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Changes in land cover and nesting habitat for the interior least tern and piping plover along the Missouri River: 1983-1991

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CHANGES IN LAND COVER AND NESTING HABITAT FOR THE INTERIOR LEAST TERN AND PIPING PLOVER ALONG THE MISSOURI RIVER: 1983 - 1991

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THESIS ACCEPTANCE

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ABSTRACT

This thesis examines land cover changes that affect shorebird habitat at four sites along the Missouri River using wetland habitat and hydrologic data. Wetland habitat data was aggregated into four land cover categories, including one which corresponded with potential shorebird nesting habitat. Type, location, and quantity of land cover changes at each site were determined between 1983 and 1991. Impacts upon tern and plover nesting habitat were assessed by analyzing changes in the corresponding land cover category. Associated hydrologic information, including gage heights and discharge records, were utilized to help understand local conditions. It was found that there were substantial changes in shorebird habitat over the study period. Greenwood, the furthest site upstream, exhibited a habitat loss of 305 acres due to vegetative encroachment. The Niobrara site, further downstream, had an increase in habitat of 343 acres because of aggradation from Niobrara River sediment and rising river stages.

ACKNOWLEDGEMENTS

A large number of people deserve my thanks in getting this project accomplished. My wife, Mary, and my parents, Dale and Judy, provided constant support and encouragement, as well as the push needed to reach the end. Despite my occasional doubts, they made me believe that it *would* get done and gave me the opportunity to do so. Thank you so much.

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I would also like to thank two of my committee members, Dr. Peterson and Dr. Bragg, for their time and feedback over the course of this project. Our many discussions have finally yielded results.

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I. INTRODUCTION

Wildlife habitat studies have proven to be important components in the protection of rare and endangered species (Carreker 1985; Herr and Queen 1993). A thorough understanding of species biology as well as hydrologic and geomorphic processes that influence habitat are important in identifying, assessing, and measuring habitat change and its resultant impact upon various species. Vegetated areas adjacent to streams provide shelter and food for local fauna and act as a buffer between land and water. These riparian regions represent only a small percentage of the total land area in the Great Plains, but are critical in maintaining many wildlife species (Carrothers et al. 1974; Bull 1978; Short and Schamberger 1979; Hesse and Mestl 1993). Because of their scarcity and ecological importance, these areas are particularly worthy of study. Activities such as flood plain development, channelization, dredging, and pollution continue to eliminate or degrade existing riparian habitat areas (Bragg and Tatschl 1977; Delong and Brusven 1991). Impacts from these and other activities are not always clear. However, computer-based systems now provide the necessary tools for evaluating changes in the physical world and displaying them in both graphic and tabular form. Geographic information systems (GIS) provide a framework for storage, management, analysis, display, and output of spatially referenced data. Using this technology it is possible to analyze complicated situations and provide meaningful interpretations to decision-makers.

This thesis will examine the land cover changes that have occurred over the period 1983 to 1991 at several sites along the Missouri River using wetland habitat data, hydrologic records and spatial analysis techniques. Impacts upon potential nesting habitat of the interior least tern (*Sterna antillarum athalassos)* and piping plover (*Charadrius melodus)* will also be determined. Past studies in the central Great Plains regarding land cover changes on the Platte and Missouri Rivers will be reviewed, as will work which describes the type of habitat required by these two shorebirds. Wetland habitat data will be aggregated into four land cover categories, including one which corresponds with potential shorebird nesting habitat. The impacts upon tern and plover nesting habitat will be assessed by analyzing the changes in this category in conjunction with associated hydrologic information.

SHOREBIRD NESTING PATTERNS

When choosing nesting locations, terns and plovers utilize riparian areas with little or no vegetative cover. In the northern and central Great Plains, these shorebirds nest along reservoir shorelines and rivers, preferring beaches and unvegetated sandbars. The reach of Missouri River from Fort Randall Dam to Springfield, SD has been identified as an 'Area of Essential Habitat' for both the piping plover (U.S. Fish and Wildlife Service 1988) and interior least tern (U.S. Fish and Wildlife Service 1990). The interior least tern is listed as an endangered species, while the Great Plains population of the piping plover is listed as threatened (U.S. Fish and Wildlife Service 1985a; U.S. Fish and Wildlife Service 1985b). Historic distribution of the interior least tern included riparian areas over the entire Great Plains region. Terns were present from Texas to Montana and from eastern Colorado and New Mexico to southern Indiana (U.S. Fish and Wildlife Service 1990). The historic distribution of the Great Plains population of the piping plover included the states of Montana, Wyoming, Nebraska, South Dakota, and North Dakota. Small populations also existed in Iowa, Colorado, and New Mexico (U.S. Fish and Wildlife Service 1988). Habitat losses and reduced populations have caused the two shorebirds to utilize only a fraction of their former range (Figure 1). By 1988, no known breeding of interior least terns was occurring in Louisiana, most of Iowa, and most of Missouri. In states where breeding continued, the range had been greatly reduced. Similar reductions in the known nesting range of the piping plover were documented by Whitman (1988). Current distribution of the piping plover includes limited areas of eastern Montana, North and South Dakota, Nebraska, and Iowa. While wintering occurs primarily along the Gulf Coast, the habitat areas in the Great Plains are critical as feeding and nesting sites during late spring and early summer (Dryer & Dryer 1985; U.S. Fish and Wildlife Service 1988). Recovery goals for these shorebirds include developing management plans which outline steps required to protect essential habitat areas and attain stable population levels, eventually permitting removal of the species from the endangered species list (U.S. Fish and Wildlife Service 1988; U.S. Fish and Wildlife Service 1990). Without effective management of these important reproductive regions, the recovery goals for the two species in the northern Great Plains will not be reached. Any management decision impacting this area must consider the presence of these species.

MISSOURI RIVER RESERVOIR SYSTEM

No longer in a natural state, the Missouri River is a complex system of reservoirs, levees, and other structures designed for several specific purposes. Fort Peck Dam, constructed during the mid-1930s in northeastern Montana, created the first reservoir built on the main stem of the Missouri. Assuring an adequate flow for downstream navigation was the primary purpose of this project. Other uses, such as power generation, were incidental (Ferrell 1993). The other five main stem dams below Fort Peck were created as multi-purpose projects, as outlined by the Flood Control Act of 1944 (the Pick-Sloan Plan). The Missouri basin reservoir system is managed as a unit to provide flood control,

Distribution of Interior Least Terns and Piping Plovers in the Northern Great Plains

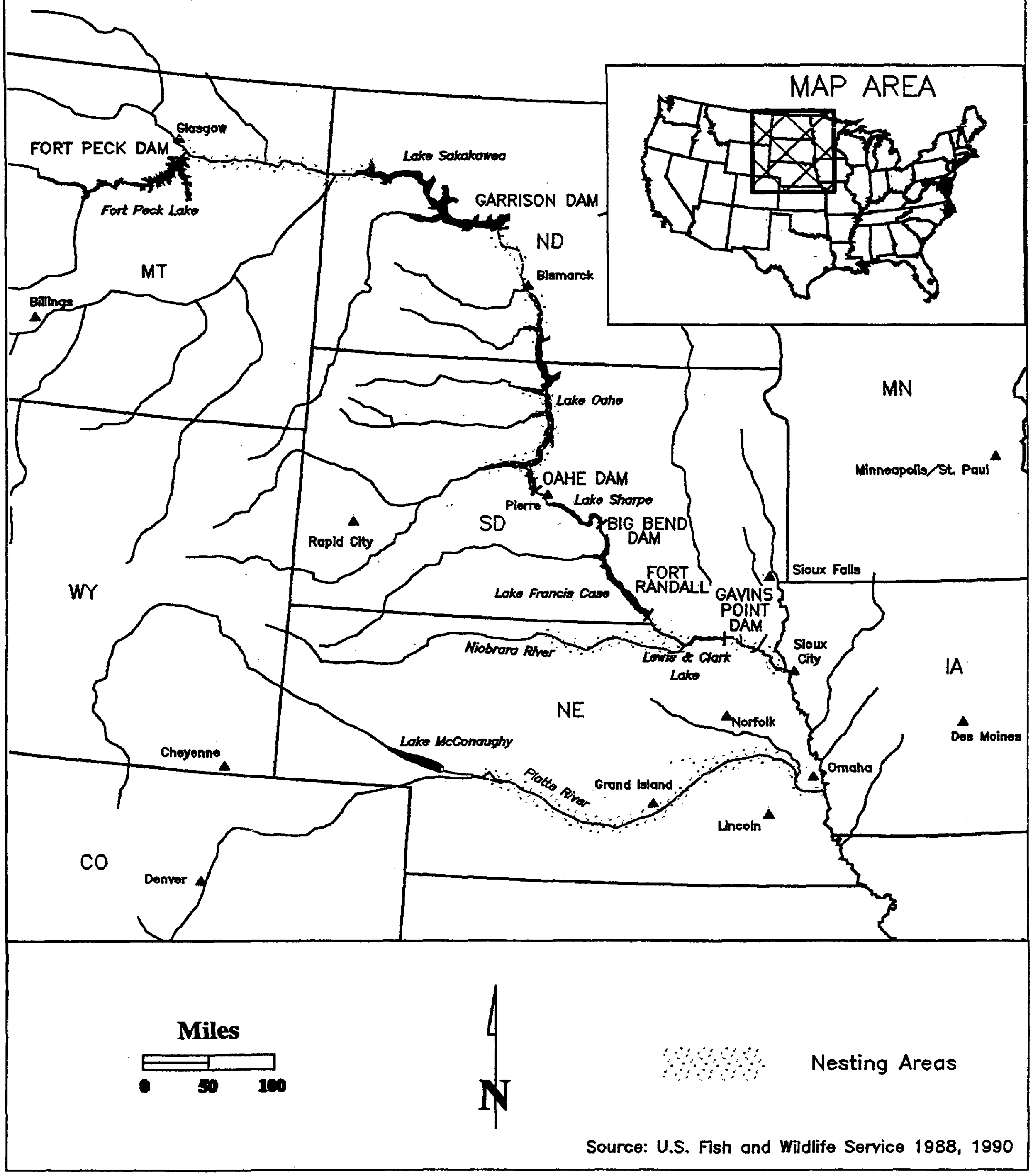

Figure 1

navigation, irrigation, hydropower, municipal and industrial water supply, recreation, and fish and wildlife habitat. Discharges from main stem dams have less variability than previous uncontrolled flows. The Army Corps of Engineers' Master Water Control Manual attempts to optimize flows for all project purposes. Because upstream states (Montana, North and South Dakota) derive Missouri River benefits primarily through recreation, they request that reservoir levels be kept high throughout the recreation season (summer). Conversely, the downstream states (Nebraska, Iowa, Kansas and Missouri) derive benefits from barge traffic and therefore request consistent, high releases from upstream dams to support navigation from April through November. Managing for multiple uses on the Missouri River is a complicated process subject to both natural and man-made influences.

