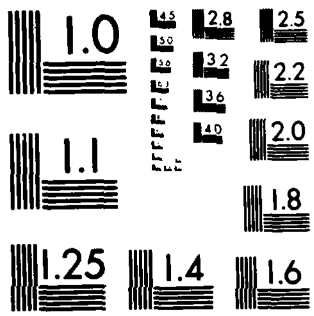
AD-A129 213 THE SHORELINE VEGETATION OF LAKE OAHE A MAN MADE FLUCTUATING WATER LEVEL..(U) SOUTH DAKOTA UNIV VERMILLION DEPT OF BIOLOGY B D VANDERVEEN ET AL. 1/1

UNCLASSIFIED 01 JUN 73 DACW45-73-C-0002 F/G 6/6. NL

END
DATE
FILMED
7-83
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

SOUTH DAKOTA UNIV., VERMILLION
DEPT. OF BIOLOGY
Contract DACW45-73-C-0002

4

THE SHORELINE VEGETATION OF LAKE OAHE
A MAN MADE FLUCTUATING WATER LEVEL RESERVOIR OF THE
UPPER MISSOURI RIVER BASIN

FINAL REPORT

June 1, 1973

by

Bruce D. Vanderveen

and

George R. Hoffman

INTRODUCTION

As one of six mainstem Missouri River reservoirs, Lake Oahe was created in 1958 when Oahe Dam, about nine kilometers north of Pierre, South Dakota, was closed off. The lake reached maximum pool level in the summer of 1971 and it now floods much of the Missouri River valley between Pierre and Bismarck, North Dakota.

The land surrounding the reservoir is used almost exclusively for grazing although some localized areas are farmed. The topography ranges from flat to rolling and dissected. In general the land along the west shore of the reservoir tends to be more dissected than that of the eastern shore. Clay soils derived from the Cretaceous Pierre Shale Formation predominate in the central and southern parts of the reservoir, while in the northern part sandy loam soils derived from Fox Hills Sandstone, a Paleocene Formation, predominate. In localized places around the reservoir silt loam and loam soils derived from Pleistocene loess and gravel deposits are present.

Man-made reservoirs having considerable water level fluctuations exhibit shorelines with little or no permanent macrovegetation. Water management practices imposed by the U. S. Army Corps of Engineers result in water level fluctuations of about 3.5 meters yearly with high water level attained in late June or early July and low water level attained in December or early January. The average water level fluctuation during the past four years is 3.3 meters with a low of 3.1 meters in 1970 and a high of 5.1 meters in 1971.

Factors working against the establishment of permanent shoreline vegetation besides water level fluctuations include wave action, poor aeration during flooding and desiccation during drawdown, type of substrate, cattle grazing and trampling, and deposition and erosion. In spite of these factors, some vegetation does become established along the shore, but mainly in bays and tributaries protected somewhat from wave action. On Lake Oahe there are even places along portions of the main reservoir where vegetation becomes established. Much of the vegetation is ephemeral and must re-establish by seed each season.

Little quantitative data have been reported concerning shoreline vegetation of fluctuating reservoirs. Penfound (1956) reported water level fluctuation to be the most important factor affecting vegetation along reservoir shorelines. Hall et al. (1946) studied reservoirs in the Tennessee Valley and reported that a reservoir with water level fluctuations of less than two feet during the growing seasons would support terrestrial vegetation from the shore down to six inches deep in the water, emergent aquatics within the top two feet of the water, and submergent aquatics in two to six feet of water. Tiemeir (1951) in a study of the Kanopolis

Reservoir in Kansas emphasized the importance of timing of water level fluctuations in relation to the timing of phenological characteristics in plants. Tiemeir listed as common on mud flats of the Kanopolis Reservoir the following plant genera: Polygonum, Helianthus, Xanthium, Erigeron, and Chenopodium. Many of these same genera are also known to colonize the bottoms of drained lakes in Kansas (MacGregor, 1948). Some studies have been done on the shoreline vegetation of reservoirs in Russia though most of the publications are in Russian and are unavailable to us. In a recent study on Lake Kariba, in Rhodesia, Magadza (1970) noted that shoreline vegetational zonation responded to lake level fluctuations. He also noted the predominance of annuals on the most frequently inundated areas.

It has been known for many years that flooding soils often decreases the availability of oxygen to plants growing on these soils. Additionally, poorly aerated soils often have certain nutrients available in toxic quantities (Conway, 1940). Gates (1948) suggested that in an aquatic environment only aquatic species can survive. As shoreline vegetation of a fluctuating reservoir is only periodically flooded the type of vegetation present is strongly dependent on the length and periodicity of flooding. Some terrestrial species actually increase production if flooded for short periods. Agropyron smithii, for example, produces increased amounts of forage when flooded occasionally (Houston, 1960). Aquatic species, however, often die of desiccation when water levels are low during the growing season. Even during the non-growing season low water levels may be detrimental to aquatic plants (Beard, 1973). Consequently, the zone of fluctuation along a reservoir presents an environment which is optimal for neither terrestrial nor aquatic plants and as a result is often devoid of any vegetation.

As a result of the significant water level fluctuations in Lake Oahe and the exposed eroding shoreline of the lake, the present study was initiated with the following primary objectives:

1. Quantitatively describe the shoreline vegetation along Lake Oahe and delimit vegetational zones which are controlled by the fluctuating water levels.
2. Relate vegetation to substrate conditions, slope, exposure and other factors.
3. Gather data and make observations bearing on the problem of water level management and succession of vegetation along the shore of this reservoir.

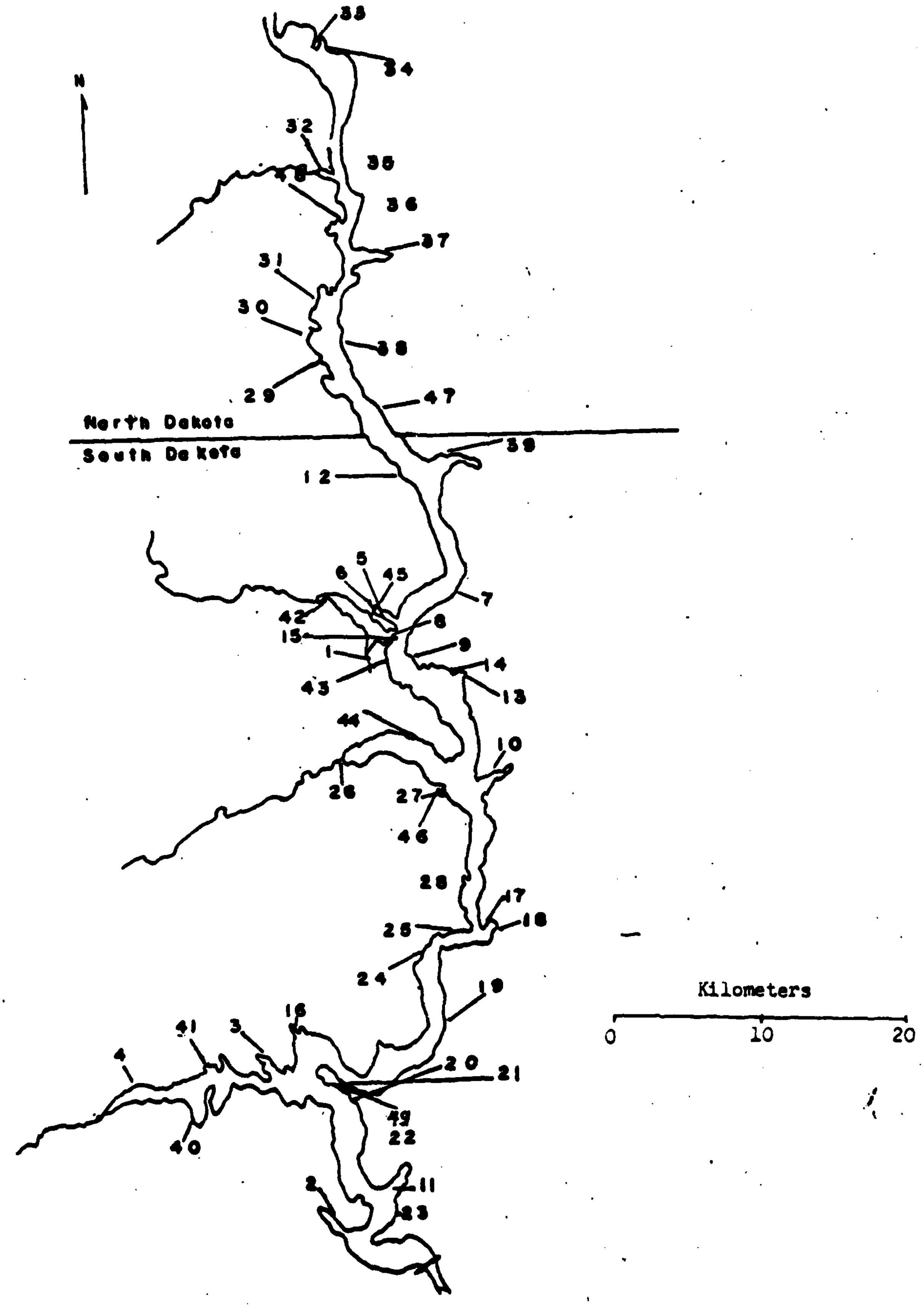
METHODS

Because much of the shore along Lake Oahe is uninhabited by plants, as a result of factors mentioned above, 49 study sites were selected where vegetation is present between high and low water levels. Figure 1 is a map giving the general location of these study sites. Appendix 1 gives the exact locations of these study sites along with their sketches and other information. Much of this vegetation is ephemeral, reestablishing from dissemmules each year; and these sites may be considered atypical for the shoreline as a whole.

At each site a permanent sampling transect was established between two stakes, the lower stake well out in the water during the growing season and the upper stake well above the highest water level. At the same time the transects were established, the slope and aspect from the top of the upper stake to the top of the lower stake were recorded.

Vegetational analyses were done during the latter part of 1971 and throughout most of the 1972 growing seasons. At each site a tape was stretched between the upper and lower stakes and canopy coverage for each species was estimated within a two by five decimeter plot frame placed along the transect at meter intervals but on opposite sides of the tape (Daubenmire, 1959). On several sites, where transects were long, the plot frame was placed every two or three meters along the tape. At all sites canopy coverage

Figure 1. A map showing the locations of study sites around Lake Oahe.


N
North Dakota
South Dakota
Kilometers
0
10
20
34
32
31
30
29
47
12
5
6
45
7
42
8
15
9
1
14
43
13
44
10
26
27
46
17
24
19
16
41
3
4
21
40
22
11
23
2

analyses were done as far into the water as vegetation extended. Ordinarily, at a given site, between eight and fifteen plots were analyzed within any one vegetational zone. By analyzing the vegetation periodically throughout the growing season it was possible to estimate maximum canopy coverage for each species, as well as account for the ephemerals which occur only during a relatively short period each growing season. A few selected sites were revisited in October of 1972 to gather data on fall seedling establishment in the zone of water fluctuation at a time when water level was low.

Vegetational data were later analyzed to determine dominance within each zone, average cover, and percentage frequency for species within vegetational groupings as they occurred on various substrates. Constancy, the percent of total sites on which a species occurred, was also calculated. Statistical analyses included multiple regression analyses to determine importance of some of the obvious environmental factors influencing vegetational development. Some of the statistical methodology is described later in the paper.

At each site a soil sample was collected from the upper two decimeters of soil in the zone of fluctuation, along the transect. These soils were later analyzed for nutrients, texture, organic matter, pH, and salinity.

Readily available calcium, potassium, magnesium, phosphorus, chlorides, and sulphates were determined using a Hellige-Truog soil testing kit. Percentage nitrogen was determined by the Soils Testing Laboratory, South Dakota State University, Brookings. The Bouyoucos method of mechanical analysis was used to determine percentages of sand, silt, and clay; and percentage organic matter was determined using a modified Walkley-Black method (Moody, Smith, and Hausenbuiller, 1963). Conductivity of the saturated soil extract in mmho/cm was determined with a Wheatstone bridge.

Plants were collected and voucher specimens of all species are filed in the University of South Dakota Herbarium, Vermillion. An annotated list of all plant species observed in the vicinity of Lake Oahe during the study is presented in Appendix 2.

RESULTS AND CONCLUSIONS

The Physical Setting. Lake Oahe, as mentioned above, floods much of the Missouri River valley between Pierre, South Dakota, and Bismarck, North Dakota. Physiographically the area consists of glacial drift and drift-free plains. The Missouri River valley roughly separates the drift covered plains to the east from the drift-free plains to the west. E. P. Rothrock (1943) describes the Missouri River valley in which Lake Oahe is located as "characterized by its steep rugged bluffs and narrow flood plains." The valley in this area averages 1.6 kilometers in width and about 130 meters in depth. Also present are "myriads of small streams cutting back into the bluffs in a labyrinth of gullies [to] form fringes on both sides of the valley locally known as 'breaks' which extend from one to five miles back of the valley proper" (Rothrock, 1943).

The area is characterized by a continental climate with hot summers and cold winters. Summer temperatures may exceed 35°C and winter temperature may drop below -30°C. Mean January temperature at Mobridge, South Dakota, for the period 1931 to 1955 was -10.4°C while mean temperature for July was 23.9°C. Mean annual precipitation over the same period at Mobridge was 40.2 cm (U. S. Dept. of Commerce, 1960).

Soils. A wide range of soil textural types is present around Lake Oahe. In the south and central part of the lake extensive outcroppings of Cretaceous Pierre Shale occur. In the north Paleocene sandstones are present. In localized places gravel and loess deposits of Pleistocene age are present. Consequently, there is a wide diversity of parent material around Lake Oahe. Figure 2 is a generalized map of the positions of these various parent materials around Lake Oahe. Due to their localized nature the Pleistocene loess and gravel deposits are not mapped in Figure 2. Loess, especially, however, is present in several localized areas as a thin "blanket" over the mapped materials.

Since soil samples were collected in Zone 2 at each study site it was possible to analyze soils derived from each of these four major types of parent materials. In general it was found that the shale, loess, gravel, and sandstones gave rise to clay, silt loam, loam, and sandy loam soils respectively. The collected soil samples were analyzed as to texture, nutrients, percent organic matter, pH, and salinity (conductivity). The results of these analyses are presented in Table 1.

Average cover, frequency, and constancy were calculated for each plant species present in the transects on each of the four previously mentioned soil types. These data are presented in Table 2 in the Description of Vegetation section. In order to calculate these data, the type of soil

Figure 2. Generalized map of parent substrates in the vicinity of Lake Oahe.

