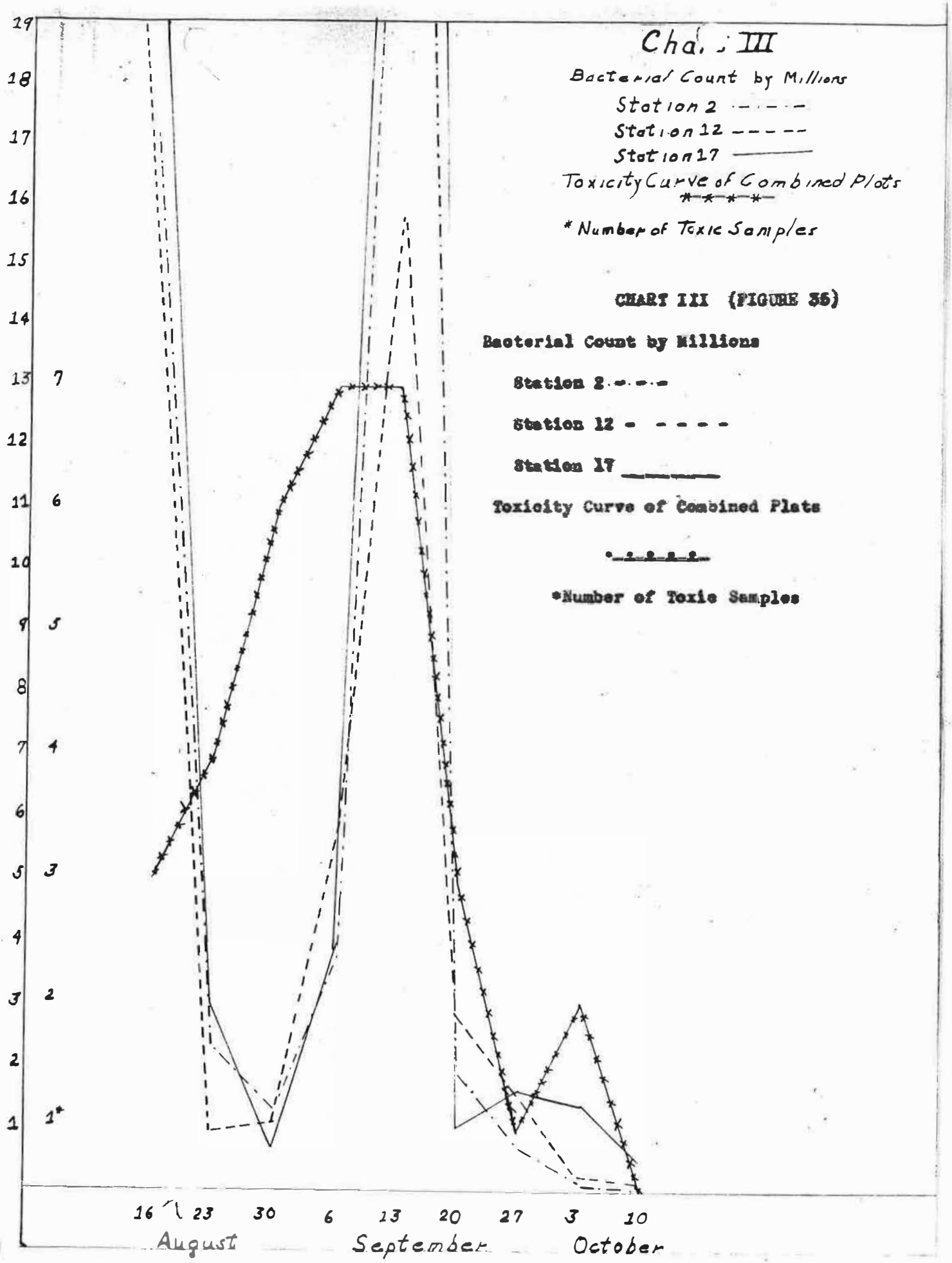


Chart III
Bacterial Count by Millions
Station 2
Station 12
Station 17
Toxicity Curve of Combined Plots
* Number of Toxic Samples
CHART III (FIGURE 36)
Bacterial Count by Millions
Station 2
Station 12
Station 17
Toxicity Curve of Combined Plots
*Number of Toxic Samples
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
7
6
5
4
3
2
1*
16
23
30
6
13
20
27
3
10
August
September
October