Fort Peck Lake is the furthest upstream of the main stem Missouri River reservoir projects. The next project downstream from Fort Peck is Lake Sakakawea in North Dakota, then Lake Oahe in North and South Dakota, Lake Sharpe and Lake Francis Case in South Dakota, and Lewis and Clark Lake on the Nebraska/South Dakota border (Figure 2). The navigation channel begins near Sioux City, Iowa and extends to the confluence of the Missouri and the Mississippi Rivers, just above St. Louis, Missouri. An extensive system of levees, floodwalls, and other flood control structures is in place along the channelized section of river. The many tributaries of the Missouri River also have structures which protect municipal and agricultural interests.

The effects of channelization and reservoir construction upon wildlife habitat on the Missouri River floodplain have been substantial. Large, scouring floods have been essentially eliminated. The natural floodplain ecosystem was approximately ten times the current width, with numerous large islands and backwater areas away from the main channel (Ferrell 1993). Now largely gone, these off-channel areas had provided habitat

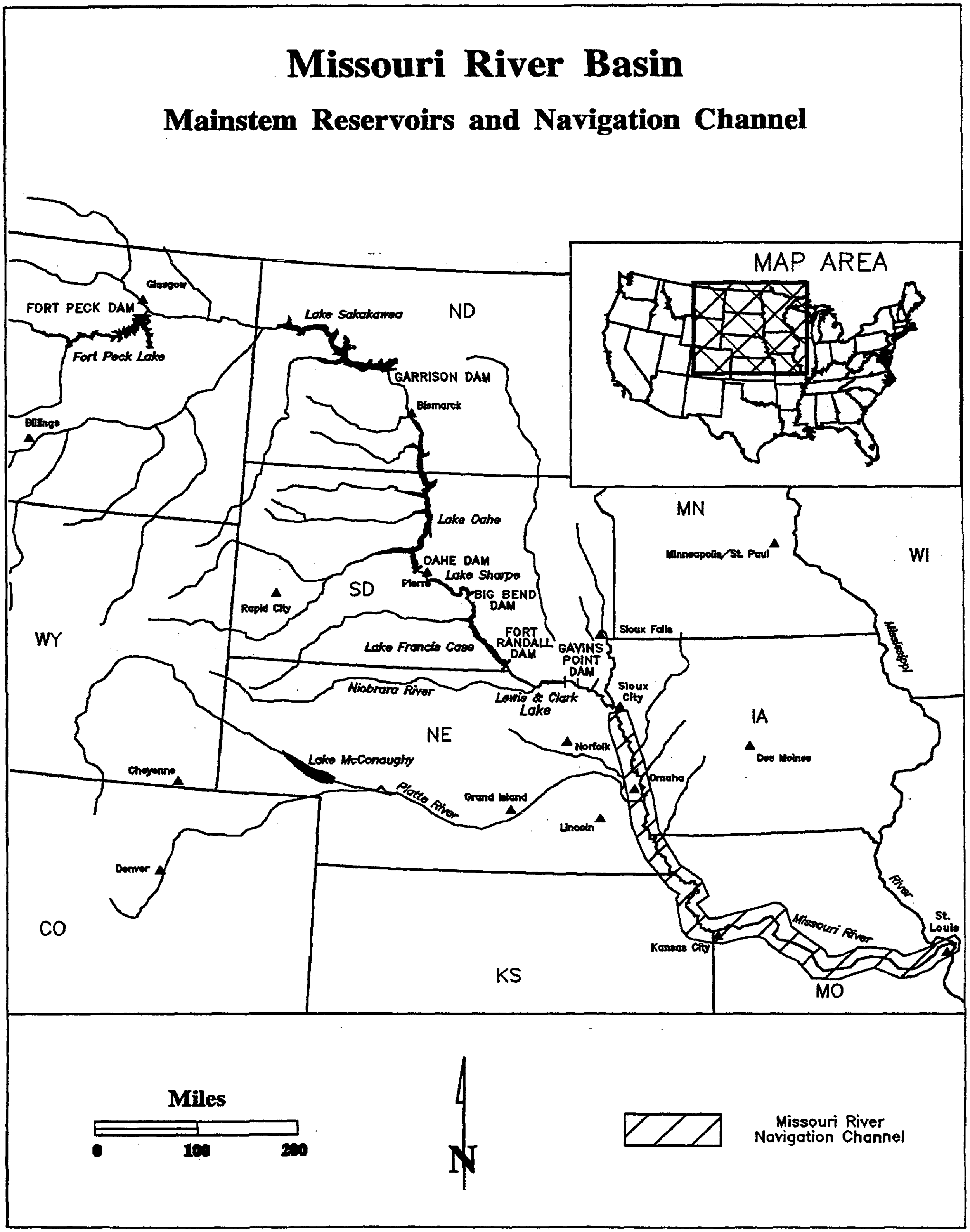
Missouri River Basin
Mainstem Reservoirs and Navigation Channel
MAP AREA
FORT PECK DAM
Glasgow
Fort Peck Lake
Lake Sakakawea
ND
GARRISON DAM
Bismarck
Billings
Lake Oahe
OAHE DAM
Lake Sharpe
Pierre
BIG BEND DAM
SD
Rapid City
WY
FORT RANDALL DAM
Lake Francis Case
GAVINS POINT DAM
Niobrara River
Lewis & Clark Lake
Sioux City
Sioux Falls
MN
Minneapolis/St. Paul
WI
Mississippi River
IA
Des Moines
NE
Norfolk
Lake McConaughy
Cheyenne
Platte River
Grand Island
Omaha
Lincoln
Denver
CO
KS
Kansas City
Missouri River
St. Louis
MO
Miles
0
100
200
N
Missouri River Navigation Channel

Figure 2

for fish, birds, and mammals. Channelization has shortened the river by 127 miles and increased the velocity of flow, allowing the river bed to be downcut. Channel degradation affects adjacent habitat areas by separating them from the main channel, their primary water source. Annual sediment loads for the Missouri River had been 150 to 200 million tons prior to dam construction and bank stabilization activities. With these structures in place, the river carries an average load of about 50 million tons (Ferrell 1993). Organic matter had been deposited regularly in riparian habitat areas, maintaining the natural cycle of nutrients through the system. Eroded sediment is now captured in the reservoirs or channel works (e.g. jetties, pile dikes). The main stem reservoirs permanently inundated 861 river miles, which included roughly 200,000 acres of riparian habitat. With the narrowing and deepening of the channel from Sioux City, IA to St. Louis, MO, habitat areas for the interior least tern and piping plover have been completely eliminated. As a result, shorebird habitat along the Missouri River has become a limited and valuable resource.

STUDY AREA

The area being examined is a portion of the Missouri River and the adjacent floodplain located on the Nebraska/South Dakota border between Fort Randall Dam and Lewis and Clark Lake (Figure 3). Four specific sites within this area will be studied. The Greenwood site (1960 River Mile [RM] 862; as measured from the mouth of the Missouri River just above St. Louis, MO) is located about 16 miles from Fort Randall Dam, and just downstream from Greenwood, SD. The Verdel site (RM 852) is located at the mouth of Choteau Creek, near Verdel, NE. This site is roughly 26 miles downstream from Fort Randall Dam. The Niobrara site (RM 844) is located 8 miles downstream from the Verdel site, at the confluence of the Missouri and Niobrara Rivers. The Bazile Creek site (RM

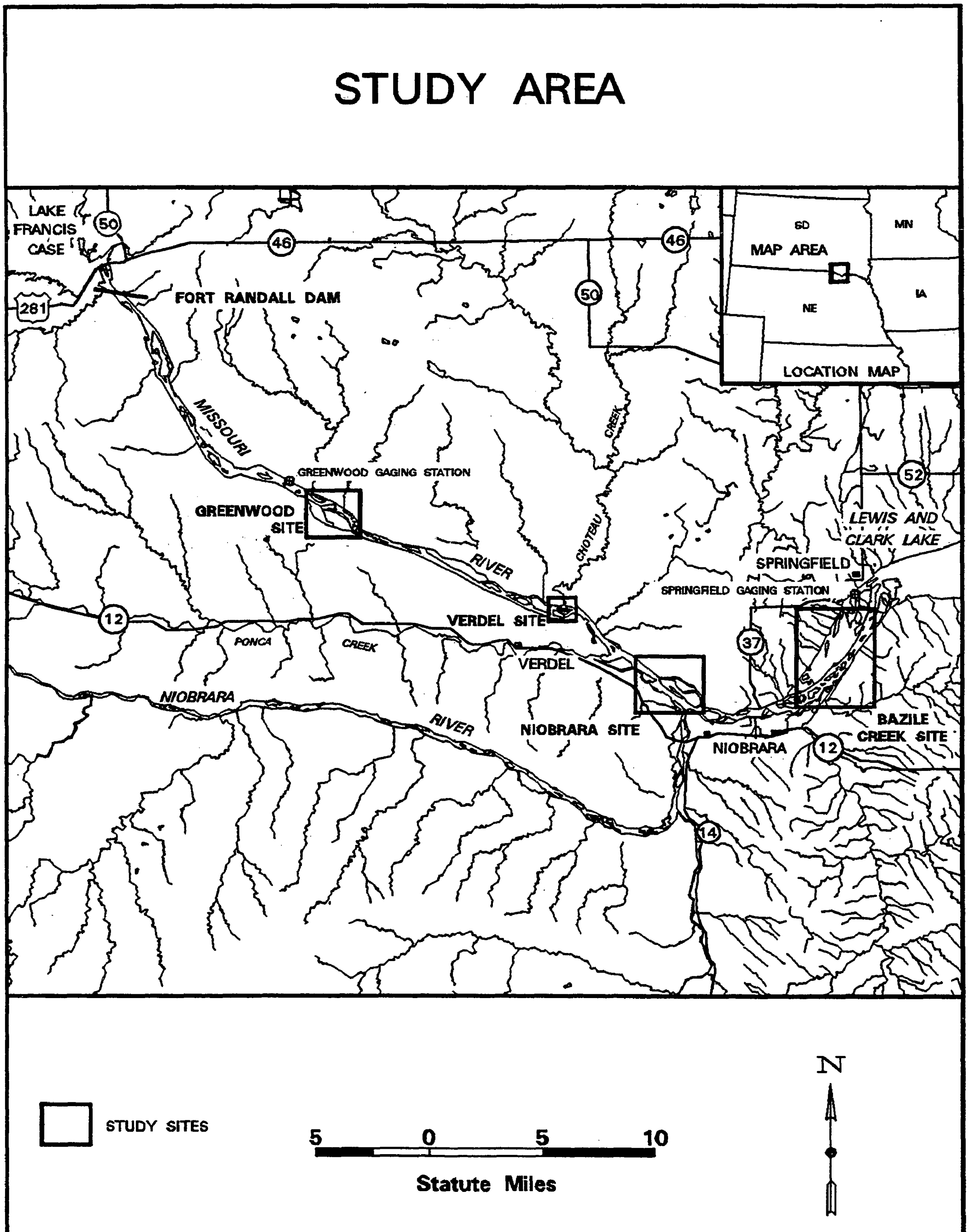
STUDY AREA
LAKE FRANCIS CASE
50
46
281
FORT RANDALL DAM
SD
MN
MAP AREA
NE
IA
LOCATION MAP
MISSOURI
RIVER
CREEK
CHOTEAU
GREENWOOD GAGING STATION
GREENWOOD SITE
52
LEWIS AND CLARK LAKE
SPRINGFIELD
SPRINGFIELD GAGING STATION
12
VERDEL SITE
PONCA
CREEK
37
VERDEL
NIOBRARA
RIVER
NIOBRARA SITE
BAZILE CREEK SITE
NIOBRARA
14
STUDY SITES
5 0 5 10
Statute Miles
N

Figure 3

838) is located just upstream from Springfield, SD, at the mouth of Bazile Creek. The sites vary in size between 1300 and 3200 acres. The bottomlands in this region are used primarily for agriculture and recreation (e.g. boating, fishing). In a few places the riverbank has been stabilized to protect small developments, but the area is generally undisturbed. Side channels and backwater areas are common. Numerous species of wildlife utilize the region, including whitetail deer, beaver, muskrat, raccoons, turtles, and a variety of birds. Other threatened or endangered species, such as the bald eagle (*Haliaeetus leucocephalus*), also use this area (Steenhof 1981).

