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EVALUATION OF MOSQUITO BREEDING ON CORPS OF ENGINEERS PROPERTIES ADJACENT TO WILLISTON, NORTH DAKOTA

by

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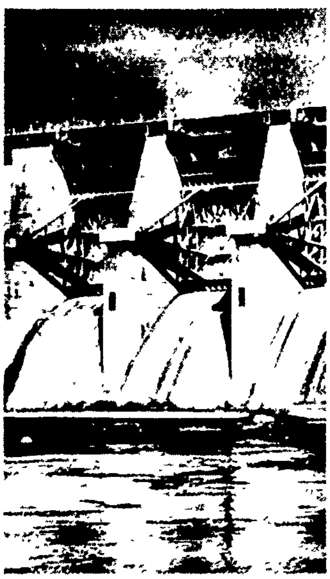

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The city of Williston, ND, is located at the confluence of the Missouri River and the Little Muddy River and has extensive river floodplains adjacent to it. Mosquito problems have been documented since the early 1800s, and nuisance levels of mosquitoes still exist.

The various habitats in the floodplain of the river were examined to determine where primary mosquito breeding sites were located. Data collected indicate that low densities of eggs are deposited in most of the floodplain habitats, with the highest numbers being collected in agricultural fields. In contrast, adult mosquitoes apparently concentrated in higher numbers in trees (willow) and alfalfa fields.

The floodplain of the Missouri River system is extensive, and even though mosquito egg density is low, large numbers of adults can be produced from the extensive acreage (24,000 acres) that exists. These floodplain mosquitoes are nuisance mosquitoes and generally are not associated with the transmission of viruses in North Dakota.

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PREFACE

This study was sponsored by the US Army Engineer District, Omaha. It was designed to evaluate mosquito breeding that was occurring on Corps of Engineers properties adjacent to the city of Williston, ND.

Principal investigator during this project was Dr. Alfred F. Cofrancesco, Jr., Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Other AHG personnel assisting in this project were Dr. Michael J. Grodowitz, Messrs. Paul H. Stokes, John Stevens, and Stewart J. Kecs, and Ms. Jan Freedman. Dr. Rose Kress and Mr. Flynn Clark of the Environmental Systems Division conducted the aerial photographic interpretation. The report was prepared by Dr. Cofrancesco. Appreciation is extended to the personnel of the Omaha District, in particular Messrs. Dwight Olson, Leroy Phillips, Bill McCann, and Jeff Keller.

The work was conducted under the general supervision of Dr. John Harrison, Chief, EL; Dr. Conrad J. Kirby, Jr., Chief, ERD; and Mr. Edwin A. Theriot, Chief, AHG.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	meters
foot-candles	10.76391	luxes
gallons (US liquid)	3.785412	cubic decimeters
inches	2.54	centimeters
miles (US statute)	1.609347	kilometers

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain kelvin (K) readings, use: K = (5/9) (F - 32) + 273.15.

EVALUATION OF MOSQUITO BREEDING ON CORPS OF ENGINEERS PROPERTIES ADJACENT TO WILLISTON, NORTH DAKOTA

PART I: INTRODUCTION

1. Williston, ND is located in the northwestern portion of the state at the confluence of the Missouri River (south) and the Little Muddy River (east). The city is located in part of the natural floodplain of these two rivers (Figure 1). A levee (8.8 miles*) on its south and east sides protects the city from high-water flooding of these rivers.

2. Mosquito problems along the Missouri River in North Dakota have been documented since the early 1800s (US Army Engineer District, Omaha 1984) and nuisance levels of mosquitoes still exist. In 1954, the US Army Corps of Engineers constructed a dam at Riverdale, ND, creating Lake Sakakawea. This impoundment inundates large areas of the Missouri River floodplain and reduces seasonal water-level fluctuations. Because floodplain mosquitoes rely on water-level fluctuations for development, reduction of the floodplain had reduced the mosquito breeding habitat in the state. However, the floodplain near Williston has not been permanently flooded by the lake itself, and this system is more typical of a natural floodplain environment.

3. Recent control efforts by the Williston Vector Control District No. 1 (WVCD) have centered on the adults. This type of treatment strategy attempts to reduce adult mosquito populations. It never addresses the source of the problem, the mosquito breeding areas. Adulticiding is a short-term control method and is usually a reaction to excessive levels of adult mosquitoes or a mosquito-related medical emergency situation.

4. Three species of mosquito dominate in the Williston area as indicated by annual reports of the WVCD. *Aedes vexans*, a common floodplain inhabitant, is abundant in the spring. It utilizes rising and falling water levels to produce successive populations (Freeborn and Bohart 1951). The next-most-abundant species, *Culex tarsalis*, breeds in a wide range of freshwater habitats and is the major vector for encephalitis in the state. The final problem mosquito, *Culiseta inornata*, is also found in a wide range of freshwater habitats (Bohart and Washino 1978).

5. In addition to knowing the species of mosquitoes that are causing problems, information is needed on mosquito life history and the importance of mosquitoes as disease vectors. The WVCD has information on adult mosquito populations; however, only minimal data have been collected on larval populations. Knowledge about the entire life cycle of problem mosquito species allows various treatment strategies to be developed. Treating larval populations early can prevent later increases in nuisance adult populations. Larval populations are typically more confined, and usually easier to treat with current control technologies. However, breeding sites for *A. vexans* and

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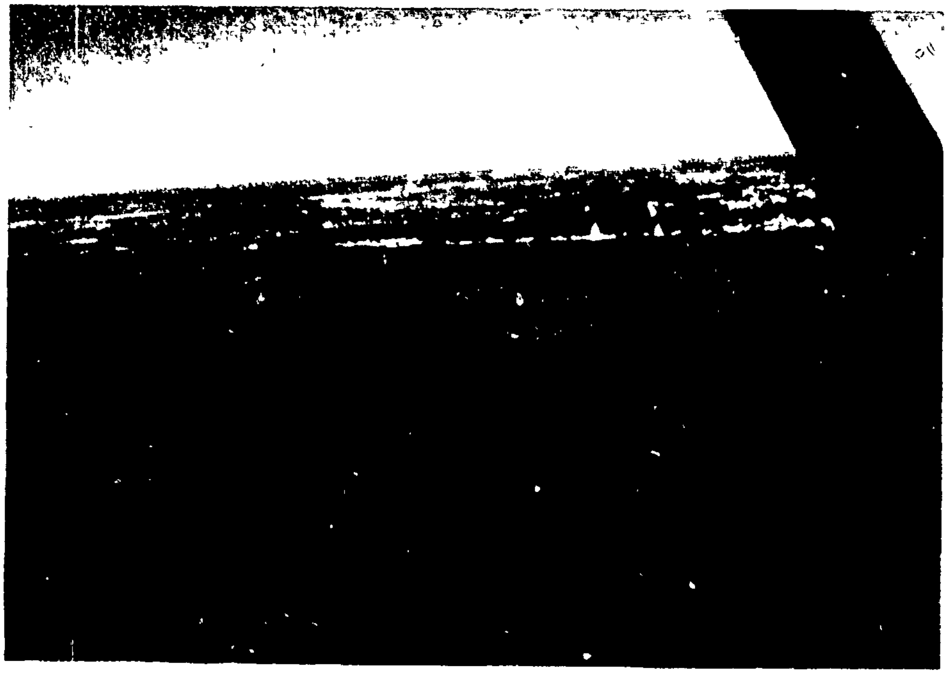
* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.



a. Floodplain south of Williston. The large channel is the main stem of the Missouri River

b. Floodplain east of Williston. The bridge in the photograph crosses the Little Muddy River

Figure 1. Aerial photographs of floodplain around the city of Williston, ND

C. Inornata may not be close to Williston, because these species can travel over long distances to find a host (Horsfall 1955; Clarke 1943).