this work has not advanced to a state where it can be incorporated in the present discussion. It was noted, however, that *Pseudomonas aeruginosa* which was shown to play a significant ecological role in the botulism picture in 1942, was very inconspicuous during the 1943 and 1944 seasons. The latter two seasons having very little botulism.

Discussion

Bacterial plate counts were made from three selected stations representing the extremes and medium in regard to water levels.

Bacterial curves appear to be seasonal rather than dependent upon water levels. There is a tendency for higher counts to appear in the drier areas. Numbers of toxic samples were found to be inversely proportional to bacterial frequency.

Further study of bacteriological ecology is indicated.

E. R. Quortrup
Veterinarian

Submitted 2-22-45

TOXICITY TESTS
by
Jensen and Quortrup

During the course of these investigations at different times during the season groups of toxicity tests were made in areas where increased sickness was present. In these habitats quadruplicate samples were usually taken representing likely habitats for toxic development. Silted duck feeding holes, watery matter below carcasses, floating drifts of algae and other organic debris, silted saltgrass, and ostracod depressions are examples of some of the types sampled. These samples were submitted to Dr. Quortrup who made the tests and diagnoses of toxicity to mice. A total of 114 samples were collected of these 9 (8%) were toxic because of botulinus toxin and 8 (7%) were toxic but could not be ascribed to botulism.

The highlights of these tests will be given.

On August 8 twenty samples were collected along the far channel area of Unit 2 .

#20 muck silting over, saltgrass, toxic, not botulism.

On August 15 twenty more samples were collected in the same general area and in Unit 5. Of these four were botulism and two not botulism.

#34, top soil sandy loam along far channel, botulinus toxin.

#35, " " " " " " ", 8" away, toxic, not botulism.

#36, muck and silt at edge of old S. paludosus ratheuse, botulinus toxin.

#41, silted old duck hole, botulinus toxin.

#42, " " " " , same (not a duplicate), botulinus toxin.

#49, " " " " , other side of pond, toxic, not botulism.

#50, " " " " , toxic, not botulism.

On September 8 eleven samples were taken in Unit 2,

#60.3, mud at edge of water where duck had been feeding in S. paludosus clump, botulinus toxin.

#60.5, fresh Anabena from water surface, botulinus toxin.

On September 13 eight samples were taken of floating Anabena drifts in decomposing state and two in ostrecod depressions.

#80.2, Ostracod depression in S. paludosus toxic, not botulism.

#80.3, old floating Anabena drift, toxic, not botulism.

#80.6, " " " " , botulinus toxin.

On September 15 two samples were taken, one in exactly the same spot as toxic #60.3, which was collected on September 8.

#90.1, Same area as #60.3, toxic, not botulism.

#90.2, " area as #60.3, but two feet away, toxic, not botulism.

On September 15 twenty samples were taken in Unit 5 around the end of the threeway lateral. Two samples from quadruplicate samples were toxic.

#5.5, drying algae scum, S. paludosus clump, toxic, not botulism.

#5.6, " " " " " , botulinus toxin.

On September 27 eleven more samples were taken in Unit 5 around the end of the threeway lateral.

#5.39, Ostracod depression, ostracods still mobile, botulinus toxin.

All other samples taken were negative, although they included many samples apparently similar to those reported above. Two of the negative samples (#53 and #80.1) were collected from beneath maggoty carcasses.

No conclusions can be reached on the basis of the data. The sampling done, however, indicates that further sampling and study of silted over pockets and

Anabena growths should be made. It is particularly surprising that a free living Anabena sample was toxic due to botulinus toxin.

