South Dakota
Department of Transportation
Office of Research

U.S. Department of Transportation
Federal Highway Administration

SD1995-08-F

Design and Performance of Created Wetlands

Study SD1995-08
Final Report

Prepared by
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December, 2000

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ACKNOWLEDGEMENTS

We would like to thank Curt Vacek, Dawn Roush, Stacey Johnson and Nathan Morey for assistance in the field. Dr. Gary Larson, SDSU, assisted with identification of aquatic plants. Data were analyzed with the help of Dr. Tim Wittig, Department of Mathematics and Statistics, SDSU. Greg Wolbrink, South Dakota GAP Analysis Office, helped create maps. The Cooperative Research Unit is jointly sponsored by the U.S. Geological Survey, South Dakota State University, South Dakota Game, Fish and Parks, U.S. Fish and Wildlife Service, and Wildlife Management Institute.

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The work was performed in cooperation with the United States Department of Transportation Federal Highway Administration.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. SD1995-08 F	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Design and Performance of Created Wetlands		5. Report Date December, 2000 6. Performing Organization Code
7. Author(s) Sara Juni, Dr. Charles Berry		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Wildlife and Fisheries Sciences South Dakota State University Brookings, South Dakota		10. Work Unit No. 11. Contract or Grant No. 310364
12. Sponsoring Agency Name and Address South Dakota Department of Transportation Office of Research 700 East Broadway Avenue Pierre, SD 57501-2586		13. Type of Report and Period Covered Final; May 1995-December 2000 14. Sponsoring Agency Code

15. Supplementary Notes: The Design and Performance of Created Wetlands Interim Report is published separately as SD95-08-I.

16. Abstract

The goal was to develop construction guidelines for compensation wetlands that fostered biodiversity. Objectives were 1) inventory birds, mammals, amphibians, fish, butterflies, and invertebrates in restored, dam-created, borrow-pit, and natural wetlands, 2) identify environmental factors associated with biodiversity, and 3) evaluate prototype wetlands constructed using design criteria to enhance biodiversity. Number of birds and invertebrates varied by wetland type (Objective 1), and was usually less in borrow pits than in other wetland types. Biodiversity was strongly influenced by shoreline development and slope; other variables with less influence were soil type, wetlands nearby, aquatic plants, and surrounding land use (Objective 2). General guidelines were proposed for planning, site preparation, construction, and management. Guidelines allow flexibility because of the variety of wetland types and sites in the prairie pothole region. Two prototype wetlands were excavated adjacent to Dry Run Creek, and monitored during May-June and August -September of 1998-99. Data were compared with that from 9 borrow-pits and 2 restored wetlands (Objective 3). We found 80 bird, 14 fish, 19 mammal, 8 amphibian, and 3 reptile species, and 38 dominant plants. Animals colonized the new wetlands rapidly. There was significantly more bird diversity (mean = 1.9) and richness (mean = 11.6) in prototype wetland than in the older borrow pits (mean diversity = 1.6, mean richness = 8.2). However, mean amphibian richness was less (0.6) in the prototype wetlands than in the older borrow pits (1.4), possibly indicating that more time would be needed for amphibian's colonization. Other taxa have too few species to be used for biomonitoring. Evaluating created wetlands for wildlife functions is difficult because of temporal changes in hydrology and habitat. Recommendations include 1) adopting the wetland engineering guidelines used to create the prototype wetlands, 2) improve knowledge about wetlands among staff and the public, 3) monitor and manage created wetlands to evaluate performance and improve engineering criteria, 4) conduct research on other values of created wetlands, and 5) maintain coordination with resource agencies on wetland conservation issues.

17. Keywords		18. Distribution Statement No restrictions. This document is available to the public from the sponsoring agency.	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 97 pages	22. Price

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RECOMMENDATIONS

It is recommended that the South Dakota Department of Transportation take the following actions:

Wetland construction and design

- Adopt the guidelines for constructing borrow pits, building embankment wetlands, and restoring wetlands that are in the Berry and Juni (2000)
- Develop protocols for defining the goals for individual wetlands, establish criteria for success, and ensure that wetlands are constructed according to the design plan, all common reasons cited by others for wetland creation failure

Staffing and public education

- Develop a staff position for a biologist who would assist in certain aspects of highway development as it relates to natural resources, and involve them in the following stages of any project: pre-planning, design, construction, and monitoring
- Disseminate the brochure produced from this research project to current staff of the South Dakota Department of Transportation, and to interested publics

Monitoring and management

- Develop a rapid biodiversity assessment program that would allow an evaluation of created wetlands and develop long-term data on the Mitchell wetlands to understand the permanency of mitigation efforts
- Visit created wetlands periodically to check on landowner compliance and detect common problems like erosion, animal damage, climate effects, and nuisance plants

Research

- Commission research on other values of wetlands such as flood control, nutrient processing, and ground water recharge
- Commission research on innovative wetland designs such as borrow pits with deep ends for maximum dirt fill harvest and shallow ends that have the design features covered in the Constructions Guidelines section of this report

Coordination

- Maintain coordination with natural resource agencies that might assist with expertise or with funding for wetland mitigation

EXECUTIVE SUMMARY

Phase I of this study was done to evaluate the influence of selected environmental factors and engineering criteria on the diversity of species in groups of animals that are indicators of wetland health (i.e. aquatic invertebrates, birds, amphibians, fish, butterflies, mammals). Studies were done on existing compensation wetlands (borrow-pit, dam-created and restored) and natural wetlands. Surveys of 27 sites in eastern South Dakota were made in spring and fall in 1995 and 1996. Multiple regression analysis showed that biodiversity was highest when wetlands had irregular shorelines (vertical and horizontal irregularity) and irregular bottom contours that fostered development of emergent and submerged aquatic vegetation. Guidelines for creating mitigation borrow pits that would foster high biodiversity were developed and implemented in two wetlands constructed in association with a highway project in Mitchell. The guidelines are included as part of this report, in an interim report, and in a public information and education brochure.

Task 10 of the study required presenting the essential results at the Research Review Board Meeting on August 17, 2000. Figure 1 was presented as the essential results of Phase I. The basic conclusion was that the bird and invertebrate communities had enough species to provide the best information on habitat suitability. Habitat components that fostered greater biodiversity were (+ = positive relationship) shoreline irregularity (+), percentage of aquatic plants (+), number of other wetlands within 5 km (+), and the amount of cropland (-) and pasture (+) near the study wetland.

In Phase II, the two prototype borrow-pit wetlands near Mitchell, SD were monitored for colonization by wetland dependent wildlife. Also sampled were nine other borrow-pits and two restored wetlands. In the two prototype wetlands, we found 35 aquatic and 55 terrestrial invertebrate taxa. There was significantly more bird species in the Mitchell prototype wetlands than in borrow pits that were not constructed according to guidelines developed in Phase I. For all wetlands studied during Phase II. Animal and plant surveys were done in spring and late summer, 1998 and 1999. We found 80 bird, 14 fish, 19 mammal, 8 amphibian, 3 reptile species and 38 dominant plants in the wetlands. Animals colonized the new wetlands rapidly. Year-to-year differences were insignificant, but the numbers of animals using wetlands varied between spring and fall.

Figure 2 shows the essential findings of Phase II that were presented to the Research Review Board.

Evaluating created wetlands for wildlife habitat functions in South Dakota is difficult because of great seasonal and year-to-year changes in hydrology and habitat. Complex research studies are needed to have enough data for statistical treatment, but a routine practical approach to evaluate a new wetland as wildlife habitat is to seek qualitative answers to the following questions: 1) Is the hydrology similar to that in surrounding natural wetlands? 2) Is there a clumped distribution of several kinds of emergent hydric plants? 3) Is there a stand of submerged vegetation? 4) Are there representatives of about 2 dozen species of nesting birds in the spring? 5) Can several kinds of frogs and toads be heard? 6) Are the tracks of about a half-dozen mammals visible in the mud?

Figure 1. Summary of main results from Phase I as presented to the SDDOT Research Review Board meeting, August 17, 2000 to partially fulfill (Task 10) the requirements of the study.

Design and Performance of Created Wetlands

Design (1995-97):

* No difference in amphibians, fish, mammals butterflies among wetlands

* Fewer birds and invertebrates in borrow pits than in natural, restored, or dam-created wetlands

* Animal-Habitat associations

Animal	Habitat	Explained
Bird	shore, soil, % aquatic plants	60%
Invertebrate	shore, 5km, % cropland	41%
Butterflies	shore, % grass, % aquatic plants	79%
Amphibians	shore, 5km	83%
Fish	soil	14%
Mammals	shore, 5km, % grass	87%

Figure 2. Summary of main results from Phase II as presented to the SDDOT Research Review Board meeting, August 17, 2000 to partially fulfill (Task 10) the requirements of the study.

Design and Performance of Created Wetlands

<u>Performance (1998-99)</u>

*** Habitat**

*monitored to explain pop trends
*water levels lower in fall
*vegetation amount and location

*** Biota**

* Colonization fast
* Richness comparable

Species	Mitchell	Restored	Borrow
Bird	12	10	8
Fish	2	3	3
Mammals	3	3	2
Amphibians	<1	2	1
Reptiles	<1	<1	<1

INTRODUCTION

Phase I of the project titled Design and Performance of Created Wetlands (SD95-08) had seven tasks to evaluate existing compensation areas and natural wetlands by determining the plant and animal life in each type, and to develop construction guidelines for 1) excavated wetlands (borrow-pits), 2) small dam-created wetlands, and 3) restored wetlands.

Data for Phase I were presented as a thesis by Kjersten Larson (1997) and in the interim report for Phase I. Larson produced lists of animals inhabiting wetlands, and reported that there was no difference among wetland types for the number of species of fish, mammals, amphibians, turtles, and butterflies. These groups of animals gave little information about physical conditions that increased the number of species, except that there was sometimes more species when vegetation emerged along shallow shorelines, shorelines were irregular compared to straight, and other wetlands were nearby.

The numbers of bird and invertebrate species were more helpful. The number of bird species was statistically lower (P<0.01) in borrow-pit wetlands than in other types. Higher bird use was also found when there were emergent plants, irregular shorelines with a low slope, and nearby wetlands.

The results from aquatic insect sampling were given in the interim report (Task 7). Aquatic insect results agreed with those of the bird community. Natural and restored wetlands supported richer invertebrate communities than dam-created and borrow-pit wetlands. Invertebrate richness in wetlands was somewhat correlated with bird richness (r^2=0.29), but invertebrate communities are just one component required for bird colonization. Wetland creation recommendations based on invertebrate richness supported those based on bird data.

The goal of Phase II of the project was to construct prototype wetland compensation areas and evaluate biodiversity. Task 8 in the original proposal called for evaluation of three types of prototype compensation wetlands, which were supposed to have been constructed using guidelines from Phase I. However, only two prototype borrow-pit wetlands were constructed (Mitchell wetlands). It was agreed that other borrow-pits would also be studied that had not been constructed using guidelines from

Phase I. Task 8 in the original proposal by Duffy and Johnson suggested that statistical analysis to compare prototype wetlands would be similar to that used to compare wetlands studied in Phase I (i.e., ANOVA). Additionally, regression analyses would be used to show colonization rates.

This is the final report for Phase II, which meets task 9 of the study. In this report we summarize the data collected over the last two years in the Mitchell prototype wetlands and in the other wetlands included in the study. A verbal report and slide show were presented to the Research Review Board on August 17, 2000 (Task 10).

METHODS AND STUDY SITES

Study sites

Twelve wetlands were sampled in 1998 and thirteen wetlands were sampled in 1999 (Table 1, Figure 3). The same wetlands were used both years, with two exceptions. The "Arlington" wetland sampled in 1998 was not a DOT project and was replaced by a DOT-restored wetland on the Kneip WPA for the 1999 sample period. Since it was not a DOT project, data from the Arlington wetland were not included in analyses. A borrow-pit near Freeman was added to the study in 1999 at the request of the DOT.

Nine study wetlands were borrow-pits, two were the prototype borrow-pits in Mitchell, and two were restored wetlands. The prototype wetlands were located on opposite sides of Dry Run Creek (Figures 4, Appendix B figures 17 & 19). About 200,000 cubic yards of soil were removed for use in constructing Highway 37. Topsoil was stockpiled and spread on side slopes after removing the borrow. The contractor was required to leave the shorelines and bottom contour "irregular" in shape. Our physical measurements and photographs show that the instructions were followed (Appendices A and B).

Sampling schedule

Wetlands were sampled during four seasons, over two years:

Season	Time period
Spring 1998	May 20 – June 10, 1998
Fall 1998	August 25 – September 15, 1998
Spring 1999	May 10 – June 9, 1999
Fall 1999	August 9 – September 25, 1999

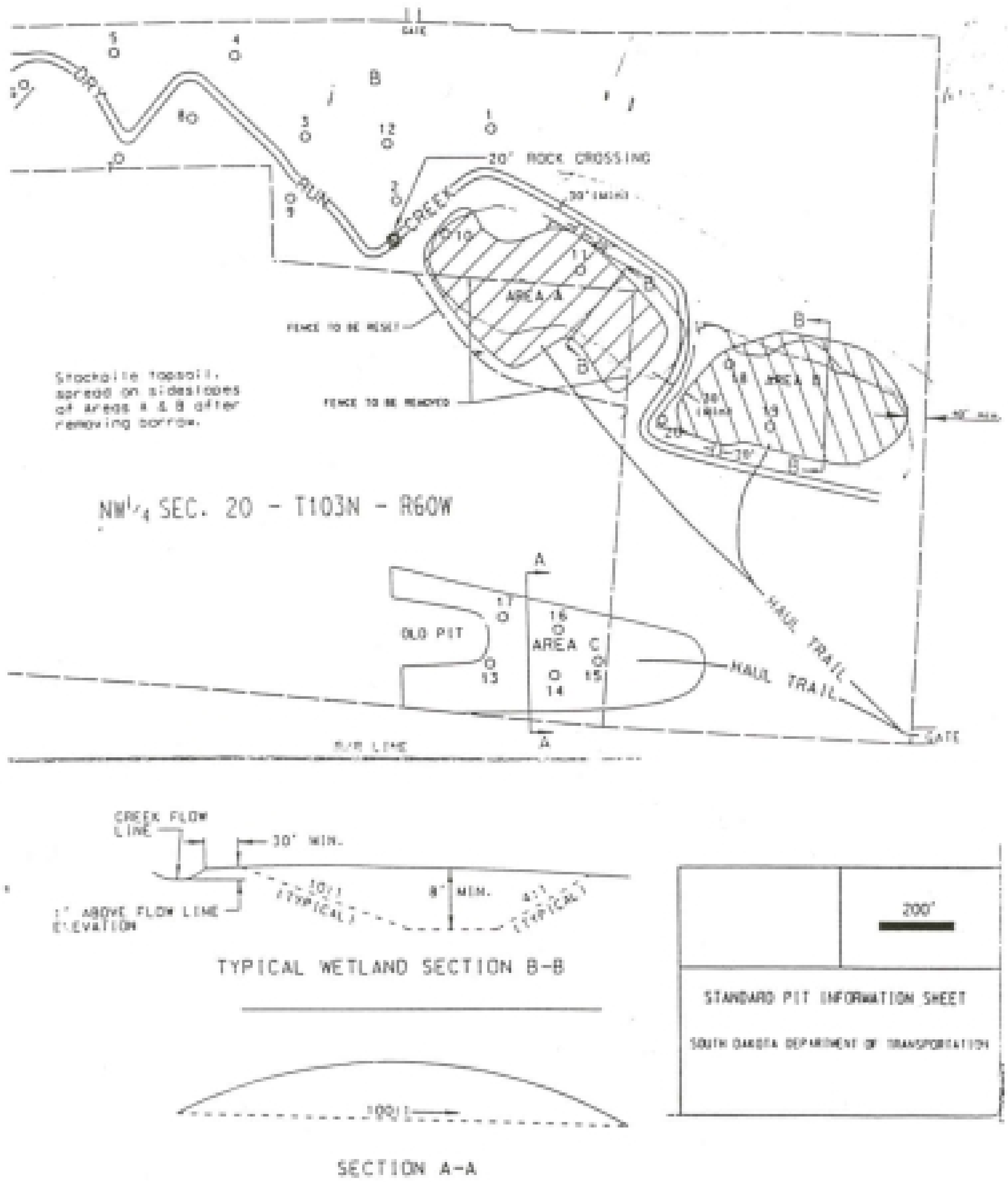
Table 1. Descriptions of eastern South Dakota mitigation wetlands used for the DOT biodiversity study, 1998-99.

Wetland	Wetland Type	Legal Description	Area (acres)	Ownership
Cottonwood East	Borrow-pit	SW¼ SW¼ Sec 34 T116N R65W Spink Co.	0.5	SD DOT
Cottonwood North	Borrow-pit	SW¼ SW¼ Sec 27 T116N R65W Spink Co.	1	SD DOT
Cottonwood South	Borrow-pit	SW¼ SE¼ Sec 18 T115N R65W Spink Co.	2	SD DOT
Dolton	Borrow-pit	SE¼ SE¼ Sec 35 T101N R55W McCook Co.	2.5	SD DOT
Elkton	Borrow-pit	NW¼ NW¼ Sec 9 T109N R47W Brookings Co.	5	SD DOT
Freeman[1]	Borrow-pit	NW¼ NW¼ Sec 24 T99N R56W Hutchinson Co.	1	SD DOT
Kneip WPA[1]	Restored wetland	NW¼ Sec 31 T111N R52W Brookings Co.	25	USFWS
Larson WPA	Borrow-pit	SW¼ NW¼ Sec 31 T110N R52W Brookings Co.	2.5	USFWS
Letcher	Borrow-pit	NW¼ SW¼ Sec 15 T105N R60W Sanborn Co.	7.5	SD DOT
Mitchell East	Prototype wetland	NW¼ Sec 20 T103N R60W Davison Co.	3	Kevin Thurman
Mitchell West	Prototype wetland	NW¼ Sec 20 T103N R60W Davison Co.	3.5	Kevin Thurman
Vanderpan	Restored wetland	NE¼ NW¼ Sec 19 T110N R51W Brookings Co.	12	N. Vanderpan
Vayland	Borrow-pit	NW¼ NE¼ Sec 14 T112N R67W Hand Co.	3	SD DOT

[1] Sampled in 1999 only

Figure 3. Eastern South Dakota DOT mitigation study wetlands, 1998-99.

Figure 4. Portions of the SDDOT Standard Pit Information Sheet showing location adjacent to Dry Run Creek, Mitchell, South Dakota, and proposed design plans for two prototype wetlands labeled Area A and Area B.



Biological sampling methods

Species richness and abundance of several species assemblages were measured at each wetland using the following methods:

- *Birds.* Two methods were used to census birds. First, a 10-minute point count was conducted at a location from which the whole wetland could be observed (Bibby et al. 1992). After waiting a few minutes, we counted each bird using the wetland. Birds flushed before the point count began were also counted. Second, the perimeter of the wetland was surveyed on foot to observe secretive birds or those that were otherwise not visible. Birds flushed during this walk were counted.
- *Fish.* Fish were collected where water was at least 50-cm deep. Three trap nets (1-m x 1-m frame with one funnel, 5-m lead, 1.2-cm mesh) were set perpendicular from shore with the lead staked on shore. Traps were set with the funnel opening submerged and some of the trap above water, so that trapped semi-aquatic animals could breathe. Other captured animals (e.g. crayfish, salamanders) were also counted.
- *Amphibians and Reptiles.* Amphibians and reptiles were sampled using pitfall traps in combination with drift fences (Cambell and Christman 1982). Two drift fences were set perpendicular to one another with a pitfall trap at each end and where the fences met. The pitfall traps were buckets with funnel traps, set flush with ground level. This fence-trap array was set overnight. Any amphibians or reptiles observed during the perimeter walk were also counted.
- *Mammals.* Small mammals were sampled by setting live traps baited with rolled oats and peanut butter (Call 1986). Twenty live traps (four lines of five traps each) were set around each wetland in the evening and retrieved the following morning. Mammals captured in pitfall traps were also recorded. The presence of larger mammals was recorded from sign observed during the perimeter walk.
- *Aquatic Invertebrates.* Aquatic invertebrate sampling was conducted only in the Mitchell prototype wetlands when water was present. Duplicate aquatic invertebrate samples were collected from each wetland using activity traps (Swanson 1978). Activity traps were constructed with two 2-liter plastic bottles

cut and fit together to form a funnel trap. Three horizontal traps were set in shallow water, with the mouth of the funnel at the surface of the water. Three vertical traps were set in deeper water (if present), with the mouth of the funnel oriented down and the top of the trap level with the water surface. All six traps were set overnight. Sampled organisms were sieved through a 149-µm screen, preserved in 80% ethanol, then identified and counted in the laboratory.

- *Terrestrial Invertebrates.* Two methods were used to sample terrestrial invertebrates in the Mitchell prototype wetlands. Pan traps (yellow bowls with a soap-water mixture), were deployed in upland habitat surrounding each wetland (Southwood 1978). Two transects of six traps were set perpendicular to the shore, with traps spaced 3-m apart. Traps were set so the edge was flush with the ground. Pan traps remained set overnight. Core samples 5-cm in circumference and 2.5-cm high were also taken just before setting the pan traps. Core samples were flushed through a 149-µm screen to remove soil. Samples were preserved in 80% ethanol, then identified and counted in the laboratory.
- *Hydrophytes.* Visual estimates of percent plant cover at each wetland were made. Two plots were used at each wetland. One plot was defined as the part of the wetland that was ponded (shallow marsh zone in the spring, deep marsh zone all year) and the other as the non-ponded area (wet-meadow zone all year, shallow marsh zone in the fall). The predominant hydrophytes that made up >10% of plant cover in each zone were listed. Plant cover data were used to classify the wetlands using guidelines of Stewart and Kantrud (1971).

The number of individuals observed was recorded for each bird, fish and invertebrate taxon, while simple presence/absence was recorded for other groups of animals. Species richness is the number of species by taxon. Species diversity was calculated for birds, fish and invertebrates using the Shannon's Diversity Index (H') as follows:

$$-\sum\left({n_i}/{n} \right)\ln\left({n_i}/{n} \right)$$

where "n_i" is the number of individuals in a taxon and "n" is the number of individuals in a sample. Shannon's Index is often used because it is an index of both species richness and distribution of individuals among the species.

Habitat sampling methods

We also assessed a group of water quality and physical parameters at each wetland. Where water was present, we measured water temperature, maximum water depth, dissolved oxygen, pH, conductivity and salinity. The general appearance of the wetlands during each sample period was recorded by taking several photographs at each study wetland. Site diagrams were drawn showing the general spatial pattern of vegetation and location of traps and other transects used for biomonitoring. Other observations at each wetland included weather during sampling, overnight weather, surrounding land uses and livestock grazing pressure. We estimated wetland area using the Natural Resource Conservation Service aerial slides taken in July, 2000.

Statistical analysis

Temporal. We used analysis of variance (ANOVA) to examine the effects of habitat factors on species richness and species diversity. First, we used t-tests to assess the possible effects of season (spring or fall), across both years, on biodiversity (defined as species richness and/or species diversity). The values for each taxa from spring and fall were compared, with season as the independent variable and richness or diversity as the dependent variable. The same approach was used to test for variation due to differences between 1998 or 1999 with seasons combined, where year was the independent and richness or diversity the dependent variable. Next, we broke down the analysis further, to test for differences due to sample period (spring 1998, fall 1998, spring 1999 or fall 1999).

Wetlands and wetland type. ANOVA was used to test for differences in richness and diversity of bird, fish, mammal, amphibian and reptile communities based on individual wetland (see Table 1 for list of wetlands). We then compared richness and diversity in two groups of wetlands, with the Mitchell prototype wetlands as one group and the other nine borrow-pit wetlands as a second group. We also used t-tests to test for differences between prototype and borrow-pit wetlands.

Colonization rate. Regression analysis was suggested in the proposal as a method to determine colonization rates (temporal change in richness or diversity) at the Mitchell prototype wetlands. However, statistical analysis revealed that four observations were insufficient for this type of analysis. Instead, we used simple statistics (i.e., means) to look at changes in species richness and diversity across the four sample periods, using only data from the two Mitchell prototype wetlands.

Because of the high variability of data collected in a rapid bioassessment method like the one used in this study, we feel that an alpha level (*P*-value) of 0.10 was appropriate for statistical analyses. That is, when *P*#0.10 results are considered statistically significant.

Data management

The data sets on computer disks, raw field data sheets, photographs, and voucher specimens are archived at the Department of Wildlife and Fisheries Science, South Dakota State University.

RESULTS AND DISCUSSION

Habitat

Photos and schematic drawings (site diagrams) of each wetland are included in Appendices A and B. Wetland areas are listed in Table 1. The surrounding land use for the study wetlands was fairly consistent between years (Tables 2-3). However, the amount of grassland and cropland around the Mitchell prototype wetlands changed somewhat. In 1998, both Mitchell East and Mitchell West were surrounded by grassland. In 1999, however, 50% of the surrounding land was cropland at Mitchell East and 60% was cropped at Mitchell West. At five wetlands in 1998 and at six in 1999, the surrounding land use was dominated by roadways or urban development. For six wetlands in 1998 and four in 1999, most of the surrounding land use was grassland or pasture.

There were 38 different dominant plants in the 13 wetlands (Appendix J), most of which are common wetland plants for this region. The plants most common to the wetlands in 1998 were water milfoil and duckweed in the ponded zone, and cattail, spikerush and reed canarygrass in the non-ponded area (Table 2). In 1999, the most common plants were duckweed and spikerush in the ponded zone and reed canarygrass, spikerush and cattail in the non-ponded zone (Table 3). Plant communities in natural prairie pothole wetlands are dynamic, undergoing continual succession because of the water level fluctuations seasonally and annually.