Health Hazards

6. The main health hazard associated with mosquitoes is the transmission of disease organisms. Mosquitoes have been shown to transmit malaria, dengue, yellow fever, encephalitis, and other diseases. Of these diseases, encephalitis is probably the greatest threat to the North Dakota human population. Both St. Louis encephalitis (SLE) and western equine encephalitis (WEE) viruses exist in this region of the country, and both viruses utilize bird populations as reservoirs. The mosquito will feed on an infected bird and obtain the virus in the bird blood. The transmission of the virus occurs when the mosquito takes another blood meal from man or other mammals. The major vector for SLE and WEE in the North Dakota area is *C. tarsalis*.

7. The State of North Dakota classifies disease risk in five levels (see Appendix A). Records for the state indicate that the last major outbreak of encephalitis was in 1975, when 54 human cases were reported and 7 deaths occurred. Although encephalitis has not been eliminated from the state, its occurrence has diminished significantly since 1975. In the last 14 years, only 16 cases of the disease were reported in North Dakota and no human deaths occurred.

Mosquito Biology

8. *Aedes vexans* is a floodwater mosquito species that is widely distributed throughout the Holartic and Oriental Regions, Pacific Islands, and South Africa (Bohart and Washino 1978). It is generally associated with wooded and vegetated areas along the floodplains of rivers and pothole depressions (Freeborn and Bohart 1951).

9. *Aedes vexans* eggs are laid on moist soil and can withstand extensive drought, cold, and premature submersion (Horsfall 1956). Two to three years after being deposited, a high percentage of the egg population is still viable (Gjullin, Yates, and Stage 1950). Eggs are generally placed 12 to 14 in. below the high-water line (Horsfall 1963). *Aedes vexans* eggs and larvae can develop at 10° C; however, 20° to 30° C is a more suitable temperature for larval development. Development time will vary depending on average temperature; at 20° C it takes approximately 10 days for emergence, while at 30° C, emergence will occur at 8 days (Trpis and Shemanchuk 1970).

10. Breeland and Pickard (1964, 1967) conducted studies which indicate that adult females survive from 6 to 48 days and take multiple blood meals. *Aedes vexans* predominantly feeds on large domestic animals (Reeves and Hammon 1944; Rempel, Riddel, and McNelly 1946; Shemanchuk, Downe, and Burgess 1963; Edman 1971), and female egg production ranges from 22 to 564 per female (Breeland and Pickard 1964).

11. Extensive flight and blood-seeking activity occurred between temperatures of 16° and 27° C (Wright and Knight 1966). Flight activity increases as light intensity decreases to about 2.0 foot-candles. Wind velocities of 3.22 km/hr or greater depress

flight and biting (Bohart and Washino 1978). Individuals have been found in mark/recapture studies from 1 to 14 miles from their release and, with changing wind patterns, could travel over 100 miles (Clarke 1943; Horsfall 1955).

12. *Aedes vexans* has been identified as transmitting eastern equine encephalitis.

13. *Culex tarsalis* mosquitoes are widespread in the semiarid regions of North America, from British Columbia to Manitoba and Michigan south to Georgia, South Carolina, Mexico, and Baja, CA (Bohart and Washino 1978). Generally, occurrences of this mosquito east of the Mississippi River are rare (Jenkins 1950).

14. Adult females lay eggs on water in the form of rafts (Bohart and Washino 1978). Larval populations are found in a wide range of freshwater habitats and usually are associated with agricultural operations such as poorly drained pastures and irrigation seepage; however, larvae have been found in almost any groundwater pool (Telford 1958).

15. Seasonal abundance patterns of C. *tarsalis* vary with latitude (Nelson 1971). In North Dakota, major populations begin to occur in July and gradually decline through October. Water temperatures of 20° to 30° C appear to be optimum for larval development (Bailey and Gieke 1968) with adults emerging 8 to 10 days after hatch. Adults remain inactive for the 6-month winter period (Anderson and Harwood 1966).

16. The feeding preference of C. *tarsalis* is generally divided equally between bird and mammal populations (Bohart and Washino 1978). In its northern range, C. *tarsalis* is the primary vector of WEE and SLE.

17. *Culiseta inornata* is found throughout the Nearctic Region from northern Mexico to southern Canada. It has a wide tolerance for altitudes, being found as high as 10,000 ft (Bohart and Washino 1978).

18. *Culiseta inornata* also lay their eggs on water in the form of rafts, similar to *Culex*. Larvae are found in a variety of aquatic habitats, including ponds, ditches, canals, irrigation seepages, and rainpools (Telford 1958). In the North Dakota area, *C. inornata* is most abundant during July (Bohart and Washino 1978). Females have been shown to overwinter in Alberta, Canada, in a form of facultative diapause (Hudson 1976). Generally, *C. inornata* is not considered a severe biter of man, as it usually prefers large domestic mammals (Reeves and Hammon 1944; Washino et al. 1962).

19. It does have the ability to travel 14 miles (Clarke 1943) for a blood meal and has been found naturally with the WEE virus in Washington (Hammon, Reeves, and Galindo 1945) and the Cache Valley virus in Utah (Holden and Hess 1959) and North Dakota (Berge 1975).

Purpose

20. The lack of information on mosquito breeding habitats and the debate over what constitutes a mosquito-induced medical emergency prompted this study for the US Army Engineer District, Omaha.

21. The purpose of this study was to evaluate the Corps of Engineers (CE) properties adjacent to Williston for potential as mosquito breeding habitats. Specific objectives were to (a) determine the extent of breeding habitats, (b) identify major breeding sites, (c) identify criteria for a mosquito emergency health hazard, (d) ensure that control of a mosquito emergency health hazard is environmentally acceptable, and (e) develop recommendations for controlling or reducing mosquito populations.

PART II: MATERIALS AND METHODS

Study Areas

22. The floodplain of the Missouri River and the Little Muddy River is the responsibility of the Omaha District. To evaluate mosquito breeding habitats in this vast floodplain, five study areas were established (Figure 2).