This portion of the Missouri River is one of only two sections between Bismarck, ND and the mouth at St. Louis, MO which is neither channelized nor a reservoir. Both areas are now National Recreational rivers (Niobrara Scenic River Designation Act 1991). The first area stretches roughly 59 miles from Gavins Point Dam to near Ponca, Nebraska, and was designated a recreational river in 1978. The second stretch, which includes the 4 study sites, was designated in 1991. This reach of river is approximately 39 miles long. Both areas are currently co-managed by the Army Corps of Engineers and the National Park Service. The study area, along with Lewis and Clark Lake and the lower Niobrara River, is being considered for increased recreational usage because of the scenic beauty and the potential for becoming a regional vacation destination. The National Park Service is currently studying the area and preparing a management plan, with input from the Army Corps of Engineers, in order to determine an optimal operational alternative for all interests, public and private.

The Army Corps of Engineers has authority to release water from Lake Francis Case (Fort Randall Dam) and Lewis and Clark Lake (Gavins Point Dam) in accordance with its system regulation plan. In the fall period, releases from Lake Oahe and Lake Sharpe are decreased in order to lower the surface level of Lake Francis Case. The stored water is used for winter hydropower generation and for refilling Lake Francis Case prior to the start of the next navigation season (Ferrell 1993). Lewis and Clark Lake experiences very little fluctuation in water levels. Outflows from Gavins Point Dam generally match inflows and local runoff. In the study area, discharges from Fort Randall Dam determine the river stage at locations above the Niobrara River confluence. Below here, the stage is determined by the elevation of Lewis and Clark Lake. Choteau, Ponca and other small creeks contribute only minor amounts of runoff to the system. The Niobrara River mean discharge (uncontrolled) is 1500 cubic feet per second (c.f.s.) during the May to August period, compared to 32,400 c.f.s. for the Missouri River (Burr et al. 1992). The controlled flows out of Fort Randall Dam and the large volume of sediment from the Niobrara have caused extensive aggradation in the confluence area. Just downstream from the confluence, the average bed elevation has increased two to six feet and the cross-sectional channel area has decreased approximately forty percent (U.S. Army Corps of Engineers 1992). Missouri River water is essentially dammed by the Niobrara delta. With reduced velocity, the Missouri River no longer scours this region and is unable to transport the sediment downstream. The town of Niobrara and the Niobrara State Park have been relocated to higher ground due to the rise in the local water table. Prior to the move, basements in the town had as much as three feet of water in them (U.S. Army Corps of Engineers 1970). Another current Corps of Engineers study is evaluating alternatives to alleviate this aggradation problem.

Nesting areas of the interior least tern and piping plover have traditionally included riparian regions throughout the entire northern Great Plains. In the past 50 years, these areas have diminished in size because of dam construction and channelization of the Missouri River by the Army Corps of Engineers. The following chapters will examine past work related to this study, describe methods used, and show results.

II. LITERATURE REVIEW

A review of past works creates a foundation for this study. Previous studies on riverine land cover change in the Great Plains will be examined here, as well as work which describes the physical characteristics of shorebird habitat and those which discuss the use of GIS for habitat evaluation. This study will draw heavily from work done in each of these areas.

LAND COVER STUDIES

In the northern Great Plains, research on riverine land cover change has largely involved the Platte River. Several studies focusing on land cover change in the Platte River Valley, including Williams (1978), Eschner et al. (1981), Currier et al. (1985) and Peake et al. (1985), were summarized by Sidle et al. (1989). Among the studies, various methods were used to assess habitat changes over time from aerial photographs and land surveys. Each study identified substantial changes in floodplain vegetation, particularly the decrease in the amount of unvegetated sandbars and the narrowing of the river channel. Peake et al. (1985) analyzed the changes in riverine habitat/land cover classes along the Platte River in central Nebraska. The term 'total channel' was used to define the (currently) active river channel and sandbar areas. Vegetative encroachment was identified spatially and statistically. Similarly, the proposed study will identify and analyze changes in the 'total channel' area using land cover data along the Missouri River.

Bragg and Tatschl (1977) identified changes in floodplain vegetation along the Missouri River between 1826 and 1972. In the State of Missouri, large areas of the floodplain were already in cultivation when bank stabilization and channelization work by the Army Corps of Engineers began in 1912. This trend continued as the flood control system was constructed. Forested land decreased from 76 to 13 percent over the period, while cultivated land increased from 18 to 83 percent. Similarities were noted in species composition between the forest condition in 1826 and the mature forest stands of 1972. This suggests that mature forest stands were widespread in 1826. The authors also stressed the negative ecological implications of extensive floodplain alterations.

Currently, the Missouri River Division of the Army Corps of Engineers is reviewing the operation of the entire Missouri River system. Part of this study, the Master Water Control Manual update (U.S. Army Corps of Engineers 1994), examined wetland and riparian areas along the Missouri River from Fort Peck Dam in Montana to St. Louis, MO. The Corps sought to inventory current conditions and evaluate the effects of various water management alternatives. In 1991, detailed field surveys and mapping were performed to assess wetland/riparian habitat conditions at 41 study sites in nineteen separate reservoir, delta, and river reaches. Data from the study sites within a reach were compared with 1983 National Wetland Inventory (NWI) data. Changes were identified and applied to the entire reach. For example, if the aggregated data for study sites within a reach showed a 20% increase in a particular habitat category, the same increase was assumed to have occurred along the whole reach (including the areas not mapped in 1991). This operation was accomplished with GIS software and incorporated into a larger model. However, no maps were produced showing the changes at specific sites, nor was any information on the nature or extent of these changes directly evaluated. Work for the Corps study concentrated on determining the quantities and elevational distribution of wetland types. From this, acreages of specific wetland habitats could be estimated at various discharge levels. Further analysis focused on vegetative succession as determined by a series of discharge scenarios (U.S. Army Corps of Engineers 1994). By comparison, this thesis uses NWI and Army Corps of Engineers wetland data to locate and analyze specific land cover changes at four sites along the Missouri River. Hydrologic data from this area is also used in the analysis. Impacts upon shorebirds are determined from the land cover changes. The wetland data utilized were the only large-scale land cover data sets available for this region.

SHOREBIRD HABITAT

Research into shorebird activity in the Great Plains is increasing. Numerous surveys have been undertaken in the last five to ten years. Because of similar nesting habitat requirements and activity patterns, terns and plovers are often studied collectively. Both have been found to prefer riparian areas with a vegetative cover of less than 30% (U.S. Fish and Wildlife Service 1988; Whitman 1988). Specifically, terns and plovers require several items in close proximity for nesting: a substrate of loose sand for creation of a nest scrape, a nearby water flow or lake to provide a food source, and favorable water levels during the nesting period (U.S. Fish and Wildlife Service 1981). It has also been noted that beach width and the abundance and distribution of vegetation and gravel are important factors affecting tern and plover habitat selection and reproductive success. One study indicated that "...wide beaches (> 20 m) with < 5% vegetative cover, with highly clumped vegetation and/or extensive gravel...provide suitable habitat..." (U.S. Fish and Wildlife Service 1988, p.29). Most nesting occurs on "...larger rivers with broad expanses and braided water channels..." (U.S. Fish and Wildlife Service 1981, p.37), but other areas are used, including salt flats (Grover 1979; Boyd 1980), sandy beaches near sand pits, (Swanson 1956; Wilson 1991), dredge piles (Moser 1940), and reservoir shorelines (Whitman 1988). Nests are normally located in areas where vegetation is completely absent, but have been found on sites with an average vegetative cover of up to 30% (Whitman 1988). In the northern Great Plains, these shorebirds nest along inland lake sites and prairie rivers, with beaches and dry, barren sandbars being the preferred habitat. Using the Cowardin wetland classification system (Cowardin et al. 1979), unvegetated sandbars and beaches can be easily identified. These areas are ideal nesting locations for terns and plovers.

Dryer and Dryer (1985) determined that habitat availability was not a limiting factor for terns in North Dakota. While the distribution of nesting sites can vary from year to year depending on location of available exposed sandbars, sufficient habitat was present. Other factors were therefore responsible for low tern populations observed at the study area. For any number of reasons, terns may have simply chosen to nest elsewhere.

Primary factors potentially affecting shorebird reproductive success are inundation and human disturbance. Fluctuating water levels (natural and artificial) during the nesting season become significant when shorebirds nest at an elevation too near the water surface. In the Great Plains, shorebird nesting generally begins between April and June and concludes by August. During this period, water levels generally rise in the study area (Figure 4). Stage changes can be as much as 3 to 4 feet over short periods between May and August (Burr et al. 1992). If flows are consistently high when nesting locations are selected, shorebirds are forced to nest at higher elevations and inundation is less likely. However, the amount of habitat available is decreased. If flows are low or variable, nesting can occur at lower elevations where a potentially greater risk of flooding exists. For this reason, biologists recommend steady, high flows be maintained on controlled river systems throughout April, May and June. The threat of inundation is also increased when, due to vegetative encroachment, shorebirds must move from traditional nesting areas to new ones (Weber and Martin 1991). These new areas may be at lower elevations or open to predators. Human disturbance is important when nesting areas are also popular recreation locations. Nests can be trampled by foot or by motorized vehicle. To help minimize human impacts, known nesting locations can be fenced or otherwise protected. Several other factors can influence fledging success, including weather, infertile eggs, and depredation from small mammals (Dryer and Dryer 1985). Of course, nothing can be done to alleviate these factors.