Chemical and physical characteristics observed at the study wetlands varied with season and year (Tables 4-6). Chemical and physical parameters are commonly influenced by season and weather. For example, many wetlands held less water in the fall than spring, a common trend in the Prairie Pothole Region, where average annual precipitation is always less that average annual evaporation (Hubbard 1988). This decline in water levels can lead to concentration of salts and increased salinity (Hubbard et al. 1987), a trend seen in some of the study wetlands.

We measured habitat characteristics to help explain animal population trends found in our study. For example, lower water levels in the fall influenced water bird counts. Additionally, our chemical and physical data will be useful to future researchers who might attempt to duplicate this study.

Table 2. Site descriptions of eastern South Dakota DOT mitigation wetlands, 1998.

Wetland	Surrounding Land Use (%)			Dominant Vegetation	
	Grassland	Cropland	Urban/Road	Ponded	Non-ponded
Cottonwood East	0	0	100	Water millfoil, Duckweed	Reed canarygrass
Cottonwood North	40	0	60	Duckweed, Marsh smartweed, Water milfoil	Cattail, Reed canarygrass, Slough sedge
Cottonwood South	40	0	60	NA	Reed canarygrass
Dolton	60	0	40	None	Cattail, Cottonwood, Spikerush, Reed canarygrass
Elkton	0	5	95	None	Cattail, Spikerush, Pale bulrush, Slough sedge
Larson WPA	95	0	5	Flatstem pondweed, Water milfoil, Claspingleaf pondweed, Leafy pondweed	Cattail, Reed canarygrass, Spikerush
Letcher GPA	90	0	10	None	Cattail
Mitchell East	100	0	0	Cattail, Slough sedge	Cattail, Slough sedge, Spikerush, Peach willow, Coarse cyperus
Mitchell West	100	0	0	Cattail, Longleaf pondweed	Cattail, Spikerush, Peachleaf willow, Coarse cyperus
Vanderpan	60	0	40	Coontail, Duckweed	Cattail, Pale bulsrush, Rayless aster, Spikerush, Red goosefoot, Biennial wormwood, Dock
Vayland	0	25	75	Coontail	Dock, Yellow foxtail, Barnyard grass, Marsh smartweed, Sunflower

Table 3. Site descriptions of eastern South Dakota DOT mitigation wetlands, 1999.

Wetland	Surrounding Land Use (%)			Dominant Vegetation	
	Grassland	Cropland	Urban/Road	Ponded	Non-ponded
Cottonwood East	25	0	75	Duckweed	Reed canarygrass, Spikerush
Cottonwood North	40	0	60	Marsh smartweed	Cattail, Reed canarygrass, Marsh smartweed
Cottonwood South	30	0	70	NA	Reed canarygrass, Kentucky blue grass
Dolton	40	0	60	Cattail, Cottonwood, Duckweed, Reed canarygrass	Reed canarygrass, Cattail, Barnyard grass, Spikerush
Elkton	0	5	95	Cattail, Spikerush, Sedge, Bulrush	Reed canarygrass, Willow
Freeman	50	25	25	None	Reed canarygrass, Spikerush, Cocklebur, Foxtail barley
Kneip WPA	40	40	20	Star duckweed, Coontail	Cattail, Spikerush, River bulrush, Reed canarygrass, Giant burreed, Cyperus, Smartweed
Larson WPA	95	0	5	Cattail, pondweed	Cattail, Reed canarygrass, Spikerush, Aster
Letcher GPA	90	0	10	Cattail	Cattail, Spikerush, Cottonwood, Sow thistle, Red goosefoot, Willow, Foxtail barley

Table 3 (continued). Site descriptions of eastern South Dakota DOT mitigation wetlands, 1999.

Wetland	Surrounding Land Use (%)			Dominant Vegetation	
	Grassland	Cropland	Urban/Road	Ponded	Non-ponded
Mitchell East	25	50	25	Cattail, Spikerush, Longleaf pondweed	Reed canarygrass, Dock, Sedge, Willow, Cocklebur, Barnyard grass, Spikerush
Mitchell West	40	60	0	Cattail, Longleaf pondweed, Spikerush	Cattail, Barnyard grass, Willow, Reed canarygrass, Spikerush, Dock, Foxtail barley, Aster
Vanderpan	80	0	20	Cattail, Spikerush, Coontail, Duckweed	Cattail, Hardstem bulrush, Reed canarygrass, Willow, Spikerush,Smartweed, Beggar’s tick, Prairie bulrush
Vayland	25	25	50	Cattail	Smartweed, Spikerush, Toothcup, Beggar’s tick, Dock

Table 4. Physical and chemical characteristics of eastern South Dakota DOT mitigation wetlands, Fall 1998. Data represent one sample collected when biota surveys were done.

Wetland	Water Temp (°C)	Conductivity (umhos)	Salinity (ppt)	pH	DO (mg/L)	Max. Depth (cm)	Water Clarity (cm)
Cottonwood East	28.2	1485	0.7	8.68	6.27	45	45
Cottonwood North	28.2	665	0.3	9.13	2.48	30	30
Cottonwood South	NA	NA	NA	NA	NA	0	NA
Dolton	25.3	1020	0.5	7.73	6.50	48	48
Elkton	24.8	465	0.2	8.69	7.60	>150*	30
Larson WPA	22.6	318	0.2	9.04	9.05	72	26
Letcher GPA	28.3	2772	1.4	8.77	8.99	>150	21
Mitchell East	33.6	2898	2.2	7.85	9.30	20	20
Mitchell West	29.6	2472	1.2	8.07	6.00	>150	55
Vanderpan	26.1	2840	1.5	8.23	9.00	50	50
Vayland	27.1	1419	0.7	8.89	6.66	>150	101

Table 5. Physical and chemical characteristics of eastern South Dakota DOT mitigation wetlands, Spring 1999. Data represent one sample collected when biota surveys were done.

Wetland	Water Temp (°C)	Conductivity (umhos)	Salinity (ppt)	pH	DO (mg/L)	Max. Depth (cm)	Water Clarity (cm)
Cottonwood East	21.4	2100	1.2	8.1	14.4	71	71
Cottonwood North	22.5	760	0.2	7.25	8.5	58	43
Cottonwood South	NA	NA	NA	NA	NA	2	NA
Dolton	21.7	870	0.5	8.03	8.03	>110	110
Elkton	14.4	400	0	8.58	10.56	>110	37
Freeman	20.2	1360	0.8	8.7	12.5	94	22
Kneip WPA	29	2000	1	10.50	16.21	78	78
Larson WPA	16.7	380	0	8.75	11.5	>110	49
Letcher GPA	19.1	1020	0.8	6.85	7.49	>110	21
Mitchell East	20.2	1600	0.9	8.24	10.15	80	80
Mitchell West	20.3	1530	0.09	8.63	10.06	>110	67
Vanderpan	28	2200	1.1	9.31	11.73	80	80
Vayland	19.4	1100	0.8	8.62	1.9	>110	72

* Depths taken while wading, ">" indicates max depth was deeper than could be measured this way.

Table 6. Physical and chemical characteristics of eastern South Dakota DOT mitigation wetlands, Fall 1999.

Wetland	Water Temp (°C)	Conductivity (umhos)	Salinity (ppt)	pH	DO (mg/L)	Max. Depth (cm)	Water Clarity (cm)
Cottonwood East	18	2950	2	7.62	0	34	34
Cottonwood North	NA	NA	NA	NA	NA	0	NA
Cottonwood South	NA	NA	NA	NA	NA	0	NA
Dolton	15.5	650	0	7.05	1.6	>110[*]	45
Elkton	-[+]	-	-	8.69	9.7	>110	28
Freeman	20.5	800	-	9.43	8.2	70	21
Kneip WPA	27	2300	1.5	8.84	6.0	72	39
Larson WPA	-	-	-	6.59	5.0	>110	62
Letcher GPA	17.5	1250	0	8.24	7.1	>110	19
Mitchell East	-	-	-	7.58	6.3	100	38
Mitchell West	16.5	1280	0	7.28	5.1	>110	20
Vanderpan	20.8	1550	0	7.57	0.9	100	32
Vayland	21	1600	1	8.68	5.2	>110	66

[*] Depths taken while wading, “>” indicates max depth was greater than could be measured this way.
[+] “-“ indicates meter not working, no data collected.

Biota

Species richness and number of individuals varied among taxa and among wetlands (Table 7). Statistical analyses were sometimes precluded because some taxa (e.g. amphibians) had few species and other taxa had none (e.g. fish).

Birds. We found 80 species of birds (Appendix C). Species common among the study wetlands were red-winged blackbird (13 wetlands), barn swallow (13 wetlands), mallard (12 wetlands), blue-winged teal (11 wetlands) and killdeer (11 wetlands).

The highest bird species richness value (26) was in the Vanderpan restored wetland. This was also the highest species richness for all animal groups. The mean number of bird species observed in borrow-pit wetlands was 9 (range 0-19). The greatest number of individual birds observed at one wetland was at the Dolton borrow-pit, which had 1014 in the fall of 1998 (most were red-winged blackbirds). The highest diversity value calculated for birds was 2.64, at the Kneip WPA restored wetland. Mean bird species richness in borrow-pits was 1.63 (range 0.41-2.58).

We saw more species of birds than were recorded during Phase I, when mean bird species richness in borrow-pit wetlands was 4.6 (range 1-8). However, bird diversity data in borrow pits from Phase I (mean=1.6) was similar to Phase II results (mean=1.56). In another study, 32 species of birds were observed using borrow-pit wetlands in South Dakota (Hop et al. 1989). In restored wetlands in west-central Minnesota and northeastern South Dakota, Sewell and Higgins (1991) observed 12 species of waterfowl but did not report on other bird use.

Fish. We observed 14 species of fish in the study wetlands (Appendix D). The most common species were fathead minnow (9 wetlands) and black bullhead (7 wetlands). There were several missing data points for fish because of shallow (<40 cm) water depths or dry conditions.

The highest number of fish species observed at one visit was 5 species. The mean number of species observed in the borrow-pits was 3 (range 0-5). The greatest species diversity calculated for fish in borrow-pits was 1.39 in the Letcher borrow-pit (mean diversity was 0.44, range 0-1.39). The greatest number of individual fish (mainly fathead minnows) was 1582 at the Dolton borrow-pit.

Our results were similar to those in Phase I, where an average of 2 fish species were observed in borrow-pit wetlands (range 1-4) (Berry et al. 1999). Fish diversity values were not calculated for Phase I. Our fish richness data agreed with that from other studies of natural (Carlson and Berry 1990) and restored (Sewell and Higgins 1991) wetlands in this region.

Mammals. We found 19 mammal species in the study wetlands (Appendix E). The most frequently observed species were muskrat (12 wetlands), whitetail deer (12 wetlands), raccoon (10 wetlands) and deer mouse (9 wetlands).

The most species of mammals observed in a wetland at one time (8) was at the Vanderpan restored wetland. The mean number of mammal species for the borrow-pits, however, was 3 (range 0-6). During Phase I, fewer mammal species were observed in borrow-pits; mean species richness was 2 (range 0-4) (Berry et al. 1999). In their survey of older borrow-pit wetlands, Hop et al. (1989) observed 7 different mammal species and also found whitetail deer, muskrat and raccoon most frequently.

Amphibians. We observed 8 amphibian species during this study (Appendix F). The most common species was the northern leopard frog, found at all but two sites.

The highest amphibian richness (5) was at the Vanderpan restored wetland. The mean number of amphibian species observed in the borrow-pits was 1 (range 0-3).

Again, our findings were similar to those from Phase I, where the mean amphibian species richness in borrow-pits was 1 (range 0-3) (Berry et al. 1999). Hop et al. (1989) found only 2 species of amphibians in their survey of borrow-pits, but they also found the northern leopard frog at the greatest number of sites.

Reptiles. We found 3 species of reptiles at the study wetlands (Appendix G). The most common was the painted turtle (9 wetlands).

There was little variation in the number of reptiles observed, and it was common to visit a site without seeing one. The mean reptile species richness was 1 (range 0-2).

In Phase I, only painted turtles were reported and mean richness was 0 (range 0-1) (Berry et al. 1999). The same three reptile species were found in a previous borrow-pit survey, but with less frequency than in our study (Hop et al. 1989).

Aquatic and terrestrial invertebrates. Aquatic invertebrates were sampled only in the Mitchell prototype wetlands (Table 8). Mitchell East had the highest number of aquatic invertebrate taxa (18), while the greatest number of terrestrial invertebrate groups was found at Mitchell West (24). The highest diversity values for both aquatic and terrestrial invertebrates were found for Mitchell East (2.37 and 2.16, respectively). Total numbers of aquatic invertebrate species observed in Phase I were: borrow pits = 56 species, restored wetlands = 38 species, and dam-created wetlands = 38 species, and natural wetlands = 40 species. (Berry et al. 1999). However, the mean number of invertebrate species did not vary among wetland types studied in Phase I.

Table 7. Summary of faunal diversity at eastern South Dakota mitigation wetlands, 1998-99.

Wetland	Sample Period	Bird			Fish			Mammal	Amphibian	Reptile
		Richness	Number	Diversity	Richness	Number	Diversity	Richness	Richness	Richness
Cottonwood East	Spring 1998	3	18	0.94	0	0	NA	4	3	0
	Fall 1998	3	60	0.41	NA	NA	NA	4	2	0
	Spring 1999	8	32	1.71	0	0	NA	0	2	1
	Fall 1999	7	61	1.49	NA	NA	NA	5	2	0
Cottonwood North	Spring 1998	8	45	1.53	0	0	NA	1	2	0
	Fall 1998	9	26	1.87	NA	NA	NA	2	1	0
	Spring 1999	8	38	1.25	0	0	NA	3	1	1
	Fall 1999	8	26	1.63	NA	NA	NA	2	2	0
Cottonwood South	Spring 1998	2	5	0.5	NA	NA	NA	1	0	0
	Fall 1998	0	0	NA	NA	NA	NA	0	0	0
	Spring 1999	9	26	1.6	NA	NA	NA	0	0	0
	Fall 1999	3	5	1.05	NA	NA	NA	2	0	0
Dolton	Spring 1998	13	91	1.67	3	206	0.73	4	3	1
	Fall 1998	4	1014	0.71	3	1582	0.59	5	1	1
	Spring 1999	13	63	2.16	3	302	0.54	4	3	0
	Fall 1999	9	28	1.87	4	1310	0.81	4	1	1
Elkton	Spring 1998	10	120	1.46	5	249	0.87	1	1	0
	Fall 1998	6	14	1.23	1	95	0	4	1	2
	Spring 1999	14	53	2.12	4	124	0.33	2	2	0
	Fall 1999	5	14	1.33	2	6	0.64	0	2	0
Freeman	Spring 1999	10	26	2.07	3	30	0.39	5	0	0
	Fall 1999	5	9	1.52	5	8	1.32	3	1	0

Table 7 (continued). Summary of faunal diversity at eastern South Dakota mitigation wetlands, 1998-99.

Wetland	Sample Period	Bird			Fish			Mammal	Amphibian	Reptile
		Richness	Number	Diversity	Richness	Number	Diversity	Richness	Richness	Richness
Kneip WPA	Spring 1999	20	205	2.21	2	58	0.65	3	2	0
	Fall 1999	24	243	2.64	3	375	0.11	5	4	2
Larson WPA	Spring 1998	1	56	1.78	5	1421	0.77	2	2	0
	Fall 1998	4	4	1.39	4	713	0.3	4	2	0
	Spring 1999	6	44	1.12	4	209	0.4	2	2	1
	Fall 1999	6	15	1.43	2	33	0.64	1	1	1
Letcher	Spring 1998	15	70	1.99	4	77	0.45	3	0	1
	Fall 1998	15	93	2.01	3	143	0.22	5	1	1
	Spring 1999	15	104	1.77	5	53	1.39	1	0	1
	Fall 1999	19	78	2.49	3	56	0.59	4	2	1
Mitchell East	Spring 1998	14	38	2.58	1	21	0	3	0	0
	Fall 1998	7	19	1.49	NA	NA	NA	6	1	1
	Spring 1999	12	55	2.04	1	6	0	1	0	0
	Fall 1999	9	104	1.12	4	743	0.28	3	1	0
Mitchell West	Spring 1998	15	58	2.41	2	98	0.45	2	0	0
	Fall 1998	13	76	2.11	2	27	0.16	5	1	2
	Spring 1999	13	57	1.8	3	28	0.8	1	1	1
	Fall 1999	10	45	1.82	3	366	0.23	6	1	1
Vanderpan	Spring 1998	11	58	1.93	1	5	0	2	2	0
	Fall 1998	25	356	2.2	2	233	0.12	8	2	0
	Spring 1999	18	169	2.31	2	698	0.11	2	5	2
	Fall 1999	26	593	2.55	2	273	0.52	3	3	1

Table 7 (continued). Summary of faunal diversity at eastern South Dakota mitigation wetlands, 1998-99.

Wetland	Sample Period	Bird			Fish			Mammal	Amphibian	Reptile
		Richness	Number	Diversity	Richness	Number	Diversity	Richness	Richness	Richness
Vayland	Spring 1998	17	82	2.5	0	0	NA	1	1	1
	Fall 1998	7	36	1.37	1	117	0	4	2	1
	Spring 1999	10	71	1.92	1	315	0	4	2	1
	Fall 1999	8	54	1.71	1	65	0	4	2	2

Table 8. Summary of invertebrate diversity at Mitchell prototype wetlands, 1998-99.

Wetland	Sample Period	Aquatic invertebrates			Terrestrial invertebrates		
		Richness	Number	Diversity	Richness	Number	Diversity
Mitchell East	Spring 1998	6	141	1.55	18	322	1.73
	Fall 1998	13	23	2.37	19	584	1.65
	Spring 1999	18	116	2.15	20	137	2.16
	Fall 1999	12	56	1.90	21	469	2.00
Mitchell West	Spring 1998	9	291	0.92	14	414	1.72
	Fall 1998	8	66	1.37	19	540	1.62
	Spring 1999	11	53	1.90	24	2355	0.93
	Fall 1999	11	80	0.87	20	269	1.98

Seasonal effects

Seasonal effects are important to understand for two reasons. First, seasonal differences can be due to biological events like migration or reproductive patterns. For example, it would be logical to expect more birds during a migration period than when birds are not migrating through our region. Second, seasonal information can be used to determine monitoring protocols. To record the maximum species richness, monitor during a season with higher use.

From the results of t-tests for seasonal effects on richness and diversity, we learned that the number of mammals was statistically greater in the fall than spring ($mean_{spring}$=2.17 and $mean_{fall}$=3.71, P=0.0023). For bird use, some wetlands had higher use in the fall, and some had higher use in the spring, probably because some wetlands offered feeding and nesting habitat in the spring, whereas others were more suitable as resting or staging areas during the fall flight.

Yearly effects

We tested for differences in biodiversity data based on years for two reasons. First, year-to-year differences in precipitation and weather greatly affect habitat. For example, the effects of the long-term wet-dry cycle might be discovered by comparing biodiversity among years. Second, the effects of years, like seasons, could help determine sampling protocols. Usually, the variation among years makes it important to schedule sampling for several years to encompass that variation. However, we found no significant differences in richness or diversity data between 1998 and 1999 for any group of animals.

Sample period effects

The effects of sample period (spring 1998, fall 1998, spring 1999, and fall 1999) were minimal. The only difference in biodiversity based on sample period was found in mammal richness (*P*=0.0027). This finding supported the seasonal differences in mammal richness discussed above.

Wetland effects

We found significant differences in biodiversity among the 13 study areas. Among-wetland variation in richness was significant for birds (*P*=0.0001), mammals (*P*=0.0692), amphibians (*P*=0.0002), and fish (*P*=0.0014). For diversity data, the wetland effect was significant for bird diversity (*P*=0.0065) and fish diversity (*P* =0.0495). The variability among wetlands was probably due to differences in habitat conditions and wetland type (see the next section), however our data represent the diversity of created palustrine wetlands in eastern South Dakota. For strict comparisons of created wetlands with natural wetlands, select sites with similar characteristics.

Mitchell prototype wetlands

We determined that there were significant differences in biodiversity between the prototype wetlands created within guidelines for good wildlife habitat and borrow-pits created using standard protocols (Table 9). There were significantly more bird species (*P*=0.0590) and a higher diversity of birds (*P*=0.0711) in the Mitchell wetlands than the other borrow-pit wetlands. It is logical that birds would be most likely to benefit from the prototype wetlands, as many of the design criteria provided in Phase I were chosen because of their influence on bird diversity and richness.

Interestingly, the number of amphibian species was significantly greater at other borrow-pits than at the prototype wetlands (*P*=0.0315). Perhaps this is because more total habitat variety is available in 9 borrow pits (water permanence, size, vegetative cover) than in only two prototype wetlands.

Table 9. Mean biodiversity values in prototype versus borrow-pit wetlands (bold values are significantly different, *P*#0.10).

Wetland Group	Bird richness	Bird diversity	Fish richness	Fish diversity	Mammal richness	Amphibian richness	Reptile richness
Mitchell prototypes	**11.6**	**1.9**	2.3	0.3	3.4	**0.6**	0.6
Other borrow-pits	**8.2**	**1.6**	2.5	0.5	2.7	**1.4**	0.5

Colonization rate

Four sampling times did not provide enough data to determine colonization rates, however, we were able to look for simple differences in biodiversity at the Mitchell wetlands based on sample period (Table 10). Only the fish richness values showed a relatively steady trend, increasing across the four sample seasons. Aquatic and terrestrial invertebrates increased over the first three sample seasons, with a slight decline in the last fall visit. The other taxa had no clear patterns (bird, mammal) or had very little variation in their values (amphibian, reptile). These data suggested that for most taxa, colonization of the wetlands occurred rapidly and did not change much since. More time and data will be needed to create a clearer picture of colonization dynamics. One recent study challenges the notion that ecosystem restoration and creation efforts follow a smooth trajectory of development (Zedler and Callaway 1999). They suggest that "long-term predictions of the time to functional equivalency may not be meaningful if they are based on short-term data from pulse-driven ecosystems."

Table 10. Mean species richness at the Mitchell prototype wetlands across four sample seasons.

Sample period	Bird	Fish	Mammal	Amphibian	Reptile	Aquatic invertebrate	Terrestrial invertebrate
Spring 1998	14.5	1.5	2.5	0	0	7.5	16
Fall 1998	10	2	5.5	1	1.5	10.5	19
Spring 1999	12.5	2	1	0.5	0.5	14.5	22
Fall 1999	9.5	3.5	4.5	1	0.5	11.5	20.5

SUMMARY

In summary, we used biomonitoring methods over two years to compare the wildlife habitat suitability among wetland types, including two prototype wetlands that were created specifically to foster high biodiversity. This short-term study provides a picture of the biodiversity in these wetlands over two years, which is a short time in the larger variation of habitat condition and population density. Bird diversity and richness values responded favorably to the prototype wetlands, indicating that the design criteria established in Phase I did influence the bird biodiversity as expected. Amphibian richness was significantly higher in borrow-pit wetlands than in the prototype wetlands, possibly because of unequal sample sizes. There was more habitat diversity in nine borrow pits than in two created wetlands. Small mammal trapping was time consuming and yielded little information beyond that obtained by observing mammal tracks.

The results should not be considered a final or permanent representation of the wetlands studied. While wetland management should take place every year, biomonitoring might be done every 3-5 years to determine what changes have occurred over a longer period of time. Evaluating created wetlands for wildlife habitat functions in South Dakota is difficult because of great seasonal and year-to-year changes in hydrology and habitat. Complex studies can be done that will provide enough data for statistical treatment, but to evaluate the new wetland as wildlife habitat, a practical approach is to seek qualitative answers to the following questions:

1) Is the hydrology similar to that in surrounding natural wetlands?
2) Is there a clumped distribution of several kinds of emergent hydric plants?
3) Is there a stand of submerged vegetation?
4) Are there representatives of about two dozen species of nesting birds in the spring?
5) Can several kinds of frogs and toads be heard?
6) Are the tracks of about a half-dozen mammals visible in the mud?

CONSTRUCTION GUIDELINES

The cost and technical complexity of saving wetlands during highway construction justifies some wetland destruction, so planning must include mitigation. Mitigation is avoiding, minimizing, rectifying or compensating wetland loss resulting form development activities. Wetland mitigation planning requires cooperation between ecologists and engineers.

One goal of the South Dakota Department of Transportation is to increase the benefits of mitigation wetlands by incorporating design standards that provide greater ecological values than did those constructed in the past. Scientists evaluated the species diversity of animal and plant communities in restored and dam-created wetlands, borrow-pit wetlands, and natural wetlands. They identified habitat factors associated with diverse and species-rich wetland communities, and used that information to create guidelines for constructing wetlands with high wildlife value.