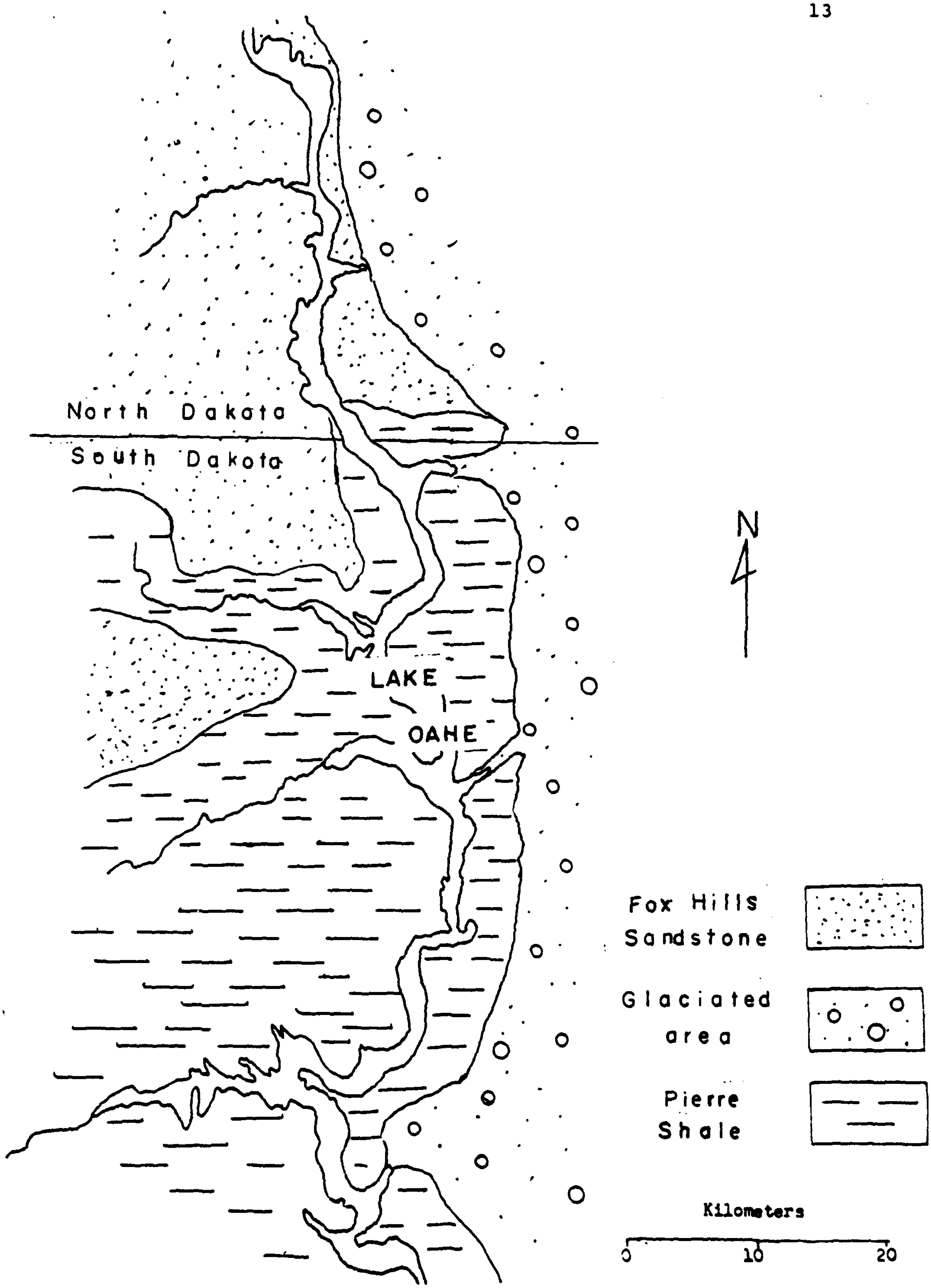

North Dakota
South Dakota
LAKE
OAHE
N
Fox Hills
Sandstone
Glaciated
area
Pierre
Shale
Kilometers
0
10
20

Table 1. Texture, parent material, nutrients, organic matter, conductivity, and pH of soil samples collected in zone 2 at each study site.

Site	Texture	% Sand	% Silt	% Clay	Parent Material	Total N (%)	P (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	SO_4 (ppm)	Cl (ppm)	Organic Matter	Cond. $\frac{mmhos}{cm}$	pH
1	clay	18	29	53	shale	.08	38	3000	100	1500	125	125	.08	.8	7.5
2	clay	24	22	54	shale	.15	100	3000	120	750	125	250	.06	.8	7.6
3	clay loam	24	40	36	shale	.08	100	2500	160	750	125	188	.05	1.4	7.9
4	clay	18	34	48	shale	.07	100	3000	160	500	2500	2500	T	3.0	7.7
5	clay	18	32	50	shale	.04	100	3000	80	375	125	500	.07	1.8	7.6
6	sandy loam	64	30	6	alluvium	.50	100	2500	140	500	750	125	.04	3.0	6.0
7	sandy loam	64	16	20	sandstone	.29	100	2500	120	500	500	250	1.01	2.9	6.5
8	silt loam	20	62	18	loess	.16	100	2500	140	250	125	500	.07	1.4	7.4
9	loam	46	44	10	gravels	.09	100	3000	160	500	125	188	T	1.4	7.9
10	loam	28	47	25	shale	.24	100	2500	140	750	125	188	.30	1.5	7.2
11					gravels										
12	silt loam	24	68	8	loess	.23	100	2500	140	750	125	188	.19	1.2	7.1
13	clay	10	38	52	?	.10	100	3000	160	750	500	188	T		7.6
14	clay	20	38	42	?	.24	100	2500	140	250	500	125	T		7.2
15	silty clay loam	20	42	38	?	.16	100	3000	160	375	125	188	T		7.1
16	clay	20	25	55	shale	.01	100	3000	160	750	500	125	T		7.4

Table 1, cont'd.

Site	Texture	% Sand	% Silt	% Clay	Parent Material	Total N (%)	P (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	SO_4 (ppm)	Cl (ppm)	Organic Matter	Cond. $\frac{mmhos}{cm}$	pH
17	loam	45	40	15	gravels	.11	100	3000	160	750	188	125	.27		6.4
18	loam	39	44	17	gravels	.20	100	3000	160	250	250	125	.40		
19	sandy clay	47	17	36	shale	.18	100	3000	160	500	500	188	T		7.3
20	clay	13	31	56	shale	.10	100	3000	160	750	2500	125	T		7.9
21	silt loam	16	57	27	loess	.20	100	3000	160	750	500	125	.14		7.0
22	sand	93	5	2	sand	.00	100	3000	160	250	125	125	T		7.4
23	loam	32	49	19	?	.21	100	3000	160	500	188	125	.74		7.1
24	clay	21	32	47	shale		100	3000	160	500	125	125	.21		6.2
25	clay	12	35	53	shale	.32	100	3000	160	1000	750	125	.28		6.5
26	clay	6	22	72	sediments	.10	100	3000	160	500	188	125	T		7.0
27	clay	18	38	44	shale	.01	77	2500	140	500	125	125	.03		5.6
28	silty clay	8	40	52	shale	.23	100	2500	140	250	125	125	.38		6.5
29	sandy loam	60	26	14	sandstone	.25	100	2500	140	750	125	125	.42		6.4
30	sandy loam	66	22	12	sandstone	.16	77	3000	160	500	125	750	.59		6.8
31	loamy sand	80	12	8	sandstone	.11	100	1000	80	375	125	500	.07		6.3
32	sandy loam	56	24	20	sandstone	.04	100	2500	120	750	250	250	T		7.5
33	sandy loam	56	24	20	sandstone	.05	100	3000	160	500	188	250	.03		7.5
34	loam	30	44	26	sandstone	.22	100	3000	160	250	250	250	.37		7.3

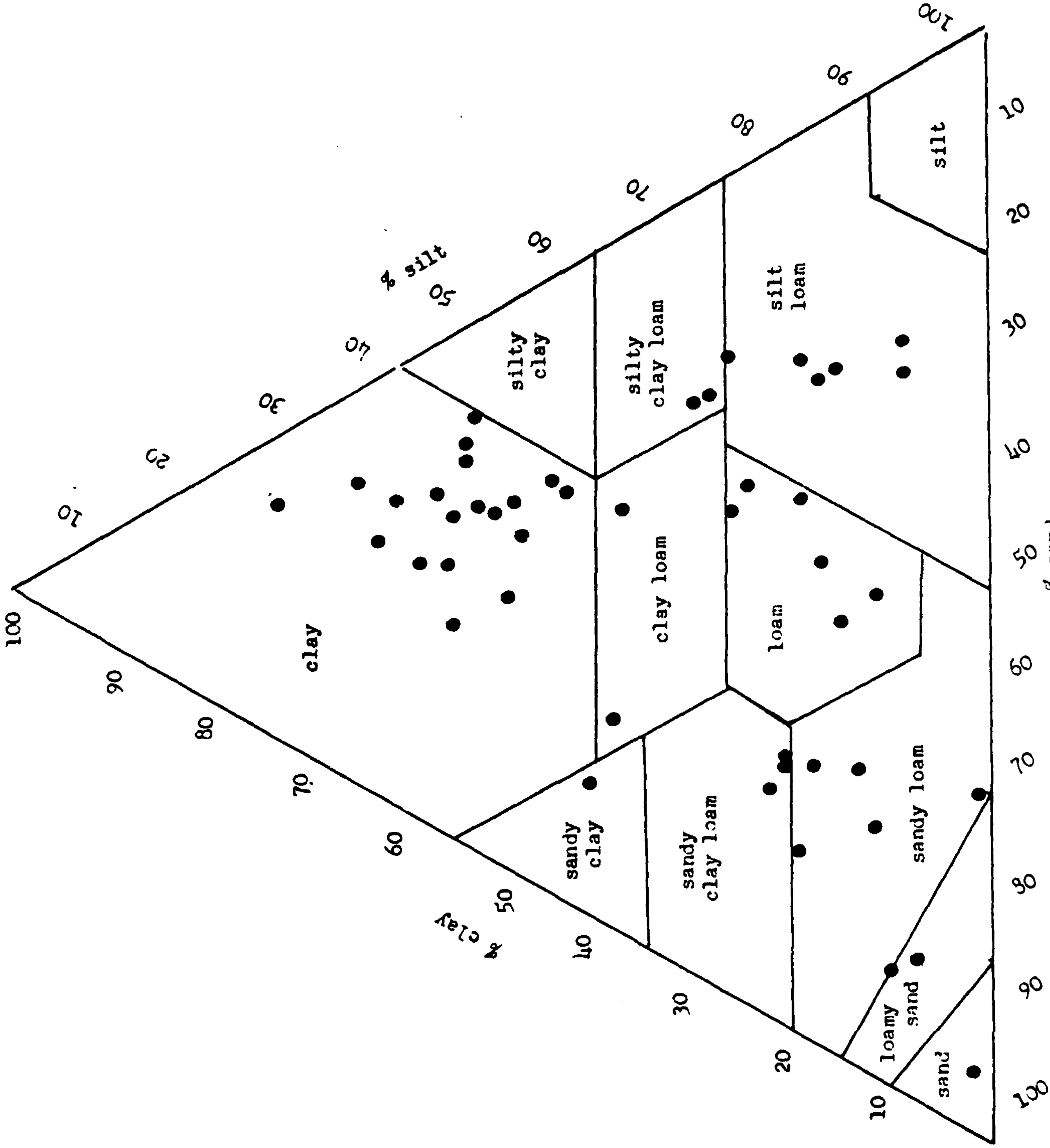
Table 1, cont'd.

Site	Texture	% Sand	% Silt	% Clay	Parent Material	Total N (%)	P (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	SO_4 (ppm)	Cl (ppm)	Organic Matter	Cond. $\frac{mmhos}{cm}$	pH
35	silty clay loam	18	52	30	?	.20	100	3000	160	750	2500	2000	T		7.7
36					sandstone	.11	100	3000	160	750	250	500			7.5
37	sandy clay loam	58	20	22	sandstone	.18	100	3000	160	500	125	750	T		7.2
38	sandy loam	58	24	18	sandstone	.23	100	3000	140	500	500	188	T		6.3
39	clay	16	32	52	?	.21	100	3000	160	750	125	125	T		6.8
40	clay	12	28	60	shale	.13	100	3000	160	500	2500	500	T		7.6
41	clay	42	18	40	shale	.07	100	3000	160	750	250	2500	.05		7.3
42	clay	8	28	64	shale	.16	100	3000	160	500	250	2000	T		7.1
43	clay	14	24	62	shale	.05	100	3000	160	1000	125	188	.10		7.1
44	silt loam	22	64	14	loess	.07	100	3000	160	750	2000	250	.14		6.6
45	clay	26	26	48	shale	.11	100	3000	160	750	2500	188	T		7.3
46	clay	16	30	54	shale		51	3000	160	375	125	125	T		
47	silty clay loam	18	54	28	loess		13	3000	160	1000	125	125	T		
48	silt loam	26	66	8	loess		100	3000	160	750	125	500	.22		
49	silt loam	22	66	12	loess		100	3000	160	1000	2500	1500	.51		

texture present for each study site was determined. Almost all of the study sites readily fell into one of these four categories. This can be seen from Figure 3. Those few sites which did not readily fall into one of these four categories were placed in that category to which they were closest. Consequently, the data in Table 2 are based on a maximum of 23 sites for clay soils, 8 sites for silt loam soils, 5 sites for loam soils, and 12 sites for sandy loam soils. The distribution of the important plant species among these four soil types is discussed later.

Textural analysis of the soil samples gave a wide range of readings as would be expected with the diversity in parent material. Available nutrients were not related to soil texture. In general the soils tended to be high in calcium (about 3000 ppm), phosphorus (about 100 ppm), and potassium (about 140 ppm). Most soils were low in sulphates (about 125 ppm) and chlorides (about 250 ppm). A few sites, however, on shale-derived clay soils were high in sulphates and/or chlorides. These are solenchak areas (Daubenmire, 1959). Magnesium and percent total nitrogen tended to vary from site to site as did the percent organic matter. A few conductivity tests were done on soil extracts to test for salinity. Even areas high in sulphates and chlorides such as site 4, however, gave readings which are not indicative of excessive salinity (3.0 mmhos/cm in the case of site 4).

Figure 3. The soil texture of each study site is shown by a dot on the soil-texture triangle.


% silt
% clay
% sand
10
20
30
40
50
60
70
80
90
100
clay
silty clay
silty clay loam
silt loam
silt
clay loam
loam
sandy clay
sandy clay loam
sandy loam
loamy sand
sand

In order to test the possible significance of substrate characteristics on vegetation we used a multiple regression program. The dependent variables, total cover, in each of the two zones, and diversity, in each of the two zones, were tested for significance against the independent soil parameters percent sand, percent organic matter, and percent nitrogen.

Data used for the independent variables in the programs were selected from Table 1 while data for the various dependent variables used were calculated independently from raw data. Total cover and diversity were calculated for equal areas, plots within eight meters on each immediate side of the ecotone between Zone 1 and Zone 2. Total cover data are not listed in this paper but diversity data are (Table 3). Total cover was calculated by summing the individual species average cover values in the areas mentioned above. Diversity was calculated using the Shannon-Wiener diversity index as explained later.

Analysis of variance for the regression provided the calculations, sum of squares and mean squares, to determine an "F" value. Critical values of "F" were exceeded at the .05 probability level in regressions of Zone 1 and Zone 2 total vegetation cover regressed against the independent soil characteristics mentioned above. Zone 1 diversity was very close to being statistically influenced by the same soil characters.

The individual computed t values of the independent variables percent organic matter, percent nitrogen, and percent sand were tested for significance in a two-tailed test at the .05 level with Student's t-distribution. Critical values were consistently exceeded for the percent sand as an independent variable in all programs. Also, the test with Zone 1 total cover as the dependent variable showed the percentage nitrogen as being significant. None of the programs showed the percent organic matter as being significant.

More work using multiple regression could be useful. In addition to the effect of selected substrate characteristics on total cover and diversity, it may be possible to satisfactorily quantify water level data, wave action, and possibly other factors for use in regression programs. Other dependent variables could include coverage values for selected species or groups of species. Ultimately, the goal is to gain sufficient data for useful predictive measures.

Description of the vegetation. The shoreline vegetation around Lake Oahe can be subdivided into two zones. Zone 1 vegetation occurs above the level of highest water and has never been inundated. It ranges from near pristine steppe vegetation to highly overgrazed pastures. Zone 2 vegetation is that which is inundated almost every year but at least has been inundated once in the past. It was primarily upland vegetation once, but because of the flooding it now consists only of remnants of the grassland along with a complex of invading species, most of which are annuals.

Zone 1 vegetation is primarily grassland. Dominant grasses include species of *Agropyron*, *Stipa*, and *Andropogon* (Kuchler, 1964). *Agropyron smithii* dominates on shale-derived clay soils while dominance is shared with *Carex* and *Stipa* species on the soils with a higher percentage of sand. A complete listing of all plant species occurring in Zone 1, their coverage, frequency, and constancy, is presented in Table 2.

Localized areas on upland shale-derived soils may become quite saline. Soils of such areas are the previously mentioned solenchak areas. An entirely different plant community develops on these areas. Total plant cover is reduced and *Atriplex* species, especially *A. dioica*, dominate. The grass *Distichlis stricta* may also be present.

Much of Zone 1 vegetation around the reservoir has been disturbed by cultivation or severe grazing. Cultivation

Table 2. Average per cent cover (Avg. Cov.), frequency (F), and constancy (C) for all species determined for all soils, as well as for individual soil types within zone 1 and zone 2; ranges of observed flowering times are also given for important species in zone 2. Maximum values for 1972 are presented.