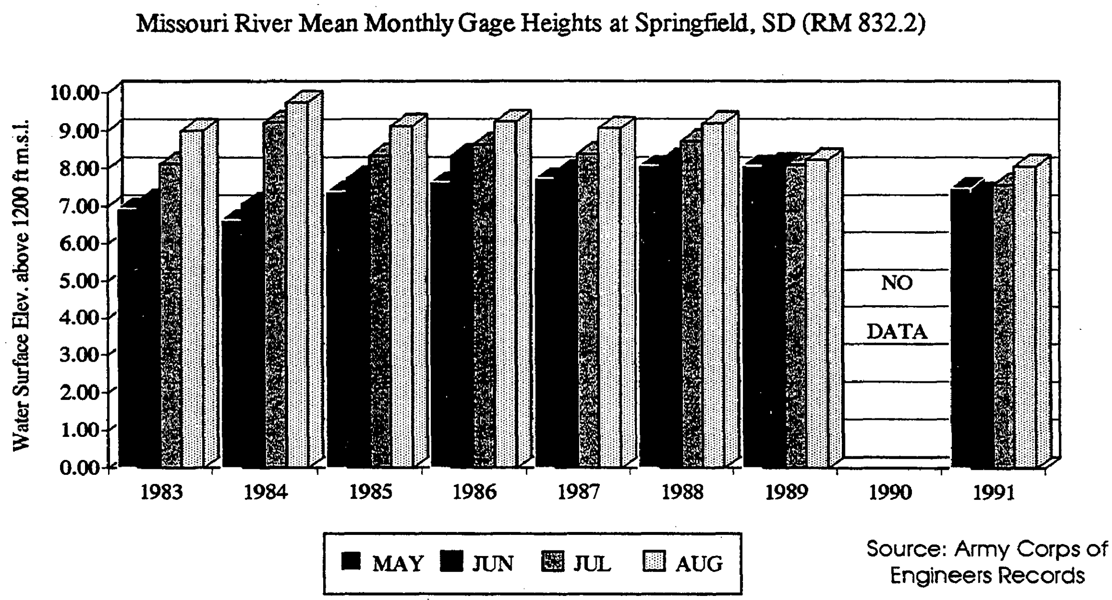

Figure 4

HABITAT EVALUATION USING GIS

Geographic Information Systems (GIS) are computer databases which permit the input, storage, analysis, display, and output of spatial information. The ability to perform locational analyses and identify spatial relationships separates GIS from other information systems. GIS is used for a wide variety of applications, one of which is the analysis of wildlife habitat conditions. Detailed knowledge of species habitat requirements and behavior patterns are of primary importance in any wildlife study. Herr and Queen (1993) used a classified Landsat Thematic Mapper (TM) image to develop a map of plant communities. This information was used to create a model for identifying potential nesting habitat of cranes in northern Minnesota. The authors found that even when plenty of optimal habitat areas existed, cranes still occasionally utilized sub-optimal areas. One explanation for the unexpected results is a lack of information regarding desired habitat components. Breininger et al. (1991) also stressed the importance of understanding the specific mechanisms affecting reproductive success and survival prior to development of a habitat model. This study used soil maps and land cover data (species and density) from color infrared aerial photographs to locate potential Florida scrub jay habitat areas. In addition to the land cover information, other data was needed to portray site-specific conditions. For instance, proximity to predator habitat was important in locating scrub jay habitat. In this thesis, potential habitat areas are identified solely by land cover information. However, hydrologic data is examined for the study period to assess local conditions and help explain land cover changes.

Numerous methods have been used to identify potential habitat areas for various species with geographic information systems. Roseberry et al. (1994) determined that potential bobwhite habitat quality on Conservation Reserve Program land in southeastern Illinois was largely a function of species composition and land management decisions. Spatial relationships between CRP land and other habitat components (woodlands, cropfields, etc.,) were also important. Aspinall and Veitch (1993) used bird survey data and a digital elevation model to classify a Landsat TM image using conditional probabilities on the presence or absence of the birds. The result was a habitat map based on the probable distribution of the species.

A study by Hodgson et al. (1988) analyzed the distribution, quantity and changes in wood stork habitat using classified TM data and GIS techniques. Land cover data was generated for two years and examined using a change matrix and a comparison of yearly area totals. The authors noted that GIS procedures can provide an excellent framework for habitat inventory and management for this endangered species. Similarly, this thesis will use a change matrix and yearly area totals to identify land cover changes and assess impacts upon protected shorebirds.

Past studies involving riverine land cover change, shorebird habitat identification, and GIS techniques for habitat evaluation have provided information which was used to develop the methodologies for this paper. From these earlier efforts, the physical requirements and preferences for tern and plover nesting have been identified, which include sandbars and shorelines with little or no vegetation. Ideally, these areas are isolated by water, elevation or dense vegetation to reduce potential reproductive threats. A specific land cover category is associated with the required habitat. Using GIS techniques, land cover changes are easily located and quantified. Impacts upon potential shorebird nesting habitat can then also be determined.

III. METHODOLOGY

This chapter outlines the methodology and describes in detail the data used. It also explains how the data were processed and what each procedure would accomplish.

ADVANTAGES OF GIS UTILIZATION

A GIS was deemed appropriate for this study for several reasons. First, the large amount of data being analyzed is handled much more easily and effectively by a GIS than any other method. The original wetland data for 1983 contained 373 polygons. After processing, the number of polygons for the study area was 224. The totals for 1991 were 541 and 229, respectively. Spatial data typically are classified by type or value and have a locational component that distinguishes them. Second, a GIS provides the opportunity to look at the data in a nearly infinite number of ways. For instance, wetland habitat data could be aggregated by any desired characteristic (e.g., flood frequency). Any grouping could be displayed and analyzed for utility. Third, a GIS also has the ability to quickly perform complex mathematical calculations, to combine digital products from various sources, and to provide storage and retrieval capabilities for future purposes.

DATA SOURCES AND DESCRIPTIONS

Digital data have been obtained from several sources to facilitate this study. U.S. Fish and Wildlife Service National Wetland Inventory (NWI) data were obtained for the area of interest. These data are derived through photointerpretive techniques using high altitude (normally 1:58,000 scale) color-infrared aerial photography and subsequent field verification (U.S. Fish and Wildlife Service 1993). The study area data were captured at a scale of 1:65,000 from photography dated May 1983. For 1991, data were obtained from the Army Corps of Engineers, Omaha District. This data set, from 1:12,000 scale color infrared aerial photography dated August 1991, contains wetland and riparian habitat information for four study sites between Fort Randall Dam and Lewis and Clark Lake (Figure 3). Both data sets were used in the Master Water Control Manual update (U.S. Army Corps of Engineers 1994). Similarities in these data made them especially useful for this thesis. Both data sets were interpreted from color infrared aerial photographs, both used the Cowardin wetland classification system, and both had some field verification process.

The NWI uses the Cowardin system of wetland habitat evaluation (Cowardin et al. 1979). It was adopted as the formal wetland classification system of the Fish and Wildlife Service in 1979 (U.S. Fish and Wildlife Service 1993). The Cowardin system uses a hierarchical arrangement based on physical characteristics of wetlands such as hydrology, geomorphology, vegetation, substrate, and water chemistry. Wetlands are classified with increasing specificity according to the following categories: System, Subsystem, Class, Subclass, and Modifier. The 1991 data set uses this system with minor modifications (e.g., riparian habitats are also included).

Hydrologic data was also collected for the study period. Mean, maximum, and minimum monthly discharges from Fort Randall Dam for April through August were obtained from U.S. Geological Survey and Army Corps of Engineers records. Mean daily river stages for the same period were also obtained for two gaging stations within the study area. One is located at Greenwood, SD, roughly 17 miles downstream from Fort Randall Dam. The other is located at Springfield, SD, approximately 45 miles downstream from Fort Randall Dam (Figure 3).

DATA PREPROCESSING

Several procedures were required in order to prepare the data for analysis. The wetland data for 1983 are stored by U.S. Geological Survey quadrangle. The study site data for 1991 was compared with the 1983 data to determine the required quads. The Greenwood site included data from two quads: Lynch NE and Marty. The Verdel site matched the geographic area of a portion of the Verdel quad. The Niobrara site matched part of the Niobrara quad and the Bazile Creek site matched a portion of the Springfield quad. The 1983 data were clipped at the upstream and downstream extent of the 1991 data set. The two data sets now covered the same area of the Missouri River.

DATA PROCESSING

The wetland data was aggregated using Arc/INFO software (ESRI, Inc. Redlands, CA) based upon the Cowardin wetland habitat Class. This part of the Cowardin wetland code, which describes either the vegetation or substrate, was used to assign land cover categories (Table 1). The four categories used in this analysis are (1) the 'total channel,' (2) early successional stage vegetation, (3) late successional stage vegetation, and (4) upland. These categories represent distinct levels of vegetative development and stability, as well as hydrology. Total channel is the category most influenced by water, while early stage, late stage, and upland are successively less influenced. As hydrologic influences decrease, vegetation becomes more stable.

The total channel category is easily identified by locating three wetland Classes: Unconsolidated Bottom, Unconsolidated Shore, and Streambed. The Class Unconsolidated Bottom includes areas of at least semi-permanent inundation "with at least 25% cover of particles smaller than stones [< 10"], and a vegetative cover less than 30%"

(Cowardin et al. 1979). The Class Unconsolidated Shore includes areas with the above characteristics except that the flood frequency is seasonal or less. Riverine areas classified with Unconsolidated Bottom and Unconsolidated Shore define water and (unvegetated) sandbar areas, respectively. The Class Streambed (in the Intermittent Subsystem of the Riverine System) includes areas where the flood regime is seasonal or less and the vegetative cover is less than 30% (Cowardin et al. 1979). Together, these three Classes represent the active river channel (or 'total channel').

The second category, early successional stage vegetation, can be identified by locating the following three wetland Classes: Emergent Wetland, Aquatic Bed, and Scrub-Shrub Wetland. The Class Emergent Wetland is characterized by perennial, herbaceous hydrophytes which are rooted, upright, and present during most of the growing season. The Class Aquatic Bed includes vegetation which grows primarily on or below the water surface in areas with seasonal to permanent flooding. The Class Scrub-Shrub Wetland consists of woody vegetation less than 6 m (20 ft) tall in any water regime (in freshwater environments). This may be a stable or successional community. These three Classes represent vegetation which prohibits shorebird nesting and has similar hydrologic characteristics.

The third category, late successional stage vegetation, is represented by the Class Forested Wetland. This Class identifies areas with woody vegetation over 6 m (20 ft) tall which meet the wetland hydrology criteria. Forested Wetlands normally have "an understory of young trees and shrubs and a herbaceous layer" (Cowardin et al. 1979).

The fourth category, upland, includes all non-wetland areas adjacent to or surrounded by wetlands. Any area not classified is considered upland. Riparian habitats were not identified in the 1983 data set. For consistency, all riparian habitats identified in the 1991 data set were classed as upland for this analysis.

By using the land cover types shown in Table 1, a more manageable and meaningful database for this study was created. Quantitative and qualitative changes in the land cover categories were then identified for each year. Assessments could then be made regarding impacts upon terns and plovers.

LAND COVER CATEGORIES	COWARDIN WETLAND CLASSES	
Total Channel (Potential Nesting Area)	SB (Streambed) UB (Unconsolidated Bottom) US (Unconsolidated Shore)	
Early Successional Stage Veg.	AB (Aquatic Bed) EM (Emergent Wetland) SS (Scrub-Shrub Wetland)	
Late Successional Stage Veg.	FO (Forested Wetland)	
Upland (Non-Wetland)	AG (Agricultural) RCF (Riparian Cottonwood Forest) RCS (Riparian Cottonwood Shrub) RF (Mixed Riparian Forest) RG (Riparian Grass) RS (Mixed Riparian Shrub) UPL (Upland)	[Non-Cowardin communities]

Wetland Habitat Data Aggregation

Table 1

Once the data were aggregated into land cover categories, an overlay analysis was performed for each site. This process created a new Arc/INFO coverage (file) in which each polygon was coded with one land cover attribute for each of the two years. Following this procedure, areas existed which had not been mapped (coded) during one of the years. All such areas were coded as upland. By doing so, the study would be examining the exact same area on the ground for two separate years. The percentage of a site occupied by a particular land cover category could now be compared.