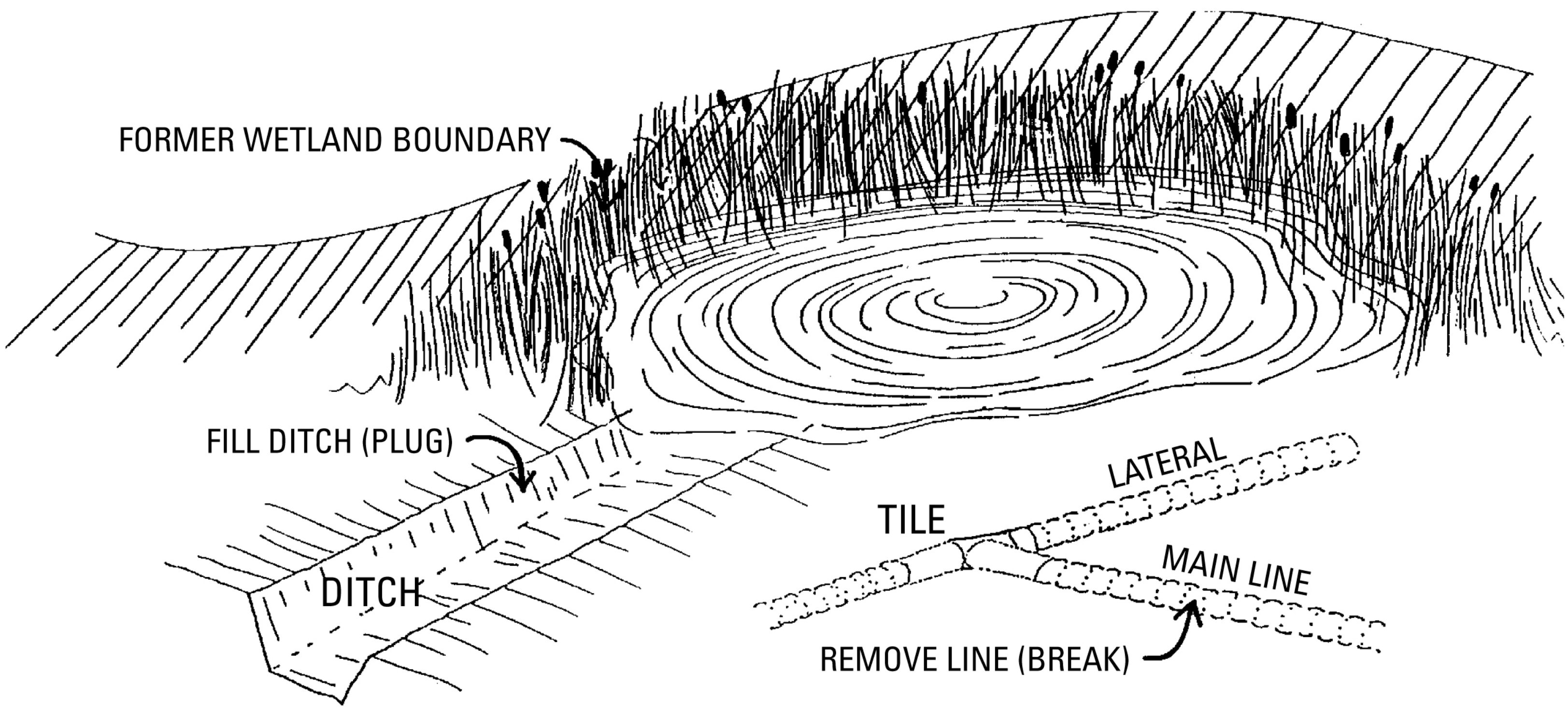
The following guidelines and other information on wetland restoration and creation are available in a booklet titled "Guidelines for Restoring and Creating Wetlands Associated with Highway Projects in South Dakota," available from South Dakota State University, Bulletin Room, LMH 112, Brookings, SD 57007. The booklet provides information on the:

- Biological, hydrological and soil factors that define a wetland.
- Need for wetland mitigation and regulations.
- Services and functions your wetland will provide society
- Design features that engineers should consider for: 1) restored wetlands made by plugging a ditch or breaking a drainage tile, 2) embankment wetlands made by building a dam in a watercourse, and 3) excavated wetlands made by excavating a depression in a level area.

Guidelines for Restored Wetlands

The Situation: Wetland restoration of a prairie pothole is the rehabilitation of a natural, depressional wetland site that has been drained by either a ditch or a subsurface tile (Figure 5). Restoration is usually by plugging (filling) the ditch or breaking (removing) the tile. The purpose of the project is to restore both the hydrologic conditions and the hydrophytic plant community for the benefit of wildlife (other purposes might be to maximize water storage for flood control or water quality). The original extent of the drained wetland basin may not be

Figure 5. Diagram of two wetland drainage methods: ditches and tiles. Ditches can be from 1 to 8 feet deep. Drainage tiles are usually 6 to 8 inches in diameter and made of clay. Concrete, metal, or plastic tiles are also used. Drains have been installed in various patterns; random systems (shown here) are common where there are many small depressions. Tiles may be perforated to collect groundwater, or be connected to a stand pipe (shown here) to remove surface water.



evident because of developments (e.g. roads, farming) so prior planning is important to predict the future size of the wetland and foresee possible effects on adjacent land, roads, railroads, or power lines.

Ditch Plugging Guidelines:

- Site: Choose a drained basin near other wetlands in an area where the restored wetland will be surrounded by permanent upland cover. Choose a basin that can be restored in its entirety (without dikes to protect adjacent land or roads) because this type are simpler to design, cheaper to construct, and less trouble to maintain.
- Mapping: The location, size, shape, and boundaries of the former wetland can be determined by locating hydric soils (e.g. Aquolls, Histosols, Fluvaquents) on county soil survey maps. Make a base map to show the restored wetland, basin topography, land ownership, drainage features, and location of tiles and ditches. The map needs to be detailed enough to show the maximum pool elevation permissible without affecting adjacent land, and to plan the locations of dikes and spillways.
- Record baseline data: Document the hydrology and vegetative characteristics of the drained site that can later be used to evaluate the project; take photos and inventory physical conditions and vegetation community.
- Size of project: Determine ditch depth. Shallow ditches (< 3 ft deep) can be easily plugged; deeper ditches may need to be sealed because they penetrate the natural seal of the basin. The length of the plug depends on the hydraulic condition of the soils.

  A general relationship is:

Hydraulic Capacity	Length of Plug
<0.6 inches/hr	50 ft
0.6-2.0	100
> 2.0	150

- Spillway**:** An excavated spillway is not needed when the watershed is small (less than 20 acres), and when water leaves the restored wetland by natural drainage ways or by ground water. High water from storms, snow melt or groundwater inflow will seek a natural drainage way. Insure that the natural spillway is vegetated and that overland flows will not cause appreciable erosion.

- Site Preparation: Remove vegetation from the ditch (including roots) for the projected length of the plug to minimize piping and seepage.
- Fill material: Borrow dirt for fill from near the ditch to match edge and fill materials, possibly borrow from within the wetland to increase storage capacity and wetland edge and to minimize upland disturbance; otherwise use a clay core. Ditch plug diagrams are shown in Figures 6 and 7; criteria are:

material ....compacted to density of adjacent materials	width.........fill ditch
length........ 50-150 ft	end slope....3:1 or flatter
height........ crown 1 foot above ditch height	cover........ top soil, seed

- Revegetation**:** Wetland plant seeds remain viable for up to 20 years, so for recently drained wetlands, simply allow water to return so vegetation and animals can invade the restored wetland. Otherwise, transplanting or using donor seed banks from nearby natural wetlands may be necessary, especially if the restored wetland is somewhat isolated. Seeds and roots of wetland plants are in the top 5 inches of hydrosoils, so scrape only the top foot or so of the donor wetland to collect the highest density of seeds.

Figure 6. Longitudinal profile of a wetland plug showing suggested 3:1 slope (horizontal:vertical) on either end. Length varies from 50 feet in nonporous soils to 150 feet in porous soils.

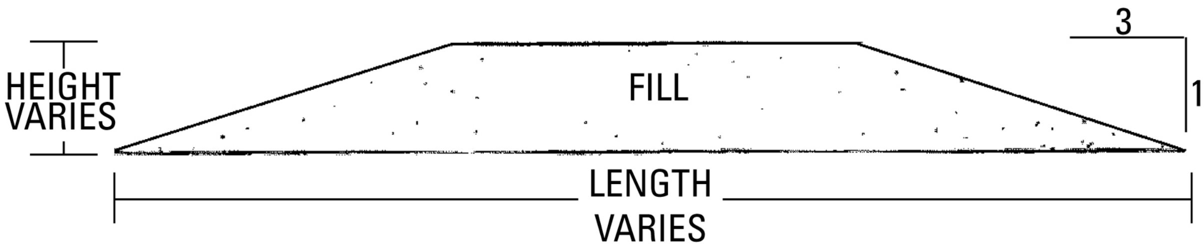
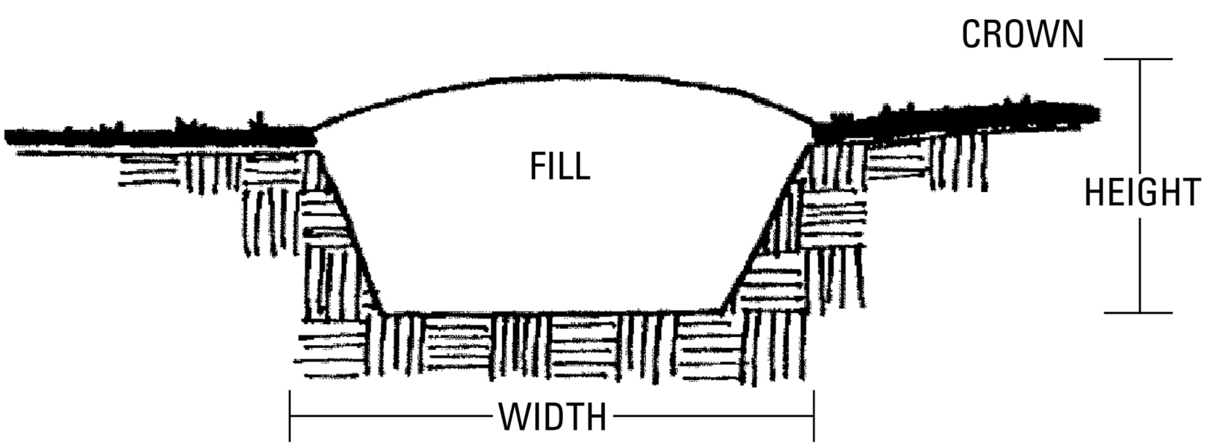


Figure 7. Cross section of a ditch plug showing a crown left to accommodate settling. Deep ditches might need to be sealed by compaction, or with clay blankets, bentonite or other materials that hold water before filling.



Tile Removal Guidelines:

- Site: Determine whether the tiled wetland is isolated or a part of a drainage complex. Changing drainage in the middle of a complex is costly and can affect other drained wetlands.
- Planning: Subsurface drain removal begins with finding records on the extent of the existing system. This is sometimes difficult to do and tile drainage patterns can be complex.
- Record baseline data: Document the hydrology and vegetative characteristics of the drained site that can later be used to evaluate the project; take photos and inventory physical conditions and vegetation community.
- Simple system tile removal: Remove a portion of the drain tile at the downstream edge of the site by digging a trench to the tile. Tile should be removed for 50 ft in heavy clay and 150 ft in sandy or organic soils. Also remove envelope filler material or other flow enhancing material.
- Complex system tile removal: If there are upstream surface and subsurface drainage systems that will be impacted, there are ways to restore the wetland while preserving the drainage tile. These include adding a stand pipe and nonperforated pipe to the existing drain. Permeable tile is replaced with impermeable tile of the same diameter. A riser is installed to bring water from upstream drained wetlands to the surface of the wetland to be restored. A second riser serves as a spill pipe with trash screen to control water level in the restored wetland. Input and output risers can be adjacent.
- Refill: Refill the trench and compact fill to the density of the adjacent material.

Management and evaluation: A restored wetland will not always appear. The wetland may not regain its former hydrology if changes in land use in the watershed have altered subsurface flows or lowered the water table. If all drain tiles are not interrupted, the basin may not retain water as anticipated. Enhancing wildlife value includes providing upland buffer zones as well as wetland habitat.

Visit the site after the first few runoff events, when the disturbed soil is most vulnerable to erosion. Evaluate results after the first summer that water is restored and periodically thereafter to compare with pre-project conditions. Evaluation is needed to learn how to improve the design of other projects. Was the restoration successful? The answer depends on the criteria for success, which can be anything from comparing before and after pictures to an expensive study of biological and hydrological functions that can last for years. At least compare post-restoration conditions with those measured as baseline data before restoration.

More specific information about site planning can be found in the Minnesota Wetlands Restoration Guide (Wenzel 1992), which provides a clear description of surveying and other restoration methods. More information about ditch plugging can be found in Chapter 13 (page 42) of the *Engineering Field Handbook* (NRCS 1992), and in Section IV (Code 657) of the South Dakota Technical Guide (NRCS 1994). The book titled Restoring Prairie Wetlands has information on site selection (conflicts with adjacent land, potential hydrology and vegetation) and methods for plugging ditches and removing tile lines. The case of the 142-acre tract in Iowa called the McBreen Marsh, illustrates most common design features used in the prairie pothole region including tile replacement, tile risers to limit pool elevation, water control structure installation, pressure release valves to avoid upstream tile line ruptures, and dike construction to increase basin depth.

Guidelines for Embankment Wetlands

These guidelines are intended to help find a site in the watershed that will become a wetland with high wildlife biodiversity. The information and figures are original. Once the site is found the task of building the embankment is complex. An earthen dike incorporating a principal spillway and an emergency spillway is the common retaining structure used in prairie pothole restorations. The embankment and spillway figures presented here are composites from several works that give engineering details. Seek help from the Natural Resource Conservation Service or the U. S. Fish and Wildlife Service. Common reasons for dike failures are 1) overtopping during high flow, 2) undermining from channel flow, 3) sloughing from wave action, 4) sloughing because of saturation, 5) piping or excavation from burrowing animals, and 6) seepage along the water control structure through the dike.

The Situation: An embankment wetland is created in a stream or water course where an embankment can be built to impound water. This type of wetland is sometimes called grade stabilization when placed in natural channels to prevent the formation or advance of gullies. The wetland is created by building an embankment, which may be termed a dike if it is less than 6 ft high, and a dam if it is greater than 6 ft high. Wetlands behind dikes are sometimes called embankment wetlands whereas those behind dams are usually called ponds. Spillways around the embankment or pipes through the embankment are usually required.

These guidelines focus primarily on how to choose a site that, when flooded, will result in a wetland that will harbor a high diversity of wildlife because it has such features as an irregular shoreline and depth. The secondary focus is on engineering specifications for embankment construction.

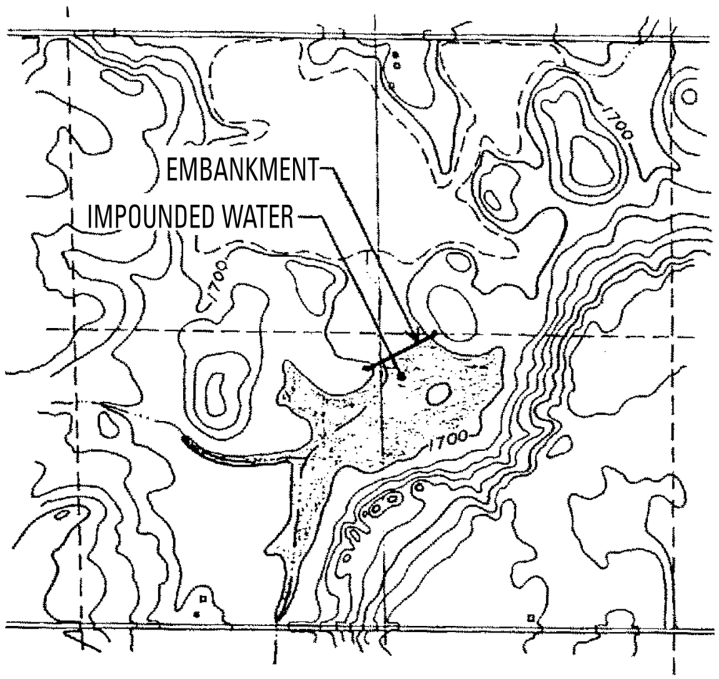
Identifying a good site in the watershed requires looking at the shape and land use in the watershed to imagine the look of the new impoundment. Figure 8 is an exact reproduction of a topographic map of a watershed in South Dakota. Impounding water at one site causes a desirable wetland with islands and an irregular shoreline, whereas impounding at the second site yields a wetland with a simple shape.

Locating a good setting:

Most smaller basins in the prairie pothole region have a clay subsoil that is suitable dike material. Soils should be impervious enough to hold water; silt, clay, or sandy and gravelly clays best; to be sure, make soil borings and do soil analyses for size, plasticity, and layer thickness.

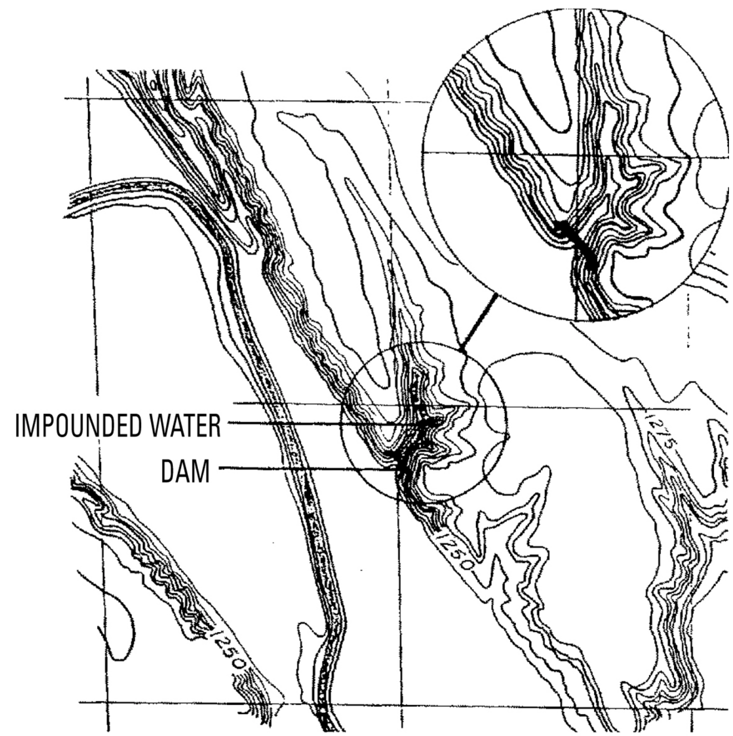
- Fill material nearby.
- Site near existing trees and shrubs can improve overall wildlife use; if waterfowl use is a priority, then trees are a detriment because they are predator perches.
- Narrow section of valley to minimize the need for fill, yet maximize surface area of impounded water that covers land to a variety of depths, emphasis should be on an area where the side slopes of the future wetland will be gentle so that a border of emergent vegetation can become established.

Figure 8. Reproduction of topographic maps showing contour lines typical of good and bad embankment locations. The bad location (right) will be the site of a deep wetland with little surface area. The good location (left) results in a shallow wetland with a large surface area and irregular shoreline and bottom, which will foster emergent wetland plant colonization.



Preferred

- Impounds large area of water
- Large amount of shoreline development
- Requires low, wide embankment
- Shallow water level promotes aquatic vegetation



Less Desirable

- Impounds small area of water
- Small amount of shoreline development
- Requires tall, narrow dam
- Deep water limits aquatic vegetation

- Site where downstream damage would not occur if the embankment failed, and upstream damage would not occur to developments such as roads and crops.
- Spillway area available as a natural spillway of adequate in size and shape to direct spillway flows away from the embankment.
- Where there are no buried cables or pipes, and no underground power lines.

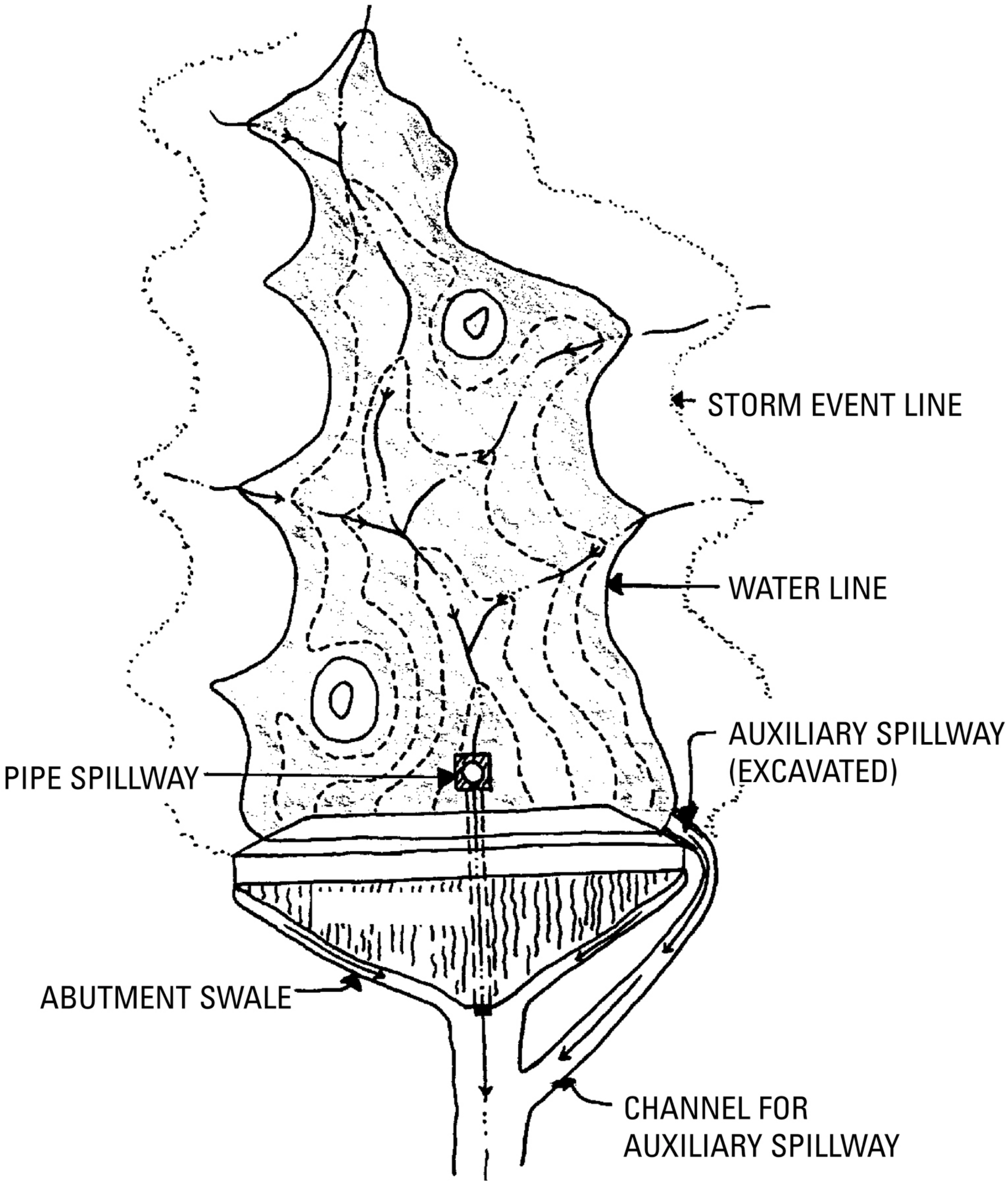
Estimating Future Wetland Capacity: Dike designs are suitable for agricultural areas where damage from dike failure is minimal and the maximum water depth against the dike is 6 ft or less for mineral soils and 4 ft or less for organic soils. The amount of impounded water will vary depending on the amount of runoff, evaporation, and seepage. On average, a pond must be 8 ft deep in eastern South Dakota to insure year-round water, so impounding 4 ft of water by capturing spring runoff may result in a semipermanent wetland in wet years and a temporary in dry years (Figure 9).

An estimate of water capacity is needed to assess how the wetland will lay in watershed and how spillways should be designed. The procedure is:

- Estimate the pond-full water elevation and stake the waterline at this elevation.
- Measure the width of the valley at this elevation at regular intervals and use these measurements to compute pond-full surface area in acres.
- Multiply the surface area by 0.4 times the maximum water depth in ft.
- Example: if the surface area is 3.2 acres and the depth at the dam is 5 ft, then

  (0.4 x 5 ft) x 3.2 acres = 6.4 acre-ft

Figure 9. Plan view of a typical earthen dam or embankment across an intermittent water course. The embankment is placed where upstream topography allows two islands in the impounded wetland. Primary (pipe) and auxiliary (grass) spillways are shown.



Assess the Contributing Drainage:

- Evaluate the contributing drainage (Figure 10). Are erosion control practices in place? Are there vegetated uplands that will promote wildlife colonization of the new wetland?
- Evaluate the contributing drainage water yield because it must be large enough to maintain water in the pond but not so large that expensive overflow structures are needed to bypass excess runoff during large storms. Precise estimates of the amount of runoff depend on assessing the cover and soil type to calculate a runoff curve number. The NRCS Agriculture Handbook 590 has detailed methods, but a general guide to the approximate drainage area needed to supply an acre-foot of water in South Dakota is:

Part of State	Drainage Area (acres)
Eastern	20
Western	35

- Practical Examples: surveys in the prairie pothole region show that wetlands in 17-acre basins have water in midsummer most years; those in < 4 acre watersheds rarely have standing water no matter what the wetland basin size. A useful figure showing the relationship can be found in Galatowitsch and van der Valk (1994: page 62)
- Consider the location in the embankment in the watershed in relation to runoff and distribution of fish; the lower in the watershed, the more likely that upstream fish migrations will be interrupted (Figure 11). Impounding water in an intermittent stream reach could help downstream conditions by reducing flooding (Moore and Larson 1980, Jacques and Lorenz 1987).

Figure 10. Perspective view of a typical earthen dam or embankment across an intermittent water course. The embankment is placed where upstream topography allows two islands in the impounded wetland. Primary (pipe) and auxiliary (grass) spillways are shown.