	ZONE 1										ZONE 2										
	All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		
Species	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Obs. Flw.
Agropyron smithii	43.0	64./72.	54.0	72./74.	35.0	53./71.	36.0	59./80.	31.0	57./67.	15.0	31./62.	18.0	38./64.	15.0	29./71.	17.0	30./50.	8.2	23./58.	Ju.
Bromus japonicus	11.0	29./34.	13.0	41./39.	16.0	34./43.	4.6	14./20.	6.3	09./17.	3.5	11./28.	1.2	12./27.	15.0	29./71.	0.8	01./17.	0.4	01./17.	Ma.-Ju.
Melilotus spp.	9.1	20./40.	3.8	18./52.	2.3	15./29.	23.0	05./20.	20.0	35./33.	0.8	05./30.	1.1	04./36.	0.9	10./30.			3.4	03./33.	Ju.-Jul.
Agropyron cristata	6.2	09./11.	9.3	13./13.					7.6	10./17.	0.1	01./02.	0.3	07./05.							
Bouteloua gracilis	6.0	04./17.	1.6	04./09.	7.0	07./29.	38.0	08./40.	0.1	01./08.											Ju.
Poa pratensis	5.5	14./23.	1.2	03./09.	14.0	22./14.	7.7	04./40.	7.0	33./50.	0.8	03./13.	0.1	01./05.			3.2	04./17.	1.6	08./33.	Ju.
Stipa spartea	4.9	10./13.			4.9	21./29.	7.4	08./20.	14.0	25./25.											Ju.
Stipa viridula	3.3	08./17.	1.7	11./22.			2.1	03./20.	10.0	10./17.	0.1	01./02.	0.1	01./05.							
Carex eleocharis	3.0	05./11.					3.3	09./20.	12.0	18./33.											Ma.-Ju.
Lactuca scariola	2.8	09./21.	2.9	09./26.	6.1	16./14.	1.9	07./20.	0.7	06./17.	0.8	04./38.	1.2	04./45.	0.1	01./14.	0.3	04./33.	1.0	07./42.	Jul.-Aug.
Sonchus arvensis	2.6	03./02.	5.6	07./04.							1.3	03./04.	2.0	04./05.	2.3	08./14.					
Lactuca pulchella	2.3	14./32.	1.4	08./30.			9.4	33./60.	3.2	29./50.	0.3	01./11.	0.1	01./09.			1.8	02./33.	0.1	02./08.	
Aster ericoides	2.2	05./13.	0.5	02./04.			19.	35./60.	0.3	02./17.	0.3	01./04.					2.2	04./17.	0.1	01./08.	Jul.-Aug.
Kochia scoparia	2.2	04./32.	0.1	01./43.			1.7	08./40.	8.6	14./33.	1.0	03./28.	0.3	02./23.	1.3	04./43.	2.0	05./33.	1.6	05./25.	
Bromus inermis	2.1	04./17.	1.7	06./17.	1.3	02./14.	5.9	08./40.	2.2	02./08.	0.6	01./09.	0.3	01./09.			0.1	02./17.	1.8	03./17.	

Table 2 , cont'd.

Species	ZONE 1										ZONE 2										
	All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		
	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Obs. Flw.
Koeleria cristata	2.1	01./06.			0.7	05./29.			8.4	01./08.											
Distichlis stricta	1.6	04./06.	7.7	08./09.					1.5	02./08.	1.4	03./09.	6.7	07./14.					0.1	01./08.	
Festuca octoflora	1.5	03./11.			4.9	08./14.	4.6	07./40.	5.6	06./17	0.2	01./04.					1.8	02./17.	3.4	03./08.	
Convolvulus arvensis	1.0	04./08.	0.1	01./04.			10.0	30./20.	0.3	02./17.	0.4	02./04.					3.3	13./17.	0.1	01./08.	
Iva xanthifolia	1.0	01./02.							4.3	05./08.											
Sphaeralcea coccinea	0.9	06./17.	0.4	04./17.	3.7	19./29.			0.1	04./17.											
Festuca ovina	0.8	01./04.			4.4	08./14.															
Tragopogon dubius	0.7	05./21.	0.2	02./13.	1.8	08./29.	2.7	20./60.	0.1	02./08.	0.3	01./13.	0.1	01./14.	1.4	05./29.	0.7	01./17.			
Ambrosia artemisifolia	0.6	02./09.					4.3	07./40.	0.9	06./17.	0.2	01./04.					0.3	02./17.	0.6	03./08.	
Artemisia frigida	0.6	04./19.	0.9	06./22.	0.2	01./14.	1.1	06./20.	0.3	03./17.	0.3	01./06.	0.7	03./09.					0.3	01./08.	
Lotus purshianus	0.6	02./02.	1.4	04./04.							0.1	01./02.	0.1	01./05.							
Conyza canadensis	0.5	03./09.	0.8	05./09.			1.3	05./20.	0.1	01./08.	0.4	02./13.	0.1	02./09.			0.1	02./17.	1.4	05./33.	
Plantago patagonica	0.5	02./05.	0.8	02./04.	0.6	06./14.					0.1	01./02.	0.1	01./05.							
Polygonum erectum	0.5	01./04.	0.4	01./04.	1.4	01./14.															
Andropogon scoparius	0.4	01./04.			2.1	08./14.															
Artemisia dracunculus	0.3	03./09.	0.3	03./09.	0.5	04./14.	0.5	05./20.													

Table 2, cont'd.

	ZONE 1										ZONE 2										
	All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		
Species	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Obs. Flw.
Artemisia cana	0.3	02./11.	0.6	04./22.																	
Grindelia squarrosa	0.3	01./06.	0.1	01./04.	1.3	05./29.			0.1	01./17.	0.1	01./09.	0.3	01./18.							
Atriplex dioica	0.3	01./04.	0.7	01./09.																	
Medicago spp.	0.3	01./04.	0.4	01./04.	0.4	01./14.															
Aristida longiseta	0.3	01./02.							1.3	02./08.											
Salsola kali	0.3	01./02.							1.1	01./08.											
Descurainia sophia	0.2	01./06.	0.1	01./04.	0.4	03./14.			0.2	01./08.	0.1	01./04.	0.1	02./05.			0.7	01./17.			
Erigeron pumilis	0.2	02./06.			0.7	11./29.			0.2	01./08.											
Gaura coccinea	0.2	01./06.			1.1	06./14.	0.1	02./20.													
Buchloe dactyloides	0.2	01./02.					1.8	04./20.													
Monolepis nuttaliana	0.2	01./02.	0.4	01./04.																	
Achillea millefolium	0.1	03./08.	0.1	01./04.	0.4	04./13.	0.3	22./20.													
Taraxacum officinale	0.1	02./08.	0.2	02./09.	0.1	05./13.	0.1	02./20.			0.1	01./02.							0.1	01./08.	
Senecio spp.	0.1	01./06.							0.1	03./08.											
Lathyrus polymorphus	0.1	01./06.	0.2	02./09.					0.3	03./08.											
Psoralea argophylla	0.1	01./06.	0.1	01./04.			0.4	04./40.			0.1	01./02.							0.1	01./08.	

Table 2, cont'd.

Species	ZONE 1 All Soils Avg. Cov.	F/C	Clay Soils Avg. Cov.	F/C	Silt Loam Soils Avg. Cov.	F/C	Loam Soils Avg. Cov.	F/C	Sandy Loam Soils Avg. Cov.	F/C	ZONE 2 All Soils Avg. Cov.	F/C	Clay Soils Avg. Cov.	F/C	Silt Loam Soils Avg. Cov.	F/C	Loam Soils Avg. Cov.	F/C	Sandy Loam Soils Avg. Cov.	F/C	Obs. Flw.
Euphorbia marginata	0.1	01./06.	0.1	01./04.	0.2	04./14.					0.1	01./02.	0.1	01./05.							
Convolvulus sepium	0.1	01./04.			0.4	02./14.															
Dalea enneandra	0.1	01./04.					0.1	02./20.	0.1	01./08.											
Elymus canadensis	0.1	01./04.	0.1	01./04.					0.2	01./08.											
Erysimum asperum	0.1	01./04.					0.6	06./40.			0.1	01./02.	0.1	01./05.							
Euphorbia podperae	0.1	01./04.	0.1	01./09.																	
Liatris punctata	0.1	01./04.					0.1	02./20.													
Linum rigidum	0.1	01./04.			0.1	01./14.															
Opuntia fragilis	0.1	01./04.	0.2	01./04.					0.1	01./08.											
Petalostemon purpureum	0.1	01./04.	0.1	01./04.																	
Solidago missouriensis	0.1	01./04.	0.2	01./04.			0.3	08./20.													
Amorpha canescens	0.1	01./02.					0.1	09./20.													
Asclepias speciosa	0.1	01./02.							0.2	03./08.	0.1	01./02.							0.2	01./17.	
Bouteloua curtipendula	0.1	01./02.	0.1	01./04.																	
Chenopodium hybridum	0.1	01./02.							0.2	01./08.											
Cirsium flodmani	0.1	01./02.							0.1	01./08.											

Table 2, cont'd.

Species	Zone 1 All Soils Avg. Cov.	Zone 1 All Soils F/C	Zone 1 Clay Soils Avg. Cov.	Zone 1 Clay Soils F/C	Zone 1 Silt Loam Soils Avg. Cov.	Zone 1 Silt Loam Soils F/C	Zone 1 Loam Soils Avg. Cov.	Zone 1 Loam Soils F/C	Zone 1 Sandy Loam Soils Avg. Cov.	Zone 1 Sandy Loam Soils F/C	Zone 2 All Soils Avg. Cov.	Zone 2 All Soils F/C	Zone 2 Clay Soils Avg. Cov.	Zone 2 Clay Soils F/C	Zone 2 Silt Loam Soils Avg. Cov.	Zone 2 Silt Loam Soils F/C	Zone 2 Loam Soils Avg. Cov.	Zone 2 Loam Soils F/C	Zone 2 Sandy Loam Soils Avg. Cov.	Zone 2 Sandy Loam Soils F/C	Obs. Flw.
Echinocystis lobata	0.1	01./02.							0.7	04./08.	0.1	01./02.							0.3	01./08.	
Elymus virginicus	0.1	01./02.	0.1	01./04.																	
Helianthus maxmilliana	0.1	01./02.	0.1	01./04.																	
Hordeum pusillum	0.1	01./02.	0.1	01./04.							0.1	01./02.	0.1	01./05.							
Lygodesmia juncea	0.1	01./02.					0.2	01./20.													
Oxalis stricta	0.1	01./02.							0.1	03./08.											
Polygala alba	0.1	01./02.							0.7	01./08.											
Polygonum convolvulus	0.1	01./02.							0.3	01./08.	0.1	01./02.							0.8	01./08.	
Potentilla arguta	0.1	01./02.					0.7	06./20.													
Psoralea esculenta	0.1	01./02.	0.1	01./04.																	
Rhus trilobata	0.1	01./02.	0.2	01./04.																	
Rosa spp.	0.1	01./02.			0.1	01./14.	0.1	01./20.													
Stipa comata	0.1	01./02.							0.4	02./08.											
Tradescantia bracteata	0.1	01./02.	0.1	01./04.																	
Viola nuttallii	0.1	01./02.	0.1	01./04.																	

Table 2, cont'd.

	ZONE 1										ZONE 2										
	All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		
Species	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Cbs. Flw.
Rumex crispus	1.5	05./26.	1.7	06./30.	0.5	03./14.	1.2	01./20.	2.3	06./25.	32.0	50./65.	30.0	48./59.	28.0	43./71.	45.0	80./84.	33.0	47./58.	Ma.-Ju.
Hordeum jubatum	0.7	04./19.	1.0	05./22.	1.0	04./14.	1.0	04./40.	0.1	01./08.	6.0	18./40.	4.7	15./36.	12.0	27./57.	8.4	30./67.	2.8	13./25.	Ju.
Rumex maritimus	0.1	01./04.	0.1	01./04.					0.1	01./08.	5.5	14./40	11.0	23./36.	1.4	09./30.	0.1	02./33.	1.9	11./58.	Ju.-Jul.
Rumex salicifolius	0.1	01./04.	0.1	01./04.			0.9	03./20.			3.2	10./32.	1.9	06./36.	0.6	03./32.	3.1	16./17.	7.4	18./33.	
Agropyron repens	3.1	06./06.	3.1	07./09.					7.2	09./08.	3.1	08./13.	4.1	09./05.	0.6	02./14.			4.5	13./33.	
Carex brevior	0.9	03./09.	0.3	03./04.	4.2	10./29.			0.1	01./08.	2.3	05./16.			2.9	07./29.	0.4	01./17.	6.5	14./33.	Ju.
Iva axillaris	0.1	01./04.	0.1	01./04.			0.8	05./20.			2.3	03./08.	5.2	08./18.							
Bidens cernua	0.1	01./04.	0.1	01./09.							2.2	06./27.	0.6	08./27.	2.9	06./29.	0.7	08./17.	5.0	03./33.	Jul.-Aug.
Helianthus annuus	1.4	05./23.	1.3	05./22.	0.9	04./14.	0.7	04./40.	2.5	09./25.	2.0	09./43.	2.1	12./55.	1.5	07./43.	4.4	11./50.	1.2	03./17	Ju.-Sept.
Polygonum ramosissimum	0.4	02./07.	0.2	01./09.	1.7	06./14.					1.8	05./27.	2.6	08./45.	3.3	05./14.			0.2	01./17.	Jul.-Aug.
Bidens frondosa	0.1	01./02.	0.1	01./04.							1.7	05./23.	1.1	03./18.	2.9	04./30.	0.3	02./17.	2.5	08./33.	
Potentilla norvegica	0.1	01./02.							0.5	01./02.	1.6	08./22.	1.0	04./13.	1.5	09./14.			3.2	16./50.	Ju.-Jul.
Thlaspi arvensis	0.5	05./11.							2.1	05./08.	1.4	04./15.	3.0	07./23.	0.1	01./14.			0.5	01./08.	
Ambrosia trifida	0.7	02./09.	0.1	01./04.			2.1	02./20.	2.2	08./17.	1.2	07./23.	0.6	04./32.			0.3	02./17.	3.6	13./25.	
Chenopodium album	0.5	05./19.	0.1	03./13.	0.2	01./14.	2.5	16./40.	0.8	07./25.	1.2	04./21.	0.4	03./23.	3.3	05./14.	1.8	04./17.	0.8	04./25.	
Ellisia nyctelea											1.2	04./11.	2.1	08./14.					1.1	05./17.	

Table 2, cont'd.

Species	ZONE 1 All Soils Avg. Cov.	F/C	ZONE 1 Clay Soils Avg. Cov.	F/C	ZONE 1 Silt Loam Soils Avg. Cov.	F/C	ZONE 1 Loam Soils Avg. Cov.	F/C	ZONE 1 Sandy Loam Soils Avg. Cov.	F/C	ZONE 2 All Soils Avg. Cov.	F/C	ZONE 2 Clay Soils Avg. Cov.	F/C	ZONE 2 Silt Loam Soils Avg. Cov.	F/C	ZONE 2 Loam Soils Avg. Cov.	F/C	ZONE 2 Sandy Loam Soils Avg. Cov.	F/C	Obs. Flw.
Bromus tectorum	0.8	02./07.	0.1	01./04.	1.6	03./13.	4.9	07./20.			1.2	04./09.	2.0	06./09.	1.7	08./29.					
Populus deltoides											1.1	04./28.	0.1	01./05.	1.1	02./14.	2.1	11./84.	2.2	08./50.	
Scirpus americana											1.1	02./11.	0.4	01./09.			4.5	06./33.	1.0	04./08.	
Typha spp.											1.1	02./10.	0.1	01./05.			2.6	07./17.	3.0	06./25.	
Agrostis hiemalis	0.1	01./02.							0.3	01./08.	1.0	02./06.							4.5	07./17.	
Potentilla paradoxa	0.1	01./04.	0.1	01./13.							1.0	06./19.	0.7	02./09.	2.2	13./29.	2.8	19./50.	0.1	01./17.	
Phalaris arundinaceae											0.9	04./04.			4.7	10./14.	0.3	02./17.			
Xanthium strumarian	0.1	01./05.	0.1	01./09.					0.2	01./08.	0.8	03./26.	0.6	04./36.	2.0	04./14.	0.3	02./33.	0.5	02./17.	
Spartina pectinata											0.7	02./06.	0.1	01./05.	3.1	07./14.			0.4	01./08.	
Mentha arvensis											0.6	03./17.	0.4	02./09.	1.0	03./14.	1.2	07./33.	0.6	02./25.	
Polygonum persicaria	0.1	01./07.	0.1	01./04.	0.2	01./13.	0.1	03./20.			0.6	03./19.	0.3	04./27.	1.9	08./29.	1.0	04./17.			
Rorippa islandica	0.1	01./02.	0.1	01./04.							0.5	03./15.	1.1	06./23.					0.2	01./17.	
Lycopus americana	0.1	01./05.	0.1	01./04.	0.2	01./13.			0.2	01./08.	0.4	02./17.	0.3	01./09.	0.1	01./14.			1.2	06./42.	
Panicum capillare											0.3	01./17.	0.2	01./04.	0.1	03./17.	0.5	03./17.	0.6	02./25.	
Salix amygdaloides											0.3	01./06.					1.5	07./17.	0.7	02./17.	
Aster falcatus											0.3	01./02.			1.6	07./14.					