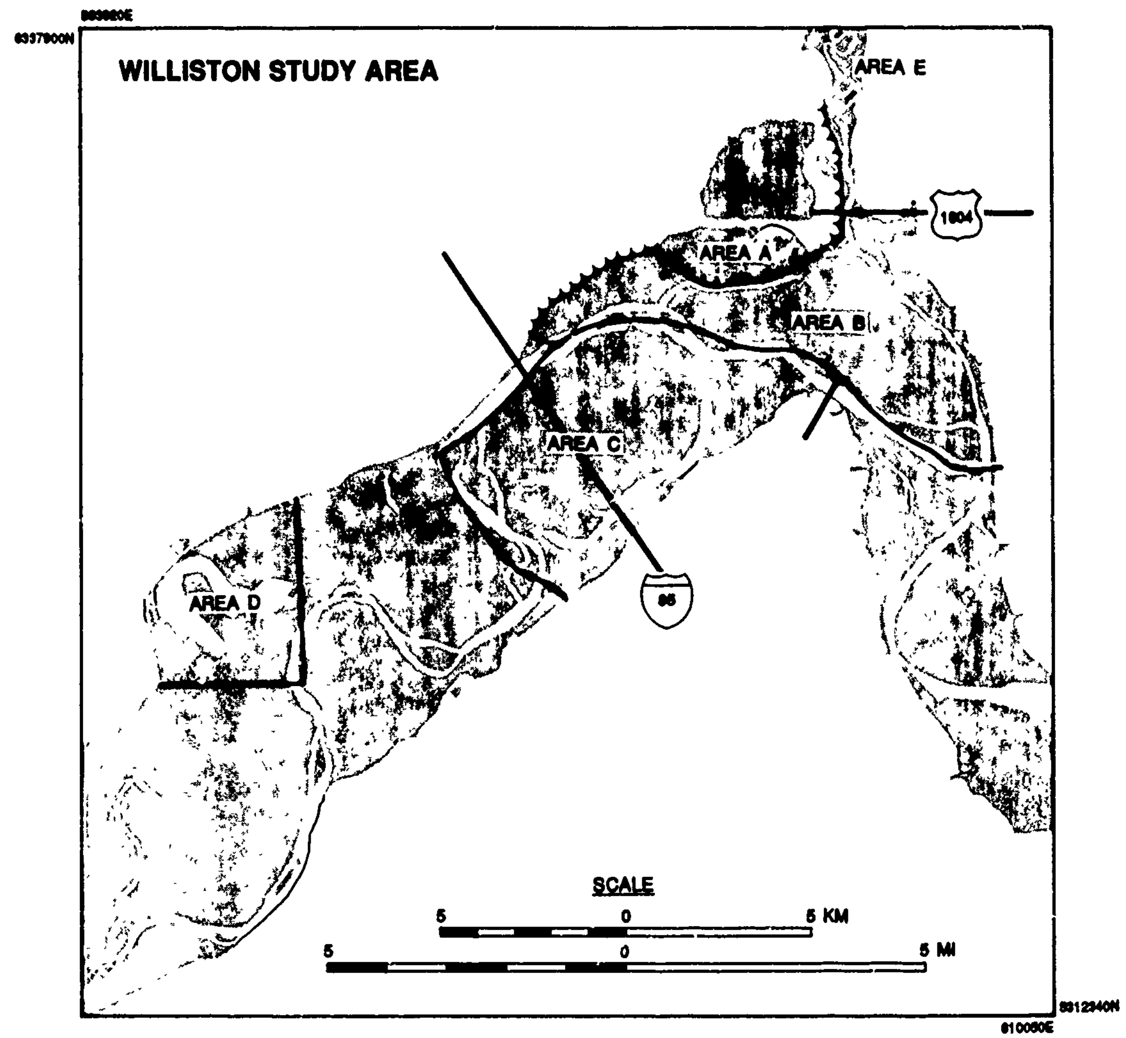


Figure 2. Five study areas (A-E) selected around Williston

23. Area A is composed of the land south of the railroad line and north of the southern levee system. This area receives water runoff from a 36,000-acre watershed. The Omaha District has a system of three pumps (25,000 gpm each), located southeast of Williston, which pump excess water over the levee into the Little Muddy/Missouri Rivers. This study area contains two active sewage treatment ponds and two old unused treatment ponds. This area also has three small lakes, one of which is spring-fed, agricultural plots of alfalfa and hay, and nonagricultural vegetated lands.

24. Area B consists of those lands south of the levee to the main stem of the Missouri River. To the east it includes the main stem of the Little Muddy River and its connection with the Missouri River. This area contains mud flats, point bars, midstream bars (vegetated and unvegetated), nonagricultural vegetated lands, and small water impoundments.

25. Area C is the Lewis and Clark Bottom. It contains the land south of the main stem of the Missouri River to the cliffs. The area extends east to the southern cliffs and west to the northern turn of the main stem of the Missouri River. It includes Skunk Hollow and the agricultural fields south to the cliffs. This area has vegetated and unvegetated bars, point bars, agricultural lands, nonagricultural lands, mud flats, and small water bodies.

26. Area D contains the land around Trenton Lake, and extends north to the railroad tracks, east to the main stem of the Missouri River, and south to the agricultural fields south of Trenton Lake. This area is composed of agricultural lands, nonagricultural vegetated lands, mud flats, point bars, and vegetated and unvegetated bars.

27. Area E contains the Little Muddy River and its floodplain north of Highway 1804 to White Bridge. This area is composed of agricultural lands, nonagricultural lands, vegetated lands, point bars, and small water impoundments.

Sampling

28. Mosquito sampling needed to begin immediately in July because floodwaters had already inundated the study areas. Five general habitats (Table 1) had to be selected for mosquito sampling while the mapping of the different land types was being conducted from the aerial photography. This caused some differences in the type of habitat sampled and interpretation of the aerial photography.

Table 1
Types of Habitat Sampled for Mosquitoes

Open water (natural and man-made bodies of water)
Native grass (mainly *Typha* and *Phragmites*)
Short grass
Tall grass
Trees (mainly willow)
Agriculture fields
Hay
Alfalfa
Sugarbeet
Mud flats (unvegetated exposed soil)

29. The most intense sampling was conducted in the study areas immediately south of Williston. Attempts were made to collect egg, larval, and adult samples from all

habitats that were identified; however, larval samples were not taken in a number of areas because there was no standing water.

30. Mosquito populations were sampled using three methods. Eggs were collected by a modification of Horsfall's (1956) method (Figure 3), larvae were sampled using the standard dipper method (Meek and Hayes 1978) (Figure 4), and adults were collected with Center for Disease Control (CDC) light traps (Meek and Hayes 1978) (Figure 5).

a. Metal sampler being pushed into substrate

b. Soil sample being removed with hand spade

Figure 3. Methods for collecting soil samples that contain mosquito eggs (modification of Horsfall 1956 method)

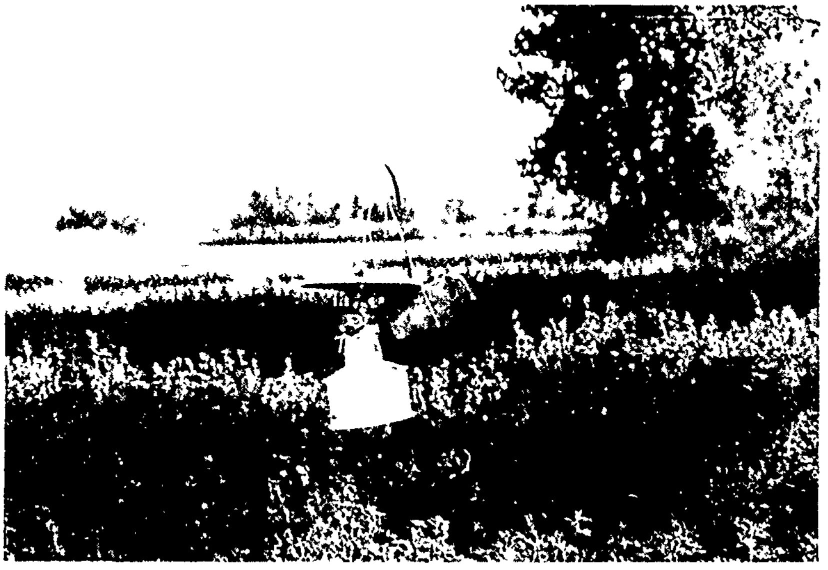
Figure 4. Dipper used for collecting samples of mosquito larvae

31. *Eggs.* Egg counts were taken during July and October, and all samples were processed as follows. Soil samples were removed from the oviposition site by a 15.24-cm square cutting tool (Figure 3). The cutting square was pushed into the substrate to a depth of 2.54 cm, and the sod was cut from the soil below with a hand spade. Samples were placed in plastic bags and transported on dry ice to the laboratory for processing.

32. Each sample was screened by washing through a series of sieves of different mesh size (meshes of 4, 8, 16, 40, and 100 squares to the linear inch). Eggs, sand, and minute detritus were trapped as a residue on the 100-mesh sieve. This residue was removed and mixed with 1.5 L of a saturated solution of sodium chloride. The solution was stirred for 1 or 2 min to allow eggs and fine organic particles to float and the soil particles to sink. The floating material was then filtered and washed. The floating process was repeated to ensure that all eggs were removed. The filtered material was then scanned with a microscope, and the eggs were removed and identified.