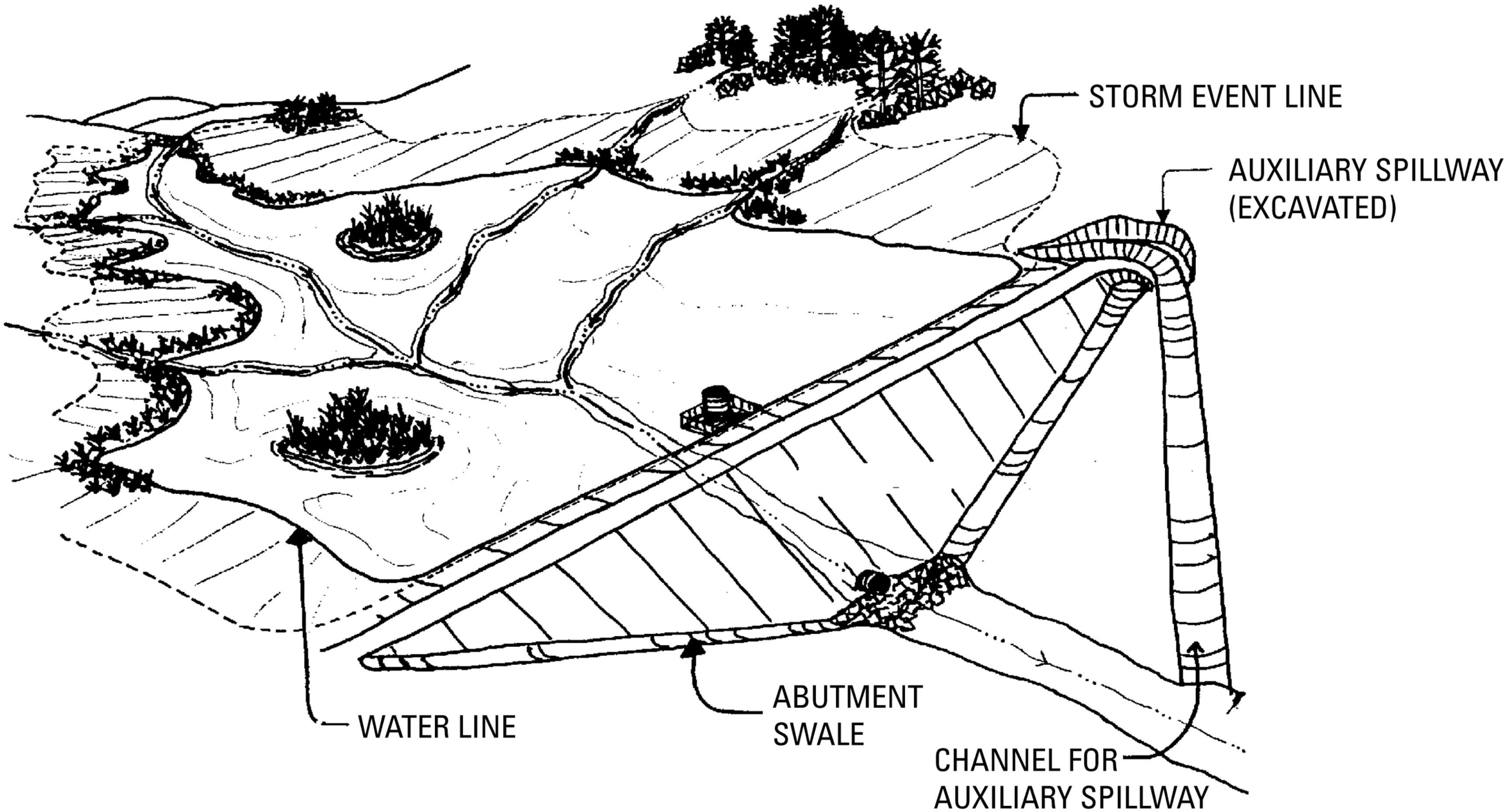
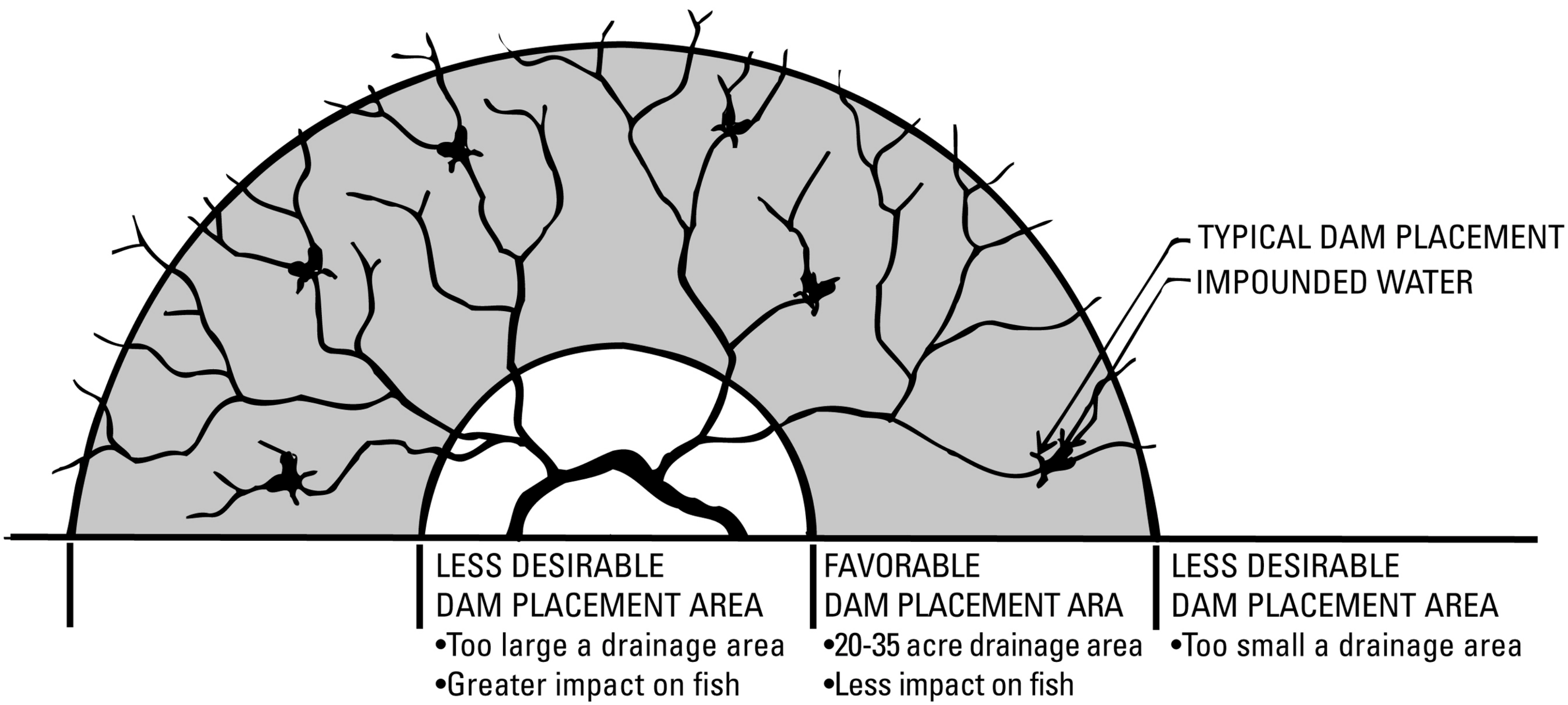


Figure 11. Hypothetical diagram showing a typical stream headwater drainage pattern in a watershed. The "rainbow-shaped lines" depict suitability zones for embankment wetlands.



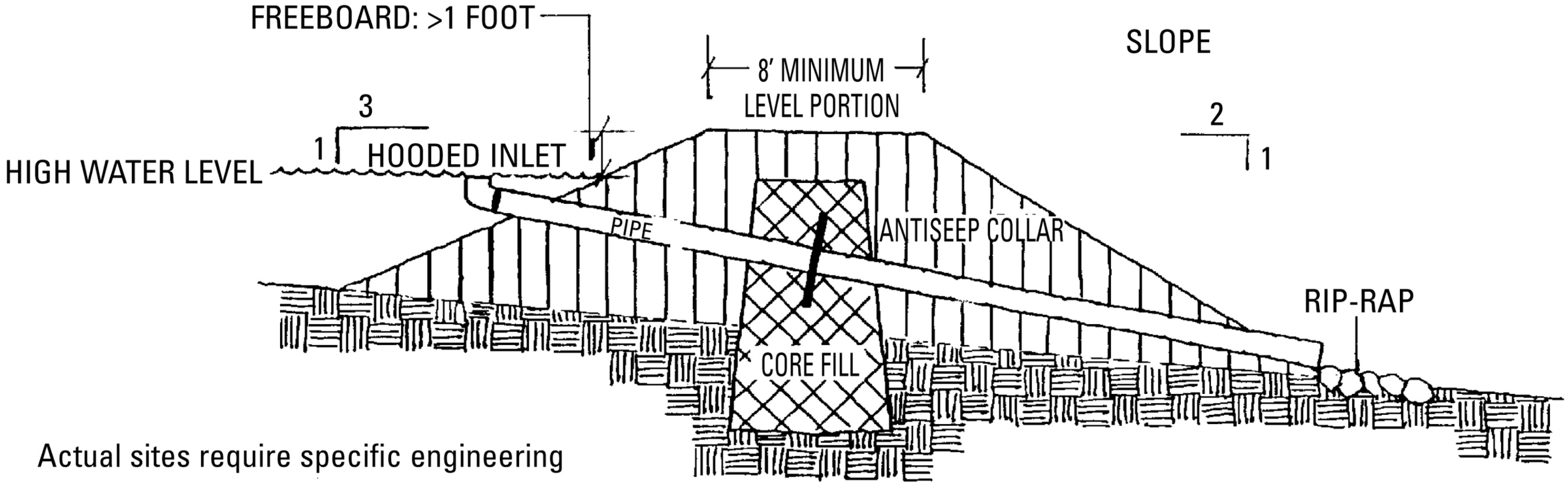
Dam Site Foundation Soils:

- Stable enough to withstand weight of embankment without excessive settlement.
- Stripped to a depth of significant root development or at least to 0.5 ft; scarified for bonding.
- Sufficiently impermeable to prevent excessive seepage; the most satisfactory foundation consists of soil underlain at a shallow depth by a thick layer (about 3 ft) of relatively impervious consolidated clay or sandy clay mixture of course and fine-textured soils is best.
- Porous or unstable foundation sites can be used, but require a "cutoff" trench filled with impervious material or a cutoff wall of sheet steel. The cut off trench dug through pervious foundation to about 2 ft into impervious underlayers. The trench should be about 8 ft wide and filled with impervious material. Reaching impermeable subsoil might be difficult in large basins or where peat, sand, or gravel deposits are thick.

The Embankment (Figure 12):

- Clearly staked to transmit information from drawings to job site; stake dam, borrow area, auxiliary spillway, and area to be covered with water.
- Top width 6 ft for dikes 6 ft high; 8 ft for embankments 10 ft high; compact successive 8 - 1-inch layers.
- Upstream slope 3:1; downstream 2:1(horizontal:vertical); more gentle slopes give dikes greater stability.
- Allow for settlement; a rule of thumb is 5% if compacted, 10% when dumped and shaped, 20% for dragline dump, and 40% if high organic material.
- Freeboard after settlement should be >1 foot above water surface to top of embankment (some guidelines call for at least 2 ft of freeboard).
- Impervious cutoff needed in pervious soils.
- Liner screens of hardware cloth under a foot of fill have been used to reduce damage by burrowing animals.
- Design must relate to surroundings, embankment shaped to blend into the landscape.

Figure 12. Schematic drawing of an embankment with a straight pipe outlet with a seepage collar. An impervious core is needed in pervious soils. The sides are sloped at a 3:1 (horizontal:vertical) ratio and the pipe inlet is set to allow at least a 1 foot freeboard.



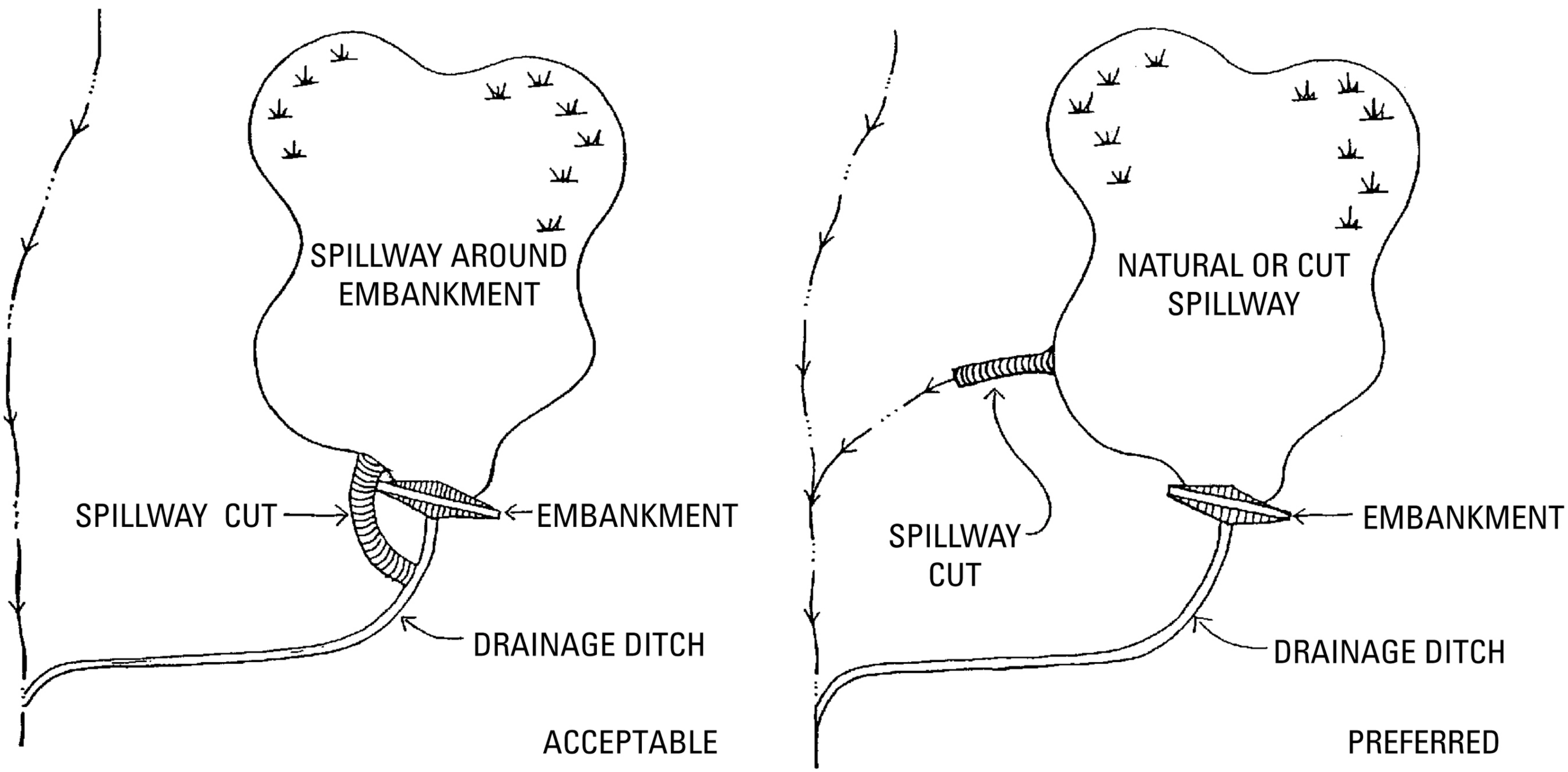
Spillway Design (Figure 13): No matter how well a dam has been built, it will probably be destroyed during the first severe storm if spillway capacities are inadequate. There are two kinds of spillways, primary pipe through the embankment, and an auxiliary vegetated spillway. The auxiliary spillway passes excess storm runoff around the dam so that water in the pond does not rise high enough to damage the dam by overtopping. Primary spillways are usually pipes through the embankment; several types of pipe spillways are recommended depending on site and water management options:

- Small dikes (about 1 foot high) will only need one vegetated spillway.
- Larger dikes need two spillways, a primary pipe buried in the embankment, and an auxiliary vegetated spillway.
- The simplest pipe spillway is a straight pipe with a diameter to handle a 10-year flood event and minimize the use of the auxiliary spillway; in the prairie pothole region, this is usually a 6 to 8 inch pipe.
- The elevation of the pipe sets the maximum pool elevation; the intake must have a trash exclosure to prevent clogging, which is a common problem in managing the wetland.
- The auxiliary spillway is usually a wide earthen overflow chute protected against erosion by seeding or sodding; mulching may be necessary.
- The auxiliary spillway can convey the water safely to the outlet channel two ways to protect the down-stream slope of the embankment; the spillway may be around the dam, or at an outlet along the side of the wetland (Figure 13).

Revegetation: Because the new wetland is in a drainage way, many wetland plant seeds will be introduced by wind or runoff. Transplanting or using donor seed banks from nearby natural wetlands may be necessary, especially if the wetland is somewhat isolated. Seeds and roots of wetland plants are in the top 5 inches of hydrosoils, so scrape only the top foot or so of the donor wetland to collect the highest density of seeds.

Aggressive weeds such as reed canary grass (*Phalaris arundinacea*) and Canada thistle (*Cirsium arvense*) can overpopulate to the detriment of more desirable species for wildlife. Cattails are common in the prairie pothole region and are thought of by many people as the symbol of a wetland. Actually, cattails hamper the establishment of many plant species and can

Figure 13. Examples of two possible auxiliary spillway locations. Spillways around the embankment are most often constructed but a preferred option is to use a natural low area or excavate a spillway away from the embankment. Spillways are usually compacted and seeded.



eventually lower the value of the wetland even for waterfowl. However, their colonization is inevitable in the prairie pothole region. Woody vegetation such as willow (*Salix* spp.) and cottonwood (*Populus* spp.) may become established.

Management and evaluation:

The dike will require periodic maintenance. Frequent visits during spring runoff the first year help identify early problems. Managers should realize that the vegetation in the new wetland will go through successional stages, and that year to year variation is natural and desirable for prairie potholes. An inspection check-off list might include:

- Seepage around spillways, settling, erosion.
- Vegetation reseeded and fertilized in the uplands.
- Mowing should be minimized and limited to after July 15 to protect nests.
- Fill rills on side slopes of the embankment, fertilize and reseed as needed.
- Keep fences in good repair; clear trash from spillway.
- Inspect for damage by burrowing animals.
- Look upstream into the watershed for new land uses or pollution sources.
- Noxious weeds must be controlled according to state regulations.

Evaluation is needed to learn how site-specific features effect the basic design so that future embankments can be better built. Judgements about the success of the mitigation depend on a comparison between before and after conditions. Complex studies can be done, but a to evaluate the new wetland as wildlife habitat, a practical approach is to seek answers to the following questions:

- Is hydrology similar to that in surrounding natural wetlands?
- Is there a clumped distribution (hemi-marsh condition) of several kinds of emergent hydric plants?
- Is there a stand of submersed vegetation?
- Are there representatives of about 2 dozen species of nesting birds in the spring?
- Can you hear several kinds of frogs and toads?
- Do you see mammal tracks in the mud?

Guidelines for a Created Depressional Wetland

The Situation: Creating a wetland is an opportunity for an engineer to convert information from studies of biological communities in natural wetlands into engineering plans. These studies have suggested that use of the wetland by animals will be enhanced if 1) shorelines are irregular, 2) depth varies along the shore and bottom, 3) emergent vegetation is present and dispersed in patches throughout the wetlands, and 4) the site is near other wetlands.

A borrow-pit wetland is also commonly known as an excavated pond, dugout, or created wetland (Figures 14 and 15). Two sources of water are surface runoff and ground water aquifers. Some are fed by both water sources. The location of a borrow pit pond is usually a compromise between a location that best serves the need for fill, and a location that produces successful mitigation. Other considerations are topography, drainage area, and impact on wildlife and habitat.

Locating the Setting:

- Performance of nearby wetlands with similar soils is a good indicator of how the finished product will function.
- Trees are not native to the prairie grassland ecosystem; their presence in the area may or may not be desirable depending on the goals of the mitigation.
- In a broad natural drainage way, a pond located to one side can be filled with diverted runoff so after the pond is filled, the runoff escapes through regular drainages.
- Soils are impervious enough (slow substrate permeability) to hold water for reasonable periods or to establish the presence of ground water, desirable soils are fine-textured clay and silty clay that extend below the pond depth; if the site has gravel or sand-gravel mixtures that do not hold water, or if the excavation is into permeable soils, then sealing by compaction or use of clay blankets or bentonite must be done to help establish wetland water conditions.
- Contributing drainage must be large enough to maintain water in the pond but not so large that expensive overflow structures are needed to bypass excess runoff during large storms. In eastern South Dakota, a 20-acre drainage usually supplies about 1 acre-foot of water.

Figure 14. Side view of a depressional wetland being created by a drag-line. The wetland will be dug into the water table. If the project is a borrow pit, the location will usually be a compromise between distance from the project site, nature of local soils, landowner desires, and potential to function like natural wetlands nearby.

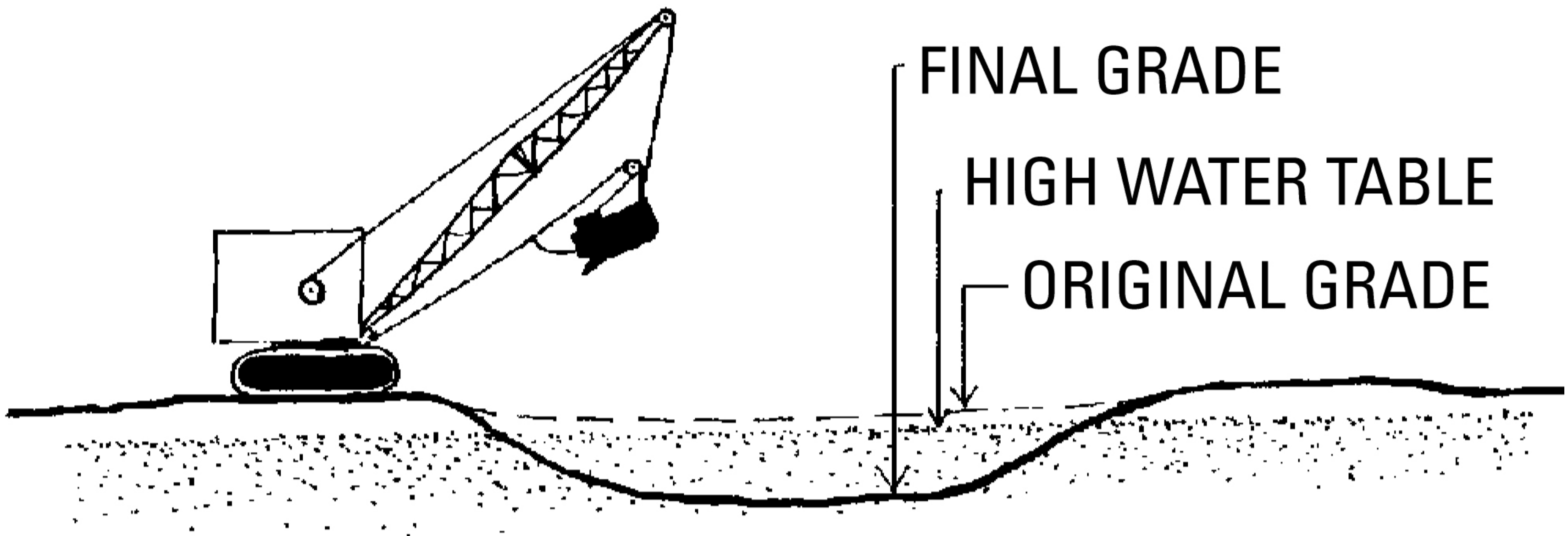
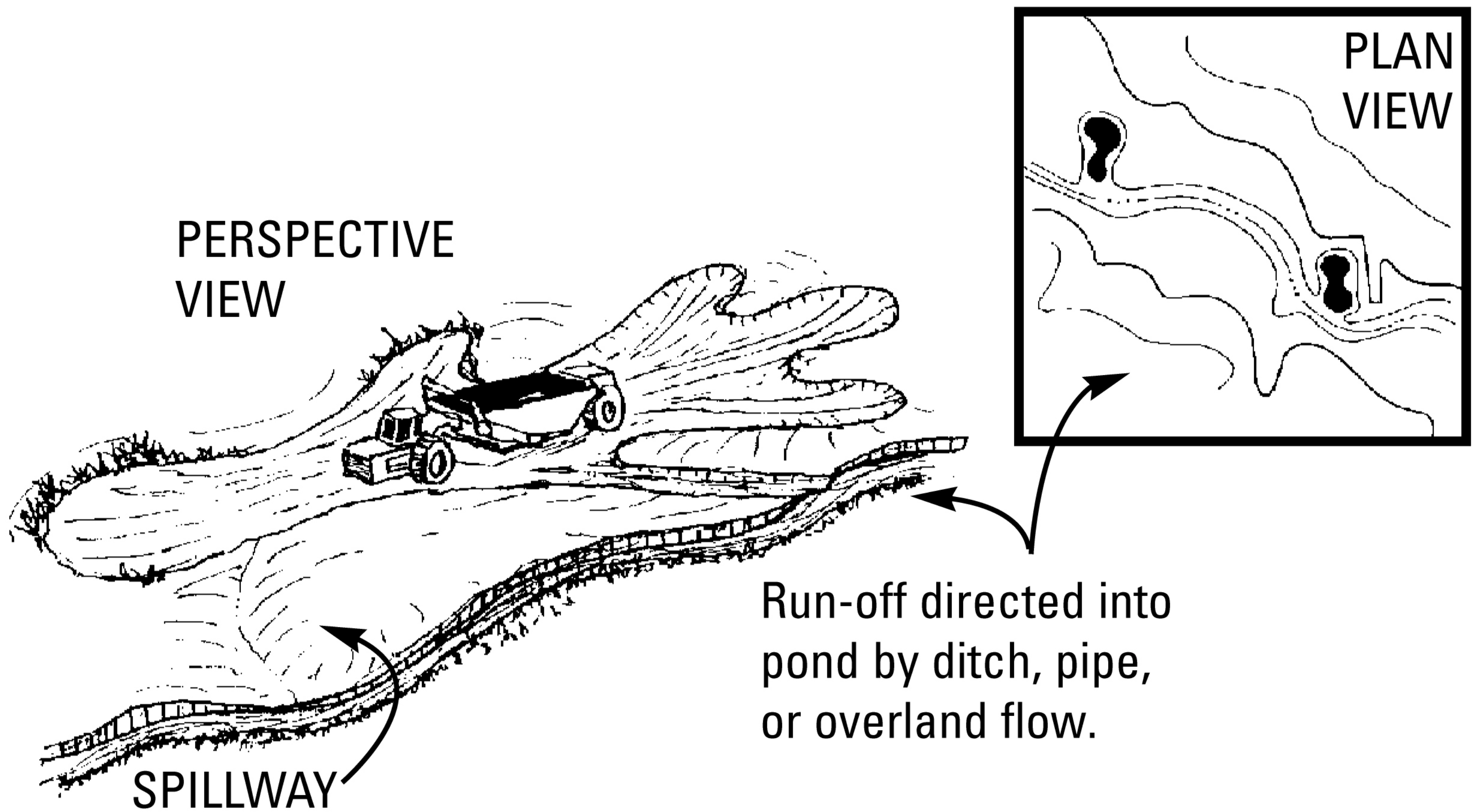


Figure 15. Perspective view of a wetland being created with an earthmover near a water course. The earthmover has created an “oak-leaf pattern” that will result in a wetland with great shoreline irregularity. An excavated ditch allows runoff to be directed into the excavated area, while a natural depression allows overflow to return to the water course.