Table 2, cont'd.

Species	ZONE 1 All Soils Avg. Cov.	ZONE 1 All Soils F/C	ZONE 1 Clay Soils Avg. Cov.	ZONE 1 Clay Soils F/C	ZONE 1 Silt Loam Soils Avg. Cov.	ZONE 1 Silt Loam Soils F/C	ZONE 1 Loam Soils Avg. Cov.	ZONE 1 Loam Soils F/C	ZONE 1 Sandy Loam Soils Avg. Cov.	ZONE 1 Sandy Loam Soils F/C	ZONE 2 All Soils Avg. Cov.	ZONE 2 All Soils F/C	ZONE 2 Clay Soils Avg. Cov.	ZONE 2 Clay Soils F/C	ZONE 2 Silt Loam Soils Avg. Cov.	ZONE 2 Silt Loam Soils F/C	ZONE 2 Loam Soils Avg. Cov.	ZONE 2 Loam Soils F/C	ZONE 2 Sandy Loam Soils Avg. Cov.	ZONE 2 Sandy Loam Soils F/C	Obs. Flw.
Aster hesperius	0.1	01./02.	0.1	01./04.							0.3	01./02.							1.5	03./08.	
Cenothera biennis	0.1	01./02.	0.1	01./04.							0.2	01./09.	0.2	01./05.					0.4	02./25.	
Apocynum cannabinum											0.2	01./02.			1.0	03./14.					
Atriplex powellii	0.1	01./02.	0.3	01./04.							0.2	01./02.	0.5	01./05.							
Lepidium densiflorum	0.1	01./04.	0.1	01./09.							0.1	02./09.	0.1	04./14.			0.3	03./17.			
Verbena bracteata	0.1	01./02.	0.1	01./04.							0.1	01./13.	0.1	01./09.	0.2	01./14.	0.1	01./17.	0.1	01./17.	
Euphorbia serpens	0.1	01./02.	0.1	01./04.							0.1	01./09.	0.1	04./18.							
Salix interior											0.1	01./09.	0.1	01./05.			0.4	03./33.	0.1	01./08.	
Beckmannia syzigachne											0.1	01./06.			0.2	01./14.	0.3	02./17.			
Lemna minor											0.1	01./06.			0.2	01./14.			0.3	01./08.	
Urtica dioica	0.1	01./02.			0.2	01./14.					0.1	01./06.							0.1	01./17.	
Artemisia biennis	0.1	01./02.					0.9	03./20.			0.1	01./04.	0.1	01./05.			0.2	04./17.			
Collomia linearis	0.1	01./02.							0.1	01./08.	0.1	01./04.	0.1	01./05.			0.5	04./17.			
Cyperus erythrorhizos											0.1	01./04.					0.3	02./17.	0.2	01./08.	
Eleocharis palustris											0.1	01./04.					0.1	02./17.	0.5	02./08.	
Acer negundo											0.1	01./02.							0.2	01./08.	

Table 2, cont'd.

Species	ZONE 1 All Soils		ZONE 1 Clay Soils		ZONE 1 Silt Loam Soils		ZONE 1 Loam Soils		ZONE 1 Sandy Loam Soils		ZONE 2 All Soils		ZONE 2 Clay Soils		ZONE 2 Silt Loam Soils		ZONE 2 Loam Soils		ZONE 2 Sandy Loam Soils		Cbs. Flw.
	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	
Agastache foeniculum											0.1	01./02.			1.3	03./17.					
Amaranthus spp.											0.1	01./02.	0.1	01./14.							
Aster sericeus											0.1	01./02.	0.1	01./14.							
Astragalus spp.											0.1	01./02.							0.1	01./08.	
Camelina microcarpa											0.1	01./02.	0.1	01./05.							
Carex laeviconica											0.1	01./02.					2.0	14./17.			
Fraxinus pennsylvanica											0.1	01./02.							0.1	01./08.	
Glycyrrhiza lepidota											0.1	01./02.	0.4	01./05.							
Lappula echinata											0.1	01./02.	0.1	01./05.							
Leersia orzyoides											0.1	01./02.							0.1	01./08.	
Malva neglecta											0.1	01./02.	0.1	01./05.							
Nepeta cataria											0.1	01./02.							0.1	01./08.	
Plantago elongata	0.1	01./02.	0.1	01./04.							0.1	01./02.	0.1	01./05.							
Polanisia dodecandra											0.1	01./02.							0.1	01./08.	
Schedonnardus panic latus											0.1	01./02.	0.1	01./05.							
Scirpus validus											0.1	01./02.							0.3	01./17.	

Table 2, cont'd.

	ZONE 1										ZONE 2										
	All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		All Soils		Clay Soils		Silt Loam Soils		Loam Soils		Sandy Loam Soils		
Species	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Avg. Cov.	F/C	Obs. Flw.
Setaria viridis											0.1	01./02.							0.3	02./08.	
Solanum rostratum											0.1	01./02.	0.1	01./05.							
Stachys palustris											0.1	01./02.			1.3	07./14.					
Teucrium canadense											0.1	01./02.					1.4	04./17.			
Ulmus americana											0.1	01./02.							0.1	02./08.	
Verbena bipinnatifida											0.1	01./02.			0.1	01./14.					

destroys the grassland though *A. smithii* may return from remnant roots and again dominant the vegetation if the cropland is abandoned (Weaver, 1942). On heavily grazed areas *A. smithii* decreases and *Bouteloua gracilis* seems to increase. Weeds such as *Plantago patagonica*, *Cirsium arvensis*, and *Solanum rostratum* may also invade heavily grazed areas. Most of Zone 1, which was sampled, is moderately grazed grasslands with *A. smithii* the dominant plant.

Zone 2 vegetation grows on land which has been inundated at least once by the reservoir but its distribution is highly localized around the reservoir. Areas of less than five percent slope which are somewhat protected from wave action support nearly all the Zone 2 vegetation though it may even be absent on this topography.

Zone 2 varies considerably in width throughout the growing season. This results not only from steepness of slope but also timing of water level fluctuation. When water level is at its maximum elevation in late June, Zone 2 is in many places little more than a narrow fringe of area just above the water line. But as the water level recedes, more area is exposed, and more plants become established. This can occur anytime after drawdown begins until climatic and/or soil conditions prevent further germination and seedling establishment. As a result, only the upper part of Zone 2 ever has dense vegetation. The lower part may have moderate to sparse vegetation or, as most frequently observed, none at all.

Zone 2 plant communities are often dominated by dense stands of *Rumex crispus*. Often the grass *A. smithii* is present, doubtlessly as a grassland remnant. Also present is a complex of other species, usually weedy grasses and herbaceous dicotyledons. A complete list of all plant species occurring in Zone 2 study sites, their coverage, frequency, and constancy is presented in Table 2.

Most of the terrestrial species in Zone 2 are herbaceous dicotyledons or monocotyledons. The two dominant species *Rumex crispus* and *Agropyron smithii* fit into this category along with the vast majority of species present in Zone 2. A few woody terrestrial species are present, however. Most common of these woody species is *Populus deltoides* and *Salix* species. Also present, but quite rare, are *Fraxinus pennsylvanica* and *Ulmus americana*.

Some aquatic and semi-aquatic plant species are present in Zone 2. In general these species seemed to occur on the coarser textured soils. *Scirpus americanus* and *Typha spp.* were the most common, but also present were *Eleocharis palustris*, *Carex laeviconica*, *Leersia oryzoides*, and *Scirpus validus*. In general, though, terrestrial plant species were by far the most common.

From Table 2 it can be noted that many species show little or no preference for soil type. In Zone 1 *Agropyron smithii* shows little preference for any particular soil type. *Bromus japonicus* is more common on the clay and silt loam soils while Melilotus spp. is more common on the loam and sandy loam soils. Agropyron cristatum shows no preference but Bouteloua gracilis is most common on silt loam soils. Poa pratensis did well on all soil types but Stipa spartea was not present on clay soils but did well on the others, especially sandy loam soils. Other obvious preferences for soil types in Zone 1 included that of Carex eleocharis for sandy loam soils, Sonchus arvensis and Distichlis stricta for clay soils, Convolvulus arvensis and Ambrosia artemisifolia for loam soils, and Polygonum erectum and Andropogon scoparius for silt loam soils.

In Zone 2 Rumex crispus and Agropyron smithii were well represented on all soil types. Hordeum jubatum, Helianthus annuus, Bromus japonicus, and others were most abundant on silt loam soils, while Rumex maritimus and Iva axillaris did best on clay soils. Bidens cernua, Ambrosia trifida, and many aquatic and semi-aquatic species such as Scirpus americanus, Typha spp., Carex brevior, C. laeviconica, and Leersia orzyoides were most common on loan and sandy loam soils.

The obvious difference between Zone 1 and Zone 2 is the sparsity of vegetation in Zone 2. If plants become established in Zone 2 when the water level is down, as in the early spring, they may be drowned when the water level rises. On the other hand, if plants become established in Zone 2 when the water level is high, they may be desiccated when the water level recedes (Daubenmire, 1968). Though aquatic species are unaffected by high water levels, they can be killed by desiccation when the water level goes back down, even if they are dormant (Beard, 1973). Because several plant species are shared by Zone 1 and Zone 2 the vegetative index of similarity between the two zones was calculated using the well-known expression:

$$I.\ S. = \frac{2w}{a+b} \times 100\%$$

where w = the sum of the lesser of the coverage values for all species shared in Zone 1 and Zone 2.

a = the sum of the coverage values for all species in Zone 1.

b = the sum of the coverage values for all species in Zone 2.

The calculated Index of Similarity for Zone 1 and Zone 2 is .619. This is an overall value and ignores differences due to slope, exposure, soil type, etc. Data in calculating this figure were taken from Table 2.

Table 1 also offers a comparison of the dominant species in Zone 1 and Zone 2. Important species with their average cover in Zone 1 include Agropyron smithii (43%), Bromus japonicus (11%), Melilotus spp. (9.1%), Agropyron cristatum (6.2%), and Bouteloua gracilis (6.0%). In comparison the species with highest average cover in Zone 2 are Rumex crispus (32%), Agropyron smithii (18%), Hordeum jubatum (6%), and Rumex maritimus (5.5%).

A. smithii is the only species dominant in both zones and in Zone 2 it is doubtlessly a remnant of the original upland grassland. The species is apparently tolerant of at least some flooding and silt deposition (Hubbell & Gardner, 1944). Whether *A. smithii* present currently around Lake Oahe will continue to survive is not now known.

The dominant species in Zone 2, *Rumex crispus*, is often found in dense, nearly pure stands on protected areas of little slope. The plants apparently germinate in late summer forming basal rosettes which overwinter and send up flowering stalks in late May with the onset of warm weather. Then, after setting seed the plants are apparently killed by the high water in July. Nevertheless, thousands of seeds have been set by this time. Young seedlings then get established again in late summer after the water level has receded. This pattern was observed in both 1971 and 1972.

We have germinated seeds of *R. crispus* simply by placing the disseminules, which float, in a container of water. This could be advantageous to disseminating the plant around the lake. Unlike numerous other species encountered, *Rumex crispus* is capable of completing its life cycle under conditions currently found in Lake Oahe.

A comparison of Zone 1 and Zone 2 vegetation can also be made by comparing diversity. For this purpose the Shannon-Wiener diversity index was used to calculate diversity for equal areas, plots within eight meters on each immediate side of the ecotone between Zone 1 and Zone 2. The results of these calculations are presented in Table 3. Data collected in July and August were used in diversity determinations. The Shannon-Wiener equation for mean diversity is as follows:

$$\bar{D} = \left(\sum_{i=1}^{m} \frac{n_i}{N} \log_2 \frac{n_i}{N} \right)$$

where n_i = the average cover of the i^{th} species.

m = the number of species.

N = the summation of the average cover values.

A two sample t-test of diversity means was done to test for significant differences between Zone 1 and Zone 2 diversity calculations. The mean of Zone 1 diversity regardless of soil types was 1.15 with a standard deviation of .74 while the mean of Zone 2 diversity was 1.79, a standard deviation of .79. The difference is significant at the .001 probability level between Zone 1 and Zone 2 diversity calculations.

The higher diversity of Zone 2 is not totally unexpected in view of the fact that some authors suggest diversity decreases with succession (Margalef, 1968) and Zone 2 is definitely occupied by seral communities. Additionally, sites were selected where vegetation occurred or potentially could occur, even though these kinds of sites are not abundant around the lake. It should be emphasized that even though vegetation diversity is greater in Zone 2 than in Zone 1 neither zone exhibits a very high diversity.

Table 3. Shannon-Wiener indices of diversity for equal areas (eight plots) in zone 1 and zone 2 at the study sites.

clay soils			silt loam soils			loam soils			sandy loam soils		
	diversity			diversity			diversity			diversity	
site	zone 1	zone 2	site	zone 1	zone 2	site	zone 1	zone 2	site	zone 1	zone 2
1	1.34	1.62	8	1.83	.92	9	1.28	.00	6	1.76	.36
2	.10	.00	12	1.32	1.97	10		2.85	7	1.14	1.83
3	.16	.35	21	.45	1.62	17	1.93	1.95	11	1.20	2.06
4	1.41	1.57	35		.40	18		2.70	22	2.22	2.69
5	.69	2.16	44		1.21	23	.45	1.49	29	1.46	1.43
13		.71	47		.00				30		2.50
14	.52	2.73	48	2.16	1.12				31		2.63
15	1.84	1.94	49	.23	2.25				32	2.03	2.18
16	1.58	1.43							33		3.37
19	1.12	1.20							34		2.41
20	.34	.00							36		1.77
24	.31	2.89							37	3.04	2.93
25	.37	2.45							39	.54	2.57
26	2.15	1.36									
27	.52	.22									
28		2.69									

Table 3, cont'd.