Maps and reports showing changes were easily generated from this information. The output from several reports was translated into Excel (Microsoft Corp.) for further processing. A cross tabulation matrix of acreage changes was produced from the land cover data. Several graphs and tables were created to display the discharge data from Fort Randall Dam and the gage height data from the Greenwood and Springfield stations (mean monthly discharge and mean monthly gage height were utilized most heavily). These data are useful in determining general hydrologic conditions for the time period involved.

The use of GIS software provides an effective tool for identifying temporal changes in geographic phenomena, such as wildlife habitat. As described in this chapter, wetland habitat data for two different years were aggregated into land cover categories. The data were analyzed to determine land cover changes both spatially and numerically and compared with hydrologic data concurrent with the study period.

IV. ANALYSIS & RESULTS

The data used to analyze the land cover changes were derived through an overlay procedure. For each site, the coverage for 1983 was overlain with the coverage for 1991 to produce a new coverage containing the change information. It was then possible to display the changes in the form of a matrix. The matrix showed the amount of land which converted from one category to another. The matrices for each site were used together with maps of each site to show both numerical and spatial changes.

GREENWOOD - LAND COVER CHANGES AND HYDROLOGY

The furthest site upstream is Greenwood at RM 862, near Greenwood, South Dakota. It is roughly 16 miles downstream from Fort Randall Dam and 18 miles upstream from the Niobrara River (Figure 5).

The Greenwood site covered 1738 acres. In 1983, there were approximately 1061 acres of total channel, which accounted for 61 percent of the site (Table 2). The early successional stage category covered 147 acres, accounting for 8 percent of the area. There were also 106 acres of late successional stage vegetation (6 percent) and 424 acres of upland (24 percent).

In 1991, the Greenwood site had 756 acres of total channel. This now represented only 43 percent of the site and was just 71 percent of the 1983 acreage for this cover type. About 725 acres (68 percent) of the total channel area remained in this category over the period. Some 245 acres converted to early successional stage (23 percent of the 1983 total channel area). Approximately 91 acres converted to upland (9 percent).

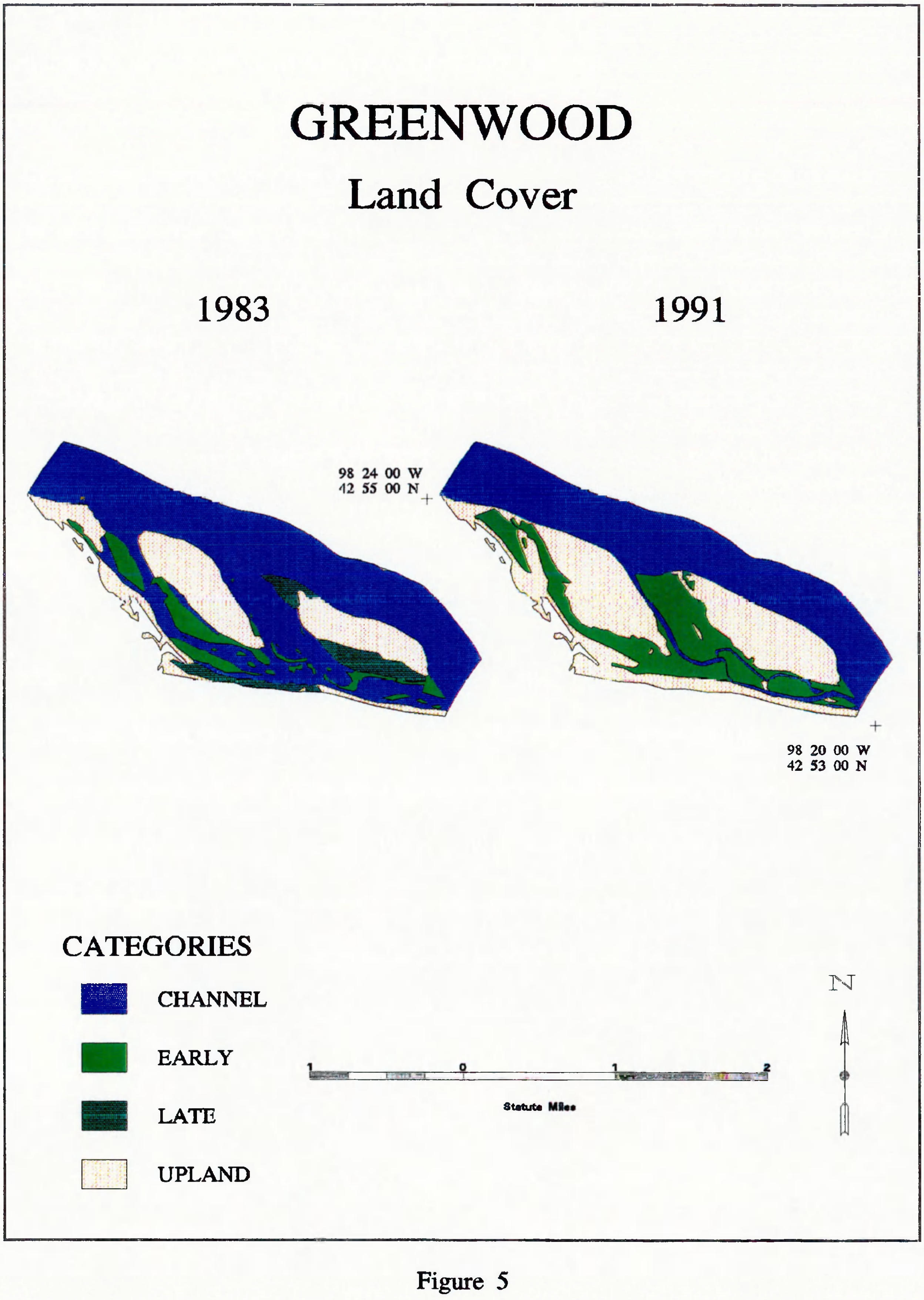
GREENWOOD
Land Cover
1983
1991
98 24 00 W
42 55 00 N
98 20 00 W
42 53 00 N
CATEGORIES
CHANNEL
EARLY
LATE
UPLAND
1
0
1
2
Statute Miles
N

Figure 5

		1991 Cover Type				
		CHANNEL	EARLY	LATE	UPLAND	1983 TOTAL
1983	CHANNEL	725.24 (68%)	245.37 (23%)	0.0 (0%)	90.87 (9 %)	1061.49 (61%)
Cover	EARLY	12.06 (8 %)	60.70 (41%)	0.0 (0%)	73.78 (50%)	146.54 (8 %)
Type	LATE	0.07 (<1%)	9.75 (9 %)	0.0 (0%)	95.95 (91%)	105.77 (6 %)
	UPLAND	18.13 (4 %)	28.53 (7 %)	0.0 (0%)	377.58 (89%)	424.24 (24%)
	1991 TOTAL	755.51 (43%)	344.36 (20%)	0.0 (0%)	638.17 (37%)	1738.04 (100%)

Acreage Change Matrix - Greenwood Site (acres)

Percentage figures represent the percentage of each category in 1983 which changed to the appropriate category in 1991. Percentage totals show the percentage of the site belonging to each category in each year.

Table 2

The early successional stage category covered 344 acres in 1991. This now represented 20 percent of the site and was 235 percent of the 1983 acreage. Roughly 61 acres (41 percent) remained in this class over the period, 74 acres (50 percent) converted to upland and 12 acres (8 percent) became total channel.

The late successional stage category was not found on the site in 1991. Most of this cover type converted to upland (96 acres, 91 percent). Roughly 10 acres (9 percent) changed to early successional stage over the period.

The upland category covered 638 acres (37 percent of the site) in 1991. This represented 150 percent of the 1983 acreage. A total of 378 acres (89 percent) were coded as upland in 1983 and remained so in 1991, 29 acres (7 percent) converted to early successional stage, and 18 acres (4 percent) changed to total channel.

A gaging station trend analysis by the Corps of Engineers (1992) determined no consistent change in river stage elevation at the Greenwood gage (RM 865) between 1960 and 1990. This study used channel cross sections, dam discharges and gage height readings to calculate stage elevation for three common discharges (20,000, 30,000, and 40,000 c.f.s.). Missing data prohibited stage calculations for several short periods, including 1987 to 1990. The trend for 1983 to 1987 showed relatively stable stages. Only minimal degradation of less than half a foot had occurred in this section of the Missouri River. Therefore, dam releases over the study period should correlate well with available gage height information and help characterize local hydrologic conditions. Fort Randall Dam mean monthly discharges for the period 1983 to 1990 showed a slight decrease compared to the longer term (1967 to 1987) figures. This decrease ranges from 5000 c.f.s. in May to 6400 c.f.s. in August (Figure 6). The maximum and minimum discharges for the study period are also considerably lower than those of the long term. These lower figures indicate that sandbars and shorelines above a certain elevation have not been scoured during the study period. Vegetative encroachment would be expected and indeed has occurred (Figure 5).

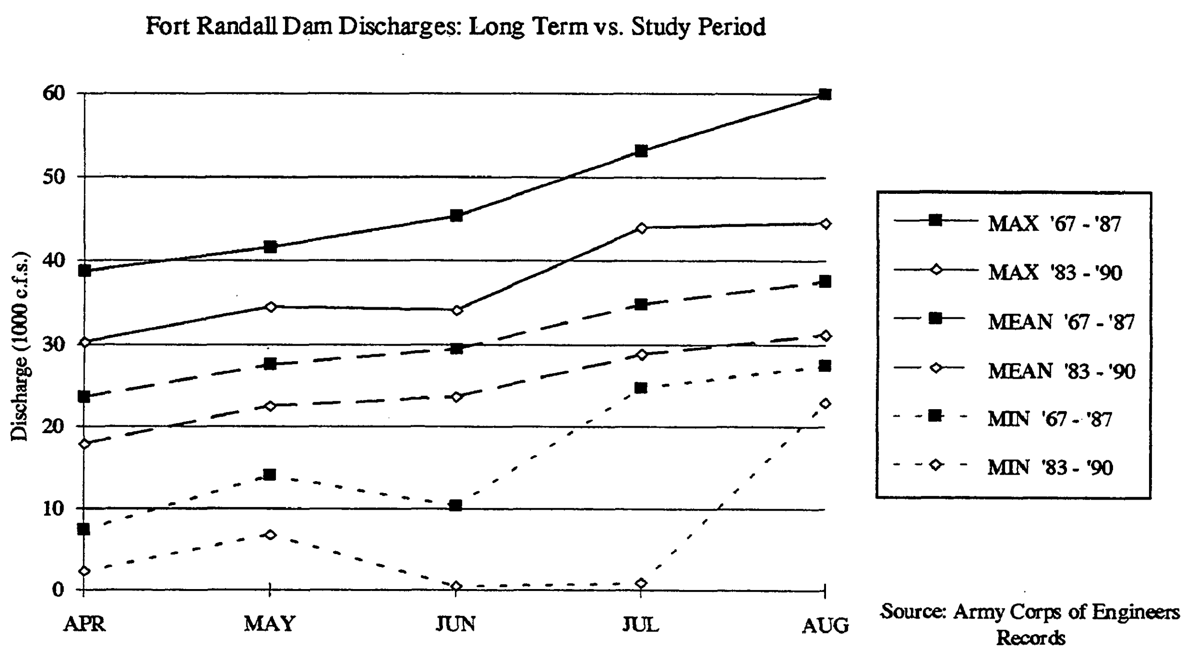

Figure 6

An examination of the specific land cover changes at the Greenwood site identified a substantial narrowing of the river channel. Two large side channels present in 1983 have almost completely converted from the total channel category to early successional stage. As noted above, this represented a loss of 23 percent of the 1983 total channel area. Other large changes include 91 acres (9 percent) of total channel, 74 acres (50 percent) of early stage vegetation and 96 acres (91 percent) of the late stage vegetation converting to upland. These changes indicate rapid vegetational succession and changing hydrologic conditions. The decrease in discharges over the study period appears to be enough to allow vegetative encroachment in these side channel areas. The reductions in maximum discharge would correspond to stage reductions of approximately 1 to 3 feet which seem adequate to prevent scouring of the side channels. At the upstream end of the site, an upland area has formed on the right bank which has completely cut off an adjacent early stage vegetation area from the main channel. If current hydrologic conditions persist, this side channel area will most likely become upland, just as surrounding areas have done. If dam discharges increase for an extended period, these side channel areas may once again carry water and be a part of the active channel.