Specifications:

- Final pond shoreline has maximum irregularity; geometric excavations can be graded to create more natural configurations (Figures 16 and 17).
- Maximum depth should be about 6 ft (this is somewhat arbitrary but conforms to one of the characteristics used by the National Wetland Inventory that separates a palustrine wetland from a deep water habitat (lake).
- Shoreline above the water line should not slough, side slopes of the pond are similar to angle of repose of the material being excavated; if excavated material is not removed from the site, shape and spread it to blend with natural land forms in the area; if a earthen mound is planned, it should be on the windward side of the pond to act as a snow fence.
- Shoreline below the water line should vary in slope around the wetland perimeter from 6:1 to 10:1(horizontal:vertical).
- Bottom contour should undulate with 40-60% of the final pond depth being about 1.5 ft deep, emergent vegetation grows to depths of 1.5 ft, so the tops of the humps would be places for natural vegetation to establish.
- Increase capacity by adding an embankment on lower end and sides; this is a combination of the excavated and embankment wetland type; embankments require spillways.

Water supply and spillway:

- At sites for groundwater-fed excavated ponds, bore test holes. The water level in the test holes indicates the normal water level in the completed pond. Check the test hole during dryer seasons if the created wetland is to be a semi-permanent wetland. Ground water levels depend on seasonal precipitation so a one-time check can be misleading.
- For wetlands filled by water from a channel or ditch, prevent erosion in the incoming and exit channel.
- For wetlands filled by water from a pipe, avoid erosion around the pipe by protecting the slope of the wetland and for a considerable distance upstream.
- For wetlands filled by over-land runoff, provide a desilting area or filterstrip in the drainage way immediately above the pond to remove the silt. The strip should be as wide as or somewhat wider than the pond and 100 ft or more long. Prepare a seedbed, fertilize and seed the area with grasses and forbs that will filter the water.

Figure 16. Two phases of borrow pit construction to yield a mitigation wetland that might promote colonization of a diversity of aquatic plants and animals. Phase one is the initial excavation of a rectangular-shaped borrow pit. Phase two is the follow-up grading of edges to increase shoreline length and irregularity, and reduce slope.

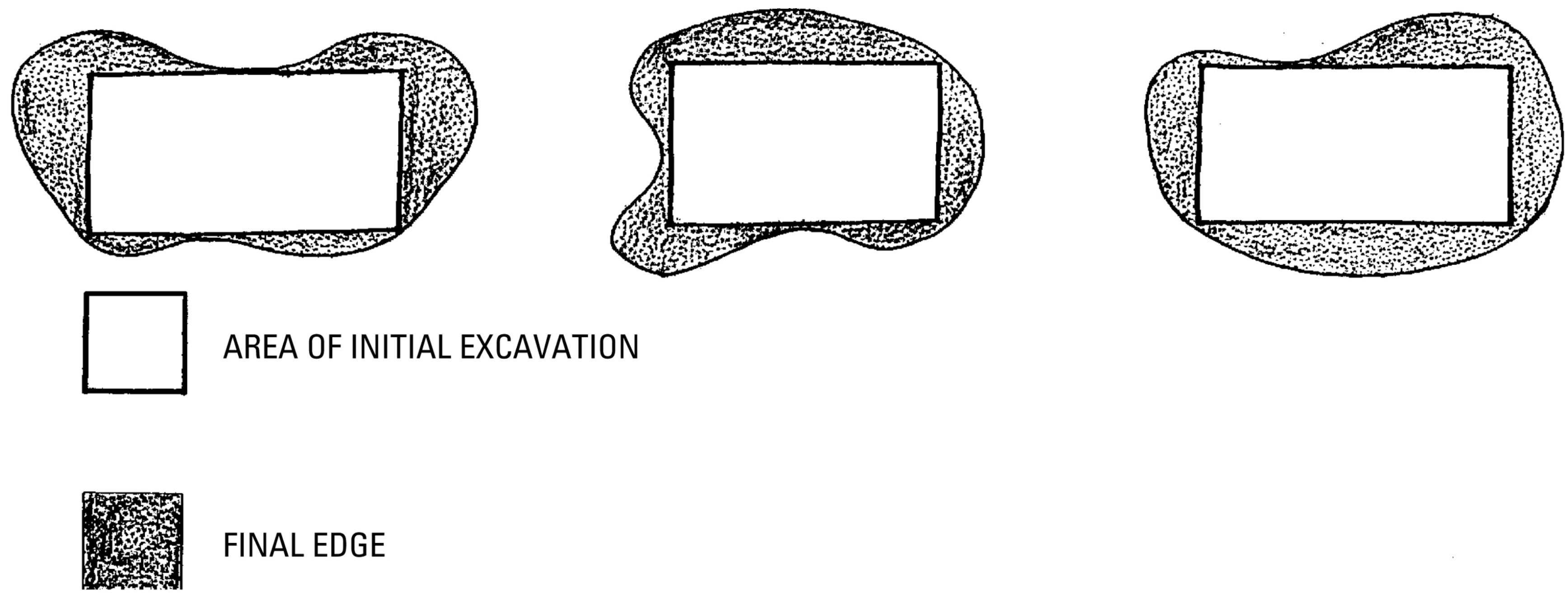
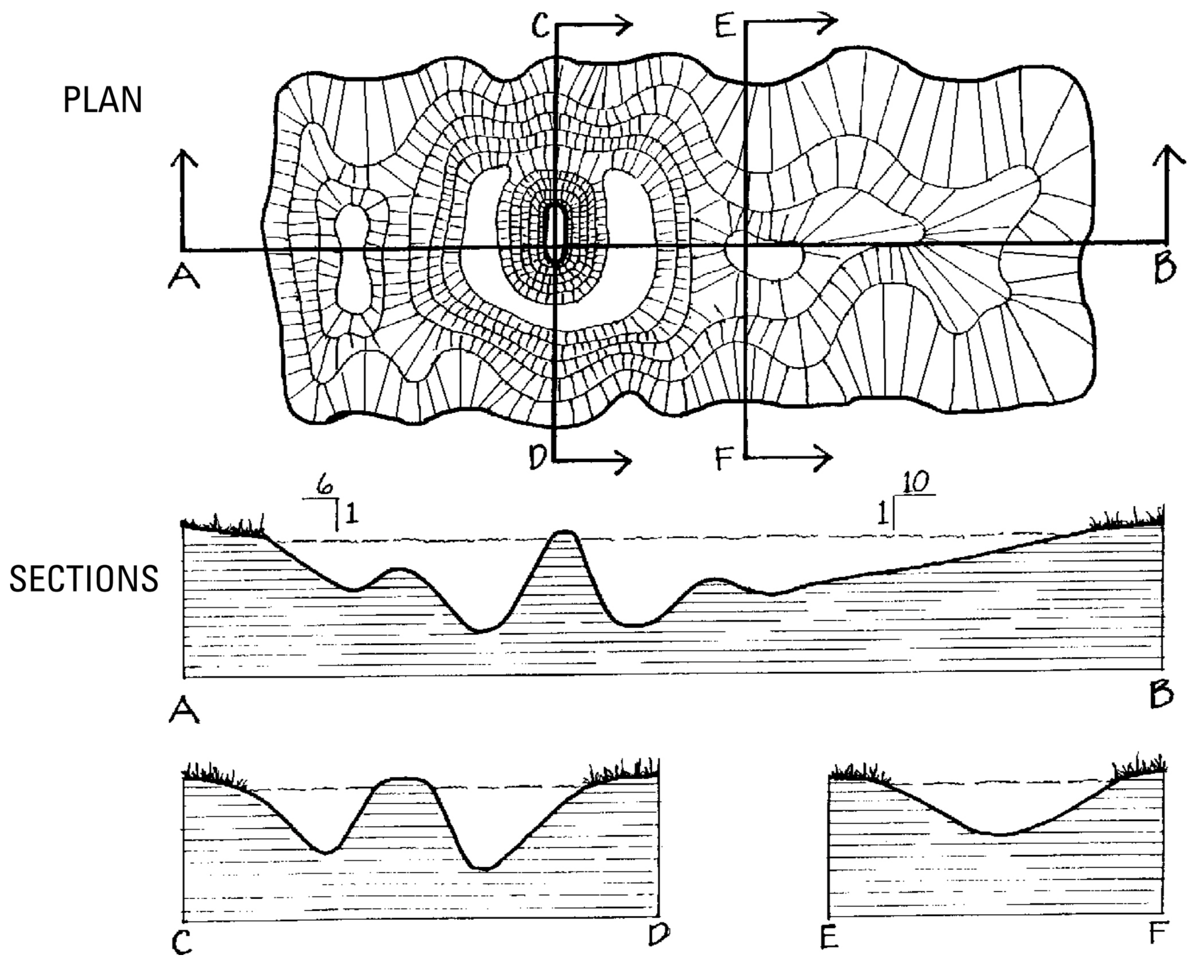


Figure 17. Plan and cross-sectional views of an excavated wetland created to promote high biodiversity. The plan view shows three islands and irregular shoreline. The longitudinal view (transect A-B) and two cross sectional views (transects C-D and E-F) show bottom irregularities and shoreline slopes needed to promote formation of a hemi-marsh or wetland with clumps of emergent vegetation scattered throughout the wetland and growing in a ring on the shoreline.



- When an embankment is used and runoff might exceed wetland capacity, plan a natural spillway if vegetation and soils are not erodible; for excavated spillways with a vegetated earth slope less than 5%, top dressed with topsoil and seeding with erosion resistant grasses.

Vegetation: Many plant seeds will be introduced by wind or runoff. Transplanting or using donor seed banks from nearby natural wetlands may be necessary. Aggressive plants such as reed canary grass, Canada thistle, and cattail are common in the prairie pothole region that can hamper the establishment of a diverse plant community, however, their colonization is inevitable in the prairie pothole region. Recommendations include:

- Allow natural aquatic regeneration by seeds usually present in flowing water.
- “Jump-start” by adding several cubic yards of hydric soil from the top one foot of a nearby donor wetland.
- Replace top soil on all disturbed areas; prepare seedbed by discing or harrowing and fertilizing.
- Seed with perennial grasses and forbs appropriate for local soil and climate; standard dense nesting cover is a mix of alfalfa, tall and intermediate wheat grass, and sweet clover.
- Plant natives if seed is available for switch grass, big bluestem, indian grass and western wheat.

Nesting islands for ducks and shorebirds: Two kinds of islands are possible to work into the created wetland design - small rock islands that hold a single nest (Figure 18), and large (>250 ft surface area) vegetated earth islands (Figure 19).

- Rock islands are usually 2-3 ft above average water level with another 2-3 ft of soil on top of the rocks; 10- 15 ft in diameter; no more than one island per 6 acres of wetland.
- Vegetated earthen islands can be planned for created wetlands larger than 5 acres.
- Spoil may be used to construct a wildlife nesting island; soils should contain 30% clay mixed with silt and sand and some aggregate if wave action is anticipated.

Figure 18. Cross-sectional diagram of a rock island created for waterfowl nesting. The surface is covered with soil so that the island will grow its own yearly supply of nesting cover. The size and shape simulates a large muskrat house. One rock island for each 6 acres of wetland surface area is optimum for nesting by one pair of waterfowl.

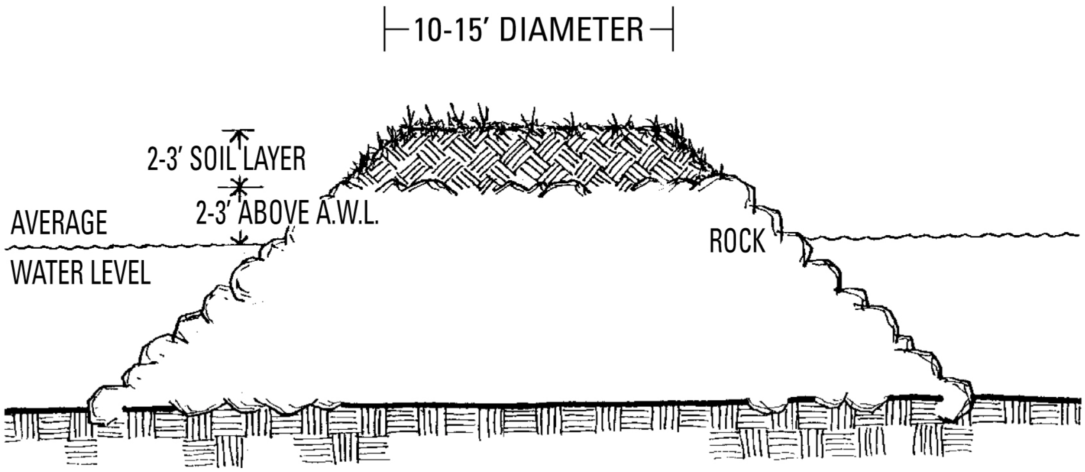
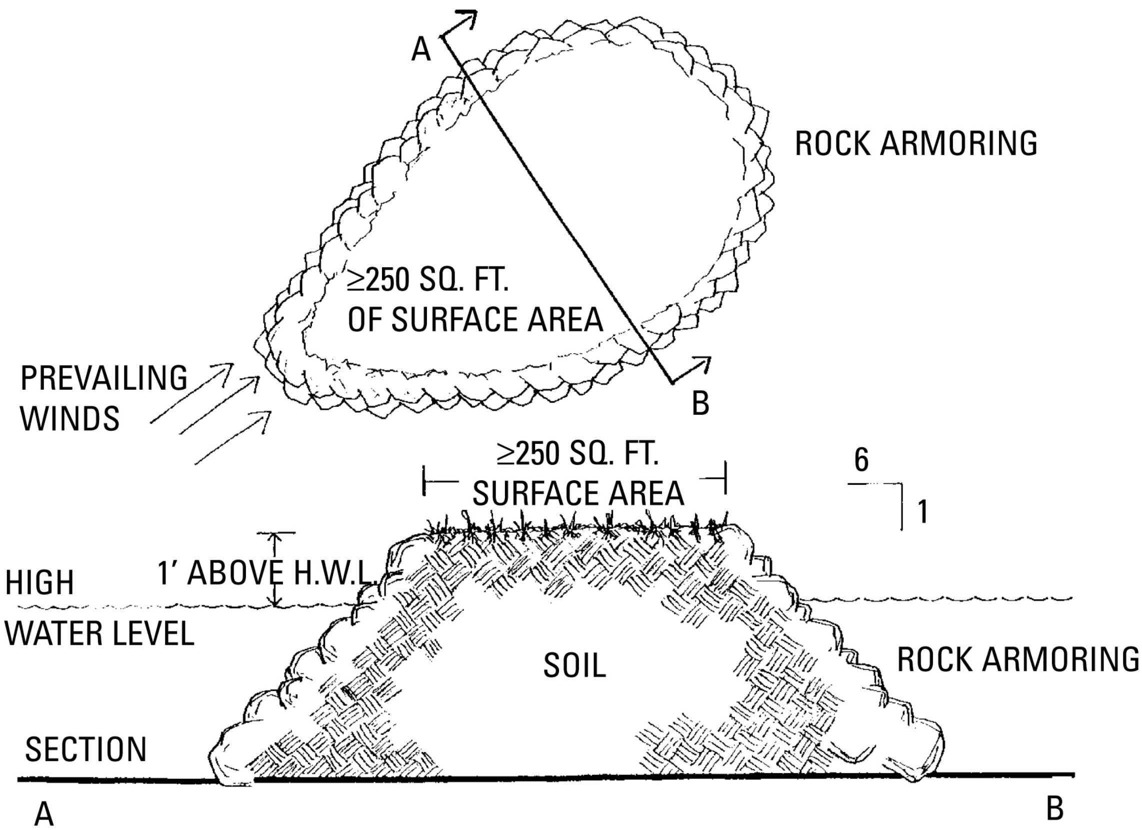


Figure 19. Plan and cross-sectional diagram of an earthen island constructed for waterfowl nesting. One 250-ft^2 island is optimal for a wetland with a surface area of 5 acres. The surface view shows the tear-drop shape that limits erosion. The cross-section (transect A-B) shows slopes and heights needed for island stability and to retard emergent vegetation growth. The surface should be seeded with a grass-legume mixture. Shrubs planted about 2.5-ft apart promote nesting.



- Island should be at least 250 ft of surface area at least 1 ft above the high water level.
- Island should be > 400 ft from shore if waterfowl nesting is a project goal.
- Island shoreline slope should be steep (1:10; horizontal:vertical) to discourage emergent vegetation if waterfowl nesting is a project goal because waterfowl prefer open, grassy shorelines.
- Surrounding wetlands within 1 mile should cover about 40 acres, because other wetlands are used by the brood, which cannot move far after hatching.
- Island should be oval, kidney or peanut shape with the point toward prevailing storm winds.
- Island top 4 ft above base; slopes 4:1 (horizontal:vertical).
- 10-ft berm if wave action is anticipated, where wave action is moderate, a single 6:1 or 8:1 (horizontal:vertical) side slope without a berm is acceptable.
- Build in compacted layers topped with 4-6 inches of topsoil.
- Seed with a grass-legume mixture; shrubs (western snowberry, Wood's rose) are waterfowl nesting cover when planted at a 2.5 ft spacing in plots 0.2-0.4 acres in size.

Management and evaluation: Managers should realize that the vegetation in the new wetland will go through successional stages, and that year to year variation is natural and desirable for prairie potholes. An inspection check-off list might include:

- Vegetation reseeded and fertilized in the uplands.
- Mowing should be minimized and limited to after July 15 to protect nests.
- Keep fences in good repair; clear trash from spillway.
- Look upstream into the watershed for new land uses or pollution sources.
- Noxious weeds must be controlled according to state regulations.
- Nesting island shrubs should be established by the end of the second growing season.
- Predators need to be controlled every few years on islands.

Evaluation is needed to learn how site-specific features effect the basic design so that future wetlands can be better built. Judgments about the success of the mitigation depend on a comparison between before and after conditions. Complex studies can be done, but a to evaluate the new wetland as wildlife habitat, a practical approach is to seek answers to the following questions: 1) Is hydrology similar to that in surrounding natural wetlands? 2) Is there a clumped distribution (hemi-marsh condition) of several kinds of emergent hydric plants? 3) Is there a stand of submersed vegetation? 4) Are there representatives of about 2 dozen species of nesting birds in the spring? 5) Can you hear several kinds of frogs and toads? 6) Do you see mammal tracks in the mud?

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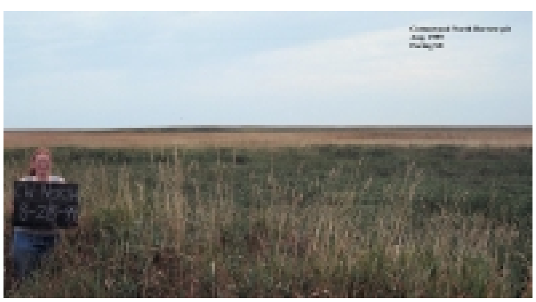
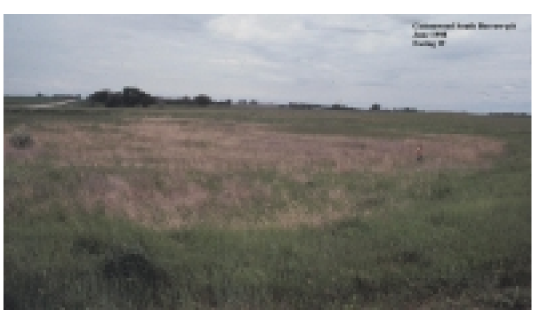
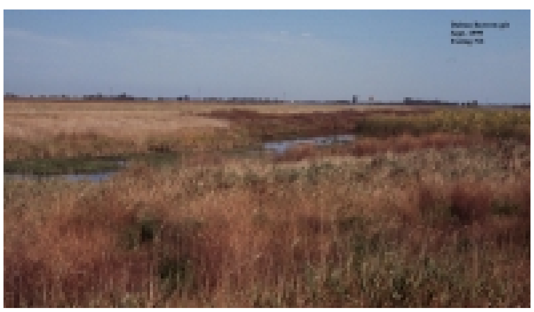
Appendix A. Photos showing the condition of each wetland studied during Phase II of the SDDOT project titled "Design and performance of Created Wetlands."

Photos of the Cottonwood borrow pits that were studied under DOT Contract 310364: Cottonwood east (2 views), Cottonwood west (2 views) and Cottonwood north (2 views.

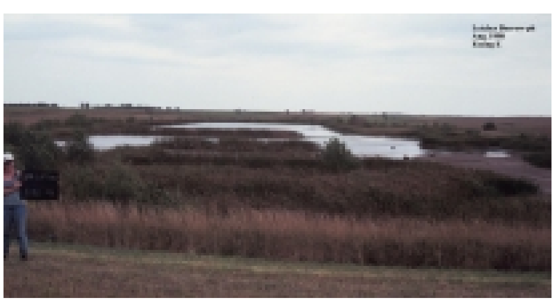




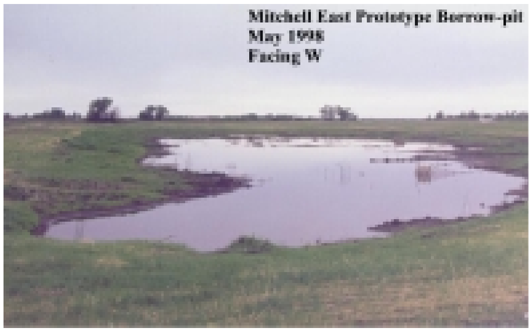
Photos of the Dolton, Freeman and Elkton borrow pits where biodiversity surveys were conducted during Phase II of DOT Contract 310364.

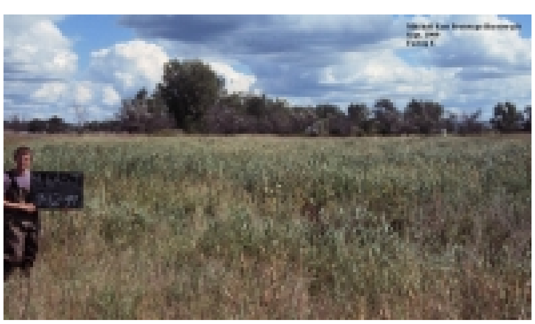


Photos of Letcher, Larson , and Vayland borrow pits that were studied for DOT Contract 310364.



Four views of the East Mitchell prototype mitigation wetland constructed in Mitchell, SD





Four views of the West Mitchell prototype wetland constructed in Mitchell SD.

Two restored wetlands where biodiversity was studied under DOT Contract 310364. Restored wetlands were studied to compare with two kinds of created wetlands: 1) standard borrow-pits, and 2) prototype mitigation borrow pits in Mitchell, SD.

Appendix B. Schematic drawings and location maps for each wetland studied during Phase II of the SDDOT study titled "Design and Performance of Created Wetlands." (Drawings not to scale)

Cottonwood East

SW ¼ SW ¼ Sec. 34 T116N R65W Spink County
44°48'32N 098°38'45W

Borrow pit wetland 0.5 miles northeast of Cottonwood Lake, along east side of Highway 26 and north side of gravel access road on east side of Cottonwood Lake (Figure 2). Owned by SD DOT. Class IV (semipermanent), cover type 4. Water present in spring and fall. Majority of wetland basin open water in spring and mud flat in fall, with a narrow band of emergent vegetation around the perimeter (Figure 1). Immediate surrounding land use was 75% mowed road-right-of-way and 25% mowed grass.

Figure 1. Map of vegetation cover at Cottonwood East study wetland, spring 1999.