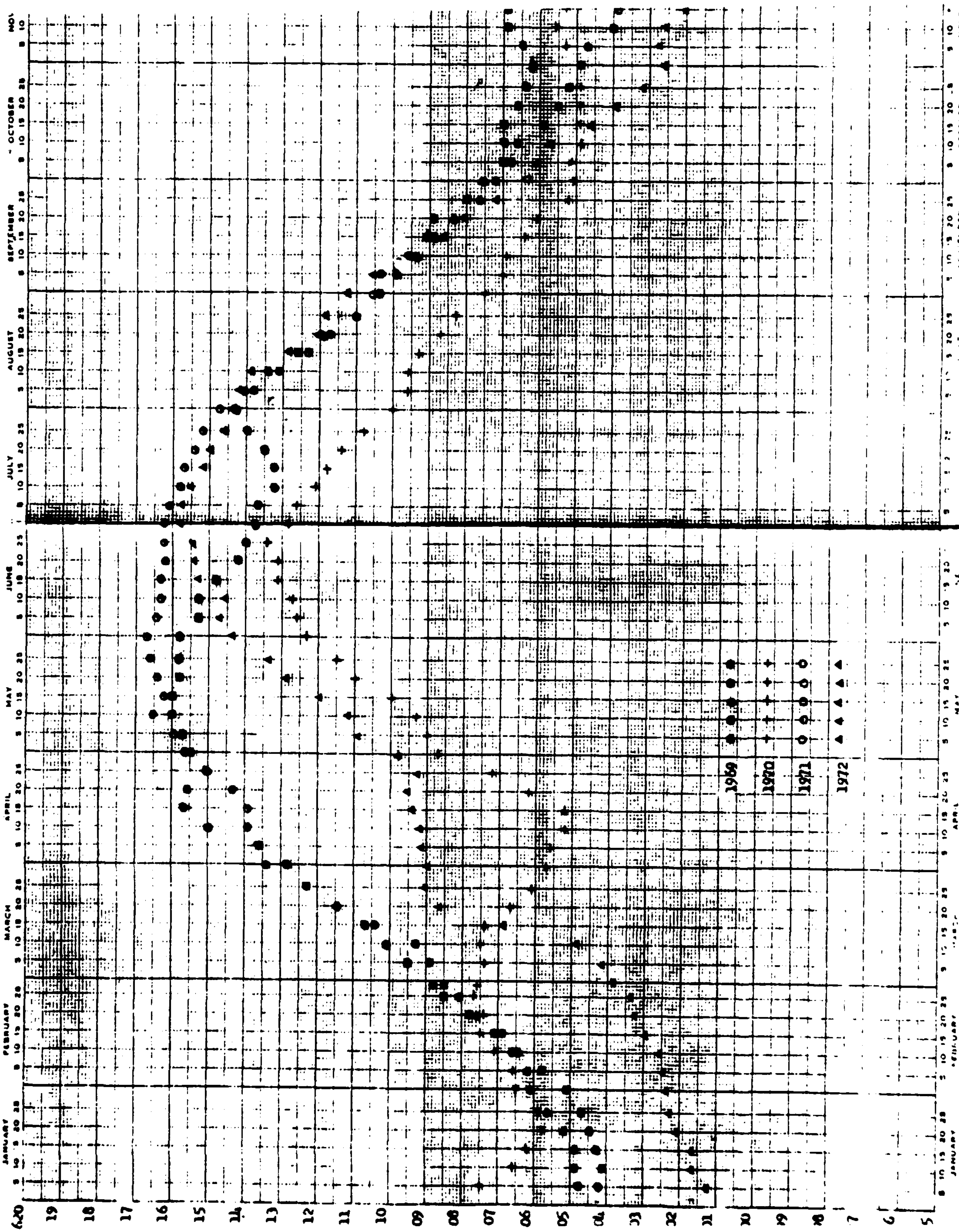
clay soils			silt loam soils			loam soils			sandy loam soils		
	diversity			diversity			diversity			diversity	
site	zone 1	zone 2	site	zone 1	zone 2	site	zone 1	zone 2	site	zone 1	zone 2
39		1.74									
40	.16	.94									
41	1.63	1.55									
42	.91	2.19									
43	.84	.92									
45	.54	2.03									
46	1.77	1.21									
Mean	.92	1.56		1.20	1.19		1.22	2.25		1.74	2.26
Stand. Dev.	± .64	± .78		± .84	± .75		± .74	± .64		± .80	± .69

Factors influencing vegetational distribution in Zone 2. There are many factors which influence plant presence and distribution in the inundated zone, Zone 2. Important factors doubtlessly include water level fluctuations, wave action, substrate characteristics, slope of shoreline, grazing pressure, and possibly others.

The magnitude and timing of water level fluctuations is probably the most important factor influencing plant distribution around Lake Oahe. Figure 4 shows the water level fluctuation of Lake Oahe from January of 1969 to December of 1972. It can be seen in Figure 4 that water levels usually peak sometime in June. This allows two possible periods of vegetative growth for terrestrial plants. Many plants can get established in the spring on bare ground exposed from the previous year's drawdown, and before they are inundated by the rising water levels. Also terrestrial plants may get established on bare ground exposed later in the year after the water level drops.

During the two years of this study, it is apparent that more vegetation is present early in the year before the peak water levels in June than later after water levels have receded. Apparently the high water kilis most of the plants in Zone 2 and seedling establishment is poor after the water level drops later in the summer. Another factor to be considered is that many temperate region plant species produce dormant seeds. The dormancy is commonly broken by a period

Figure 4. Water level fluctuations in Lake Oahe from January of 1969 to December of 1972


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1969
1970
1971
1972

of exposure to moist and cold conditions to which the seeds are exposed during the winter. This eliminates the possibility of many species becoming established following the summer drawdown even though soil moisture conditions may be suitable. *Rumex crispus* is an exception to this as it does become established in late August under old dead *R. crispus* plants. Since vegetation is more lush before the peak water level a later peak in water level may help increase vegetation on the shoreline of Lake Oahe.

The magnitude of water level fluctuation is also of considerable importance in determining vegetational distribution. Terrestrial vegetation has a greater chance of being flooded and aquatic vegetation a greater chance of being desiccated with progressively larger increases in water level fluctuation. Conversely, the less the fluctuation, the greater the possibility for development of shoreline vegetation. In any case the maximum shoreline vegetation possible would be no more than that expected for nonfluctuating natural lake of the same dimensions.

Although the timing and magnitude of water level fluctuations are probably the most important factors influencing vegetation, wave action is another very important factor in large reservoirs such as Lake Oahe. Few plants grow in the zone of wave action no matter how favorable other conditions. When, as is the case in Lake Oahe, vigorous wave action is combined with a fluctuating water level a series of terraces often forms as the water level drops. All areas with terracing around Lake Oahe are almost without exception completely devoid of plants. Wave action will always work against the establishment of some shoreline vegetation. But it is still significant that in certain places vegetation which could be permanent is becoming established along the shoreline.

A third factor influencing shoreline vegetation is substrate type. The wide range of soil textural types present around Lake Oahe has already been mentioned with total cover and diversity being positively correlated with the percentage sand in the soil.

Another important factor influencing plant distribution is the slope. I recorded the slope from the top of the upper stake to the top of the lower stake. These data in many cases are not accurate of the situation. The lower part of the transect very often has much less slope than the upper part of the transect. But other slope measurements show that vegetation was most abundant, when it occurred, on slopes not exceeding five percent in Zone 2. Appendix I presents profiles, drawn to scale, of the slope present at each study site.

Grazing is another factor influencing plant distribution. Cattle will readily graze many of the shoreline plants and consequently where these plants are accessible to the cattle vegetative cover is usually destroyed or reduced. This also enhances the erosion problem.

Vegetation Succession. The future development of vegetation along the shoreline of Lake Oahe cannot be predicted with any certainty at this time. At best one can estimate the possible trends if water levels in the future continue as they have in 1971 and 1972, but since higher than normal water levels occurred in 1971 and 1972 it is extremely difficult to predict what the successional trend, if any, on Lake Oahe will be.

Some observations during 1971 and 1972 may be relevant and are presented here. Vegetational trends which were observed from the summer of 1971 to the summer of 1972 included a slight increase in some aquatic species. Clones of Typha spp. increased in size in several localities. Most of the Typha spp. is in North Dakota on sandy loam soils. Also, a colony of Leersia orzyoides, on loam soil also increased significantly in size over this period. The status of Scirpus validus, S. americanus, and Sagittaria latifolia remained relatively unchanged, however.

A significant factor which will undoubtedly affect successional trends is the reworking of the shorelines by water action. Since much of the shoreline consists of loosely consolidated fine textured soils, reworking of the shoreline of Lake Oahe is proceeding at a rapid rate, currently. Two immediately obvious trends are noticeable.

The erosion of headlands and the cutting off of embayments by the formation of bars is obvious along much of the shoreline of Lake Oahe. The net effect is to reduce the total length of the shoreline. Sometimes the area within an embayment cut off by a bar is favorable for plant growth. Site 16 is set up on such an area. Typha spp. and Atriplex species were present on the moist clayey saline soil behind the bar cutting off the embayment at one of the study sites (site 16).

Another obvious trend is the building up of mud flats in the upper reaches of some of the major tributaries of Lake Oahe. The Grand, Moreau, and Cheyenne Rivers have all built up large mud flats where they empty into Lake Oahe. These mud flats build up because the heavy sediment load of these rivers is dropped when water velocity is reduced upon entering Lake Oahe. As time goes on it is obvious that these mud flats will become more and more extensive. It is uncertain whether plants will colonize these areas under the present water management program. On similar flats extensive Typha spp. marshes appeared quite suddenly in Lewis and Clark Lake (Hoffman and Stanley, 1972). Lewis and Clark Lake is a smaller, older reservoir on the Missouri River in South Dakota below Lake Oahe and the Typha spp. marshes at the upper end of Lewis and Clark Lake all occur on sandy soils. Currently, however, the mud flats in the upper reaches of the Grand, Moreau, and Cheyenne River arms are barren of any vegetation and they are also very heavy textured substrates. Continuing vegetational analysis over many years is needed to determine successional trends, if any, in Lake Oahe.

CONCLUSIONS

Shoreline vegetation along Lake Oahe can be divided into two zones. Zone 1, the zone never inundated by the reservoir, consists primarily of upland grassland dominated by the grass Agropyron smithii. Zone 2, the zone inundated at least once by the reservoir, is mostly barren of vegetation. In a few selected areas, however, vegetation in Zone 2 is quite lush, with Rumex crispus often the dominant plant.

Factors influencing vegetational distribution in Zone 2 are many. Timing and magnitude of water level fluctuations along with wave action are probably the two most important of these factors. Large fluctuations in water level drown out terrestrial species and leave aquatics high and dry to die of desiccation. Also, influencing plant distribution are substrate characteristics. Several different substrate types occur around Lake Oahe. Much of the substrate consists of clay soils; also present, however, are sandy loam, silt loam, loam soils. Multiple regression programs indicate that the total cover and diversity of plant communities are significantly determined by the percentage sand in the substrate. Generally the higher the percentage sand, the higher the total cover and diversity. Other factors influencing plant distribution are slope and grazing pressure.

It is difficult to predict the future status of plant communities on the shoreline of Lake Oahe. Much depends on future water level management. Certain trends which were observed from the summer of 1971 to the summer of 1972 included a slight increase in the aquatic species *Typha spp*. and *Leersia orzyoides*. Also noted is an extensive reworking of the reservoir shoreline. The erosion of headlands and the isolation of embayment by bar formation along with the build-up of extensive mud flats on the upper reaches of the Grand, Moreau, and Cheyenne arms of Lake Oahe may all have a strong influence on future plant distribution.

ACKNOWLEDGEMENTS

This project was supported by the United States Army Corps of Engineers, Omaha District, through a grant administered by North Central Reservoir Investigations, United States Bureau of Sport Fisheries and Wildlife (Department of the Interior). Dr. Theodore Van Bruggen helped with plant identification.

LITERATURE CITED

Beard, Thomas D. 1973. Overwinter drawdown impact on the aquatic vegetation in Murphy Flowage, Wisconsin. Tech. Bull. No. 61, Dept. of Nat. Res., Madison, Wisconsin.

Conway, V. M. 1940. Aeration and plant growth in wet soils. Bot. Rev. 6: 149-163.

Daubenmire, R. 1959. Plants and environment a textbook of plant autecology. John Wiley and Sons, Inc. New York. 422p.

Daubenmire, R. 1968. Plant communities. Harper and Row, New York. 300p.

Gates, Frank C. 1948. Colonization of certain aquatic plants on an open shoal. Ecology 8(3): 339-340.

Hall, T. F. et al. 1946. Water level relationships of plants in the Tennessee valley. Tenn. Acad. Sci. 10: 18-60.

Houston, W. R. 1960. Effects of water spreading on range vegetation in eastern Montana. J. Range Manage. 13: 289-293.

Hubbell, D. S., and J. L. Gardner. 1944. Edaphic and ecological effects of water spreading on rangelands. Ecology 25: 27-44.

Kuchler, A. W. 1964. Potential vegetation of the conterminous United States. American Geographical Society, New York. Map and manual.

McGregor, R. L. 1948. First year invasion of plants on an exposed lake bed. Trans. Kan. Acad. Sci. 51(3): 324-327.

Magadza, C. H. D. 1970. A preliminary survey of the vegetation of the shore of Lake Kariba. Kirkia 7(2): 253-267.

Margalef, Ramon. 1968. Perspectives in ecological theory. Univ. of Chicago Press, Chicago. 111p.

Moody, C. D. et al. 1963. Laboratory manual for soil fertility. Wash. State Univ., Pullman, Wash. 198p.

Penfound, W. T. et al. 1956. Primary production of vascular aquatic plants. Limnology and Oceanography 1: 92-101.

Rothrock, E. P. 1943. A geology of South Dakota, Bulletin 13, S. Dak. Geol. Survey.

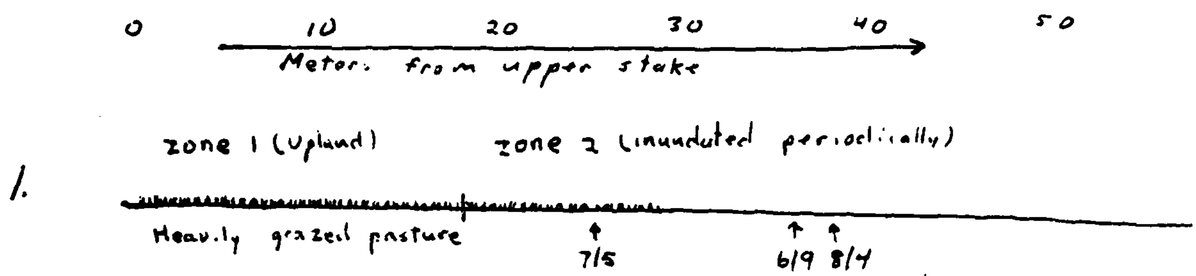
Tiemeier, Otto. 1951. Studies on Kanopolis reservoir in 1950. Trans. Kans. Acad. of Sci. 54: 175-189.

U. S. Dept. of Commerce, Weather Bureau. 1960. Climatography of the United States No. 60-39, 16p.

Weaver, J. E. 1942. Competition of western wheat grass with relict vegetation of the prairie. Amer. J. of Botany. 29(5): 366-236.

Appendix I. Sketches and locations of study sites.

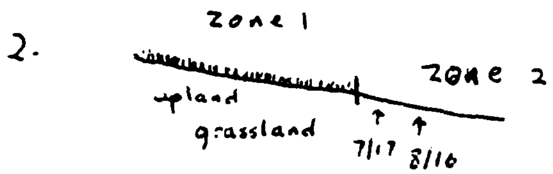
Profile, Location, aspect, and general information concerning Lake Oahe vegetational study trosects, 1972.



Corson Co., So Dak.
No. 1/2, Sec 2
T18 No, R29 E.

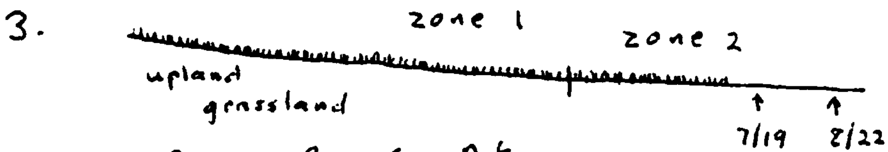
(Water levels on dates of vegetation analysis indicated.)

54° W (Aspect)



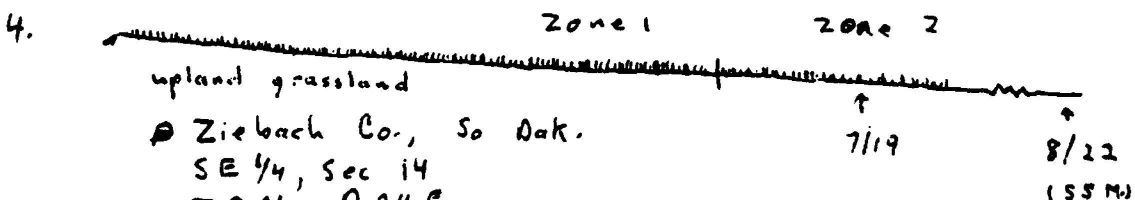
Stanley Co., So Dak.
So. 1/2, Sec. 31
T17 No, R29E

119° W (?)



Dewey Co., So. Dak.
NE 1/4, Sec 26
T10 No., R 26 E

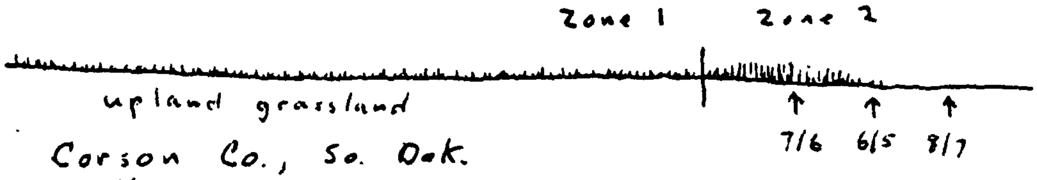
118° W



Ziebach Co., So Dak.
SE 1/4, Sec 14
T 9 No., R 24 E

147° W

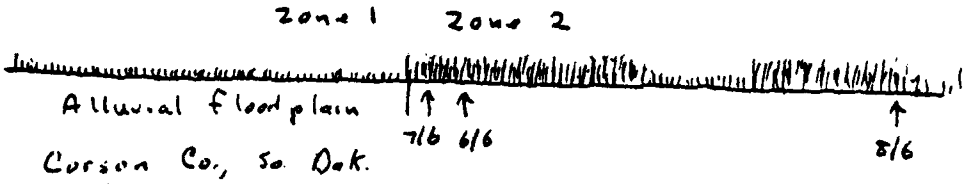
5.