33. In July, 10 soil samples of each habitat type were randomly taken for egg counts. The majority of these collections were made in study areas A and B. Additional samples were taken from other study areas for comparison.

34. During the second sampling trip in October 1989, soil samples were taken along a transect to estimate mosquito egg density. Seven transects that traversed the changing elevation were randomly established. The lowest point on a mud flat was the starting point of the transect, and it was laid out across the rising elevation. Transects were limited to less than 30 m, and soil samples were taken in pairs at each 7.62-cm rise in elevation. A 1.8-m pole was placed at the starting point of the transect, and a second pole was placed at the highest elevation along the transect. A nylon cord was stretched between the two poles and leveled using a line level (Figure 6). The first pair of samples was selected from the starting point, and additional paired samples were taken at each 7.62-cm change in elevation. Changes in the elevation were determined by



a. Light trap placed in alfalfa field

b. Light trap placed in trees

Figure 5. Center for Disease Control light traps used to collect adult mosquitoes. (Brown bags contained dry ice, which gives off CO_2)

placing a graduated stick adjacent to the leveled line and determining where the next 7.62-cm change occurred. This process was repeated along the entire transect, with one 15.24-cm square of substrate being taken from each side of the transect line.

Figure 6. Transect along which soil samples containing mosquito eggs were collected from various habitats. (Flags were placed at each 7.62-cm increase in elevation. A soil sample was collected from each side of the transect at each flag)

35. *Larvae.* During July, four 50-m transects were established in habitats containing water. Mosquito larvae were sampled at three locations along the transects, with five dippers of water being taken at each point. This water was then passed through a 100-mesh sieve, and the larvae were counted.

36. *Adults.* Adult samples were taken by using CDC light traps. Both baited (CO_2) and unbaited traps were used on the first collection night. Collections conducted on all other nights used baited (CO_2) CDC light traps. Traps were placed in the various habitats at 1800 to 1900 hr and were allowed to run 12 hr. Adults were preserved and shipped in containers to the laboratory. Adult numbers and identifications were determined in the laboratory, and subsampling techniques were utilized to determine insect counts for the larger samples (1,000 individuals).

Habitat Mapping

37. To determine the types of habitats that are present and to develop acreage values, black-and-white aerial photography was used to map land types in the floodplain of the Missouri River near Williston, upriver from Lake Sakakawea. The photography was 1:24,000 scale taken 10 May 1988. US Geological Survey 7.5-min 1:24,000-scale maps were photographically reproduced on clear film and used as overlays so the photography could be registered to the maps. Transparent drafting film was subsequently overlaid onto the maps and photography, and different land types were delineated onto the Mylar.

38. Eleven classes of habitat types were delineated from the aerial photography, as listed in Table 2.

Table 2
Land Type Classifications

Land Type Category	Class Number
Levee	1
Water (natural)	2
Impoundments	3
Midstream bar (vegetated)	4
Midstream bar (bare)	5
Point bar (bare)	6
Agriculture	7
Nonagricultural vegetation	8
Bare (mud flat)	9
Highway right-of-way	10
Urban locations	11

39. Class 1, the levee, begins northeast of Williston, runs along the east side of the city, and wraps around the southern edge of the city, running west along the bank of the Missouri River. Water (natural), class 2, is any natural body of water and includes river channel and oxbow lakes. Impoundments (class 3) are man-made ponds. Midstream bars are divided into two classes, vegetated (class 4) and nonvegetated (class 5). Point bars (bare) (class 6) are bars associated with the riverbank and mapped as shown on the May 1988 photography. Only the nonvegetated portion of the point bar is included in class 6. Agriculture (class 7) is the area within the floodplain that is devoted to agriculture (either crops or pasture). Nonagricultural vegetation (class 8) includes all of the floodplain excluding bars, mud flats, and agriculture. Bare (mud flats) (class 9) includes the nonvegetated mud flats exposed at the time of the photography. The highway right-of-way (class 10) identifies where US Highway 85 passes through the floodplain, and includes the road, the berm on which the highway is constructed, and the canal on either side of the highway. The urban locations class (class 11) shows the approximate shape and location of the urban areas near the study area. These locations are marked on the map only to give perspective to the map, not to estimate acreage of urban area.

40. The overlays were digitized and the area of each land class cover determined. The files were gridded at a 30-m spatial resolution. The minimum mapping criterion was a 100-m^2 area. Any area smaller than the minimum mapping criterion was not mapped as a separate class. The study area was plotted at 1:48,000 scale.

Statistics

41. Means and two standard errors (2 SE) were calculated for all of the egg and adult counts taken from the different habitats. An analysis of variance was performed on the egg count data and the CDC light trap data to determine whether statistically significant differences occurred. Statistical differences were presented in a Tukey grouping of means.

PART III: RESULTS

Eggs

42. Data for 94 egg samples collected in July are presented by habitat and study area in Appendix B. The mean number of eggs for the 15.24-cm square of substrate ranged from 0.10 egg in the mud flats to 2.90 eggs in the hay field. An analysis of variance was conducted on the July egg samples. No significant difference ($p > 0.05$) was found between any of the habitats sampled (Table 3).

Table 3
Tukey Grouping of Mosquito Egg Counts Taken in Different Habitats During July 1989

Habitat	Tukey Grouping	Mean*	N
Hayfield (Area A)	A	2.900	10
Alfalfa field (Area A)	A	2.000	9
Tree (Area A)	A	1.700	10
Grass (Area B)	A	1.600	10
Sugarbeet field (Area D)	A	1.556	9
Grass (Area A)	A	0.500	10
Tree (Area B)	A	0.333	9
Mud flat (Area B)	A	0.100	10

* Means with the same Tukey Grouping letter are not significantly different.

43. The agricultural fields sampled had some of the highest egg values recorded. It is not known, however, if standing water is maintained long enough in these fields for mosquitoes to develop.

44. An estimate of mosquito egg density in areas A and B was obtained by totaling the number of eggs for each area and calculating a mean. Thirty-nine egg samples were examined for area A, and 69 *Aedes* eggs were collected which resulted in a mean of 1.77 ± 0.68 (2 SE) for each 15.24-cm square of substrate. For area B, 33 soil samples were taken, with 23 eggs being collected for a mean of 0.70 egg ± 0.61 (2 SE) for each sample. Extrapolation of these data would indicate that, on average, between 121,968 and 308,404 eggs would be found in each acre of habitat.

45. In October, seven transects were established along which egg samples were collected. Transects 1 through 6 were taken in Area B and passed through the majority of habitat types, while Transect 7 was taken along mud flats in Area A. The numbers of eggs found in each soil sample are presented in Appendix B. Two adjacent egg samples were taken at each 7.62-cm change in elevation along the transect. No clear pattern or areas of highest egg density could be established. An analysis of variance was conducted to determine if egg-laying differences in oviposition could be detected between

transects. The results of the analysis and Tukey Grouping are depicted in Table 4. No significant difference ($p > 0.05$) was noted between transects.

Table 4
Tukey Grouping of Mosquito Egg Counts Taken from Transects During October 1989

Transects	Tukey Grouping	Mean*	N
4	A	0.810	21
3	A	0.769	26
7	A	0.667	6
6	A	0.562	16
1	A	0.444	9
5	A	0.273	11
2	A	0.167	12

* Means with the same Tukey Grouping letter are not significantly different.

Larvae

46. Larval samples were collected in two habitats (open water and grass) in Areas A and B. The number of individuals collected was low. No larvae were collected along any of the transects in the open water habitat for area A or B. In the grass habitat a total of seven larvae were collected from all four transects, which represented 60 dipper samples. *Culex tarsalis* was the only species collected.