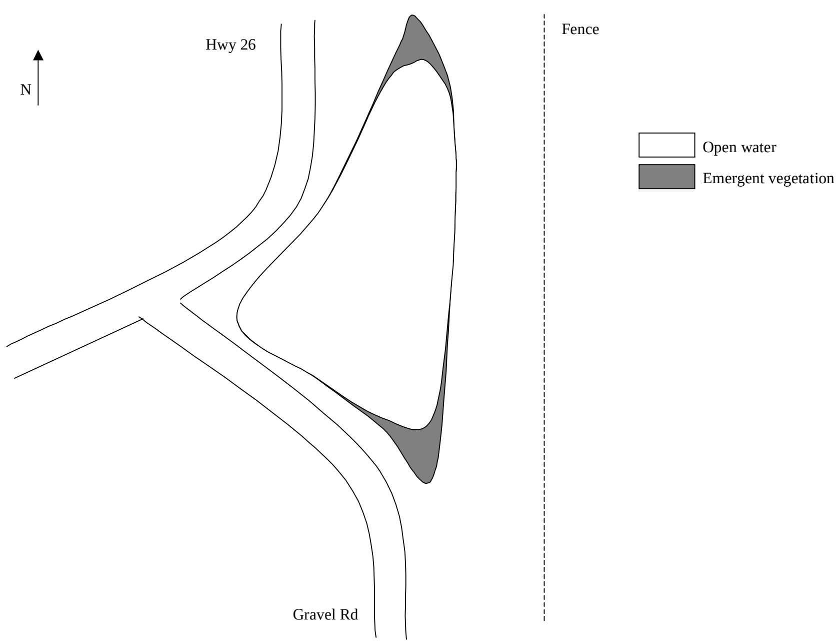
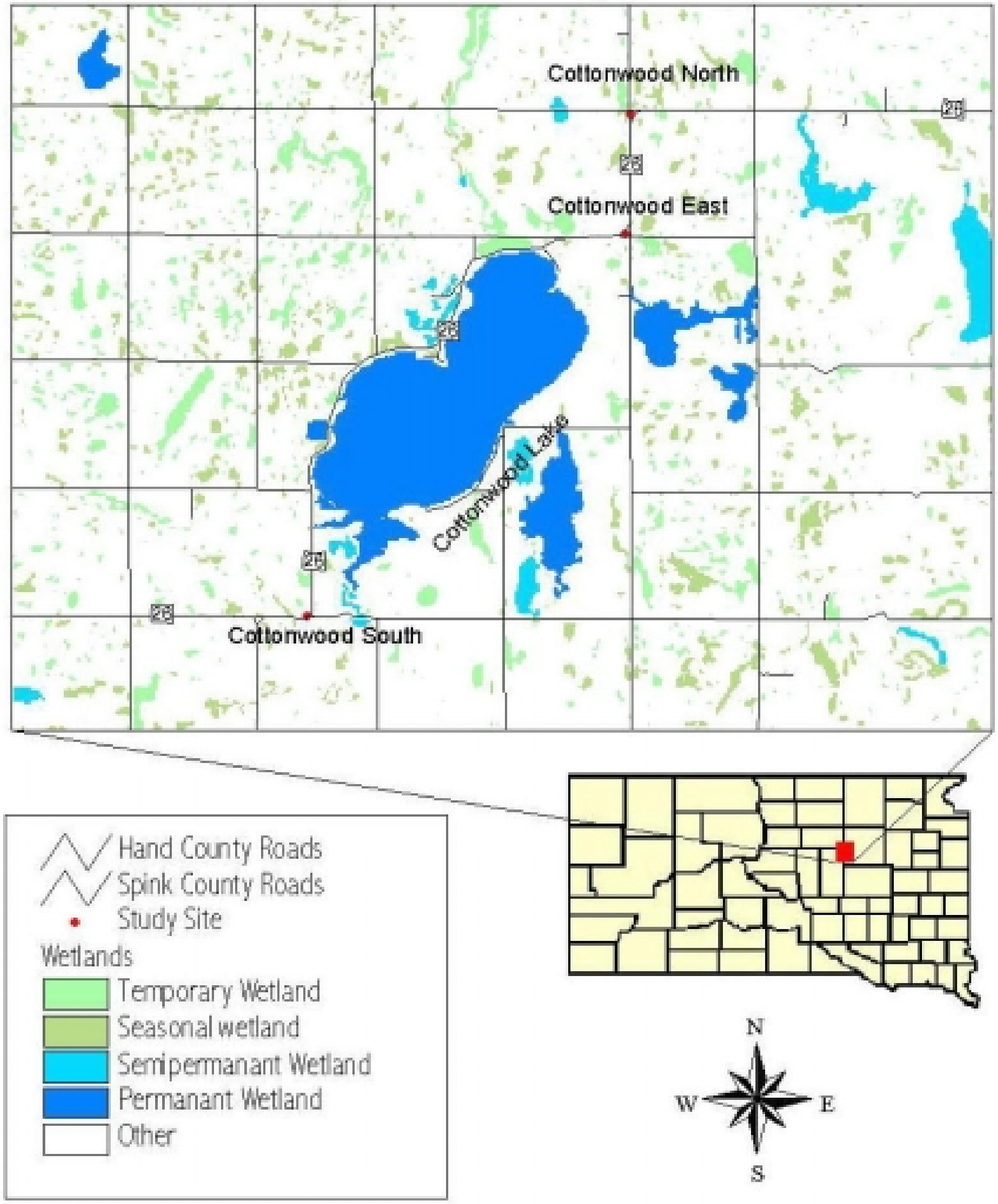


Figure 2. Location map for Cottonwood East, Cottonwood North, and Cottonwood South study wetlands.

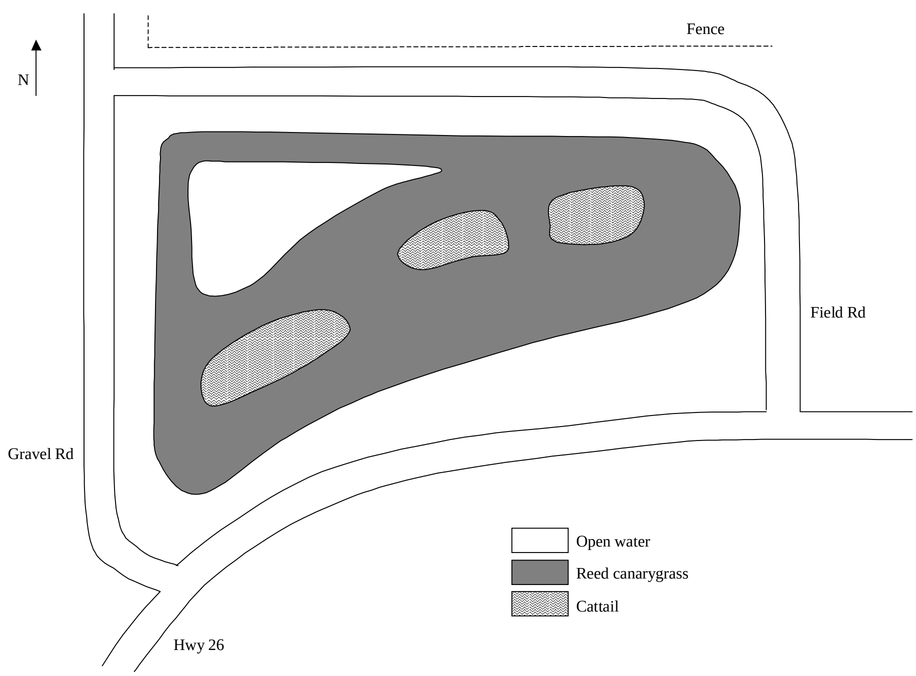


Cottonwood North

SW ¼ SW ¼ Sec. 27 T116N R65W Spink County
44°49’27N 098°38’37W

Borrow pit wetland southwest of Redfield, along north side of highway 26 and east side of gravel road intersecting the highway (Figure 2). Owned by SD DOT. Class III (seasonal), cover type 1. Water present in spring but basin dried by fall. Most of basin comprised of a variety of emergent vegetation, with one small open water/mudflat zone in the northwest corner (Figure 3). Most (60%) surrounding land use was mowed right-of-way, with 40% being a grassed field road and another wetland basin to the north.

Figure 3. Map of vegetation cover at Cottonwood North study wetland, spring 1999.

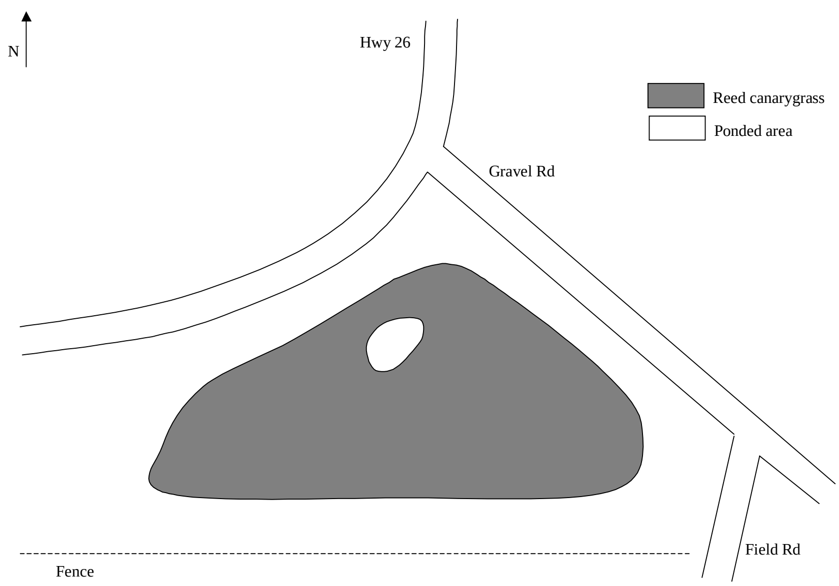


Cottonwood South

SW ¼ SE ¼ Sec. 18 T115N R65W Spink County
44°45’52N 098°41’51W

Borrow pit wetland 1 mile south of Cottonwood Lake. Owned by SD DOT. Along southeast side of Highway 26 and south of gravel road intersecting the highway (Figure 2). Class II (temporary), cover type 1. Minimal water (2 cm) present in spring and none in fall. Basin dominated by monotypic stand of reed canarygrass (Figure 4). Surrounding land use included 70% road-right-of-way and 30% hayfield (mowed in fall).

Figure 4. Map of vegetation cover at Cottonwood South study wetland, spring 1999.



Dolton

SE ¼ SE ¼ Sec. 35 T110N R55W McCook County
43°30’05N 097°23’23W

Borrow pit wetland 1 mile north of Dolton, between three roads (Highway 81 on the northwest, the gravel road to Dolton on the east, and a gravel bypass between the highway and Dolton gravel road) (Figure 6). Owned by SD DOT. Class IV (semipermanent), cover type 2. The water was too deep both seasons to wade in chest waders. Most of basin ponded, with areas of open water and clusters of a variety of emergent vegetation (Figure 5). Surrounding land use was 60% mowed road right-of-way and 40% grassland.

Figure 5. Map of vegetation cover at Dolton study wetland, spring 1999.

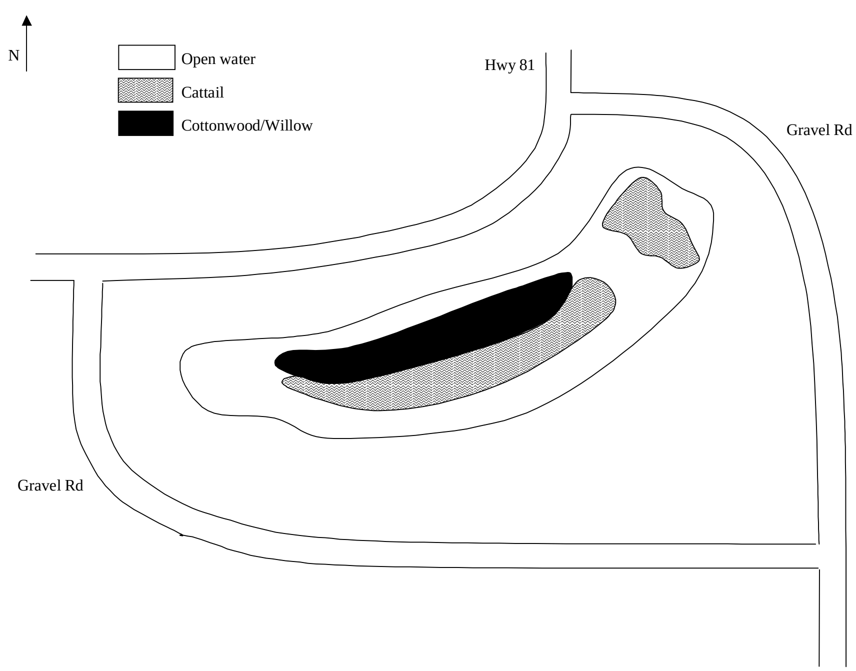
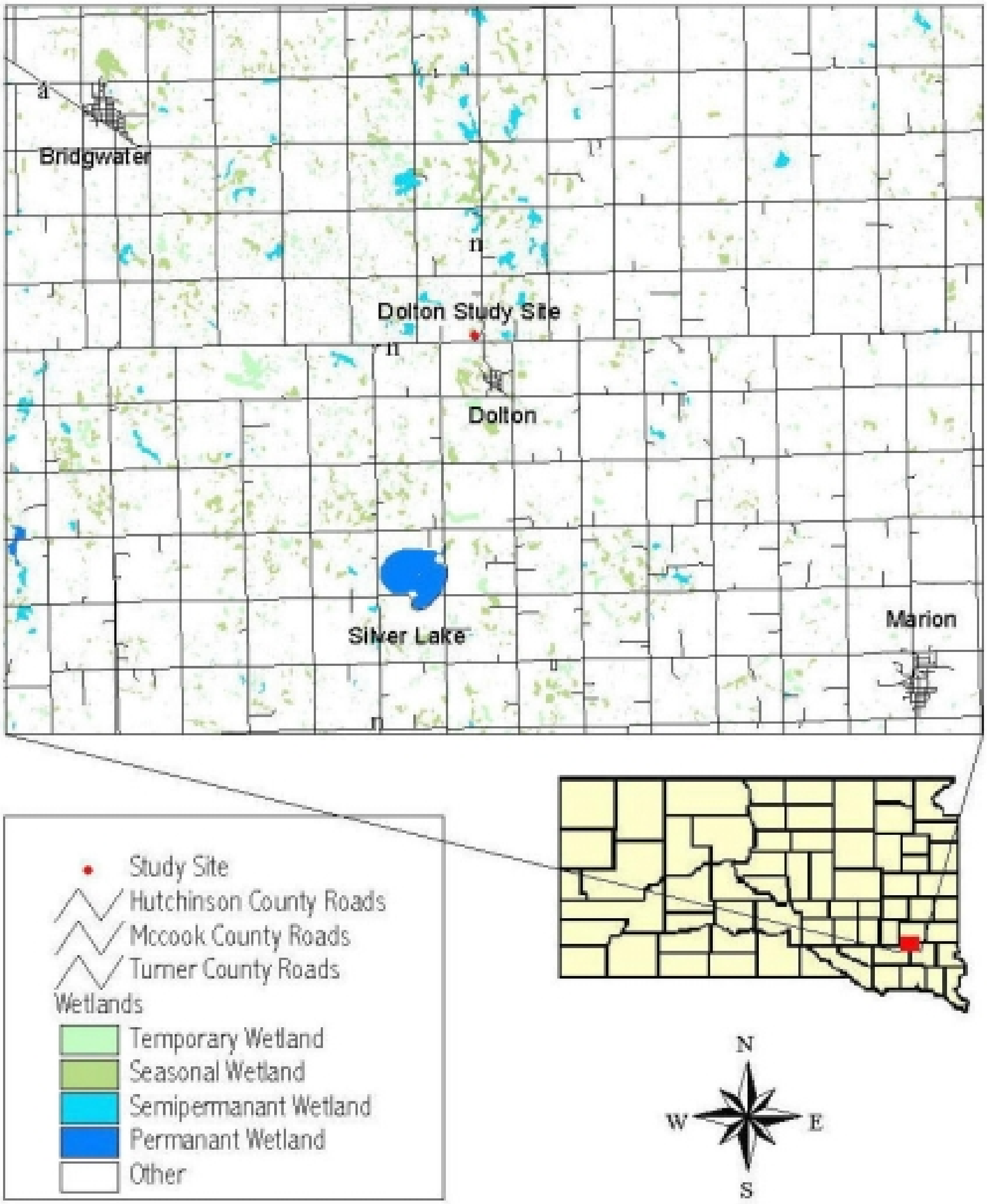


Figure 6. Location map for Dolton study wetland.



Elkton

NW ¼ NW ¼ Sec. 9 T109N R47W Brookings County
44°16'19N 096°29'59W

Borrow-pit wetland 2 miles north of Elkton, on the southeast side of the Highway 14 and Highway 13 intersection (Figure 8). Owned by the SD DOT. Class IV (semi-permanent), cover type 3. Water was too deep to wade with chest waders both seasons. Wetland basin primarily deep open water, surrounded by a narrow band of emergent vegetation. Non-ponded area widens at eastern corner (Figure 7). Surrounding land use was 95% mowed road right-of-way and 5% agricultural use.

Figure 7. Map of vegetation cover at Elkton study wetland, spring 1999.

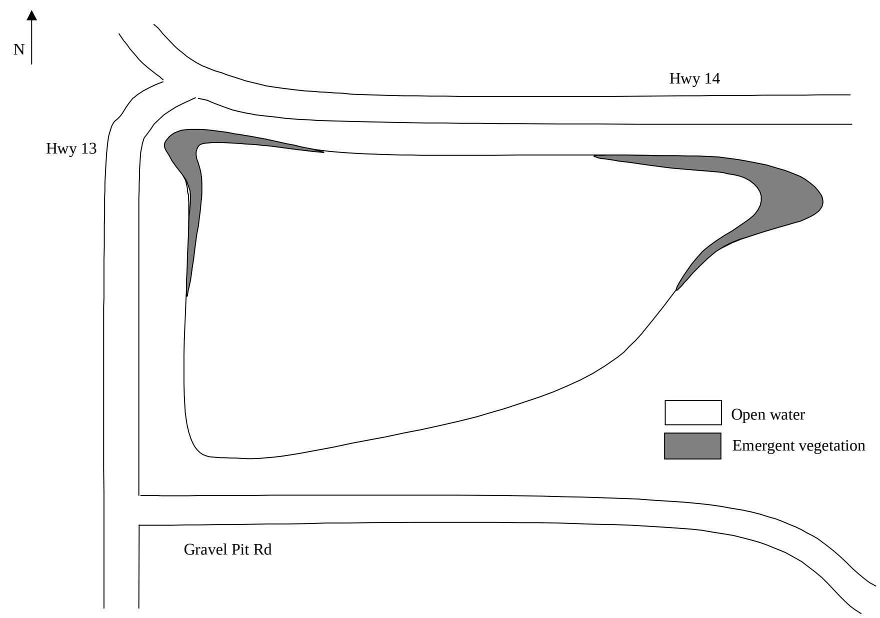
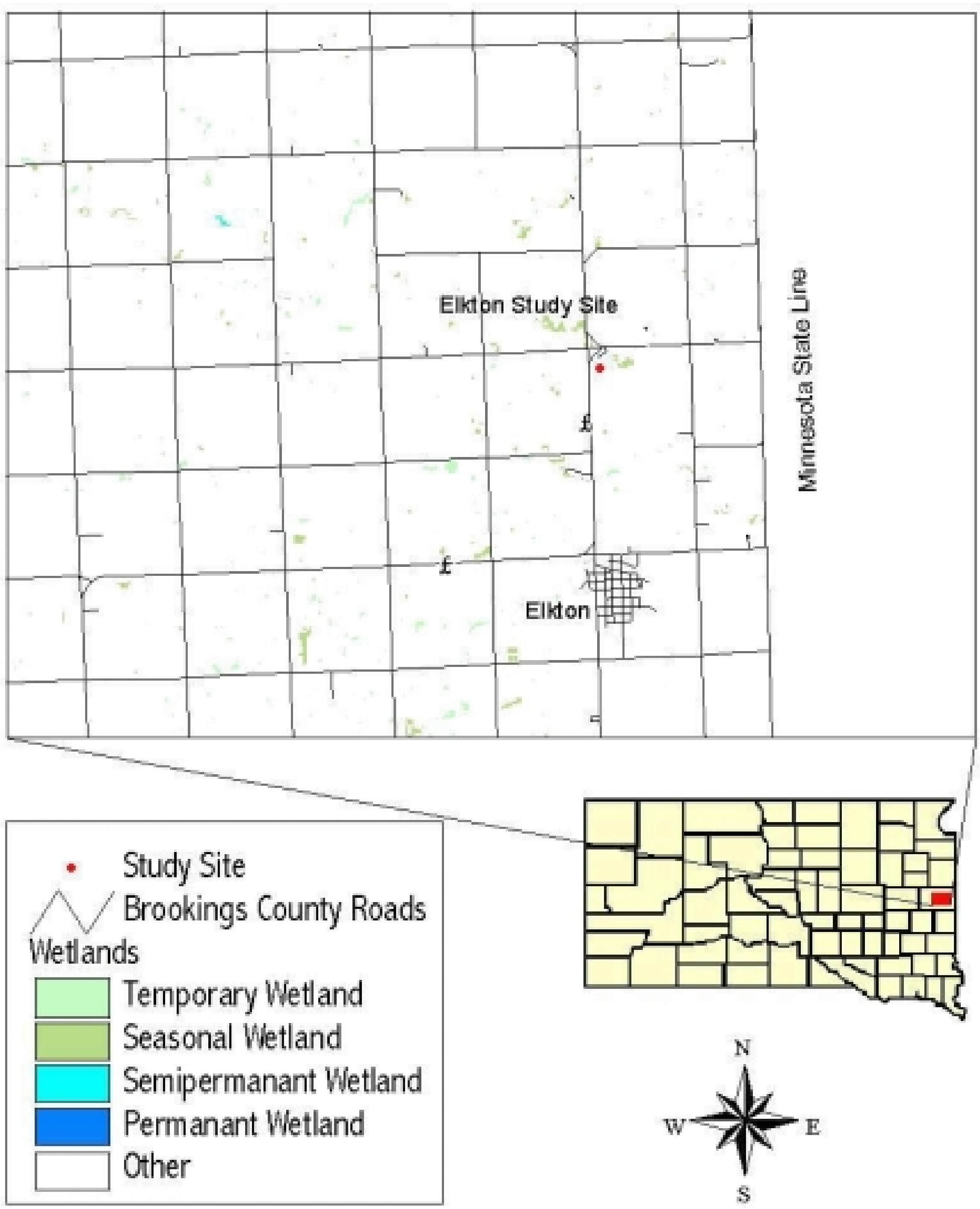


Figure 8. Location map for Elkton study wetland.



Freeman

NW ¼ NW ¼ Sec. 24 T99N R56W Hutchinson County
43°23'08N 097°25'03W

Borrow pit wetland located 2 miles north of Freeman, east of Highway 81 and immediately south of a gravel road that intersects the highway (Figure 10). ?? Creek connects with the wetland at the northeast corner. Owned by SD DOT. Class IV (semipermanent), cover type 4. Water was present in the spring and fall. Majority of basin was open water with little emergent vegetation and a narrow band of hydrophytes (Figure 9). Surrounding land use was 50% grassland, 25% crops (corn), and 25% mowed road right-of-way.

Figure 9. Map of vegetation cover at Freeman study wetland, spring 1999.