Corson Co., So. Dak.
SE 1/4, Sec. 3
T 19 No., R 29 E

95° E.

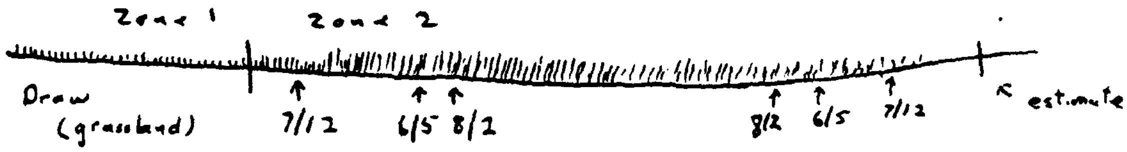
6.



Corson Co., So. Dak.
E 1/2, Sec. 3
T 19 No., R 29 E.

69° E

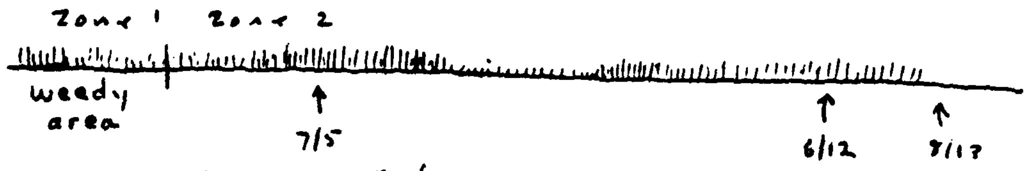
7.



Campbell Co., So. Dak. Transect is across flooded draw
Middle of Sec. 22
T 125 No., R 79 W.

126° W

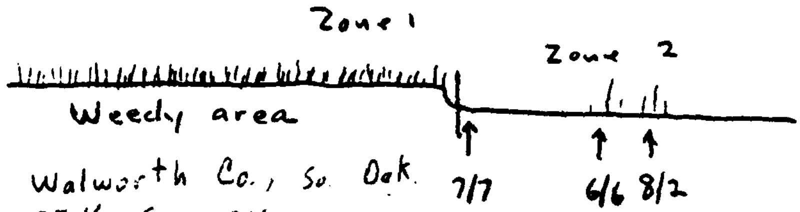
8.



Corson Co., So. Dak.
No. 1/2, Sec. 31
T 19 No., R 30 E

57° W

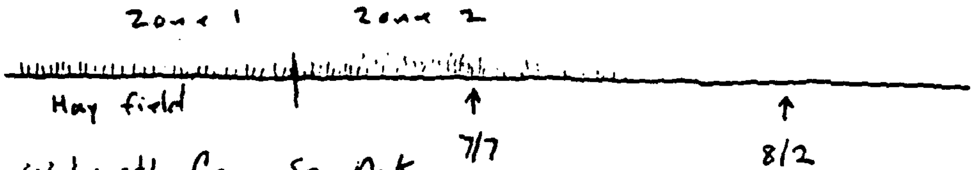
9.



Walworth Co., So. Dak.
SE 1/4, Sec. 24
T 124 No., R 80 W.

124° W

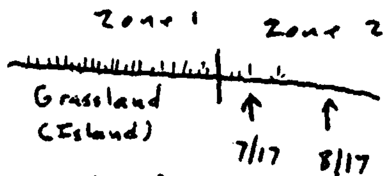
10.



Walworth Co., So. Dak.
So. 1/2, Sec. 3
T 121 No., R 78 W

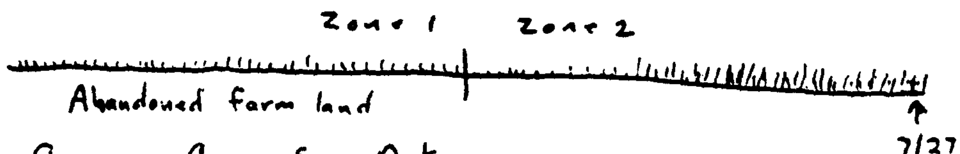
172° E

11.



Sully Co., So. Dak. (island in Okoboji arm)
82° W

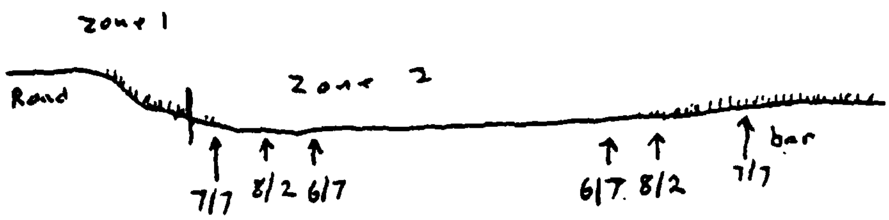
12.



Corson Co., So. Dak.
E 1/2, Sec. 1
T 122 No., R 30 E

86° E

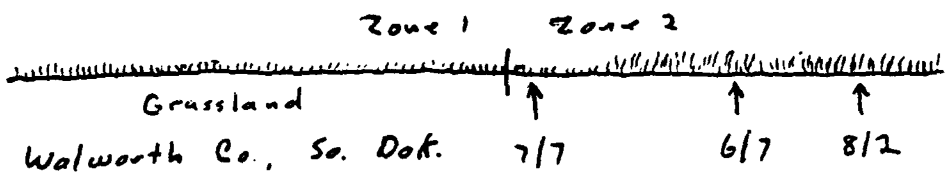
13.



Walworth Co., So. Dak.
NE 1/4, Sec. 2
T 123 No., R 79 W

28° W

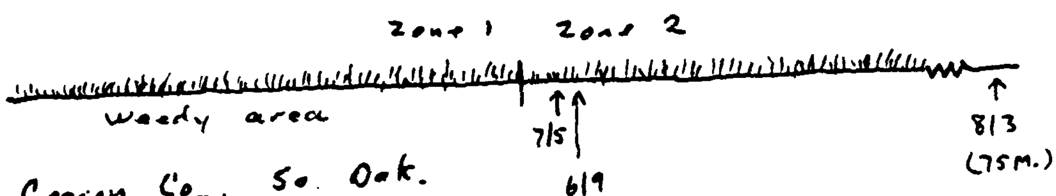
14.



Walworth Co., So. Dak.
Central, Sec. 28
T 124 No., R 79 W

155° E

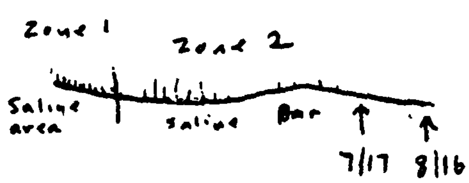
15.



Corson Co., So. Dak.
SW 1/4, Sec. 31
T 19 No., R 30 E

113° E

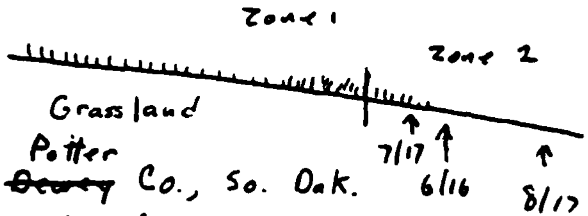
16.



Dewey Co., So. Dak.
Sec. 9
R 30 E, T 10 No

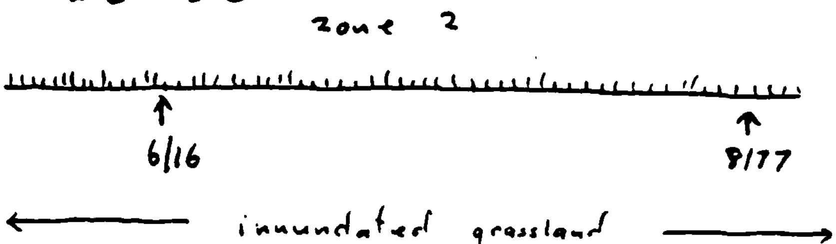
102° E.

17.



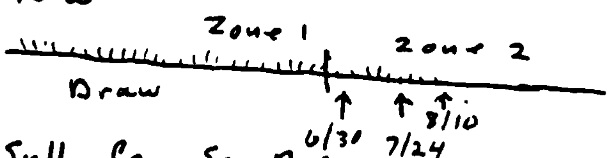
Potter
~~Dewey~~ Co., So. Dak.
W ½, Sec. 25
T118N. R78W.
1~~00°~~ 53°E

18.



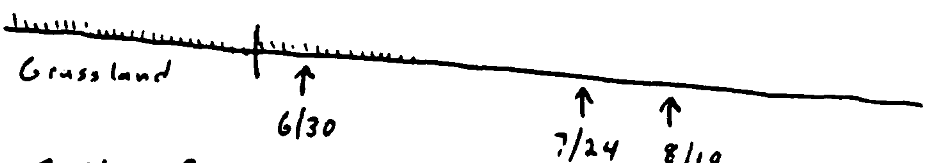
Potter Co., So. Dak.
T118 No., R78 W
Sec. 9, E ½
15°W

19.



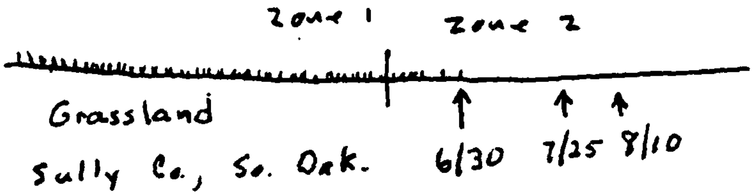
Sully Co., So. Dak.
NE ¼, Sec. 4
T116N., R80W.
99° W

20.

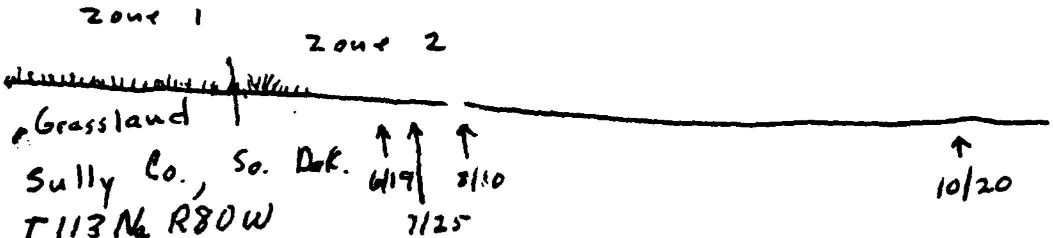


Sully Co., So. Dak.
NE ¼, Sec. 12
T115 No., R82W.

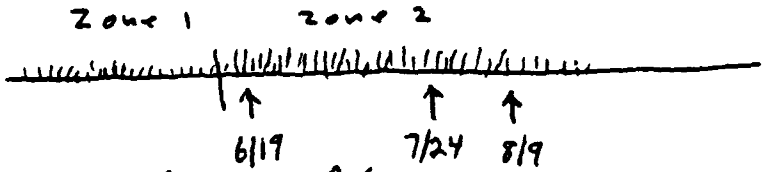
122°E

21


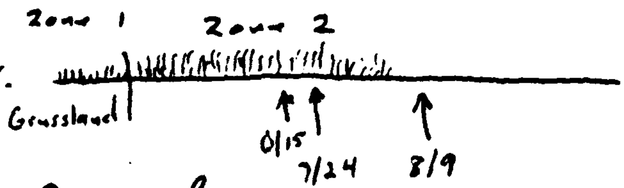
Sully Co., So. Dak.
Sec. ?
T115 No., R81W.
?

22.


Sully Co., So. Dak.
T113 N., R80W
Sec. 10, SW 1/4
85°W

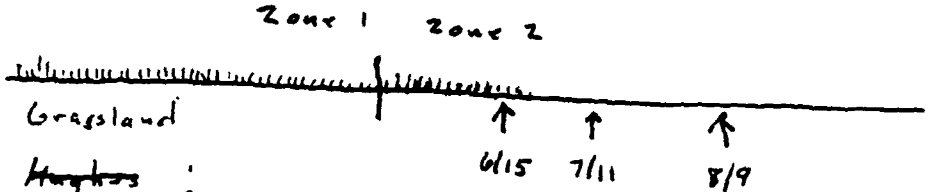
23.


Hughes Co., So. Dak.
NE 1/4, Sec. 9
T112 No., R80W
132°E

24.


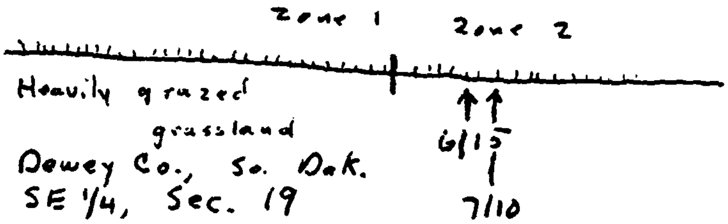
Dewey Co., So. Dak.
SW 1/4, Sec. 32
T12No., R30E.
63°W

25.



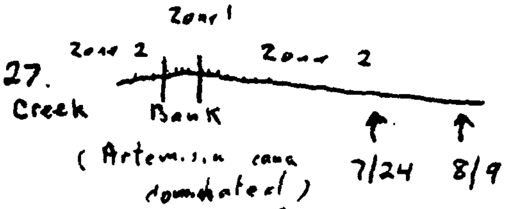
~~Hughes~~
Dewey Co., So. Dak.
SE 1/4, Sec. 2
T12 No., R31 E.
178°E.

26.



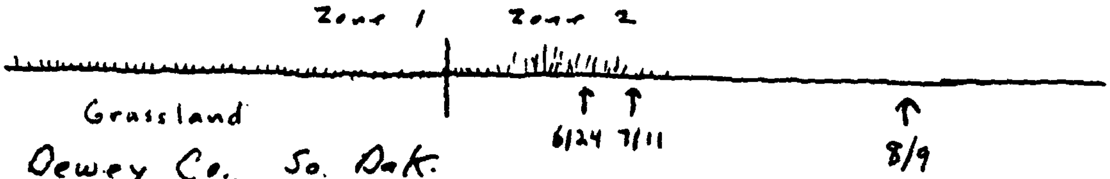
Dewey Co., So. Dak.
SE 1/4, Sec. 19
T16 No., R28E
93° E

27.



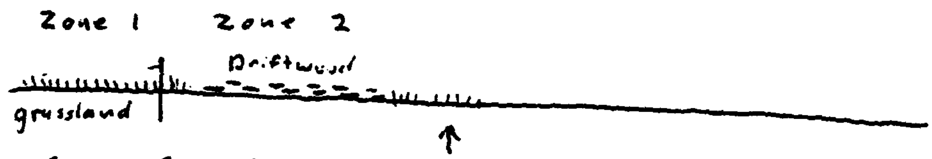
Dewey Co., So. Dak.
SE 1/4, Sec. 36
T16 No., R30E
65°E

28.



Dewey Co., So. Dak.
Se 1/2, Sec. 36
T114N, R30E
42°E

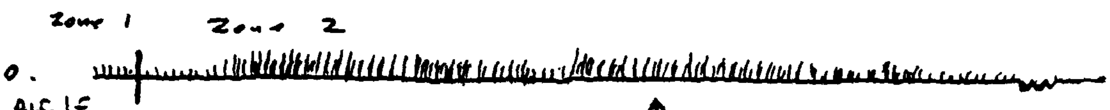
29.



Sioux Co., No. Dak.
NE 1/4, Sec. 21
T129No., R79W

133° E

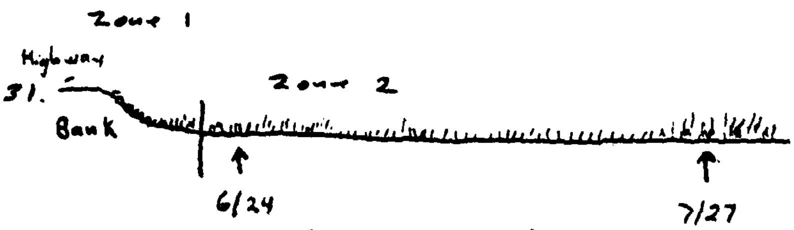
30.