PERCENTAGE OF RECOVERY OF TREATED AND UNTREATED BOTULISM BIRDS

Additional data on the value of hospitilization of botulism birds were assembled in 1944 by continuing field and laboratory experiments. The objective of this phase of the botulism research was to determine the percentage of recoveries of botulism birds receiving medical treatment and hospitilization compared with that of afflicted birds left in the field without treatment. Results to guide management practice.

Laboratory. During the 1943 and the early part (to August 19) of the 1944 botulism outbreaks at Bear River, 561 afflicted birds were collected in the field and taken to the laboratory where they were grouped as to degree of sickness (Table 14). Medical treatment was given to 75 percent (417) of these sick birds while 25 percent (144)were left untreated. All birds receiving treatment, regardless of size, were given intraperitoneal injections of 2 c.c. botulinus antitoxin. Both treated and untreated birds were placed in pens and given access to water and grain. It is commonly assumed that untreated birds handled in this manner would have a better chance of survival than comparable birds left in the field to supposedly unfavorable physical conditions and to gull predation.

This prolonged experiment clearly proves that treatment with antitoxin is of value directly proportionate to the degree of sickness of the birds treated. Thus nearly two-thirds (64 percent) of the helpless birds -- prostrate or nearly so -- that would have died if untreated were saved by injections of antitoxin. An appreciable number (18 percent) of those less severely affected and half as

TABLE 14

RESULTS OF LABORATORY TREATMENT OF DUCKS AFFLICTED WITH BOTULISM

Bear River Wildlife Disease Research Station

1943 and 1944

Degree of Sickness	Treatment	Number Treated	Number Recovered	Percent Recovered	Percent Actually Saved	Cost per Bird Saved
Severe	Botulinus Antitoxin 2 c.c.	127	104	81.88%	64.03%	$ .078
Severe	No Treatment	28	5	17.86%	*	
Moderate	Botulinus Antitoxin 2 c.c	240	220	91.66%	18.13%	$.285
Moderate	No Treatment	102	75	73.53%		
Mild	Antitoxin 2 c.c.	50	44	88.00%	9.43%	$.330
Mild	No Treatment	14	11	78.57%		

many (9 percent) of those only slightly affected likewise were saved by antitoxin treatment. It may be objected that you cannot differentiate between an apparently mildly affected bird which may show severe symptoms in a few hours and a bird exposed to an actual sub-lethal dose of toxin. This is true, but the exception rather than the rule, and the table shows fairly accurately what may be expected in mass treatment.

Hospital. On the basis of laboratory findings in 1943, the use of antitoxin in the general treatment of sick ducks during hospitalisation was recommended by Dr. Quortrup for the 1944 season on all refuges where botulism is prevalent but with the reservation that only those birds which were prostrate and apparently hopeless cases be given antitoxin. Such a practice was followed by Asst. Refuge Manager Mark Nelson at the Bear River Refuge during the 1944 botulism season. Fresh water and grain were available in the holding pens at all times but the birds received no other treatment than antitoxin. The treated birds were segregated until they were able to move around freely and then placed in covered cages with untreated birds. When any of the latter became severely effected they also were given antitoxin and isolated until recovered sufficiently to be able to eat and drink.

Thirty-seven percent (380) of the 1015 birds received at the hospital were given antitoxin (Table 16). The remainder of the birds were either sufficiently recovered, or had received only mild doses of toxin in the field. Seventy-nine percent of all of the ducks which entered the hospital recovered, but the percentage of recovery for each of the three months listed is not a true index of the efficacy of treatment with antitoxin because no attempt was made to follow the individual cases through to completion. Many of the birds

TABLE 15

RESULTS OF THE USE OF ANTITOXIN IN THE REFUGE DUCK HOSPITAL
OF DUCKS AFFLICTED WITH BOTULISM

Bear River Refuge, 1944

Date	Number Birds Received Hosp.	Number Treated With Antitoxin	Percent Treated With Antitoxin	Total Number Recovered	Percent Recovery
August	398	141	35	350	88
September	583	231	40	436	75
October	34	8	23	19	56
TOTAL	1015	380	37	805	79

treated in August died in September and the same condition held for September and October.