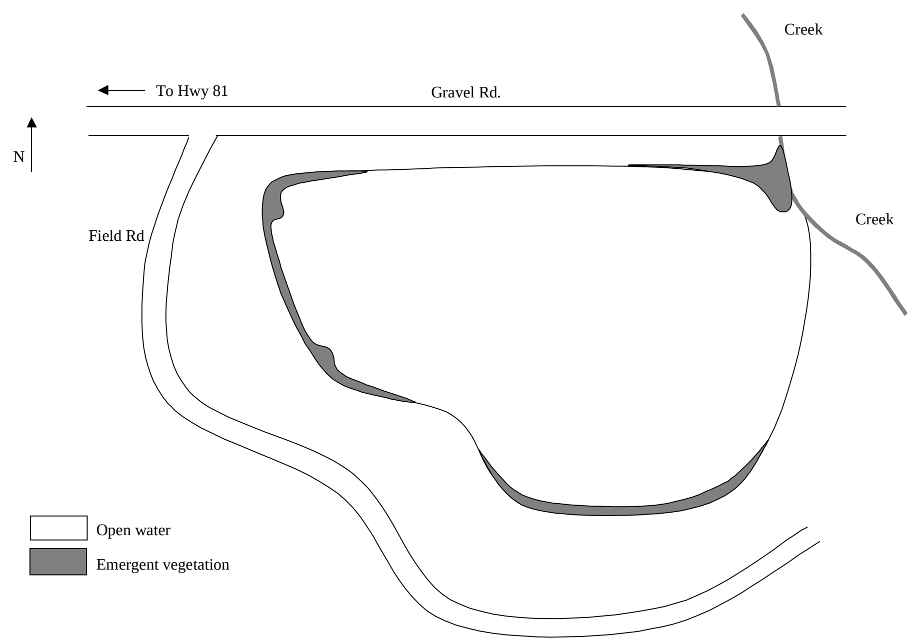
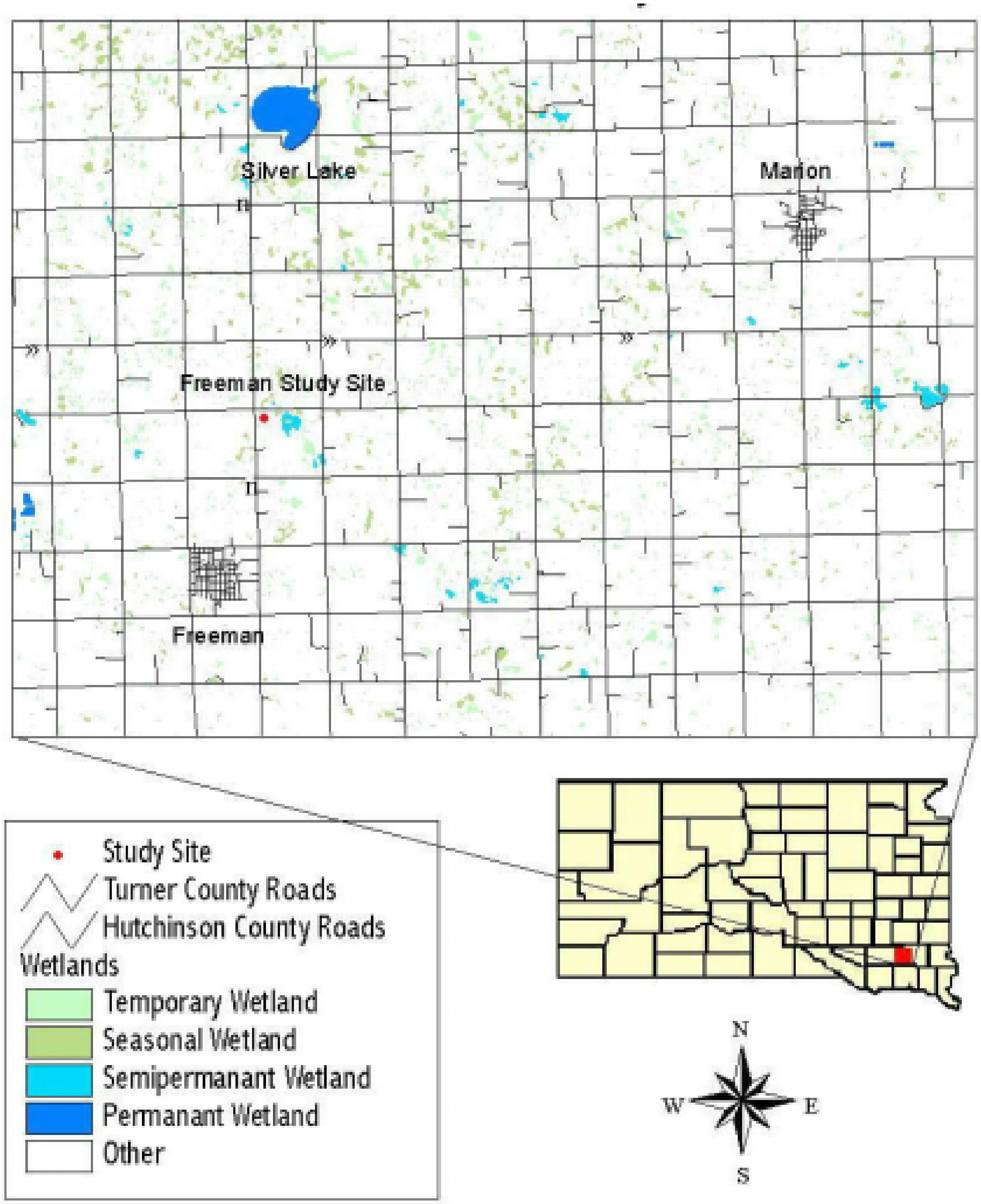


Figure 10. Location map for Freeman study wetland.



Kneip WPA

NW ¼ NW ¼ Sec. 31 T111N R52W Brookings County
44°22’53N 097°07’43W

Restored wetland 1 mile north of Arlington, immediately east of Highway 81 and south of paved road that intersects the highway (Figure 12). Owned by US Fish and Wildlife Service and managed as part of a Waterfowl Production Area. Class IV (semipermanent), cover type 3. Water was present in the spring and fall. Most of basin is open water with submergents, with two islands in the center. Width of emergent vegetation band around the open water varies, with the widest part at the northeast (Figure 11). In the spring, surrounding land use was 90% grassland and 10% mowed road right-of-way. This changed in the fall to 40% grassland, 40% cropland, and 20% mowed road right-of-way.

Figure 11. Map of vegetation cover at Kneip WPA study wetland, spring 1999.

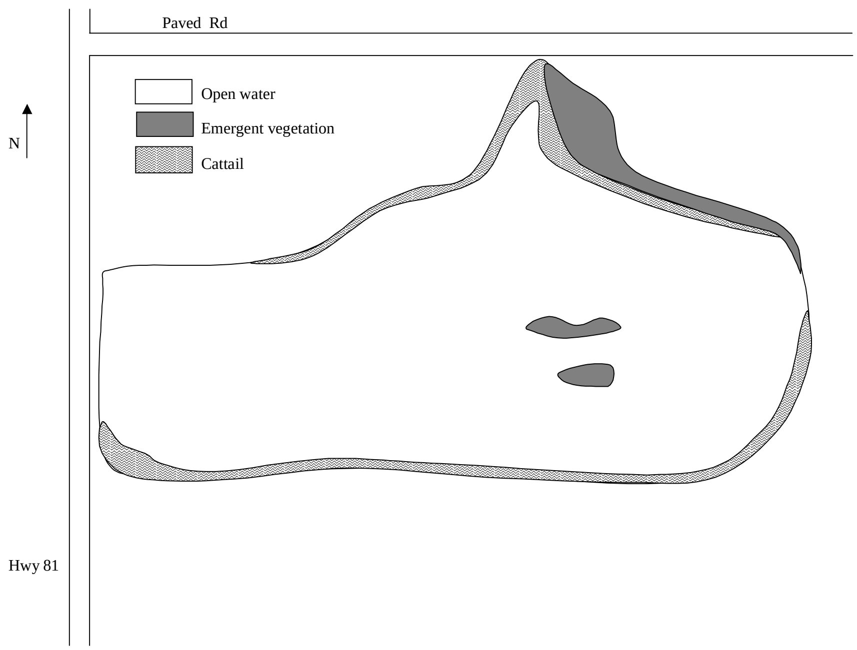
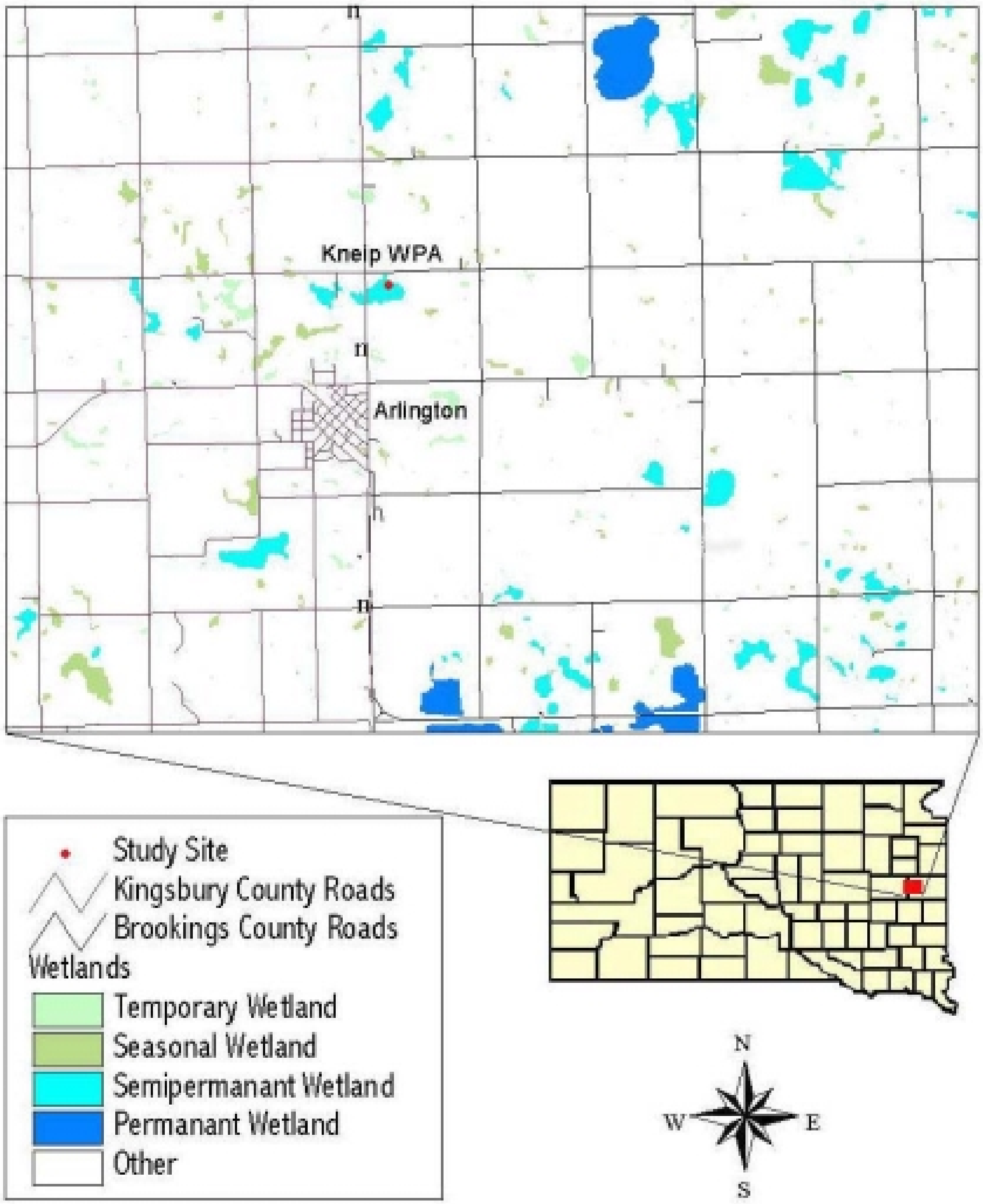


Figure 12. Location map for Kneip WPA study wetland.



Larson WPA

SW ¼ NW ¼ Sec. 31 T110N R52W Brookings County
44°17’26N 097°07’42W

Borrow pit wetland 4.5 miles south of Arlington, immediately east of Highway 81 (Figure 14). Owned by US Fish and Wildlife Service, and managed as part of a Waterfowl Production Area. Class IV (semipermanent), cover type 3. Water was present in the spring and fall. Wetland is deepest at southern side, with wide band of cattail and other emergent vegetation at northern side (Figure 13). Most of open water with submergent vegetation. The majority of surrounding land use was grassland, with a small amount (5%) being road right-of-way.

Figure 13. Map of vegetation cover at Larson WPA study wetland, spring 1999.

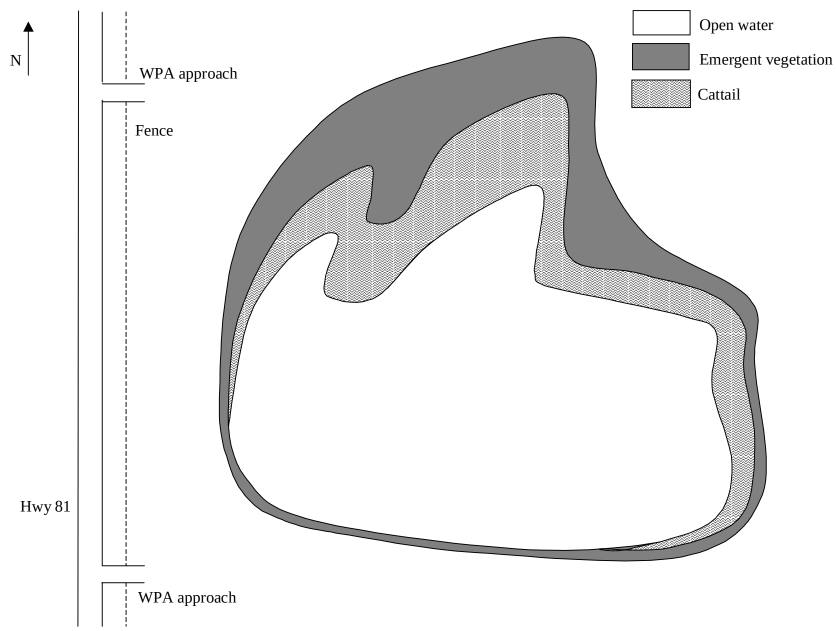
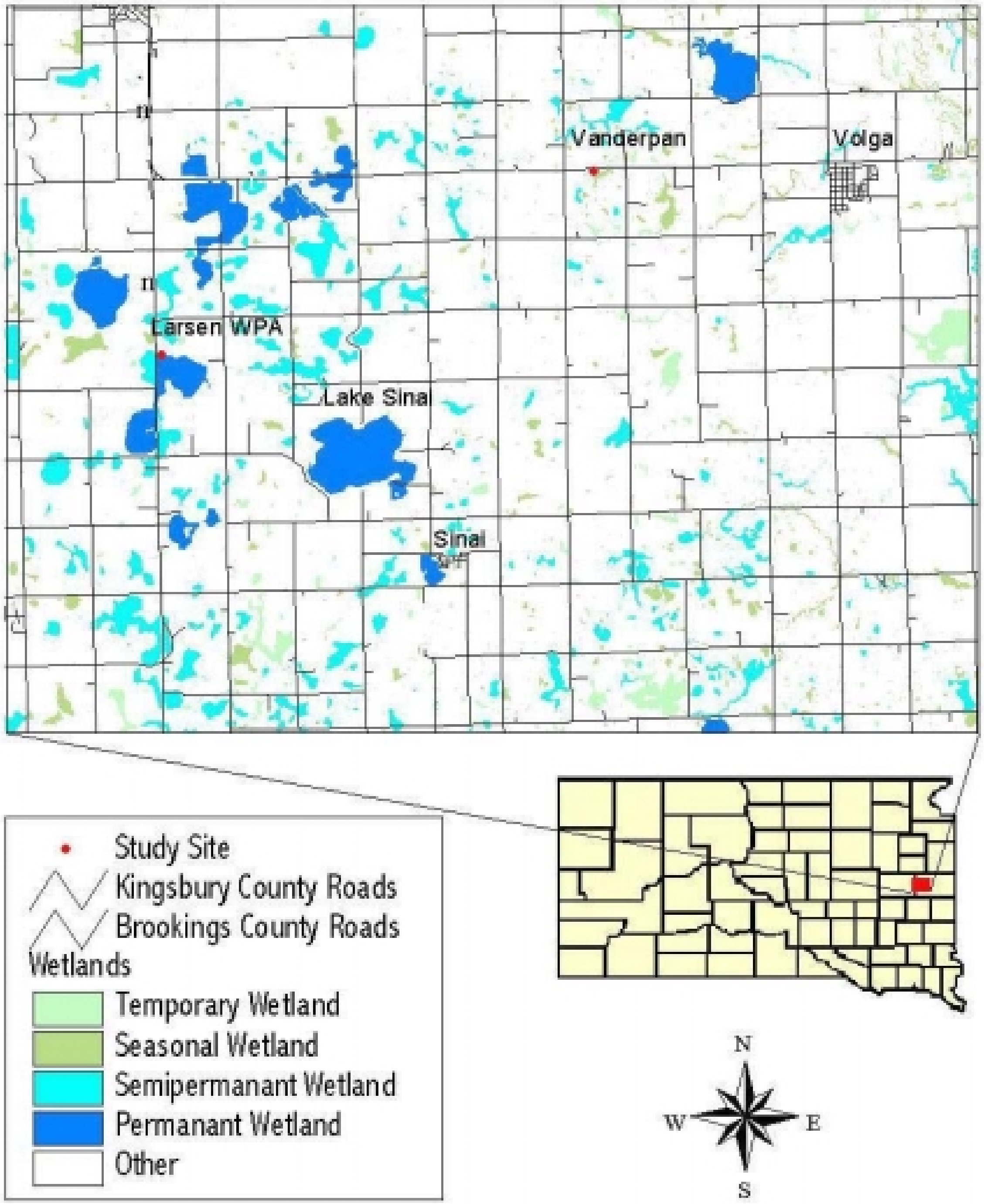


Figure 14. Location map for Larson WPA and Vanderpan study wetlands.



Letcher

NW ¼ SW ¼ Sec. 15 T105N R60W Sanborn County
43°54'12N 098°01'43W

Borrow pit wetland 12.5 miles north of Mitchell, immediately east of Highway 37 (Figure 16). Owned by the SDDOT. Class IV (semipermanent), cover type 3. Water present in spring and fall. Western half of wetland with irregular shorelines, islands, points of dense cattail, and shallow basin slope. Eastern half is regular, deep dugout with a somewhat narrow band of emergent vegetation (Figure 15). Surrounding land use was 90% grassland and 10% mowed road right-of-way in the spring, but in the fall the grassland had all been mowed.

Figure 15. Map of vegetation cover at Letcher study wetland, spring 1999.

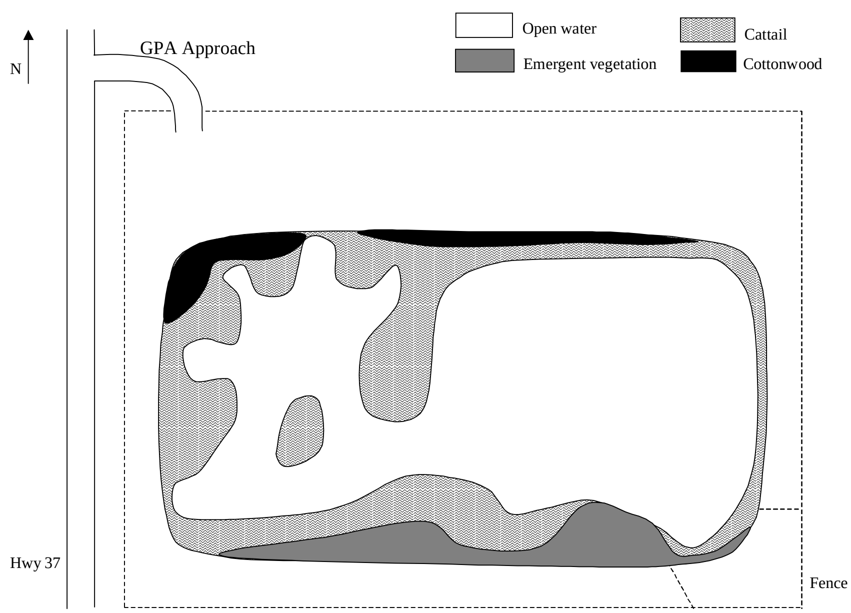
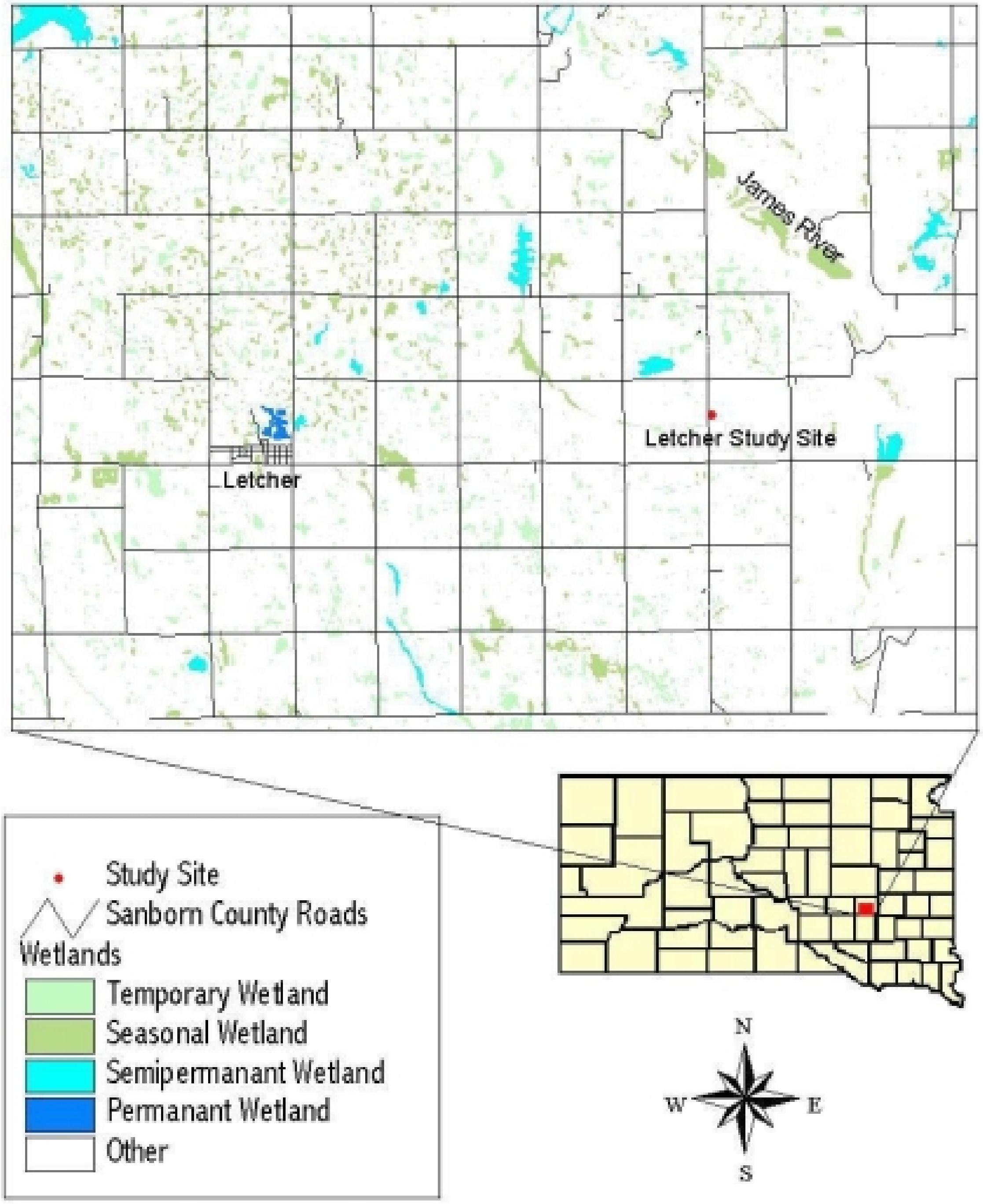


Figure 16. Location map for Letcher study wetland.



Mitchell East

NW ¼ Sec. 20 T103N R60W Davison County
43°42’45N 098°03’31W

Borrow pit wetland 0.5 miles northwest of Mitchell, adjacent to Dry Run Creek (Figure 18). Immediately east of Mitchell West wetland, the two separated by a grassed berm. Privately owned by Kevin Thurman of Mitchell. Class IV (semipermanent), cover type 3. Water present in spring and fall. Cover is interspersed stands of dense cattail and open water, with shallow water and emergent vegetation (mudflat in the fall) in the western half and a smaller pocket of deeper open water at the eastern edge (Figure 17). Surrounding land use was 50% crops (corn), 25% residential yards, and 25% grassland.

Figure 17. Map of vegetation cover at Mitchell East study wetland, spring 1999.

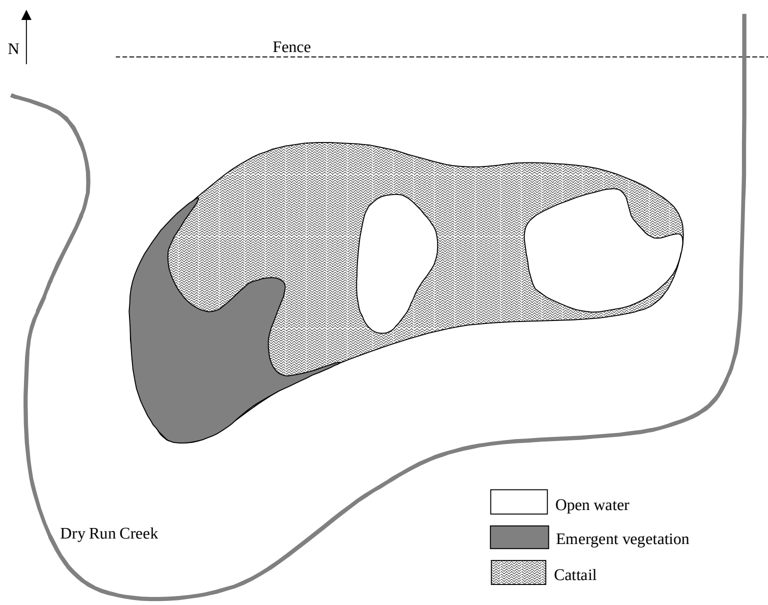
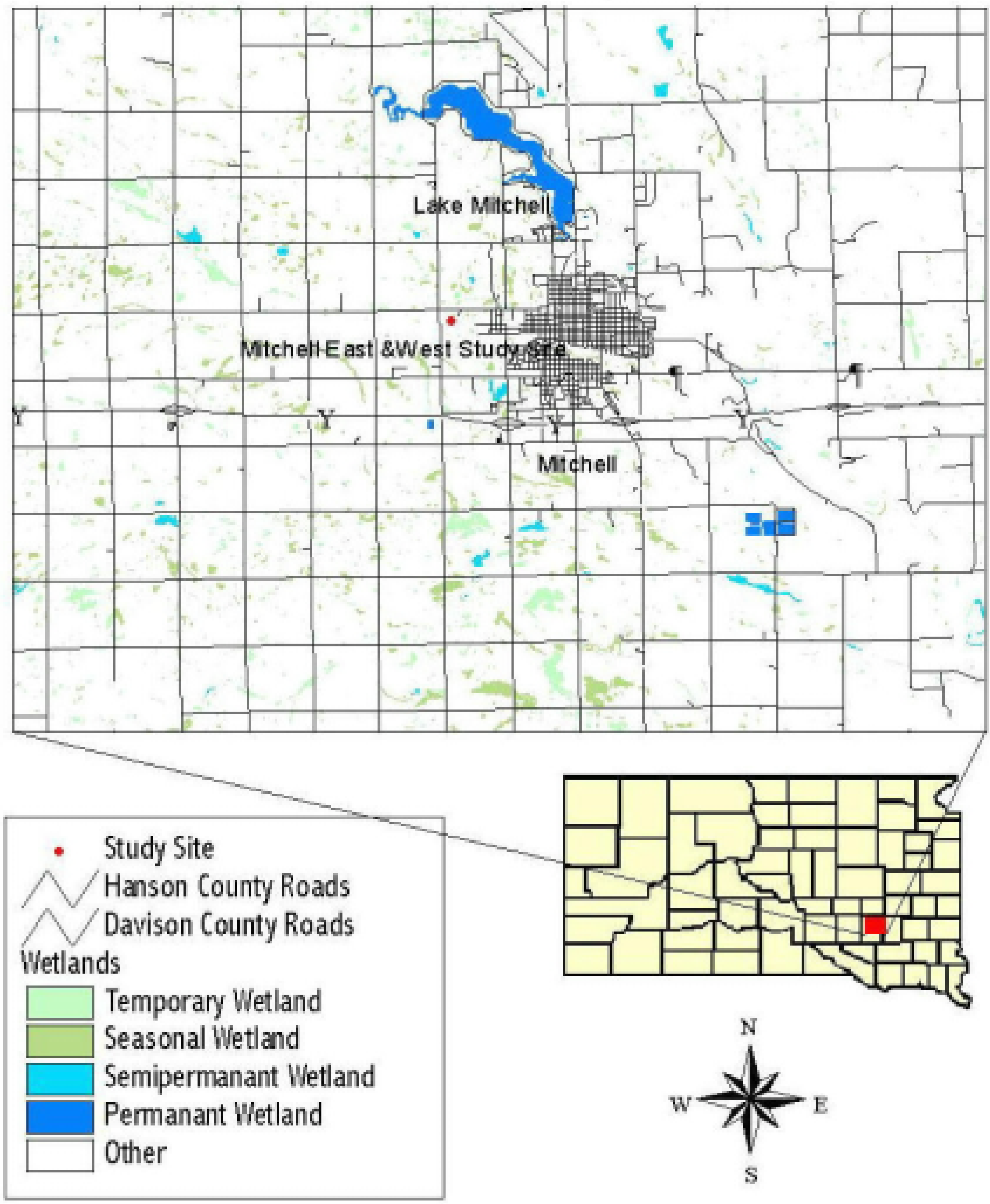


Figure 18. Location map for Mitchell East and Mitchell West study wetlands.