VERDEL - LAND COVER CHANGES AND HYDROLOGY

The next site downstream is Verdel at RM 852, near Verdel, Nebraska. It is roughly 26 miles downstream from Fort Randall Dam and 8 miles upstream from the Niobrara River (Figure 7).

The Verdel site covered 1330 acres. In 1983, there were approximately 744 acres of total channel, which accounted for 56 percent of the site (Table 3). The early successional stage covered 341 acres, accounting for 26 percent of the site. There was also less than one acre of late successional stage and 245 acres (18 percent) of upland.

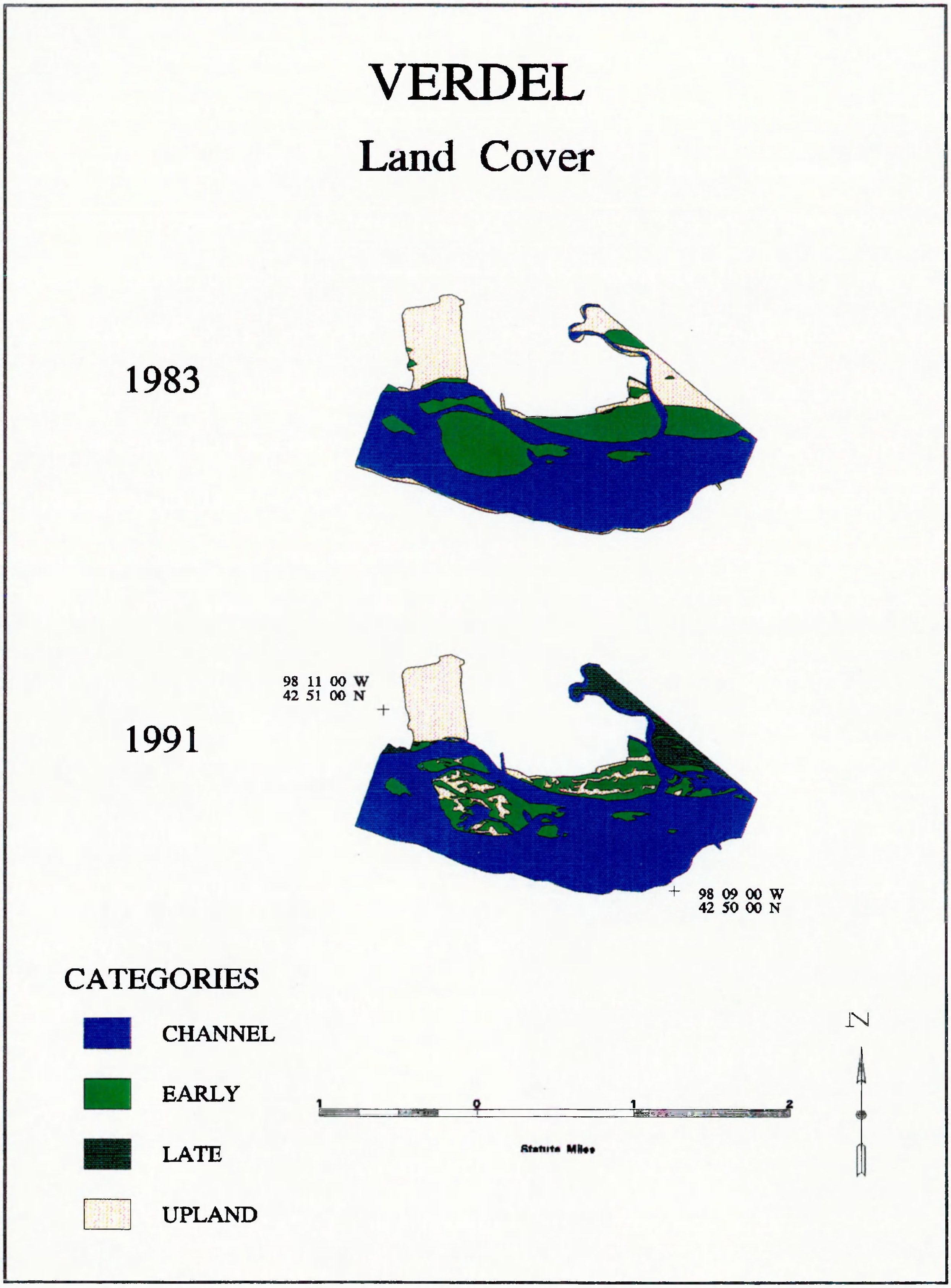
VERDEL
Land Cover
1983
1991
98 11 00 W
42 51 00 N
98 09 00 W
42 50 00 N
CATEGORIES
CHANNEL
EARLY
LATE
UPLAND
1
0
1
2
Statute Miles
N

Figure 7

		1991 Cover Type				
		CHANNEL	EARLY	LATE	UPLAND	1983 TOTAL
1983	CHANNEL	715.22 (96%)	21.42 (3 %)	4.09 (1 %)	3.07 (<1%)	743.80 (56%)
Cover	EARLY	69.24 (20%)	193.85 (57%)	14.14 (4 %)	63.31 (19%)	340.54 (26%)
Type	LATE	0.00 (0 %)	0.73 (88%)	0.00 (0 %)	0.10 (12%)	0.83 (<1%)
	UPLAND	30.88 (13%)	16.57 (7 %)	69.87 (29%)	127.76 (52%)	245.08 (18%)
	1991 TOTAL	815.33 (61%)	232.57 (17%)	88.11 (7 %)	194.24 (15%)	1330.25 (100%)

Acreage Change Matrix - Verdel Site (acres)

Table 3

In 1991, the Verdel site had 815 acres of total channel. This now represented 61 percent of the site and was 110 percent of the 1983 acreage for this cover type. Over the period, most of this category (96 percent) remained total channel. Some 21 acres converted to early successional stage (3 percent of the 1983 total channel area). Even smaller amounts converted to late stage and upland.

The early successional stage category covered 233 acres in 1991. This now represented 17 percent of the site and was 68 percent of the 1983 acreage. Roughly 194 acres (57 percent) remained in this class over the period, 14 acres (4 percent) converted to late stage, 63 acres (19 percent) converted to upland, and 69 acres (20 percent) became total channel.

The late successional stage covered 88 acres in 1991. This represented 7 percent of the site and was up from less than one acre in 1983.

The upland category covered 194 acres (15 percent of the site) in 1991. This represented 79 percent of the 1983 acreage. A total of 128 acres (52 percent) were coded as upland in 1983 and remained so in 1991, 70 acres (29 percent) converted to late successional stage, 31 acres (13 percent) became total channel, and 17 acres (7 percent) changed to early successional stage.

The gaging station trend analysis performed by the Army Corps of Engineers (1992) identified a steady increase in stage between 1977 and 1990 at the Verdel gage (RM 846.5). Increases ranged from 1.2 feet at 30,000 c.f.s. to 1.9 feet at 40,000 c.f.s.. This gage, located only 3 miles upstream from the Niobrara River confluence, is affected by the aggradation occurring in that area. The Verdel study site is located another 5 miles upstream from this gage and appears to be unaffected.

An examination of the specific land cover changes at the Verdel site identifies substantial variations within the early stage category. Areas of early stage vegetation have converted to upland (63 acres, 19 percent of 1983 early stage acreage) and to total channel (69 acres, 20 percent). Early stage vegetation coverage dropped from 26 percent of the site in 1983 to 17 percent in 1991 (a loss of 108 acres). With decreased flows in the area, some areas with sufficient elevation were no longer scoured. These areas converted to upland. Other areas were at lower elevations and did experience scouring, accounting for the areas that converted to total channel.

NIOBRARA - LAND COVER CHANGES AND HYDROLOGY

The next site downstream is Niobrara at RM 844, near Niobrara, Nebraska. It is roughly 34 miles downstream from Fort Randall Dam and is at the confluence of the Missouri and Niobrara Rivers (Figure 8).

The Niobrara site covered 3147 acres. In 1983, there were approximately 954 acres of total channel, which accounted for 30 percent of the site (Table 4). The early successional stage covered 1029 acres, accounting for 33 percent of the site. There were also less than two acres of late successional stage and 1163 acres (37 percent) of upland.