Sioux Co., No. Dak
E 1/2, Sec. 11
T130No., R80W.

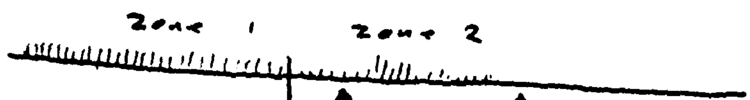
86°E

31.



Sioux Co., No. Dak.
W 1/2, Sec. 15
T131No., R80W
48°W

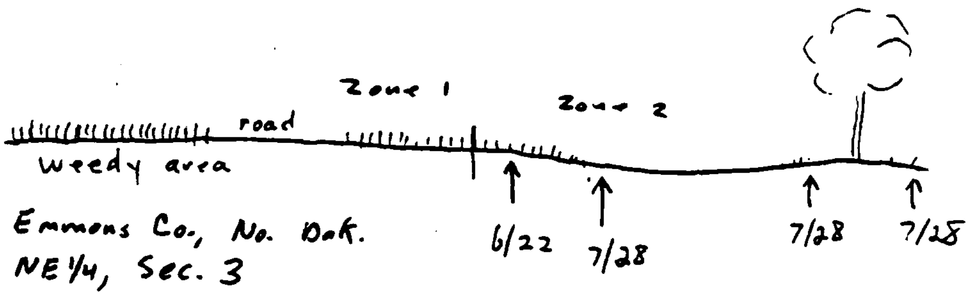
32.



Morton Co.
No. Dak.
W 1/2, Sec. 30
T134No., R80W.

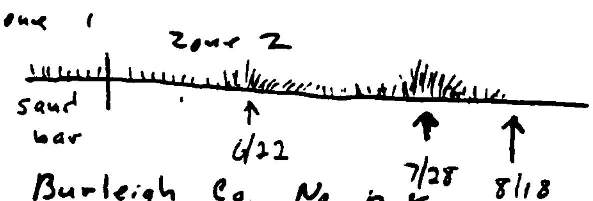
95°E

33



Emmons Co., No. Dak.
NE 1/4, Sec. 3
T136 No., R79W.
160°E.

34

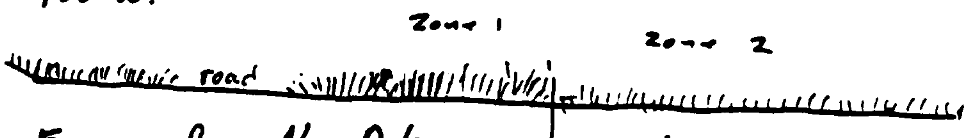


Burleigh Co, No. Dak.
SE 1/4, Sec. 35
T137 No., R79W.
90°E.

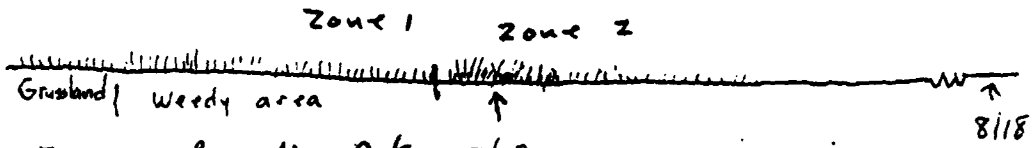
35

Emmons Co., No. Dak.
E 1/2, Sec. 30
T136 No., R78W.
100°W.

36

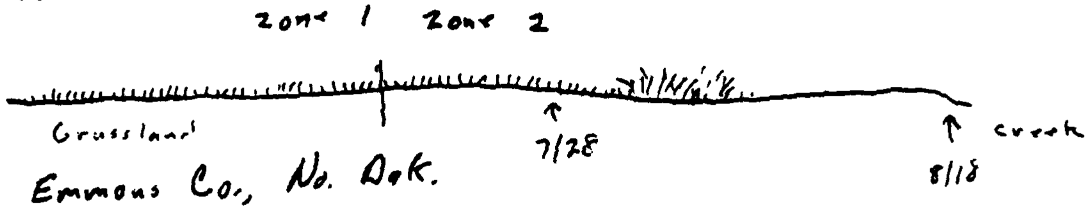


Emmons Co., No. Dak.
Central, Sec. 24
T135 No., R79W.
61°E.

37


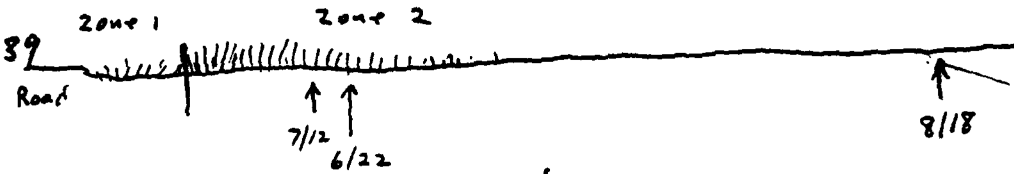
Emmons Co., No. Dak.
S ½, Sec. 14
T132No., R79W.

168°E.

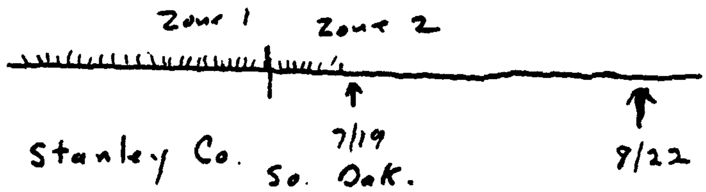
38


Emmons Co., No. Dak.
E ½, Sec. 4
T130 No., R79W.

17'E.

39


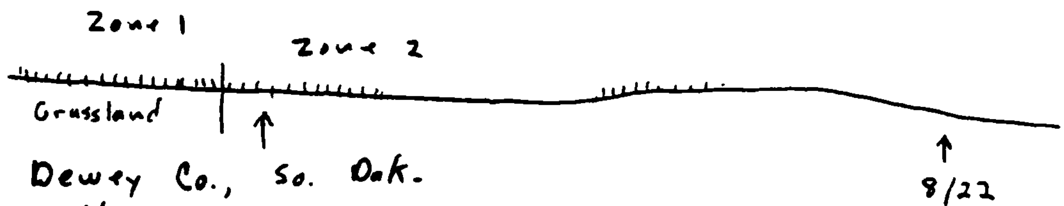
Campbell Co., So. Dak.
N ½, Sec. 18,
T128No., R78W.
161°E

40


Stanley Co. So. Dak.
W ½, Sec. 3
T8N, R26E.

119°W.

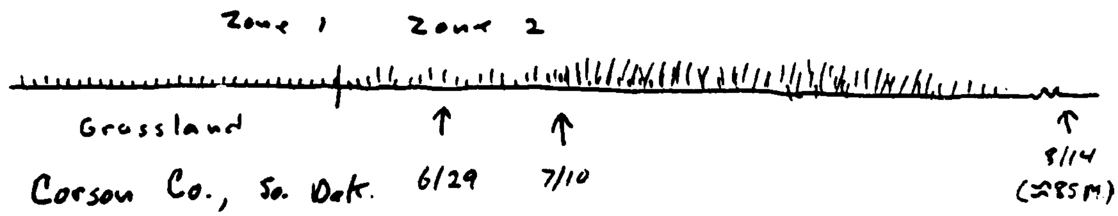
41.



Dewey Co., So. Dak.
SE 1/4, Sec. 26
T10No., R27E.

145°W.

42.



Corson Co., So. Dak.
N 1/2, Sec. 3
T19No., R28E.

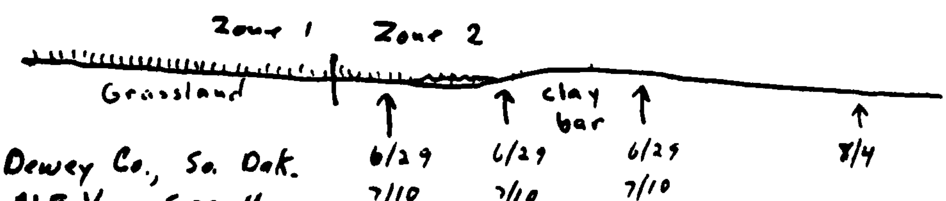
13°W.

43.

Corson Co., So. Dak.
~~T18N~~ W 1/2, Sec. 17
T18 No., R30E.

67°E.

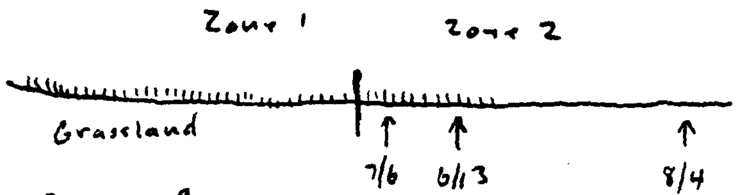
44.



Dewey Co., So. Dak.
NE 1/4, Sec. 4
T16 No., R30E.

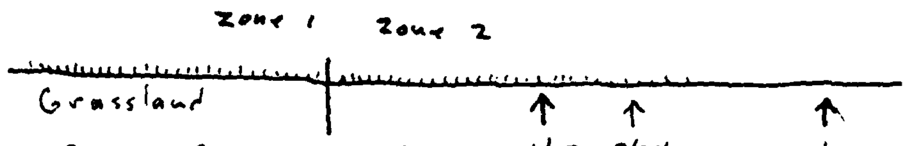
144°E.

45.



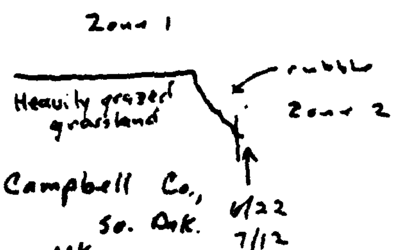
Corson Co., So. Dak.
Central, Sec. 15
T19 No., R28E

46



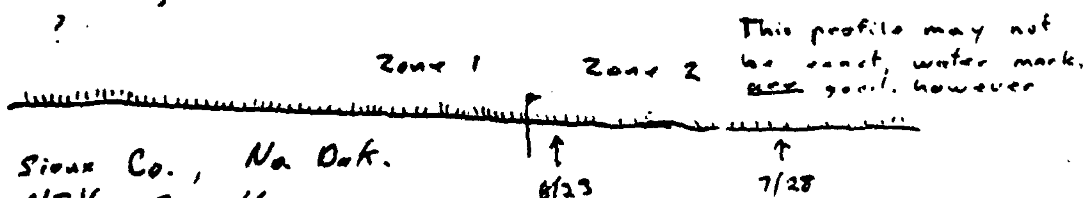
Dewey Co., So. Dak.
SW¼, Sec. 31
T15 No., R31E.
?

47



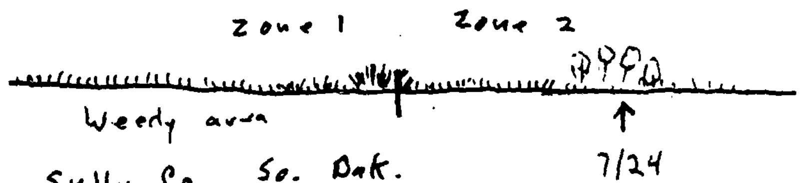
Campbell Co., So. Dak.
N½ ~~[illegible]~~, Sec. 17
T132 No., R79W.
?

48



Sioux Co., No. Dak.
NE¼, Sec. 16
T132 No., R79W.
?

49.



Sully Co., So. Dak.
W½, Sec. 19
T115 No., R81W.
?

Appendix II. An annotated species list of all vascular plant species observed in the vicinity of Lake Oahe.

I. "Pterdiophytes" and Gymnosperms

Equistaceae
Equisetum laevigatum A. Br. Occasional along floodplains.

Aspidiaceae
Cystopteris fragilis (L.) Bernh. Uncommon in wooded draws.

Cupressaceae
Juniperus horizontalis Moench. Rare in buttes along the Grand River.
J. virginiana L. Occasional to common over area.

II. Monocotyledons

Alismaceae
Alisma plantago-aquatica L. Common in moist areas.
Sagittaria latifolia Willd. Occasional to common in moist areas.
Commelinaceae
Tradescantia bracteata Small. Occasional in moist areas.
T. occidentalis (Britt.) Smyth. Occasional on eroded hill sides.
Cyperaceae
Carex atherodes Spreng.
C. brevior (Dew.) Macken. Common in rich moist areas.
C. eleocharis Bailey. Common on upland sandy prairies, not on shale, however.
C. emoryii Dewey.
C. filifolia Nutt.
C. gravida Bailey.
C. heliophila Macken.
C. hystricina Muhl.
C. laeviconica Dewey. Common in moist areas and along shorelines.
C. lanuginosa Michx.
C. meadii Dewey.
C. scoparia Schk.
C. sprengelii Dewey. Common in wooded draws.
C. vulpinoidea Michx.
Cyperus erythrorhizos Muhl. Common along sandy shores.
Eleocharis acicularis (L.) R. & S. Occasional in moist alluvial woods.
E. palustris (L.) R. & S. Common along shorelines and wet areas.
Scirpus americanus Pers. Common in wet places.
S. validus Vahl. Common in shallow water areas.
Graminaceae
Agrostideae
Agrostis hiemalis (Walt.) B. S. P.
Alopecuras aequalis sobol.
Aristida longiseta Steud. Occasional to common on sandy upland prairies.
Calamagrostis canadensis (Michx.) Gray.
Calmovilfa longifolia (Hook.) Scribn. Common on sandy prairies.
Muhlenbergia racemosa (Michx.) B. S. P.

Oryzopsis hymenoides (R. & S.) Ricker. Rare on sandy areas.
O. micrantha (T. & R.) Thurb. Infrequent.
Sporobolus cryptandrus (Torr.) A. Grey.
Stipa comata Trin. & Rupr. Occasional on sandy prairies.
S. spartea Trin. Common on sandy prairies.
S. viridula Trin. Common on both sandy and clayey prairies.

Andropogoneae
Andropogon gerardi Vit. Occasional in ditches and moist floodplains.
A. scoparius Michx. Occasional on hill sides.
Sorghastrum nutans (L.) Pers. Rare, my only speciman was from North Dakota.

Avenae
Avena fatua L. Occasional to common on cultivated and disturbed areas.
Koeleria cristata (L.) Pers. Occasional on sandy prairies.
Sphenopholis obtusata (Michx.) Scribn.

Chlorideae
Beckmannia syzigachne (Steud.) Fern. Common in moist areas.
Bouteloua curtipendula (Michx.) Torr. Occasional on sandy prairies.
B. gracilis (H. B. K.) Lag. Common on all prairies.
Buchloe dactyloides (Nutt.) Engelm. Infrequent to occasional on prairies.
Munroa squarrosa (Nutt.) Torr. Infrequent around ant hills and prairie dog towns in the southern part.
Schedonnardus paniculatus (Nutt.) Trel. Infrequent in prairies.
Spartina pectinata Link. Occasional in ditches and other moist places.

Festuceae
Bromus inermis Leyss. Common along roadsides, often planted.
B. japonicus Thunb. Common in waste places and prairies.
B. tectorum L. Common in waste places and occasional in dry prairies.
Distichlis stricta (Torr.) Rydb. Common in localized saline areas.
Festuca octoflora Walt. Common in dry prairies.
F. ovina L. Common in prairies.
Phragmites communis Trin. Occasional in sloughes.
Poa arida Vasey. Common in North Dakota.
P. palustris L.
P. pratensis L. Common on moist prairies and ranges.
Puccinellia airoides (Nutt.) Wats. and Coult

Hordeae
Agropyron cristata (L.) Gaertn. Commonly planted and persisting.
A. repens (L.) Beauv. Common in moist waste areas.
A. smithii Rydb. The dominant plant on all prairies, especially in South Dakota.
Elymus canadensis L. Common in ditches and other moist places.
E. cinereus Scribn. & Merr. Rare.
E. macounii Vasey. Infrequent.
E. villosus Muhl. Common in wooded draws.
E. virginicus L. Common in thickets and moist areas.
Hordeum jubatum L. Common in waste areas.
H. pusillum Nutt. Common on dry prairies.
Sitanion hystrix (Nutt.) J. G. Smith. Occasional on shale in South Dakota.