Adults

47. Ten CDC light traps were randomly placed in the natural grass habitat on 27 July 1989. Five of the traps were baited with CO_2, and five were not baited. Numbers of mosquitoes collected in each trap are presented in Appendix B. The baited traps had a mean of 880.4 ± 908.53 (2 SE) adults, while the unbaited trap had a mean of 59.8 (± 100.47). High variations were recorded within the baited and unbaited traps, and an analysis of variance indicated that the baited and unbaited traps were not significantly different ($p > 0.05$) (Table 5). Baited CDC traps were utilized during the four other

Table 5
Tukey Grouping of Adult Mosquitoes Collected in Baited and Unbaited CDC Light Traps

Traps	Tukey Grouping	Mean*	N
Baited trap	A	808.4	5
Unbaited trap	A	58.6	5

* Means with the same Tukey Grouping letter are not significantly different.

sampling nights (28, 29, 30, and 31 July). Three light traps were placed in different habitats of each area. Appendix B presents the light trap data collected from all habitats. The highest mean number of adults was 9,153 (±11,159.59) in the tree habitat. The lowest mean was 144 (±140.17) in the grass habitat. An analysis of variance and Tukey grouping indicated no significant differences ($p > 0.05$) in the number of mosquitoes collected from any habitat (Table 6).

Table 6
Tukey Grouping of Adult Mosquitoes Collected with CDC Light Traps in Different Habitats

Habitat/Area/Date	Tukey Grouping	Mean*	N
Trees (area A, 28 July)	A	9,153	3
Trees (area A, 31 July)	A	5,500	3
Alfalfa field (area A, 28 July)	A	3,495	3
Mud flats (area B, 29 July)	A	3,090	3
Alfalfa field (area C, 30 July)	A	2,617	3
Grass (area B, 29 July)	A	1,867	3
Trees (area B, 29 July)	A	1,317	3
Grass (area A, 31 July)	A	967	3
Grass (area C, 30 July)	A	950	2
Grass (area C, 30 July)	A	873	3
Trees (area C, 30 July)	A	305	3
Grass (area E, 31 July)	A	267	3
Grass (area A, 28 July)	A	238	3
Grass (area B, 29 July)	A	144	3

* Means with the same Tukey Grouping letter are not significantly different.

Habitat Mapping

48. The District's properties (represented in Figure 7) include a variety of land types. A breakdown of acreage for each land type is given in Table 7, along with the percentages of the total area that they represent. The nonagricultural vegetation class is the largest, comprising 43.4 percent of the total area examined. The next largest class is agriculture, comprising 27.9 percent of the total area. The other major classes are water (natural), comprising 11.9 percent, and bare (mud flat), making up 9.2 percent. The remaining classes are small and together represent only 7.7 percent of the total site.

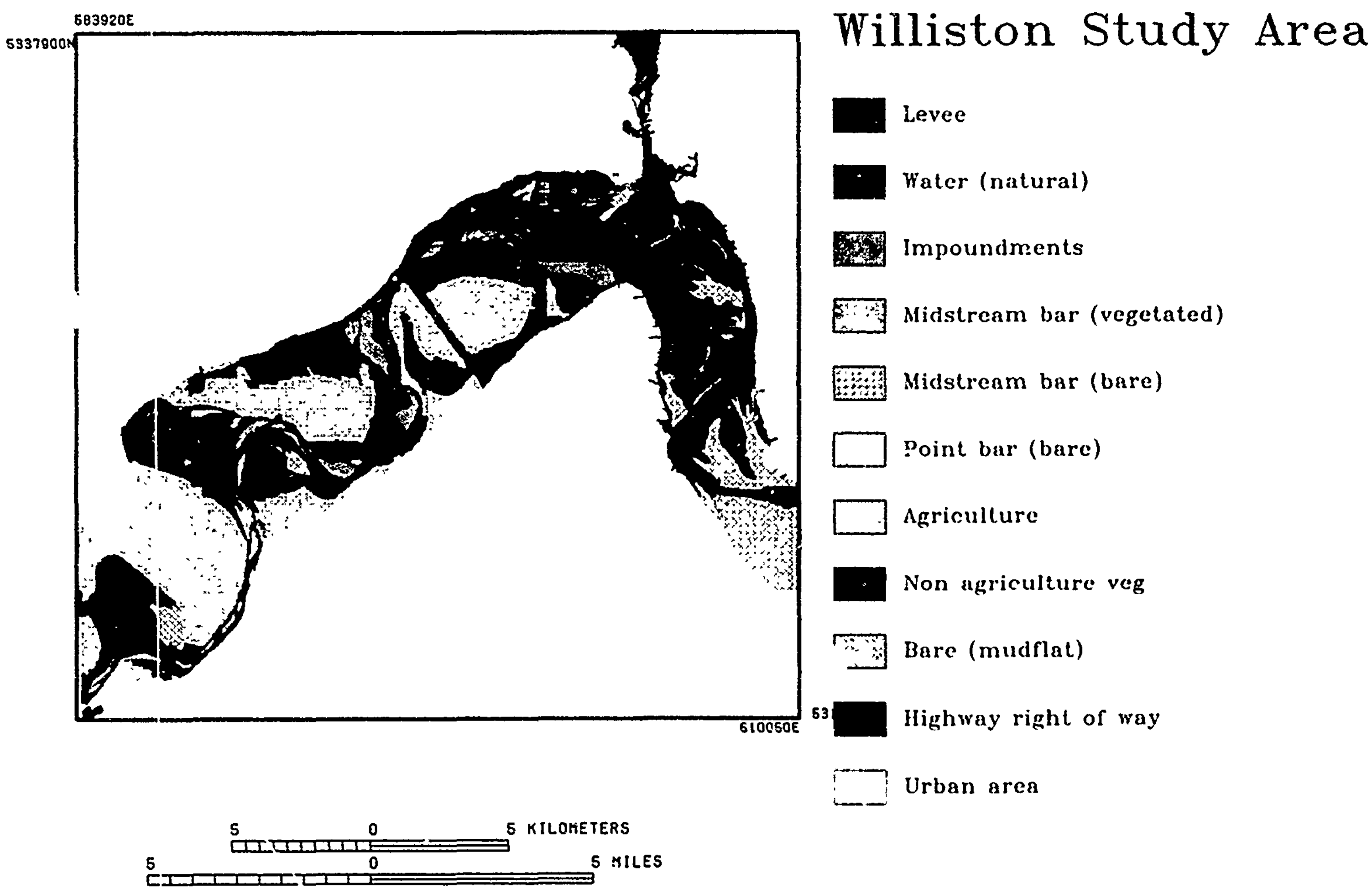


Figure 7. Map of land types in Missouri River floodplain adjacent to Williston

PART IV: DISCUSSION AND RECOMMENDATIONS

49. The data collected in this study provide information on the types of habitats that occur on CE properties and the number of eggs and adults associated with these habitats. Initiation of this study in July 1989 restricted the amount of information that could be collected on larval populations. Preflood sampling and larval sampling still have not been conducted, and these data may significantly alter the recommendations for mosquito population management.

50. Egg counts over both collection periods were generally low by most standards. It is not uncommon to have *A. vexans* egg counts of over 100 eggs per 15.24-cm square of soil. The general even distribution of eggs across habitats indicates that all habitats contribute to the *A. vexans* problem. The large acreages (> 24,000 acres) where breeding can occur, however, offset the low egg densities, and large numbers of mosquitoes are produced. This wide, even distribution of eggs makes it difficult to manage mosquito populations. It is apparent, however, that further examination is needed to determine the ability of mosquitoes to develop in agricultural fields or in the various communities that exist in the nonagricultural vegetated area.