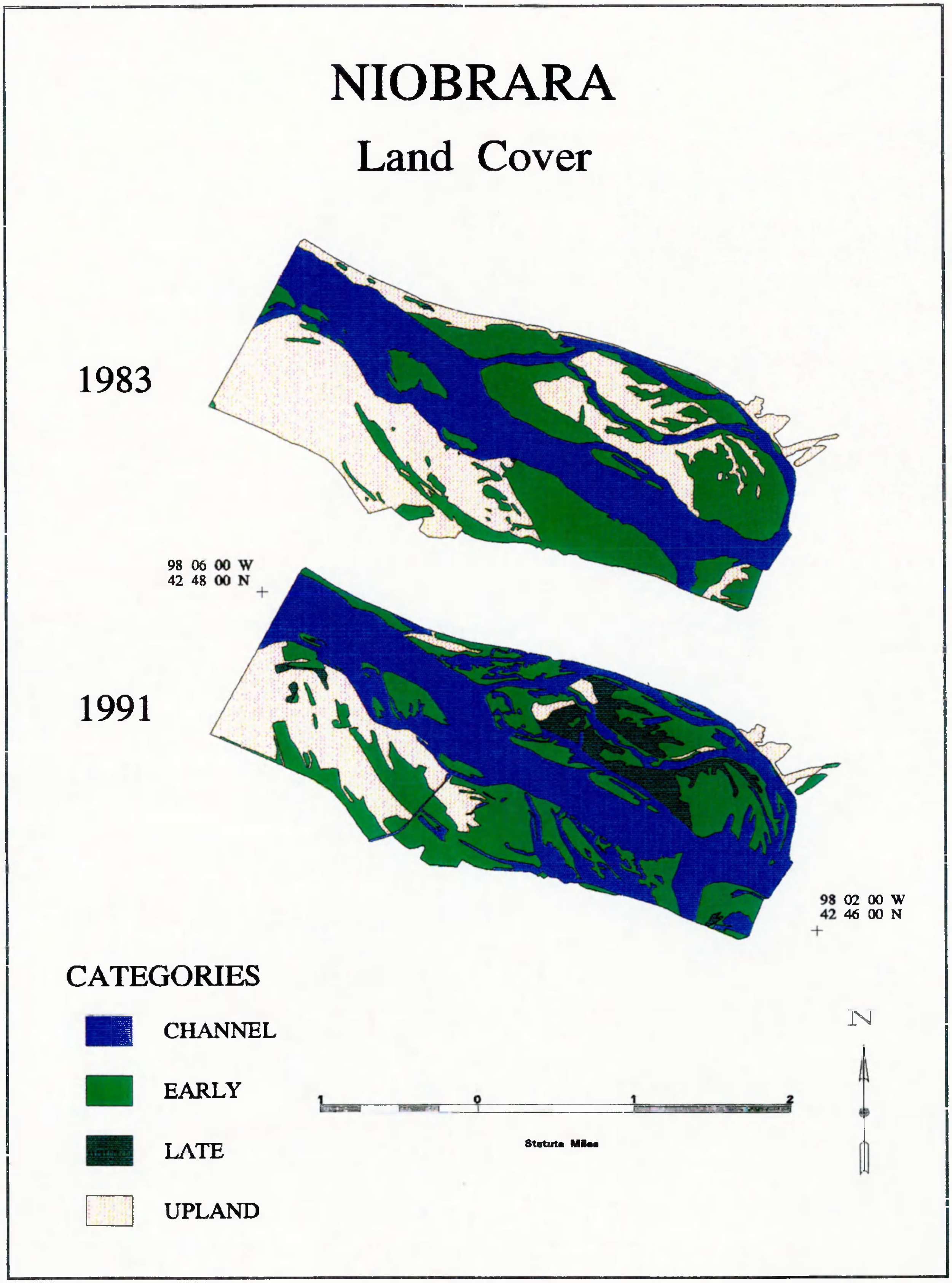
NIOBRARA
Land Cover
1983
1991
98 06 00 W
42 48 00 N
98 02 00 W
42 46 00 N
CATEGORIES
CHANNEL
EARLY
LATE
UPLAND
1
0
1
2
Statute Miles
N

Figure 8

		1991 Cover Type				
		CHANNEL	EARLY	LATE	UPLAND	1983 TOTAL
1983	CHANNEL	858.25 (90%)	81.98 (9 %)	5.52 (1 %)	8.26 (1 %)	954.01 (30%)
Cover	EARLY	368.90 (36%)	626.16 (61%)	20.71 (2 %)	13.52 (1 %)	1029.29 (33%)
Type	LATE	0.25 (16%)	0.59 (36%)	0.00 (0 %)	0.80 (49%)	1.64 (<1%)
	UPLAND	69.82 (6 %)	407.98 (35%)	172.48 (15%)	512.22 (44%)	1162.50 (37%)
	1991 TOTAL	1297.23 (41%)	1116.71 (35%)	198.70 (6 %)	534.79 (17%)	3147.43 (100%)

Acreage Change Matrix - Niobrara Site (acres)

Table 4

In 1991, the Niobrara site had 1297 acres of total channel. This now represented 41 percent of the site and was 136 percent of the 1983 acreage for this cover type. Over the period, most of this category (90 percent) remained total channel. Some 82 acres converted to early successional stage (9 percent of the 1983 total channel area). Smaller amounts converted to late stage and upland.

The early successional stage category covered 1117 acres in 1991. This now represented 35 percent of the site and was 108 percent of the 1983 acreage. Roughly 626 acres (60 percent) remained in this class over the period, 369 acres (36 percent) became total channel, and the remainder (less than 4 percent) converted to late stage and upland.

The late successional stage covered 199 acres in 1991. This represented 6 percent of the site and was up from less than two acres in 1983.

The upland category covered 535 acres (17 percent of the site) in 1991. This represented 46 percent of the 1983 acreage. A total of 512 acres (44 percent) were coded as upland in 1983 and remained so in 1991, 408 acres (35 percent) changed to early successional stage, 172 acres (15 percent) converted to late successional stage, and 70 acres (6 percent) became total channel.

The gaging station trend analysis by the Army Corps of Engineers (1992) identified a general trend of increasing stage elevation at the Verdel gage (RM 846.5) and at the Niobrara gage (RM 842.9). The Niobrara study site covers virtually the entire area along the Missouri River between these two gages. In the 1992 analysis, other hydraulic parameters were calculated to help characterize the area. Average bed elevations showed general increases between 1954 and 1985. Also identified were decreases in cross sectional area and reductions in channel depth of 2 to 5 feet.

An examination of the specific land cover changes at the Niobrara site identifies substantial changes in each of the categories. The early stage lost roughly 40 percent (403 acres) over the period but gained back 491 acres from the other three categories. This resulted in an overall increase in coverage of 8 percent. Much of the area lost from this category was converted to total channel. The majority of the area gained was from upland. An additional 252 acres was converted from upland to total channel and late successional stage vegetation. These changes are all largely explained by the high volume of sediment being deposited by the Niobrara River. The sediment in this area cannot be moved downstream without occasional scouring discharges (which have not occurred since the closure of Fort Randall Dam). Average discharges during the study period were lower than the long term average (1967 to 1987). Even with decreased discharges, large areas were converted from upland to wetland at this site. This indicates rising water levels and generally wetter conditions in the area. Water flowing down the Missouri approaches the confluence area and loses velocity due to the reduced channel capacity. The result is a backwater effect over the entire confluence area. As seen on the map of this site (Figure 8) and in Table 4, the total channel and late successional stage categories have increased greatly. Large areas of early stage vegetation changed to total channel, while backwater areas (both early and late stage vegetation) expanded by overtaking upland.

BAZILE CREEK - LAND COVER CHANGES AND HYDROLOGY

The furthest site downstream is Bazile Creek at RM 838, 5 miles upstream from Springfield, South Dakota. It is roughly 40 miles downstream from Fort Randall Dam and is 6 miles downstream from the confluence of the Missouri and Niobrara Rivers (Figure 9).

The Bazile Creek site covered 3198 acres. In 1983, there were approximately 1120 acres of total channel, which accounted for 35 percent of the site (Table 5). The early successional stage covered 1785 acres, accounting for 56 percent of the site. There were also 96 acres (3 percent) of late successional stage and 198 acres (6 percent) of upland.

		1991 Cover Type				
		CHANNEL	EARLY	LATE	UPLAND	1983 TOTAL
1983	CHANNEL	997.87 (89%)	121.06 (11%)	0.00 (0 %)	.79 (<1%)	1119.73 (35%)
Cover	EARLY	180.99 (10%)	1558.76 (87%)	9.96 (1 %)	35.72 (2 %)	1785.42 (56%)
Type	LATE	2.06 (2 %)	44.11 (46%)	33.24 (35%)	16.33 (17%)	95.74 (3 %)
	UPLAND	7.57 (4 %)	60.65 (31%)	0.00 (0 %)	129.27 (66%)	197.49 (6 %)
	1991 TOTAL	1188.49 (37%)	1784.59 (56%)	43.20 (1 %)	182.11 (6 %)	3198.39 (100%)

Acreage Change Matrix - Bazile Creek Site (acres)

Table 5

In 1991, the Bazile Creek site had 1189 acres of total channel. This now represented 37 percent of the site and was 106 percent of the 1983 acreage for this cover type. Over the period, most of this category (89 percent) remained total channel. The remainder, some 121 acres, converted to early successional stage (11 percent of the 1983 total channel area).

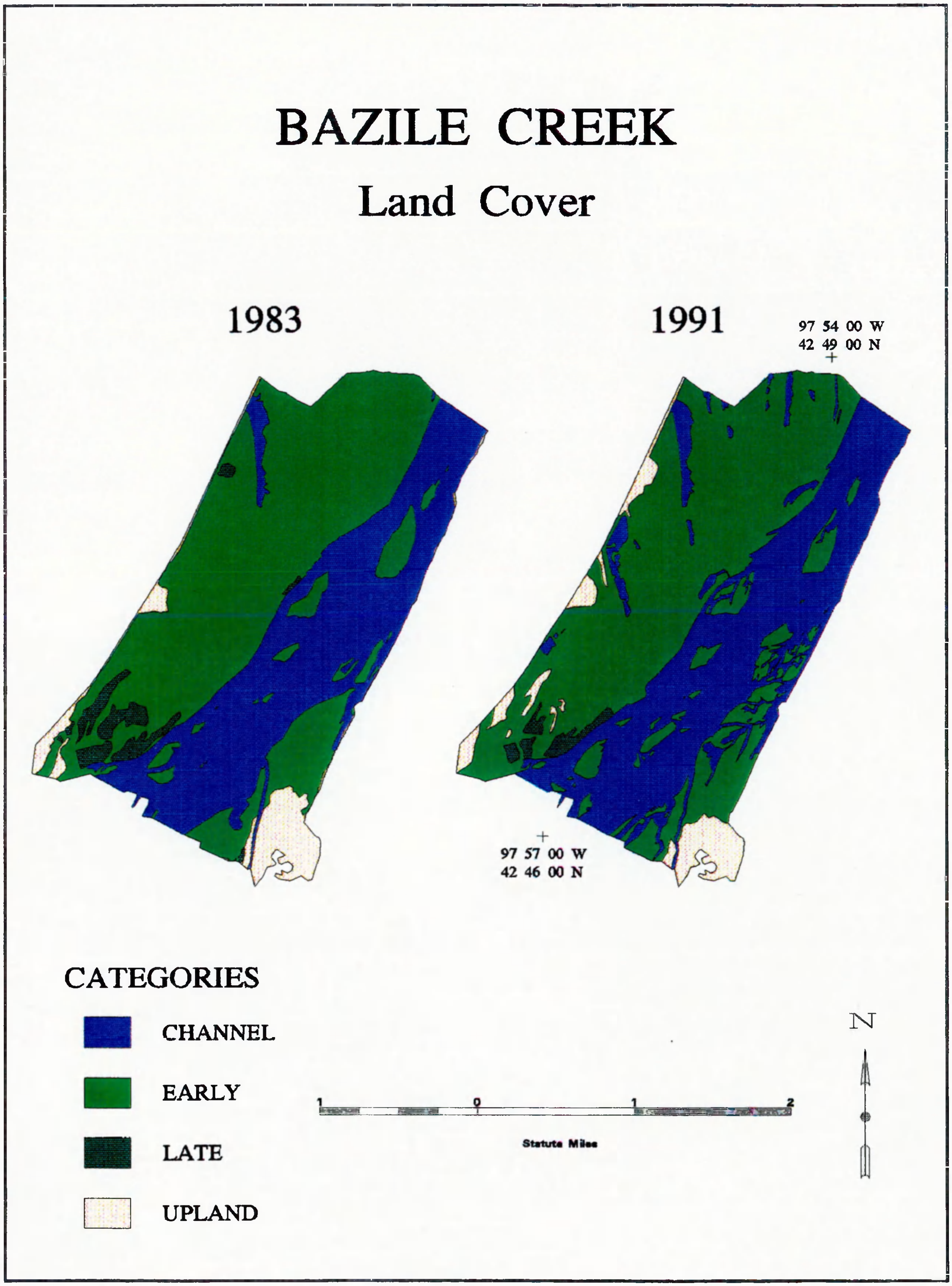
BAZILE CREEK
Land Cover
1983
1991
97 54 00 W
42 49 00 N
97 57 00 W
42 46 00 N
CATEGORIES
CHANNEL
EARLY
LATE
UPLAND
1
0
1
2
Statute Miles
N

Figure 9

The early successional stage category again covered 1785 acres in 1991 (56 percent of the site). 1559 acres (87 percent) remained in this class over the period, 181 acres (10 percent) became total channel, and the remainder (less than 3 percent) converted to late stage and upland.