Oryzeae
Leersia orzoides (L.) Sw. Infrequent, in wet areas.

Paniceae
Cenchrus longispinus (Hack.) Fern. Occasional on sandy waste areas.
Panicum capillare L. Common on waste areas.
P. milliaceum L. Infrequent on waste areas.
P. virgatum L. Infrequent to occasional on moist lowland prairies.
Setaria viridis (L.) Beauv. Common on waste and cultivated areas.

Phalarideae

<u>Phalaris arundinaceae</u> L. Common in wet areas.

Iridaceae

<u>Sisyrinchium angustifolium</u> Miller. Occasional in prairies.

Juncaceae

<u>Juncus bufonius</u> L.

<u>J. torreyi</u> Coville.

Lemnaceae

<u>Lemna minor</u> L.

Liliaceae

<u>Alium textile</u> Nels. & Mac Br. Common on dry prairies.

<u>Asparagus officinalis</u> L. Rare.

<u>Calochortus gunnisonii</u> S. Wats. Rare.

<u>Polygonatum biflorum</u> (Walt.) Ell. Occasional in alluvial wooded areas.

<u>Smilax herbacea</u> L. Occasional in wooded alluvial areas.

<u>Yucca glauca</u> Nutt. Common on dry hill sides.

Najadaceae

<u>Potamogeton filiformis</u> Pers.

Sparganiaceae

<u>Sparganium eurycarpum</u> Engelm.

Typhaceae

<u>Typhus latifolia</u> L.

III. Dicotyledons

Aceraceae

<u>Acer negundo</u> L.

Amaranthaceae

<u>Amaranthus albus</u> L.

<u>A. graezanus</u> L. Common in waste areas.

<u>A. retroflexus</u> L. Common in waste and cultivated areas.

Anacardiaceae

<u>Rhus trilobata</u> Nutt. Occasional on hill sides.

Apocynaceae

<u>Apocynum cannabinum</u> L. Occasional in draws and moist areas.

Asclepidaceae

<u>Asclepias incarnata</u> L. Infrequent in wet areas.

<u>A. pumila</u> (A. Grey) Vail. Common on dry prairies.

<u>A. speciosa</u> Torr. Occasional in ditches and waste places.

<u>A. viridiflora</u> Raf. Infrequent on buttes.

Boraginaceae

<u>Cryptantha celosioides</u> (Eastw.) Payson. Badlands in North Dakota.

<u>Lappula echinata</u> Gilib. Waste areas.

<u>L. redowskii</u> (Hornem.) Greene.

<u>Lithospermum incisum</u> Lehm. Rare on dry prairies.

<u>Mertensia lanceolata</u> (Pursh) A. D. C. Infrequent on moist hill sides.

<u>Onosmodium molle</u> Michx.

Cactaceae

<u>Coryphantha vivipara</u> (Nutt.) Britt. & Br. Occasional on prairies.

<u>Echinocereus viridiflorus</u> Engelm. Rare.

<u>Opuntia fragilis</u> (Nutt.) Haw. Common on dry prairies.

<u>O. tortispina</u> Engelm. Common on dry prairies.

Campanulaceae
Campanula rotundifolia L. Occasional in North Dakota.
Triodanis leptocarpa (Nutt.) Nieuwl.
Capparidaceae
Cleome serrulata Pursh. Occasional on floodplains and moist areas.
Polanisia dodecandra (L.) D. C. Occasional to common on sandy areas.
Caprifoiaceae
Symphoricarpos occidentalis Hook. Common in draws.
Caryophyllaceae
Silene cucubalus Wibel. Rare.
Celastraceae
Celastrus scandens. L. Infrequent in alluvial woods.
Chenopodiaceae
Atriplex argentea Nutt.
A. dioica (Nutt.) MacBride. Common saline areas.
A. patula L. Common on saline areas.
A. powellii Wats. Infrequent.
A. rosea L.
Chenopodium album L. Common in waste areas.
C. hybridum L.
Cycloloma atriplicifolium (Spreng.) Coult. Floodplain of Cheyenne River.
Kochia scoparia (L.) Schrad.
Monolepis nuttalliana (Schyltes) Green. Infrequent.
Salsola kali L. Infrequent on sandy soils.
Compositae
Achillea millefolium L. Common on prairies.
Ambrosia artemisifolia L. Occasional.
A. psilostachya D. C. Infrequent.
A. trifida L. Common in moist waste areas.
Antennaria parvifolia Nutt. Sandy soil near buttes, occasional.
Arctium minus (Hill) Bernh. Infrequent in North Dakota.
Artemisia biennis Willd. Infrequent along streams.
A. cana Pursh. Common on dry prairies.
A. dracunculus L. Occasional on dry prairies.
A. frigida Willd. Common on dry prairies.
A. ludoviciana Nutt.
Aster canescens Pursh.
A. ciliolatus Lindl. Rich wooded draw in Corson County, rare.
A. ericoides L. Occasional.
A. falcatus Lindl.
A. hesperius Gray.
A. laevis L.
A. sericeus Vent. Occasional on dry prairies.
A. simplex Willd.
Bidens cernua L. Common in moist waste areas.
B. frondosa L. Common in moist waste areas.
Chrysothamnus nauseosus (Pall.) Britt. Common on dry prairies.
Cirsium arvense (L.) Scop. Locally common in waste places.
C. flodmani (Rydb.) Arthur. Occasional on dry prairies.
Conyza canadensis (L.) Cron. Common in waste places.
Dyssodia papposa (Vent.) Hitchc. Infrequent.

Echinacea angustifolia D. C.
Erigeron philadelphicus L.
E. pumilis Nutt. Common on dry prairies.
Grindelia squarrosa (Pursh) Dunal. Common on waste areas.
Haplopappus spinulosus (Pursh) D. C.
Helianthus annuus L. Common in waste areas and road sides.
H. maxmilliana Schrad. Occasional in ditches and moist prairies.
H. petiolaris Nutt.
H. rigidus (Cass.) Desf. Occasional on prairies.
H. tuberosus L.
Heliopsis helianthoides (L.) Sweet. Occasional near wooded areas.
Heterotheca villosa (Pursh) Shinners. Common on sandy prairies.
Hymenopappus filifolius Hook.
Iva axillaris Pursh. Locally abundant on saline areas.
I. xanthifolia Nutt. Occasional on moist waste areas.
Kuhnia eupatorioides L. Occasional on dry prairies.
Lactuca pulchella (Pursh) D. C. Occasional on moist areas.
L. scariola L. Common on waste areas.
Liatris punctata Hook. Infrequent on sandy prairies.
Lygodesmia juncea (Pursh) D. Don. Common on dry prairies.
Nothocalais cuspidata (Pursh) Greene. Rare on sandy prairies.
Petaostemon candidum (Willd.) Michx.
P. Purpureum (Vent.) Rydb.
Picradeniopsis oppositifolia (Nutt.) Rydb.
Ratiba columnifera (Nutt.) Woot. and Standl. Common on prairies.
Senecio integerrimus Nutt.
Solidago altissima L.
S. missouriensis Nutt. Common on prairies.
S. mollis Bartl.
S. rigida L. Occasional on dry prairies.
Sonchus arvensis L. Locally common in low moist waste areas.
Taraxacum officinale Weber. Infrequent in waste places.
Townsendia sericea Hook. Rare.
Tragopogon dubius Scop. Common in waste areas.
Vernonia fasiculata Michx. Infrequent in low moist areas.
Xanthium strumarium L. Common in waste areas.

Convolvulaceae
Convolvulus arvensis L. Occasional in waste and cultivated areas.
C. sepium L. Infrequent along streams.
Ipomoea leptophylla Torr. Occasional in sandy soil along Cheyenne River.

Cornaceae
Cornus stolenifera Michx. Occasional along streams.

Cruciferae
Arabis divaricarpa A. Nels.
Brassica nigra (L.) Koch. Common on moist waste areas.
Camelina microcarpa Andrz. Occasional in waste places.
Chorispora tenella (Pall.) D. C. Infrequent along edge of Oahe Reservoir.
Conringia orientalis (L.) Andrz.
Descurainia sophia (L.) Webb. Common in cultivated and waste places.
Draba reptans (Iam.) Fern. Gravelly soil in Sully County, occasional.
Erysimum asperum (Nutt.) D. C. Occasional in waste areas.
Hesperis matronalis L. Infrequent.
Lepidium densiflorum Schrader. Occasional in waste places.
L. perfoliatum L. Infrequent.

Lesquerella ludoviciana (Nutt.) Wats.
Rorippa amoracia (L.) Hitch. Infrequent.
R. islandica (Oeder) Borbas. Common along edge of Oahe Reservoir.
R. sinuata (Nutt.) Hitch. Infrequent along edge of Oahe Reservoir.
Sisymbrium altissimum L.
Stanleya pinnata (Pursh) Britt. Occasional on shale prairies.
Thlaspi arvense L. Common on waste areas.

Cucurbitaceae
Echinocystis lobata (Michx.) T. & G. Alluvial areas.

Elaganaceae
Euphorbia podperae Croiz.
E. marginata Pursh. Occasional on prairies.
E. serpens H. B. K. Occasional along edge of Lahe Reservoir.
E. serpyllifolia Pers. Rare along edge of Oahe Reservoir.

Fagaceae
Quercus macrocarpa Michx. Common on bluffs.

Hydrophyllaceae
Ellisia nyctelea L. Occasional along shoreline of Oahe Reservoir.

Labiatae
Agastache foeniculum (Pursh) Ktz.
Lycopus americanus Muhl. Occasional in low wet areas.
Hedeoma hispida Pursh.
Mentha arvensis L. Common in low wet areas.
Monarda fistulosa L. Infrequent in draws and wooded areas.
Nepeta cataria L. Occasional to common in wooded areas.
Salvia reflexa Hornem. Occasional along road sides.
Scutellaria lateriflora L.
Stachys palustris L.
Teucrium canadense L.

Leguminosae
Amorpha canescens Pursh. Common on dry upland prairies.
A. nana Nutt. Infrequent.
Astragalus agrestis Dougl.
A. mondii Dougl. Common on shale prairies.
A. missouriensis Nutt. Common in dry prairies.
A. plattensis Nutt.
Caragana arborescens Lam. Infrequent as a wind break.
Dalea aurea Nutt. Rare along the Cheyenne River.
D. ennandra Nutt. Common on sandy prairies.
Glycyrrhiza lepidota Pursh. Moist places in draws.
Lotus purshianus (Benth.) Clem. & Clem. Common on eroded areas.
Lathyrus polymorphus Nutt. Common on dry prairies, not shale, however.
Medicago lupulina L.
M. sativa L.
Melilotus alba Desr. Common in dry prairies.
M. officinalis (L.) Lam. Common in dry prairies.
Oxytropis lambertii Pursh. Common in dry prairies.
Petalostemon candidum (Willd.) Michx. Infrequent on prairies.
P. purpureum (Vent.) Rydb. Occasional on prairies.
Psoralea argophylla Pursh. Common on sandy prairies.
P. cuspidata Pursh.
P. esculenta Pursh. Infrequent on sandy prairies.
P. lanceolata Pursh.

Schrankia nuttallii (D. C.) Standl. Rare along Cheyenne River area.
Trifolium repens L. Lawns in Mobridge.

Linaceae
Linum rigidum Pursh. Common on dry prairies.
L. usitatissimum L. Cultivated in areas, rarely escaped.

Loasaceae
Mentzelia decapetala (Pursh) Urb. & Gilg. Common along Cheyenne River on clay banks.

Lythraceae
Ammania coccinea Rottb. Rarely along edge of Oahe Reservoir.

Malvaceae
Abutilon theophrasti Medic. Infrequent in cultivated places.
Malva neglecta Wallr. Occasional in waste areas.
Sphaeralcea coccinea (Pursh) Rydb. Occasional in prairies.

Nyctaginaceae
Mirabilis hirsuta (Pursh) MacMill
M. nyctaginea (Michx) MacMill. Infrequent in waste places.

Oleaceae
Fraxinus pennsylvanica Marsh. Occasional in alluvial areas.

Onagraceae
Gaura coccinea (Nutt.) Pursh. Occasional in prairies.
Oenothera albicaulis Pursh. Occasional on prairies.
O. biennis L. Occasional on waste places.
O. caespitosa Fraser. Infrequent on eroded clay areas.
O. serrulata Nutt. Occasional on dry prairies.

Orobanchaceae
Orobanche fasciculata Nutt. Infrequent.
Orobanche ludoviciana Nutt. Infrequent.

Oxalidaceae
Oxalis stricta L. Infrequent in waste areas.

Phrymaceae
Phryma leptostachys L. Infrequent in alluvial woods.

Plantaginaceae
Plantago aristata Michx. Rare along edge of Oahe Reservoir.
P. elongata Pursh. Rare in low areas which have been heavily grazed.
P. major L. Occasional in moist waste areas.
P. patagonica Jacq. Common in waste places and overgrazed prairies.

Polemoniaceae
Collomia linearis Nutt. Occasional along edge of Oahe Reservoir.
Phlox hoodii Rich. Infrequent on dry prairies.

Polygalaceae
Polygala alba Nutt. Occasional on sandy prairies.

Polygonaceae
Eriogonum annuum Nutt.
Polygonum aviculare L.
P. coccineum Muhl. Occasional in shallow water.
P. convolvulus L. Infrequent in alluvial areas.
P. erectum L. Infrequent.
P. lapathifolium L.
P. ramosissimum Michx. Common along edge of Oahe Reservoir.
Rumex crispus L. Common in moist areas and along edge of Oahe Reservoir.
R. maritimus L. Common along edge of Oahe Reservoir.
R. salicifolius Weinm. Common along edge of Oahe Reservoir.
R. venosus Pursh. Infrequent along road sides in North Dakota

Primulaceae

Steironema ciliatum (L.) Raf.

Ranunculaceae

Anemone canadensis L. Common along streams.

A. cylindrica A. Gray. Occasional in wooded areas in North Dakota

Aquilegia canadensis L. Common in thickets.

Clematis virginiana L. Occasional in thickets.

Ranunculus aquatilis L. Occasional in shallow water.

R. circinnatus Sibth.

Thalictrum dasycarpum Fisch. and Ave-Lall.

Rosaceae

Potentilla arguta Pursh. Occasional on prairies.

P. norvegica L. Occasional along Oahe Reservoir.

P. paradoxa Nutt. Occasional along Oahe Reservoir.

P. rivalis Nutt.

Rosa blanda Ait. Common in draws and thickets.

R. woodsii Lindl. Common in draws and thickets.

Rubiaceae

Galium aparine L. Occasional in wooded areas.

Salicaceae

Populus deltoides Marsh. Common in alluvial areas.

Salis amygdaloides Anderss. Common in alluvial areas.

S. discolor Muhl. Infrequent in alluvial areas.

S. interior. Rowlee. Infrequent.

Santilaceae

Comandra umbellata (L.) Nutt.

Saxifragaceae

Ribes missouriense Nutt.

Scrophulariaceae

Bacopa rotundifolia (Michx.) Wetts. Rare in sloughes.

Penstemon albidus Nutt. Infrequent in prairies.

P. angustifolia Pursh. Occasional in prairies.

P. grandiflorus Nutt. Infrequent in prairies.

Solanaceae

Physalis heterophylla Nees. Infrequent.

P. virginiana Mill. Infrequent in ditches and other moist places.

Solanum nigrum L.

S. rostratum Dunal. Occasional in waste and overgrazed areas.

Ulmaceae

Ulmus americana L.

Umbelliferae

Cicuta maculata L. Infrequent in alluvial areas.

Musineon divaricatum (Pursh) Nutt. Common on dry prairies.

Sium suave Walt. Infrequent in alluvial areas.

Urticaceae

Urtica dioica L. Common.

Verbenaceae

Verbena bipinnatifida Nutt. Rare in dry prairies.

V. bracteata Lag. & Rodr. Common in sandy waste areas.

V. stricta Vent. Infrequent on prairies and alluvial areas.

Violaceae

Viola nuttallii Pursh. Infrequent on dry prairies.

V. pedatifida G. Don.

Vitaceae

Parthenocissus quinquefolia (L.) Planch.

Vitis riparia Michx. Infrequent in alluvial woods.

- 8

DTIC