The percentage of recovery would probably be somewhat higher if accurate records were kept on the losses occurring from lead poison, birds picked by sea gulls, or other causes of death. However, the table lists only the total birds recovered. Seven birds were noted as having been mutilated by sea gulls and later died from this cause, and two cases of lead poisoning were recorded. There were also thirteen birds included in the hospital losses which died after having been banded and released.

Generally speaking, the use of antitoxin as part of the hospitalization of sick ducks was found to be easy, quick, and effective.

Very few refuge managers took advantage of the offer that botulism toxin was available in 1944 at the Bear River Refuge laboratory. This is thought to be due to two factors, 1) the botulism outbreaks were exceptionally mild during the past season at most refuges and, 2) the various refuge managers were too busy with routine work to spend much time collecting sick birds for treatment. It is hoped that antitoxin treatment will be more generally practiced when more labor becomes available as it is without a doubt the simplest, most time saving, and most effective treatment known.

Field. Banding and release in the field of untreated sick ducks, begun in 1942 as a check on the value of current hospitilization methods, was continued during the 1944 botulism season. The original thought was that banding returns from such birds compared to returns from healthy birds banded in the same area would give an index to survival of ducks afflicted with botulism. In order to make returns of the same banding year available for comparison, a trap was placed in a marshy channel of Unit 5 in late July of 1944 and drives

of moulting birds made. The 1943 record indicated that both pintail and green-winged teal would be plentiful. The green-wings were not present as expected but 519 healthy pintails were trapped, banded, and released at a time when there was no indication of botulism in that or adjacent areas.

The 1942 idea of banding and releasing sick birds where found in the field was modified during the 1944 season by selecting 2 specific release areas --- sections of outside, marsh-fringed, borrow pit canals. This decision was prompted by the fact that it was impractical to release sick birds on units that were being drained because of interference with daily appraisals of botulism trends as well as by the thought that release in a limited habitat would facilitate a more thorough pickup of carcasses of such banded birds.

Banding for this experiment was confined to the 2 dominant botulism casualties --- pintail and green-winged teal, and a total of 417 (240 pintails and 177 green-winged teal) were banded and released in August and September. The banded birds were classified as to degree of sickness (severe, moderate, or mild) at the time of release; completely helpless individuals were placed at the water's edge with heads resting on their backs or on the bank.

Both release areas were periodically and thoroughly searched for carcasses. Usually the birds that were postrate when released were in place along the bank the following day and often with a high percent of mortality. Dead from this group along with those found in painstaking search of the release areas totalled 105 which was 25 percent of those banded and released (Table 16). It is believed that most of the remaining 75 percent recovered sufficiently to enable them to leave the release areas. Comparison with the more complete data on survival of untreated botulism ducks in the laboratory is suggestive (Table 17). Thus we note that the greatest recovery shown as possible by field data is

TABLE 16

Field release of untreated botulism ducks
Bear River Refuge, 1944

Ducks	Degree of sickness severe	moderate	mild	Total
Released	137	136	144	417
pintail	96	90	54	240
g.w. teal	41	46	90	177
Found dead	61	27	15	103
pintail	50	19	8	77
g.w. teal	11	8	7	26
Percent dead	45	20	10	av. 24.7

TABLE 17

Comparison of field and laboratory data
on mortality of untreated botulism ducks.

Degree of Sickness	Number of birds field	lab.	Mortality field	lab.	Dead percentage field	lab.	Recovery percentage field*	lab.
severe	137	28	61	23	45	82	55	17
moderate	136	102	27	27	20	26	80	74
mild	144	14	15	3	10	22	90	78
total	417	144	103	53	av. 24.7	37	av. 75.5	63

*greatest possible percentage.

only 10.5 percent greater than the actual recovery recorded in the laboratory in all but severe botulism cases. In the latter group, however, field data indicate a possible recovery more than 5 times as great as was found in the laboratory ---- perhaps the limited number of laboratory specimens used was inadequate. Nevertheless, we conclude that the collection of helpless botulism ducks for antitoxin treatment and hospitalization is completely justified but that capture of ducks less seriously affected by botulism is not worthwhile except to assist in appraising botulism trends or to gather birds for banding.