The late successional stage covered 43 acres in 1991. This represented just over 1 percent of the site and was 45 percent of the 1983 acreage. The majority of the lost acreage (44 acres, 46 percent) was converted to early stage vegetation.

The upland category covered 182 acres (6 percent of the site) in 1991. This represented 92 percent of the 1983 acreage. A total of 129 acres (66 percent) were coded as upland in 1983 and remained so in 1991, 61 acres (31 percent) changed to early successional stage and 8 acres (4 percent) became total channel.

The Army Corps of Engineers (1992) analyzed the aggradation occurring near the mouth of the Niobrara River. The study identified an increase in average bed elevation of between 2 and 6 feet downstream from the confluence of the Missouri and Niobrara Rivers between 1954 and 1985. It also identified a similar reduction in channel depth and related decreases in cross sectional area.

An examination of the specific land cover changes at the Bazile Creek site identifies only minor changes over the study period. The total channel and early successional stage categories represented 91 percent of the site in 1983 and 93 percent in 1991. In 1983, there was more of a homogeneous total channel area. By 1991, there was more total channel found interspersed within early stage regions. This was true both adjacent to the main channel and in off-channel areas.

The sediment originally dropped at the mouth of the Niobrara River is slowly being transported downstream through the Bazile Creek study area. Stream flow velocity is low in this area due to both the Niobrara delta and the proximity of Lewis and Clark Lake.

Another large delta has formed in the headwaters of this lake. The entire area between the towns of Springfield and Niobrara has experienced aggradation and rising water levels. With this trend of increasingly wetter conditions, adjacent upland areas would be expected to convert to wetland. Upland areas did show a slight decrease. Given similar future conditions, this should continue.

UPSTREAM SITES VS. DOWNSTREAM SITES

Hydrologic conditions along the study reach are influenced by several factors. The two upstream sites are generally controlled by releases from Fort Randall Dam. The two downstream sites are more affected by the Niobrara delta and Lewis and Clark Lake. Because of these separate influences, different land cover changes were observed throughout the study area.

The Greenwood and Verdel sites are part of the Missouri River which has experienced little overall change in channel geometry during the study period. While individual sandbars change size and location continually, this stretch of river has not undergone any consistent change in stage (U.S. Army Corps of Engineers 1992). Therefore, discharges from Fort Randall Dam in 1991 had the same relationship to river levels (gage heights) in this area that they had in 1983. Because of the relative stability in channel morphology in this reach of river, dam discharges act as a good indicator of local hydrologic conditions. Increased local or regional precipitation would have an effect on mean monthly gage heights only if the event occurred over an extended period. Gage height data, although sporadically available, did not exhibit any unexpected figures in this area (Burr et al. 1992). Between 1983 and 1991, mean monthly discharge was substantially lower than the longer term (1967 - 1987) average (Figure 6).

Hydrologic conditions (i.e., Missouri River stages) at the two upstream sites permitted land cover changes (vegetative succession) to occur overwhelmingly in one direction: toward later successional stages. For instance, large areas of total channel converted to early stage vegetation, while early stage converted largely to upland. Few late stage areas (forested wetlands) were found at either site. Upland areas generally remained upland. Some small areas did convert back from early stage to total channel or from upland to late stage. However, the dominant land cover change was toward drier categories.

The Niobrara and Bazile Creek sites are located along a geomorphologically dynamic stretch of river. The Corps of Engineers (1992) identified substantial changes in the channel geometry of the Missouri River over the last thirty years, as well as during the study period. Sediment from the Niobrara River has caused aggradation to occur throughout the confluence area. The Verdel gage (RM 846.5) is approximately 3 miles upstream from the confluence, but has had significant aggradation. The situation is the same downstream to Lewis and Clark Lake. As sedimentation has occurred, water levels have risen from Springfield to Niobrara.

With rising stages in the area, the Niobrara and Bazile Creek sites exhibited appropriate land cover changes. The majority of changes have been toward earlier successional stages. Many upland areas converted to the early stage category, while early stage vegetation converted to total channel or remained as early stage. Comparatively fewer changes were seen in the opposite direction. Given the local hydrology, changes of this nature were expected.

IMPLICATIONS FOR NESTING SHOREBIRDS

Successful reproduction of terns and plovers requires sufficient nesting habitat and favorable hydrologic conditions. As mentioned earlier, ideal habitat includes beaches and unvegetated sandbars. In the study reach, availability of these areas is dependent upon the water level. At lower discharges, more habitat is exposed. As discharges increase, less habitat is available. Because of the continual variation in flow volume, the water and sandbar areas were combined in order to represent the entire active channel area. Land cover data could then be analyzed irrespective of discharge. Increases or decreases in the acreage of the total channel category will represent more permanent changes in potential habitat availability.

The changes in the total channel category varied among the sites. At the Greenwood site, 1061 acres of potential nesting habitat existed in 1983. The acreage decreased 29 percent to 756 acres in 1991 (Table 2). At the Verdel site, potential habitat acreages changed from 744 to 815, an increase of roughly 10 percent (Table 3). The Niobrara site showed an increase of 36 percent, changing from 954 acres to 1297 acres (Table 4). The Bazile Creek site underwent the least amount of change, with a 6 percent increase from 1120 acres in 1983 to 1188 acres in 1991 (Table 5). The changes in the total channel category are summarized in Table 6.

	Study Site				
	Greenwood	Verdel	Niobrara	Bazile Creek	TOTAL
Acreage Change	-305	71	343	68	177
% Change	-29%	10%	36%	6%	4%

Changes in Total Channel Category (acres)

Table 6

As shown in Table 6, acreage of potential shorebird nesting habitat has declined in the upstream portion of the study area. Being located closest to Fort Randall Dam and furthest from the aggradation occurring downstream, the Greenwood area is dependent upon seasonal variations in dam discharges to keep sandbars free of vegetation. With the decrease in maximum and mean discharges during the study period (compared to the long term), large areas of habitat have become vegetated. If flows return to previous levels, the vegetation would slowly be scoured and these areas could once again become potential nesting areas.

Further downstream, especially at the confluence of the Niobrara River, substantial increases in available habitat have occurred. In these areas, discharges from Fort Randall Dam play less of a role in temporal changes in potential habitat. The Verdel site showed only a small increase in habitat area, mostly from the erosion of islands and shorelines. As at Greenwood, changes at Verdel are controlled primarily by dam discharges. The Niobrara site is influenced by the Niobrara River delta. Water from the Missouri and Niobrara Rivers is ponded by the huge amount of sediment deposited at the confluence. The Niobrara site had a large increase in potential habitat acreage. The Bazile Creek site showed very minor changes in the total channel category. This site is located between the Niobrara delta and the headwaters of Lewis and Clark Lake. Large areas of potential nesting habitat were present in both 1983 and 1991.

Water and sandbar areas were combined into the total channel category in order to identify more enduring changes in potential nesting habitat. If examined separately, acreages of water and sandbar would vary constantly as normal geomorphic and hydrologic processes occurred along the Missouri River. Sediment is continually being eroded, transported and deposited throughout the channel area. Because of the shape of channel cross sections, small variations in stage often expose large amounts of sandbar and shoreline (U.S. Army Corps of Engineers 1992). Certain areas, due to their depth, will remain water for years, regardless of discharge level. Other areas will remain sandbars for years. In an area as geomorphically dynamic as this, it is nearly impossible (and arguably meaningless) to accurately classify all areas as one or the other.

Between 1983 and 1991, there has been an overall increase in potential shorebird nesting habitat of 4 percent at the sites examined in this study. Habitat acreage at the Niobrara confluence area increased 36 percent over the period. Interior least terns and piping plovers did not appear to face a shortage of habitat at these sites, given favorable water levels during the nesting season.

V. CONCLUSIONS

This thesis developed and executed a methodology for measuring changes in land cover categories, especially as they impact shorebird nesting habitat. Changes were assessed using data from several sources. Results indicated substantial changes in land cover and potential nesting habitat at several study sites along the Missouri River between 1983 and 1991.

Findings were varied throughout the study area. Large losses of habitat were identified at the Greenwood site, primarily due to reduced stages from decreased discharges in recent years. As water levels dropped, scouring floods no longer reached many areas. Vegetation became established as areas converted from water and sandbar to early stage and upland. The dominant land cover changes were toward drier categories, characterized by more stable vegetation. Further downstream, this pattern was reversed. Sedimentation at the confluence of the Niobrara River helped create over 300 acres of additional habitat. Land cover changes at the Niobrara and Bazile Creek sites were driven by aggradation-induced stage increases. Changes were almost exclusively toward less stable categories.

The land cover changes identified in this study provide a detailed look at the Missouri River over an 8 year period. Under natural conditions, normal vegetative succession would occur until a flood of sufficient magnitude was able to remove it. The concept of dynamic equilibrium states that natural systems undergo numerous short term changes which cancel each other out over the long term. Applied here, this means that the area of each land cover category (over a large stretch of river) would remain relatively constant, while spatial changes would be many and varied. The total channel area would occupy the largest area, as sandbars were destroyed and created. Hydrologic conditions in the study area are heavily controlled. Even over the short study period, substantial changes in vegetative succession have occurred.

The methodologies utilized in this study were effective in analyzing land cover changes, identifying shorebird habitat, and determining impacts upon habitat availability. The aggregation of wetland data and incorporation of hydrologic data proved especially useful in understanding local conditions. Future studies focusing on habitat changes for these species could be performed using these procedures. The NWI data sets provide baseline conditions for many important habitat areas. If another data set for an area of interest can be developed using similar methods (as was the case for this study), valuable temporal analyses may proceed.

The usefulness of a geographic information system (GIS) for management of habitat data cannot be understated. When data exist with a locational component, various types of spatial relationships can be identified. Data from numerous sources can be combined with the habitat data to determine impacts from existing or proposed activities, to model habitat suitability, or to assess temporal changes.

This thesis has been important for its synthesis of data from diverse sources in an attempt to identify habitat changes for several protected species. Understanding habitat preferences and identification of potential nesting areas are the first steps toward recovery of these species. The eventual goal is to return these shorebirds to healthy population levels. The present goal is to mitigate human impacts such as habitat destruction and degradation. It is hoped that this study will provide information to help further our understanding of habitat change in an area critical to the survival of two rare species.

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