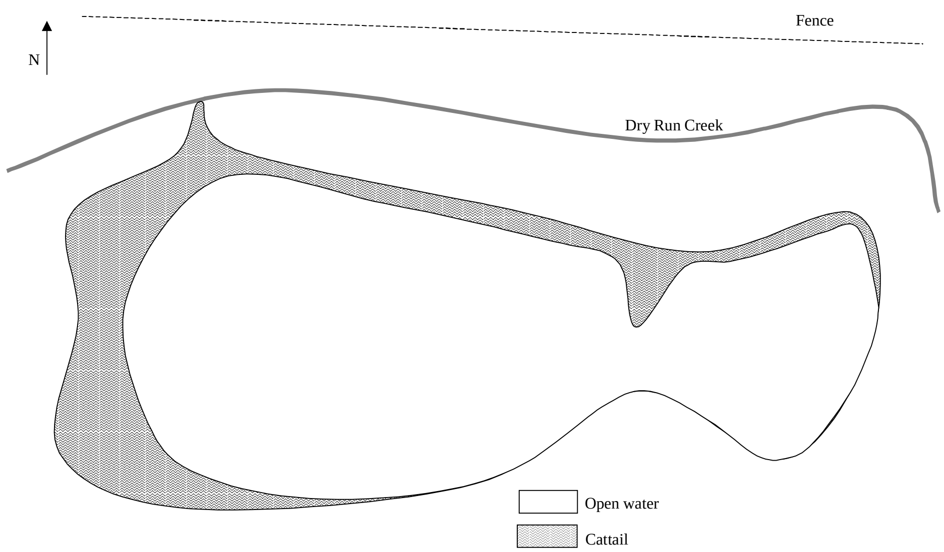


Mitchell West

NW ¼ Sec. 20 T103N R60W Davison County
43°42’45N 098°03’31W

Borrow pit wetland 0.5 miles northwest of Mitchell, adjacent to Dry Run Creek (Figure 18). Immediately west of Mitchell East wetland, the two separated by a grassed berm. Privately owned by Kevin Thurman of Mitchell. Class IV (semipermanent), cover type 3. Water present in spring and fall. Deepest portion of the wetland is at eastern side, western side of basin with more gradual slope and sparse cattail. Band of emergent vegetation (mostly cattail) most significant around north and western edges (Figure 19). Surrounding land use was 60% crops (corn) and 40% grazed grassland.

Figure 19. Map of vegetation cover at Mitchell West study wetland, spring 1999.

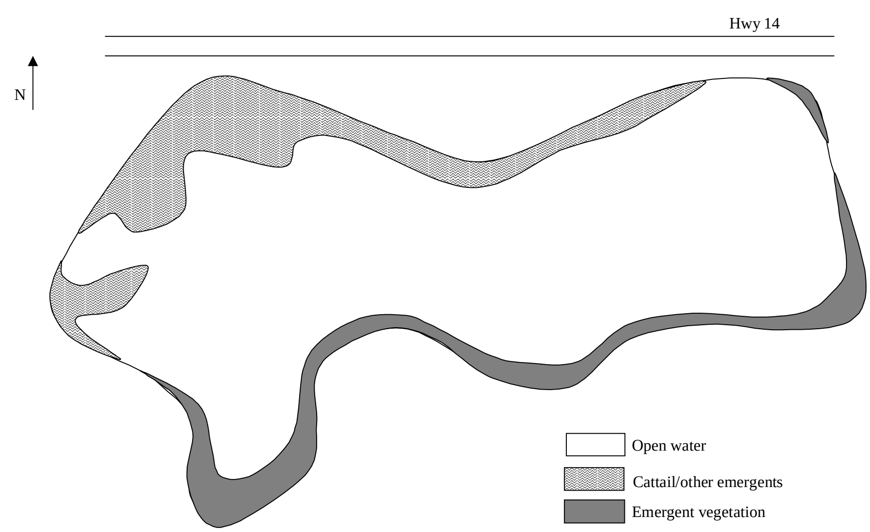


Vanderpan

NE ¼ NW ¼ Sec. 19 T110N R51W Brookings County
44°19’32N 096°59’53W

Restored wetland 3.5 miles west of Volga, immediately south of Highway 14 (Figure 14). Privately owned by N. Vanderpan of Brookings. Class IV (semipermanent), cover type 3. Water was present in spring and fall. There were extensive mudflats present the first day of sampling in the fall but because of an overnight rainstorm most of the basin was inundated the second fall sampling day. Deepest part at eastern portion of basin, shallow slope to the west. A variety of emergent vegetation around the entire wetland, with a thick stand of cattail at the northwestern corner. Most open water with submergents (Figure 20). Surrounding land use was 20% mowed road right-of-way and 80% grassland.

Figure 20. Map of vegetation cover at Vanderpan study wetland, spring 1999.



Vayland

NE ¼ NW ¼ Sec. 14 T112N R67W Hand County
44°30’52N 098°51’05W

Borrow pit wetland 2.5 miles northwest of Vayland, immediately northwest of Highway 14 and south of gravel road that intersects the highway (basin is just east of the intersection) (Figure 22). Owned by SD DOT. Class IV (semipermanent), cover type 3. Water was present both spring and fall, with the western part of the basin dry in the fall. Eastern part of wetland with steep slope and little emergent vegetation. Western side has more gradual slope and wider band of emergent vegetation (Figure 21). Surrounding land use was 50% road right-of-way, 25% grassland, and 25% agricultural crops.

Figure 21. Map of vegetation cover at Vayland study wetland, spring 1999.

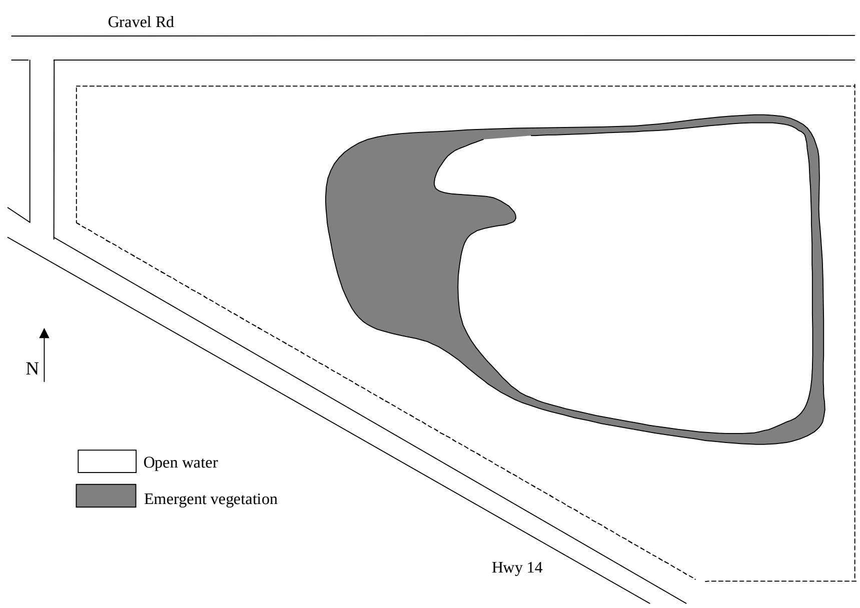
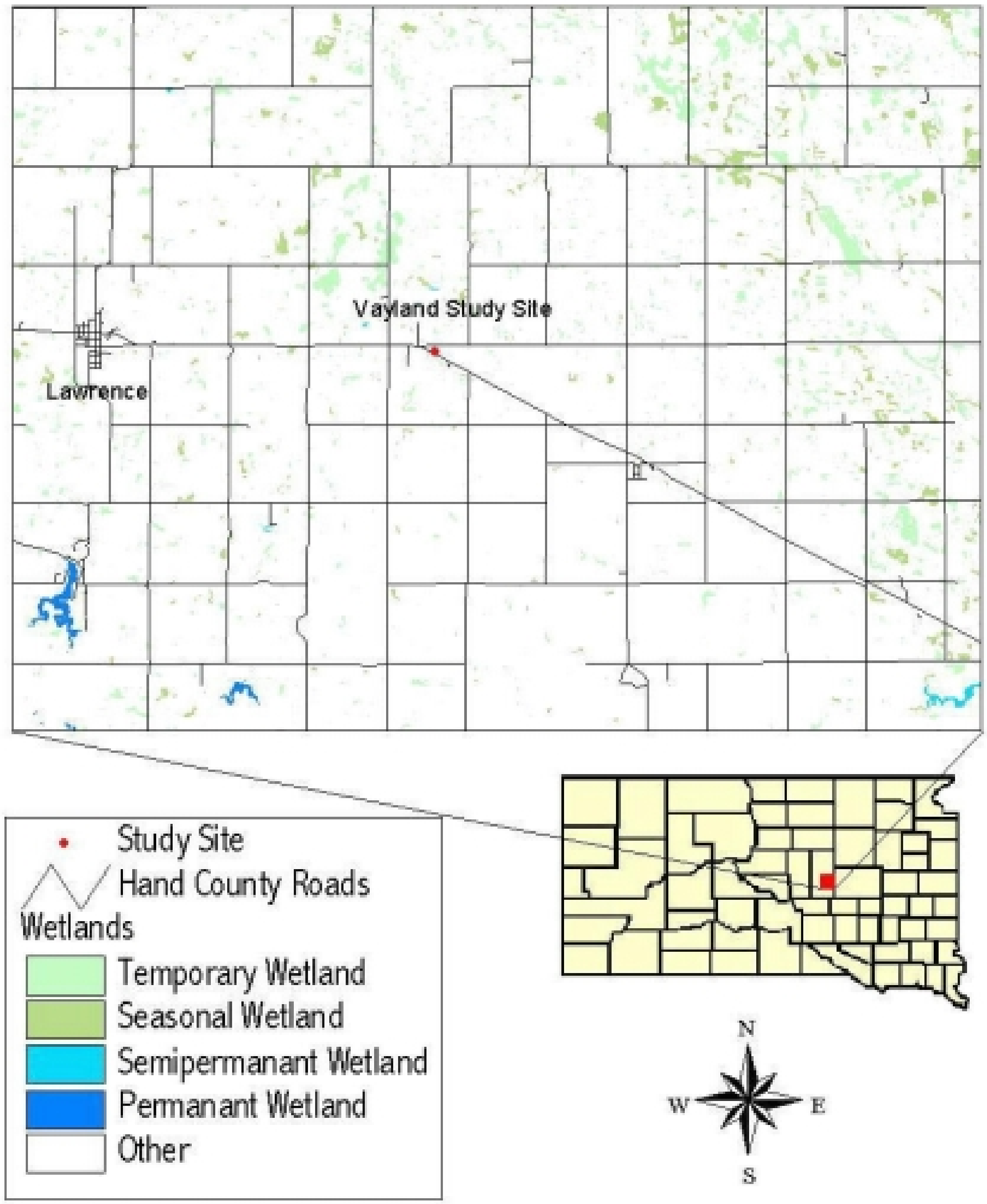


Figure 22. Location map for Vayland study wetland, 1999.



Appendix C. Bird species observed at study wetlands, 1998 and 1999.

Common name	Scientific name	Number of wetlands where present
American bittern	*Botaurus lentiginosus*	6
American coot	*Fulica americana*	7
American goldfinch	Carduelis tristis	4
American kestrel	*Falco sparverius*	1
American robin	*Turdus migratorius*	4
Bank swallow	*Riparia riparia*	8
Barn swallow	*Hirundo rustica*	13
Belted kingfisher	*Megaceryle alcyon*	3
Black-crowned night heron	*Nycticorax nycticorax*	1
Black tern	*Chlidonias niger*	1
Blue-winged teal	*Anas discors*	11
Bobolink	*Dolichonyx oryzivorus*	3
Brewers blackbird	*Euphagus cyanocephalus*	1
Brown-headed cowbird	*Molothrus ater*	3
Canada goose	*Branta canadensis*	3
Clay-colored sparrow	*Spizella pallida*	1
Cliff swallow	*Petrochelidon pyrrhonota*	5
Common flicker	*Colaptes auratus*	1
Common grackle	*Quiscalus quiscula*	9
Common nighthawk	*Cordeiles minor*	1
Common snipe	*Capella gallinago*	2
Common yellowthroat	*Geothlypis trichas*	8
Dicksissel	*Spiza americana*	1
Double-crested cormorant	*Phalacrocorax auritus*	3
Eastern kingbird	*Tyrannus tyrannus*	6
Eastern phoebe	*Sayornus phoebe*	1
European starling	*Sturnus vulgaris*	1
Franklin’s gull	*Larus pipixcan*	3
Gadwall	*Anas strepera*	8
Grasshopper sparrow	*Ammodramus savannarum*	1
Great blue heron	*Ardea herodias*	6
Great egret	*Casmerodius albus*	3
Greater yellowlegs	*Tringa melanoleuca*	2
Green heron	*Butorides striatus*	1
House sparrow	*Passer domesticus*	2
Killdeer	*Charadrius vociferus*	11
Least bittern	*Ixobrychus exilis*	1
Least sandpiper	*Calidris minutilla*	2
Lesser golden plover	*Pluvialis dominica*	1
Lesser scaup	*Aythya affinis*	2
Lesser yellowlegs	*Tringa flavipes*	5
Mallard	*Anas platyrhynchos*	12
Marsh wren	*Cistothorus palustris*	2
Mourning dove	*Zenaida macroura*	10
Northern harrier	*Circus cyaneus*	1
Northern pintail	*Anas acuta*	4
Northern shoveler	*Anas clypeata*	6
Pectoral sandpiper	*Calidris melanotos*	4
Pied-billed grebe	*Podilymbus podiceps*	5
Redhead	*Aythya americana*	2
Red-winged blackbird	*Agelaius phoeniceus*	13

Appendix C (continued). Bird species observed at study wetlands, 1998 and 1999.

Common name	Scientific name	Number of wetlands where present
Ring-billed gull	*Larus delawarensis*	3
Ring-necked pheasant	*Phasianus colchicus*	8
Savannah sparrow	*Passerculus sandwichensis*	4
Sedge wren	Cistothorus platensis	5
Semi-palmated plover	*Charadrius semipalmatus*	1
Semi-palmated sandpiper	*Calidris pusilla*	2
Snow goose	*Chen caerulescens*	1
Song sparrow	*Melospiza melodia*	9
Sora	*Porzana carolina*	4
Spotted sandpiper	*Actitis macularia*	4
Stilt sandpiper	*Micropalama himantopus*	1
Tree swallow	*Iroidoprocne bicolor*	5
Unknown		1
Unnown dowitcher	*Limnodromus* sp.	1
Unknown peep	*Calidris* sp.	4
Unknown rail	Family: Rallidae	1
Unknown sparrow	Family: Emberizidae	10
Unknown swallow	Family: Hirundinidae	1
Unknown wren	*Cistothorus* sp.	3
Upland sandpiper	*Bartramia longicauda*	1
Vesper sparrow	*Pooecetes gramineus*	2
Western kingbird	*Tyrannus verticalis*	3
Western meadowlark	*Sturnella neglecta*	7
White pelican	*Pelecanus erythrorhynchos*	1
White-rumped sandpiper	*Calisris fuscicollis*	3
Wilson’s phalarope	*Steganopus tricolor*	1
Wood duck	*Aix sponsa*	4
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	9
Yellow warbler	*Dendroica petechia*	1

Appendix D. Fish species observed at study wetlands, 1998 and 1999.

Common name	Scientific name	Number of wetlands where present
Black bullhead	*Ictalurus melas*	7
Brassy minnow	*Hybognathus hankinsoni*	1
Brook stickleback	*Culaea inconstans*	4
Common carp	*Cyprinus carpio*	1
Creek chub	*Semotilus atromaculatus*	1
Fathead minnow	*Pimephales promelas*	9
Green sunfish	*Lepomis cyanellus*	5
Iowa darter	*Etheostoma exile*	3
Johnny darter	*Etheostoma nigrum*	2
Northern pike	Esox lucius	1
Orangespotted sunfish	*Lepomis humilis*	4
Unknown minnow	Family: Cyprinidae	1
Unknown sunfish	Family: Centrarchidae	1
White sucker	Catostomus commersoni	1

Appendix E. Mammal species observed at study wetlands, 1998 and 1999.

Common name	*Scientific name*	Number of wetlands where present
Coyote	*Canis latrans*	1
Deer mouse	*Peromyscus maniculatus*	9
Eastern cottontail	*Sylvilagus floridanus*	2
Masked shrew	*Sorex cinereus*	6
Meadow jumping mouse	*Zapus hudsonius*	3
Meadow vole	*Microtus pennsylvanicus*	3
Mink	*Mustela vison*	7
Muskrat	*Ondatra zibethica*	12
Northern grasshopper mouse	*Onychomys leucogaster*	1
Prairie vole	*Microtus ochrogaster*	1
Pygmy shrew	*Microsorex hoyi*	1
Raccoon	*Procyon lotor*	10
Red fox	*Vulpes fulva*	5
Shorttail shrew	*Blarina brevicauda*	4
Striped skunk	*Mephitis mephitis*	2
Thirteen-lined ground squirrel	*Citellus tridecemlineatus*	1
Whitetail deer	*Odocoileus virginianus*	12
Whitetail jackrabbit	*Lepus townsendi*	1
Woodchuck	*Marmota monax*	1

Appendix F. Amphibian species observed at study wetlands, 1998 and 1999.

Common name	*Scientific name*	Number of wetlands where present
American toad	*Bufo americanus*	4
Canadian toad	*Bufo hemiophrys*	1
Chorus frog	*Pseudacris triseriata*	1
Northern leopard frog	*Rana pipiens*	11
Northern X Plains leopard frog		1
Tiger salamander	*Ambystoma tigrinum*	5
Tadpole	*unknown*	7
Unknown toad	*Bufo* sp.	3

Appendix G. Reptile species observed at study wetlands, 1998 and 1999.

Common name	Scientific name	Number of wetlands where present
Painted turtle	Chrysemys picta	9
Plains garter snake	*Thamnophis radix*	4
Snapper turtle	*Chelydra serpentina*	1

Appendix H. Aquatic invertebrate species identified from Mitchell prototype wetlands, 1998 and 1999.

Taxa		Number of wetlands where present
Amphipoda	Taltridae	1
Bivalvia		1
Coleoptera	Carabidae	1
Coleoptera	Dytiscidae	2
Coleoptera	Gyrinidae	1
Coleoptera	Haliplidae	1
Coleoptera	Hydrophilidae	2
Coleoptera	Unknown	1
Collembola	Isotomidae	2
Collembola	Sminthuridae	1
Collembola	Unknown	2
Decapoda	Cambaridae	2
Diplopoda		1
Diptera	Ceratopogonidae	1
Diptera	Chaoboridae	1
Diptera	Chironomidae	2
Diptera	Stratiomyidae	1
Diptera	Unknown	2
Ephemeroptera	Baetidae	2
Ephemeroptera	Caenidae	1
Ephemeroptera	Unknown	1
Hemiptera	Corixidae	2
Hemiptera	Gerridae	1
Hemiptera	Macrovellidae	1
Hemiptera	Saldidae	2
Hemiptera	Unknown	1
Homoptera	Unknown	1
Hirudinea		1
Hydracarina		2
Limnophila	Lymnaeidae	2
Limnophila	Physidae	2
Limnophila	Planorbidae	2
Odonata	Lestidae	1
Odonata	Libellulidae	1
Oligochaeta		2

Appendix I. Terrestrial invertebrates identified from Mitchell prototype wetlands, 1998 and 1999.

Taxa		Number of wetlands where present
Acari		2
Annelida		2
Araneae		2
Coleoptera	Anthicidae	1
Coleoptera	Carabidae	2
Coleoptera	Chrysomelidae	2
Coleoptera	Cincindelidae	2
Coleoptera	Curculionidae	2
Coleoptera	Dytiscidae	1
Coleoptera	Heteroceridae	1
Coleoptera	Hydrophilidae	2
Coleoptera	Meloidae	1
Coleoptera	Oedemeridae	1
Coleoptera	Scarabaeidae	2
Coleoptera	Staphylinidae	2
Coleoptera	Tenebrionidae	1
Coleoptera	Unknown	2
Collembola	Isotomidae	2
Collembola	Sminthuridae	2
Collembola	Unknown	2
Diplopoda		2
Diptera	Stratromyidae	1
Diptera	Unknown	2
Hemiptera	Cydnidae	2
Hemiptera	Gerridae	1
Hemiptera	Mesovelidae	1
Hemiptera	Pleidae	2
Hemiptera	Reduviidae	1
Hemiptera	Saldidae	1
Hemiptera	Unknown	2
Homoptera	Aphididae	2
Homoptera	Cicadellidae	2
Homoptera	Unknown	2
Hymenoptera	Anthophoridae	1
Hymenoptera	Braconidae	2
Hymenoptera	Encyrtidae	1
Hymenoptera	Formicidae	1
Hymenoptera	Unknown	2
Isopoda		2
Lepidoptera	Pieridae	1
Lepidoptera	Pyralidae	2
Lepidoptera	Tortricidae	1
Lepidoptera	Unknown	2
Limnophila	Lymnaeidae	2

Appendix I. Terrestrial invertebrates identified from Mitchell prototype wetlands, 1998 and 1999.

Taxa		Number of wetlands where present
Limnophila	Planorbidae	2
Limnophila	Unknown	1
Odonata	Libellulidae	1
Opiliones		2
Orthoptera	Acrididae	2
Orthoptera	Gryllidae	2
Orthoptera	Tetrigidae	2
Orthoptera	Tridactylidae	2
Orthoptera	Unknown	2
Thysanoptera	Thripidae	1
Thysanoptera	Unknown	2

Appendix J. Dominant plant species observed at study wetlands, 1998 and 1999.

Common Name	Scientific Name
Aster	*Aster* spp.
Barnyard grass	*Echinochloa* spp.
Beggar's tick	*Bidens* spp.
Biennial wormwood	*Artemisia biennis*
Bulrush	*Schoenoplectus* spp.
Cattail	*Typha* spp.
Claspingleaf pondweed	*Potamogeton richardsonii*
Coarse cyperus	*Cyperus odoratus*
Cocklebur	*Xanthium strumarium*
Coontail	*Ceratophyllum demersum*
Cottonwood	*Populus deltoides*
Cyperus	*Cyperus* spp.
Dock	*Rumex* spp.
Duckweed	*Lemna* spp.
Flatstem pondweed	*Potamogeton zosteriformis*
Foxtail barley	*Hordeum jubatum*
Giant burreed	*Sparganium eurycarpum*
Hardstem bulrush	*Schoenoplectus acutus*
Kentucky bluegrass	*Poa pratensis*
Longleaf pondweed	*Potamogeton nodosus*
Marsh smartweed	*Polygonum coccineum*
Peachleaf willow	*Salix amygdaloides*
Pale bulrush	*Scirpus pallidus*
Pondweed	*Potamogeton* spp.
Prairie bulrush	*Schoenoplectus maritimus*
Rayless aster	*Aster brachyactis*
Red goosefoot	*Chenopodium rubrum*
Reed canarygrass	*Phalaris arundinacea*
River bulrush	*Schoenoplectus fluviatilis*
Sedge	*Carex* spp.
Slough sedge	*Carex atheroides*
Smartweed	*Polygonum* spp.
Sow thistle	*Sonchus arvensis*
Spikerush	*Eleocharis* spp.
Star duckweed	*Lemna trisulca*
Sunflower	*Helianthus* spp.
Toothcup	*Ammania robusta*
Yellow foxtail	*Setaria glauca*
Water milfoil	*Myriophyllum* spp.
Willow	*Salix* spp.