Table 7
Total Acreage for Each Land Type Developed From Aerial Photography

Land Type Category	Area acres	Percent of the Study Area in Each Class
Levee	98	0.2
Water (natural)	6,233	11.9
Impoundments	204	0.4
Midstream bar (vegetated)	1,110	2.1
Midstream bar (bare)	381	0.7
Point bar (bare)	612	1.2
Agriculture	14,604	27.9
Nonagricultural vegetation	22,733	43.4
Bare (mud flat)	4,798	9.2
Highway right-of-way	1,637	3.1

51. The adult CDC light trap data indicate that the largest population of *A. vexans* occurred in area A. Light trap samples from other areas (B, C, or E) were high, but area A always had the highest counts, although they were not significantly different. Also, certain habitats such as alfalfa fields and trees are apparently congregation areas. This type of information is critical when developing an overall approach to mosquito control.

52. At least two distinct types of mosquito problems occur. The first is the problem of potential outbreaks of WEE or SLE. This problem occurs when high encephalitis

titer is found or when animal or human cases are reported. This constitutes a medical emergency, and the recommendations outlined for this situation should be implemented (pages 23 and 24).

53. The main vector for encephalitis is *C. tarsalis*. Larval collections and adult light trap samples taken on CE properties indicated that only low levels of this mosquito were present. In addition, the majority of habitat found in CE properties is not suitable for *C. tarsalis* breeding. These factors would indicate that major populations of *C. tarsalis* are not being produced on CE properties.

54. Nuisance mosquitoes are the second type of problem. These mosquitoes breed in floodplains and pothole depressions and have the ability to fly 15 miles for a blood meal (Clarke 1943). In the floodplain alone, the lands having potential to produce these mosquitoes exceed 24,000 acres. The lands where mosquito breeding occurs are valuable natural wetland communities that are acting as they have for hundreds of years before the city of Williston was founded. This floodplain represents some unique and desirable ecological habitat along the Missouri River that has not yet been destroyed.

55. At the present time the best long-range solution would be to reduce mosquito breeding habitat but retain the valuable wetland. A management plan is needed that will cause minimal but important modifications to the wetlands community, while increasing wetland values, such as waterfowl production areas. Permanent water bodies will increase waterfowl production and reduce mosquito breeding habitat. In addition, permanent water bodies could support a population of natural predators that feed on mosquito larvae and, as spring floods occur, these predators could migrate into the floodplain and feed on the mosquito population, similar to the open-marsh management program used in the eastern United States (Bruder 1980). A small-scale but effective larviciding program also needs to be implemented to test the ability to regulate larval populations close to the city, especially in areas A and E.

56. The city of Williston should investigate the possible use of chemical barriers set up on the flight path of *A. vexans* that enter the city. This method requires that a band of insecticide be sprayed on vegetation and physical structures in the flight path of the mosquito. This method has been used on a small scale in St. Paul, MN.*

57. The nuisance mosquito population at Williston has not been caused by the Omaha District operations on the Missouri River. It is the direct result of the natural environment that exists in the area. Mosquitoes are breeding on the Corps properties; however, other lands around the city of Williston, especially pothole wetlands, are probably also producing mosquitoes. The twin cities of Minneapolis and St. Paul, MN, have *Aedes vexans* as their major problem mosquito. The majority of their mosquito breeding occurs in pothole wetlands and temporary pools, not the Mississippi River system.* This pothole wetland type of habitat is prevalent around Williston, and could be producing large numbers of mosquitoes; however, this survey did not examine these areas as they are not on Corps properties.

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* Personal Communication, 1990, Dr. Sojogren, Metropolitan Mosquito Control District, Minneapolis/St. Paul, MN.

58. In developing mosquito treatment strategies, the problem mosquito species needs to be identified and its food and habitat preferences established. Once this information has been compiled, surveys should be conducted to locate these habitats. In examining the three problem mosquito species for the WVCD No. 1, different behavioral patterns are exhibited in egg laying, flight activity, and food preference. *Aedes vexans* lays its eggs on moist soil, while *Culex tarsalis* and *Culiseta inornata* lay eggs in rafts on temporary water surfaces. Flight patterns also vary. *Culex tarsalis* is a weak flier, while *Aedes vexans* and *Culiseta inornata* are strong fliers (Clarke 1943). Precipitin tests on feeding preference indicate that *Culex tarsalis* has a wider host preference than *Aedes vexans* or *Culiseta inornata* (Shemanchuk, Downe, and Burgess 1963; Edman 1971; Bohart and Washino 1978; Reeves and Hammon 1944). This type of information on the behavioral patterns of particular mosquitoes allows the pest manager to develop a control program for a particular mosquito pest.

Medical Emergency

59. If a true medical emergency exists, that is, where high encephalitis titer is found or where human or animal cases are reported in the area, immediate action is needed to control the *Culex tarsalis* population.

60. Medical emergency situations for encephalitis occur when high numbers of host, vector, and encephalitis reservoirs are in proximity. Western equine encephalitis and St. Louis encephalitis have the same general cycle with birds acting as the reservoir for the arboviruses. Titer level of the arbovirus in the bird population varies; however, when high levels are present, mosquitoes (*C. tarsalis*) will pick up the arbovirus from birds during a blood meal and transmit it to a host (human, other mammal) the next time it feeds. The equal preference of *C. tarsalis* to feed on birds and mammals makes it the most important vector of encephalitis in North Dakota. The fact that *A. vexans* has a low feeding preference for birds significantly reduces its role, if any, in the transmission of encephalitis in North Dakota (Reeves and Hammon 1944; Rempel, Riddel, and McNelly 1946; Edman 1971).

61. The following sequence of items should be addressed for a medical emergency.

a. Public information should be distributed on the emergency. Information should emphasize the seriousness of the emergency and give a description of symptoms. The human population should be advised on how to avoid contact with mosquitoes and on the proper clothing to wear.

b. Adult mosquito light traps (CDC type) should be placed at key locations on Corps properties to determine the population of *Culex tarsalis*.

c. Areas where adults are resting during daylight hours need to be treated with adulticide. Areas identified for treatment on the Corps properties should be treated, starting near the city and working outward. Major emphasis should be placed on trees (willow), alfalfa fields, and areas where high adult counts are found. The adulticide of choice should be a product that has no restriction for use over open-water areas. If no such product is available, an organophosphorus or pyrethroid-based broad spectrum insecticide should be used. A public health exemption to

US Environmental Protection Agency regulations should be requested, in accordance with the Code of Federal Regulations 166.3(c,d), so that areas restricted on the label could be treated during the medical emergency.

d. Field surveys of larval breeding sites should be conducted near agricultural operations, in areas such as drainage ditches, pastures, and irrigation canals, and also in standing water areas in nonagricultural lands.

e. Larval surveys should be followed by larviciding operations in areas where large populations of *C. tarsalis* are detected. Depending on the extent of the larval population and the mosquito instars present, either spot or general larviciding treatments need to be conducted. Generally, larviciding should be conducted first in areas where the most mature larvae appear. If the population is uniform in age, treatment should be prioritized by larval population numbers and proximity to the city. The larvicide used will depend on the maturity of the larval population. For general purposes a larvicide such as Altosid, which is effective on most larval stages and the pupae, would be preferred.

f. Bird trapping or live mosquito collections should be conducted, to determine the titers of the virus in the natural reservoir population.

The Mosquito Vector Control District should have the expertise to perform these operations.