DUCK CARCASSES AS A CAUSE OF BOTULISM OUTBREAKS

Field and laboratory experiments have shown that maggots from botulism duck carcasses sometimes produce botulism when ingested by healthy ducks. Such data have led some students to conclude that duck carcasses left in the field will cause or prolong outbreaks of botulism. Other workers, equally as sincere in accepting the factual experimental data, suggest that field observations fail to support the conclusion that carcasses are a major botulism hazard. Additional data are needed by Refuge Managers who must justify their greatly increased work program if the decision is to collect carcasses. Such a decision would be momentuous indeed if the gathering of carcasses were to include thorough coverage of marsh and fringe as well as the more accessible dikes.

Preliminary experiments with carcass exposure in 1943 were a prelude to the large scale pen experiment with captive ducks in a maggot environment planned for the 1944 season at Bear River Refuge. Much labor seemingly went for naught when high winds wrecked the pens and released the captive ducks that had been trapped in advance of the botulism season. Prompt repair of some of the pens, however, permitted short preliminary tests of carcass exposure to confined ducks.

It was necessary to use birds that had recovered from botulism so we are unwilling to give a detailed report on the meagre data lest erroneous conclusions be drawn. We can say, however, that both botulism symptoms and death were noted among ducks confined in pens where several maggot-ridden carcasses were introduced. It is believed that the additional information obtained during 1944 will be of considerable value in improving the carcass experiments in the 1945 program -- including pen construction, carcass exposure, and season selection.

Appendix

Thoughts on matters of area treatment so far indicated (but not necessarily proved) in the studies conducted. They are submitted largely as a basis of discussion in connection with some of the practical water-handling problems that arise at the Bear River Refuge.

1. The elimination of some water areas from the botulism picture by drainage during part of the botulism season is indicated. That dry areas do not produce sickness has long been recognized, but nevertheless, the drying of an area under some conditions should be considered a management procedure (Units 1, 3, 4).

2. One of these conditions, is when the water from a botulism area can be drained and put elsewhere over land on which the danger of botulism developing is small. A unit after it has been dried out can likely be reflooded without sickness becoming severe. Putting the drained water over Salicornia flats also seems not to be a waste of water but rather a means of attracting birds to new and less dangerous areas where the feed is good. (Units 1, 4, and 2) .

3. The rate at which levels go down in the process of draining affects the degree of sickness. Theoretically, if a unit could be drained instantly sickness would stop immediately. The faster the lowering, the less likelihood of sickness, a process in which reflloodings by wind action play an important part. The faster the drop, the less likelihood of wind action flareups, and the faster the destruction of habitats producing toxin.

4. Stabilization of water levels (particularly along the shallow fringe), a condition often described in earlier work as "stagnant mud flats" is conducive to toxin development. Reflooding these due to influxes or wind action before they dry out tends to increase sickness by attracting birds to the danger spots or zones.

Under such conditions strong winds (150/more miles per 24 hours) tend to foster flareups of the disease. Any checking procedure or distribution of water to smaller impoundments or sloughs that would reduce the spread of water would help.

5. Evaluation of sickness cannot be made adequately from some shorelines. Where marsh is involved and a considerable distance from dikes, sickness may be high but the dikes show no evidence of it. When shallow water fringes approach the dikes, however, sickness becomes evident on such structures.

6. Impoundment of an area to high levels and against steep shorelines or over clay lands tends to keep sickness from being general in the area, but does not preclude the existence of toxic spots developing at the mouths of channels where water enters the Unit (Units 2 and 5). Where scarcity of water makes it impossible to maintain high levels on all areas during the botulism season, the consistent dropping of levels for the area is indicated and the putting of water into a dry unit or over another dry area. In other words, it might be possible, for example, to have little sickness in Unit 4 by draining the water out at .5 inch per day and then when dry being a refill with levels going up steadily.