Nuisance Situation

62. The control of nuisance mosquitoes like *A. vexans* presents a different problem. Population levels of this species are dependent on a number of factors, of which water runoff is critical. It will be extremely difficult to eliminate populations of *A. vexans* within a natural or seminatural wetland community. If the annual rise in the water level was eliminated, the population of *A. vexans* would be significantly reduced. Water-level fluctuations could be regulated by creating a lake that would cover over the wetland, regulating the flow of water discharged on the Missouri and Yellowstone Rivers, or dredging and leveeing the Missouri River from the existing lake to the Yellowstone River. Although impossible for a number of reasons, these changes would reduce mosquito-breeding habitat. However, they would also eliminate valuable wetland areas and produce many negative ecological impacts to the area, such as reduced waterfowl production areas.

63. Mosquito breeding occurs in the floodplain when the melting snow or rains cause rises in the water level of the Missouri River. The rising water inundates the mosquito eggs that have been oviposited on soil in vegetated areas. In the immediate area of Williston, the floodplain has over 24,000 acres of this type of habitat. The amount of this area that is inundated regulates how much mosquito breeding occurs.

64. The following recommendations are made for the control of floodplain-mosquito populations:

a. Develop a long-range wetland plan.

b. A program should be developed to reduce mosquito breeding habitat by increasing waterfowl habitat. *Aedes vexans* does not breed in stable water bodies.

Stable water bodies increase natural predators of mosquitoes (fish and invertebrates). When these water bodies are flooded, they would provide predators to the floodplain that feed on mosquito larvae.

c. The CE should allow the city to larvicide selected areas since treatment of the entire wetland is not feasible. The larvicide (i.e., *Bacillus thuringiensis* var. *israelensis* (Bti) or Altoside) should be as specific as possible for mosquitoes and not harm the natural predators.

d. A change in the water level pumping scheme in study area A should be explored. If water levels could be stabilized at a higher level the production of *A. vexans* will be reduced. If *A. vexans* eggs are inundated with cold water and kept submersed, they generally will not develop.

e. The city should also examine barrier treatments for adults as they enter the city. Records have shown which light traps have the highest numbers of adults. The utilization of a pyrethroid along some resting habitat adjacent to the city (like vegetation along or adjacent to the railroad) may reduce the amount of mosquitoes that enter the city.

PART V: CONCLUSIONS

65. Data collected in this study indicate that:

a. *Aedes vexans* deposits eggs in all floodplain habitats with the highest counts being recorded from a hay field.

b. Low numbers of *Culex tarsalis* larvae occurred in drainage ditches on Corps properties.

c. Adult *A. vexans* populations have their highest concentrations in willow trees and alfalfa fields near the city of Williston, ND.

d. The two major types of habitat found in the floodplain were nonagricultural vegetation and agricultural fields, both of which support mosquito breeding when flooded.

e. A long-range wetland plan that will reduce mosquito breeding habitat, yet still maintain valuable wetland areas, needs to be developed.

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APPENDIX A: NORTH DAKOTA LEVELS TO CLASSIFY DISEASE RISK, WEE SURVEILLANCE, AND DISEASE PREVENTION

Method of Assessment

a. **Mosquito Population Surveillance.**

(1) New Jersey traps - trapping begins Memorial Day and ends approximately Labor Day.

(2) Center for Disease Control (CDC) live trapping at specific chosen sites during third and fourth week of July.

(3) CDC live trap sites with greater than 200 *Culex tarsalis* (NJ count/week) for two weeks in a row, or one week of greater than 600 *Culex tarsalis.*

b. **Equine Cases Surveillance.**

(1) Send letters to veterinarians before season requesting blood samples of suspect cases.

(2) Call veterinarians each week beginning in July.

c. **Human Illness Surveillance.**

(1) Encephalitis is a reportable disease. The Division of Disease Control may intensify efforts in the event of a potential epidemic.

LEVEL I - Very Low Risk of Disease

a. **Criteria.**

(1) *Culex tarsalis* concentrations below the long-term mean (1977-present mean trap counts). No virus isolation in July.

(2) No report of suspect equine cases.

(3) No report of suspect human cases.

b. **Action.** General information releases on mosquito concentrations, including the difference between pest mosquitoes and disease vectors and the influence of rainfall and temperature on population buildup.

LEVEL II - Low Risk of Disease

a. **Criteria.**

(1) *Culex tarsalis* concentrations near long-term mean **and** low-level virus isolation. (Mean infection rates (MIR's) of 3.0 or less **and** less than 500 *C. tarsalis* per CDC trap baited with dry ice.) First significant rise in *C. tarsalis* numbers later than the second week of July. No virus isolation until first week of August.

(2) Few and sporadic suspect horse cases.

(3) No suspect human cases.

b. **Action.**

(1) Contact specific cities where virus is isolated and advise adult mosquito control action. Contact cities in areas near virus isolation that have greater than or equal to 1,000 *C. tarsalis* in one week's New Jersey trap catch and advise control action.

(2) Prepare press releases indicating higher vector populations. Include information on virus cycle, peak times of vector bites, and use of repellents and protective clothing.

LEVEL III - Moderate Risk of Disease

a. **Criteria.**

(1) *Culex tarsalis* population numbers higher than long-term mean (for two consecutive weeks) **and** moderate virus isolation (MIR's of 4.9 or less) **and** less than 1,000 *C. tarsalis* per CDC trap with CO_2. First significant rise in *C. tarsalis* numbers during the second week of July. First virus isolation during last week of July.

(2) Increasing reports of suspect horse cases.

(3) A few suspect human cases.

b. **Action.**

(1) Prepare press releases indicating increased virus isolation and potential for disease. Suggest not letting children play at dusk. Those who must be outdoors should wear protective clothing and repellent.

(2) Contact specific cities where virus is isolated and advise adult mosquito control action. Contact cities in areas near virus isolation that have greater than or equal to 1,000 *C. tarsalis* in one week's New Jersey trap catch and advise control action.

(3) Maintain active contact with hospitals and clinics. Encourage collection of acute and convalescent serums on all suspect human cases as well as cerebrospinal fluid and stool samples.

LEVEL IV - High Risk of Disease

a. **Criteria.**

(1) *Culex tarsalis* concentration **significantly** higher than long-term mean. First significant rise in *C. tarsalis* numbers during the first week of July. First virus isolation during second or third week of July. Larger vector population persisting and widespread **and** high virus isolation (MIR's of 5.0 and greater) **and** greater than 1,000 *C. tarsalis* per CDC trap with CO_2 per night.

(2) Confirmed horse cases and/or large increases in reports of suspect horse cases.

(3) One or more confirmed human case(s) and/or increasing reports of suspect cases.

b. **Action.**

(1) Contact specific cities where virus is isolated and advise adult mosquito control action. Contact cities in areas near virus isolation that have greater than or equal to 1,000 *C. tarsalis* in one week's New Jersey trap catch and advise control action.

(2) Prepare press releases indicating high risk of western equine encephalitis. Emphasize seriousness of illness and neurological sequelae in children.

Advise all people to wear protective clothing and use repellent when outdoors. Advise no exposure during evening hours.

(3) Maintain active contact with clinics, etc.

LEVEL V - Extreme Risk of Human Disease

a. **Criteria.** All Level-IV criteria plus increased confirmed human cases and more than two weeks to anticipated minimum evening temperatures of less than or equal to 60° F.

b. **Action.** Aerial-spray specific areas.

APPENDIX B: RAW DATA, EGG AND ADULT SAMPLES COLLECTED IN WILLISTON, ND

Table B1
Egg Counts of Soil Samples Taken for the Natural Grass Habitat (July 1989)

Replicate	Area A*	Area B-1*	Area B-2**	Area D**	Area E**
1	0	0	2	0	10
2	3	0	1	0	2
3	0	2	0	0	
4	0	6		0	
5	0	8			
6	0	0			
7	0	0			
8	0	0			
9	2	0			
10	0	0			
Total	5	16	3	0	12
$\overline{X}$†	0.50	1.6	1.0	--	6.0
2SE††	0.65	1.85	1.15	--	4.0

* Data collected from tall grass areas (> 50 cm).
** Data collected from short grass areas (< 50 cm).
† $\overline{X}$ = mean.
†† 2SE = two standard errors.

Table B2
Egg Counts of Soil Samples Taken for the Tree Habitat (July 1989)

Replicate	Area A	Area B	Area D
1	0	2	0
2	1	0	0
3	1	0	
4	2	0	
5	0	0	
6	6	1	
7	0	0	
8	1	0	
9	2	0	
10	4	--	
Total	17	3	0
$\overline{X}$*	1.7	0.3	--
2SE**	1.23	0.43	--

* $\overline{X}$ = mean.
** 2SE = two standard errors.

Table B3
Egg Counts of Soil Samples Taken for Agriculture Fields (July 1989)

Replicate	Hayfield Area A	Alfalfa Field Area A	Sugarbeet Field Area D
1	0	0	0
2	5	3	0
3	4	3	0
4	1	0	0
5	0	0	--
6	1	2	9
7	3	--	0
8	9	5	5
9	2	3	0
10	4	2	0
Total	29	18	14
$\overline{X}$*	2.9	2.0	1.56
2SE**	1.75	1.15	2.16

* $\overline{X}$ = mean.
** 2SE = standard errors.

Table B4
Egg Counts of Soil Samples Taken for Mud Flats (July 1989)

Replicate	Area B	Area D	Area E
1	0	0	0
2	1	0	0
3	0		
4	0		
5	0		
6	0		
7	0		
8	0		
9	0		
10			
Total	1	0	0
$\overline{X}$*	0.10	--	--
2SE**	0.20	--	--

* $\overline{X}$ = mean.
** 2SE = two standard errors.

Table B5
Egg Counts for Transects (October 1989)

	Sampling Points*												
Location	1	2	3	4	5	6	7	8	9	10	11	12	13
Transect 1 14.9 m	0 u** 2	0 u --	0 u 0	0 u 2	0 u 0								
Transect 2 30 m	0 u 0	0 u 0	0 u 0	0 u 0	2 u 0	0 u 0							
Transect 3 22.4 m	1 u 0	0 u 1	0 u 0	1 u 1	0 u 3	0 u 2	0 u 0	1 u 0	0 u 0	0 u 0	2 u 2	4 u 0	2 0
Transect 4 30 m	0 u 2	0 u 5	0 u 2	1 u 0	4 u 1	0 u 0	0 u 3	0 d† 0	0 d 0	2 d 0	1 0		
Transect 5 24.6 m	0 u --	0 u 0	0 u 2	0 d 0	1 d 0	0 0							
Transect 6 18.1 m	0 u 0	0 u 1	3 u 0	0 u 0	0 u 0	0 u 4	0 u 1	0 u 0					
Transect 7 15.2 m	0 u 0	2 u 0	2 u 0										

* Two samples were taken at each sampling point, and they are presented under the sampling point.
** u indicates next sample taken after a 3-in. rise in elevation.
† d indicates next sample taken after a 3-in. drop in elevation.

Table B6
Baited and Unbaited CDC Light Trap Collections in Natural Grass Habitat (27 July 1989)

Trap	Baited		Unbaited	
1	30	*A. vexans*	26	*A. Vexans*
2	1,960	*A. vexans*	2	*Anopheles punctipennis*
3	2,000	*A. vexans*	260	*A. vexans*
4	12	*A. vexans*	8	*A. vexans*
5	400	*A. vexans*	3	*A. vexans*
Total	4,402		299	
$\overline{X}$*	880.40		59.80	
2SE**	908.53		100.47	

* $\overline{X}$ = mean.
** 2SE = two standard errors.

Table B7
Adult Mosquitoes Collected from CDC Light Traps in Area A (28 July 1989)

Trap	Grass		Trees		Alfalfa Field	
1	250	*A. vexans*	6,000(E)*	*A. vexans*	12,000(E)	*A. vexans*
			10	*Anopheles*		
2	430	*A. vexans*	20,000(E)	*A. vexans*	1,286	*A. vexans*
			4	*C. tarsalis*		
3	35	*A. vexans*	1,460	*A. vexans*	8,000(E)	A. vexans
	2	*C. tarsalis*			20	*A. sollicitans*
$\overline{X}$**	239.00		9,158.00		7,102.00	
2SE†	227.17		11,159.59		6,253.48	
		Total	*A. vexans*	49,461		
			A. sollicitans	20		
			C. tarsalis	6		
			Anopheles			

* (E) = number extrapolated from subsamples.
** $\overline{X}$ = mean.
† 2SE = two standard errors.

Table B8
Adult Mosquitoes Collected from CDC Light Traps in Area B (29 July 1989)

Trap	Grass (Tall)		Grass (Short)		Trees		Mud Flats	
1	68	*A. vexans*	4,000(E)*	*A. vexans*	3,000(E)	*A. vexans*	452	*A. vexans*
2	284	*A. vexans***	100	*A. vexans*	652 1	A. vexans *Culiseta inornata*	818 2	*A. vexans*** A. sp. (*dorsalis*)
3	80	*A. vexans*	1,500(E)	*A. vexans*	300	*A. vexans*	8,000(E)	*A. vexans*
$\overline{X}$†	144		1,866.67		1,317.67		3,090.67	
2SE††	140.17		2,281.33		1,694.63		4,913.93	

Total	*Aedes vexans*	19,267
	Aedes sp.	2
	Culiseta inornata	1
		19,270

* (E) = number extrapolated from subsamples.
** Light on trap went out during sampling.
† $\overline{X}$ = mean.
†† 2SE = two standard errors.

Table B9
Adult Mosquitoes Collected from CDC Light Traps in Area C (30 July 1989)

Trap	Grass (Tall)		Grass (Short)		Trees		Alfalfa Field	
1	300 20	*A. vexans* *C. tarsalis*	60	*A. vexans*	75	*A. vexans*	850	*A. vexans*
2	1,600(E)*	*A. vexans*	2,500(E)	*A. vexans*	651	*A. vexans*	3,000(E)	A. vexans
3	--	*A. vexans***	60 4	*A. vexans* *C.* sp.	190	*A. vexans***	4,000(E)	*A. vexans*
$\overline{X}$†	960.00		874.67		305.33		2,616.67	
2SE††	1,280.00		1,625.33		352.00		1,858.61	

Total	*Aedes vexans*	13,303
	Culex tarsalis	20
	Culex sp.	4
		13,327.00

* (E) = number extrapolated from subsamples.
** Light on trap went out during sampling.
† $\overline{X}$ = mean.
†† 2SE = two standard errors.

Table B10
Adult Mosquitoes Collected from CDC Light Traps in Areas A and E (31 July 1989)

Trap	Area A Grass (Tall)		Area A Trees		Area A Alfalfa Field		Area E Grass (Tall)	
1	150	*A. vexans*	7,500(E)*	*A. vexans*	6,000(E)	*A. vexans*	300	*A. vexans*
2	1,250(E)	*A. vexans*	3,000(E)	*A. vexans*			181	*A. vexans*
	2	*A. dorsalis*						
3	1,500(E)	*A. vexans*	6,000(E)	*A. vexans*			320	*A. vexans*
							2	*Culex* sp.
							3	*A.* sp. (*dorsalis*)
$\overline{X}$**	967.33		5,500.00				268.67	
2SE†	829.78		2,645.75				88.85	

Total	*Aedes vexans*	25,712
	Aedes dorsalis	2
	Aedes sp.	3
	Culex sp.	2

* (E) = number extrapolated from subsamples.
** $\overline{X}$ = mean.
† 2SE = two standard errors.