May 1996

Fate of Wetlands Associated with the Central Nebraska Irrigation Canal System

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Great Plains Research 6 (Spring 1996): 41-60

FATE OF WETLANDS ASSOCIATED WITH THE CENTRAL NEBRASKA IRRIGATION CANAL SYSTEM

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Abstract. *Changes in wetlands in the vicinity of the Phelps and E65 canals operated by Central Nebraska Public Power and Irrigation District in Southcentral Nebraska were examined using aerial photographs taken on seven occasions from 1938 to 1981. According to previous research, nearly 90% of the original wetlands within the surrounding Rainwater Basin were destroyed or altered by draining and filling between 1900 and 1980. Within a zone extending 10 kilometers on each side of the Phelps and E65 canals, however, we observed an increase in the number and total area of wetlands, which we hypothesize to have been caused by an elevated groundwater table. Of additional importance for wildlife management, there was a notable decrease in wetlands temporarily flooded for 2 months or less, and a notable increase in wetlands seasonally flooded for 3 to 5 months each year. These changes were most conspicuous after 1969.*

The Rainwater Basin in southcentral Nebraska continues to be a region of considerable significance for wildlife management purposes. The Rainwater Basin as a whole still contains over one million hectares of wildlife habitat, including numerous and collectively important wetland depressions that are interspersed among agricultural lands. Each spring, 90% of the mid-continental white-fronted geese (*Anser albifrons*), 50% of breeding mallards (*Anas platyrhynchos*), and 30% of breeding pintails (*Anas acuta*) use wetland depressions in the Rainwater Basin for staging and foraging before flying on to their breeding grounds elsewhere in the United States and Canada (D. Gersib et al. 1990).

With the encouragement and support of state and federal agencies, landowners in the Rainwater Basin started to convert wetlands into additional cropland acreage beginning about the time of the turn of the century. Draining and filling progressed slowly during the first third of the century, partly because of a poor farm economy. But the pace of wetland conversion in the Rainwater Basin quickened in the 1940s, due to wartime agricultural prosperity coupled with technological advances in earth-moving equipment and farm machinery (R. A. Gersib et al. 1992). By 1965, 82% of the

estimated 3,907 separate original major wetlands in the Rainwater Basin had been eliminated, and nearly 65% of the estimated total original 38,350 hectares of wetlands area were gone (Nebraska Game and Parks Commission 1984). By the early 1980s, 90% of the original wetlands in the Rainwater Basin of Nebraska had been lost or substantially altered by draining, filling or ditching (R. A. Gersib et al. 1992).

The increased area of cultivation in a region of highly variable rainfall put pressure on available supplies of moisture. Assertions of a need for a stable water source to supplement rainfall for agricultural development in central Nebraska had been put forward as early as the 1920s (Smith 1924). In 1936 the Central Nebraska Public Power and Irrigation District initiated development of a canal system to provide water for farmland irrigation in Gosper, Phelps, and Kearney Counties.

Platte River water is stored in Lake McConaughy, near Ogallala, Nebraska, and then diverted from the river near North Platte into canals that serve the tri-county area. The main canal system totals 85 kilometers in length, and consists of unlined channels, which range from 1 to 12 meters wide and from 1 to 5 meters deep, with a maximum capacity of 39 cubic meters of water per second. Lateral distributary lines connect at various points along the main canals to transport water to adjacent croplands.

The completion of the canal system in 1941 prompted rapid and widespread adoption of surface irrigation within the service region. Since 1941, the local groundwater table in Gosper, Phelps, and Kearney counties has risen by at least 3 meters and as much as 34 meters (Steele and Wigley, 1992). An apparent consequence of the elevated groundwater table has been the seepage of water into lowlying depressions and the formation of permanent and semipermanent wetlands. During the period since the canal system was established, local residents have reported the formation of new wetlands where they had not previously existed (U.S. Soil Conservation Service 1994; Tri-Basin Natural Resources District 1994; UNL Extension Service 1994). In several instances, the emergence of new wetlands and resulting loss of cropland acreage prompted legal or political actions which have made the canal system a somewhat controversial issue in Nebraska. However, the overall pattern of wetland expansion in the area has not heretofore been systematically studied in terms of extent and significance over time.

Study Area

There has been much speculation but relatively little evidence has actually been collected about the possible influences which the canal system

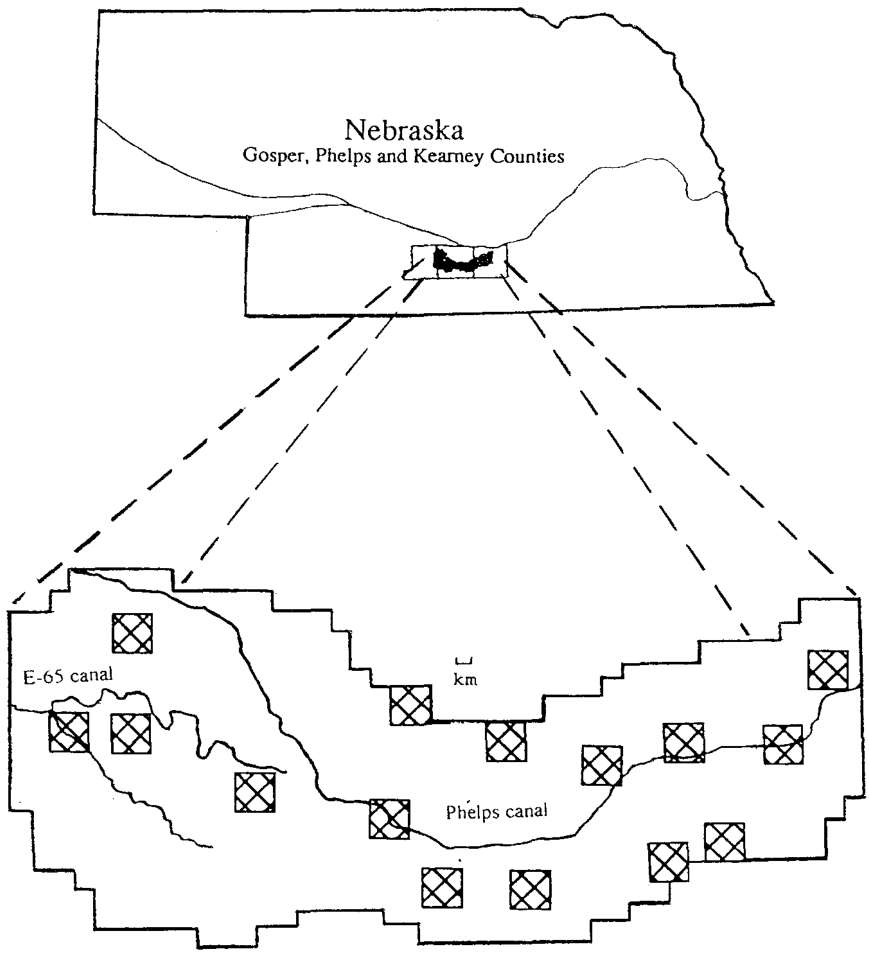

Figure 1. Central Nebraska Irrigation canal system, wetland study area and 15 sample subareas in Southcentral Nebraska.

may have exerted on the extent and character of wetlands in the Rainwater Basin. In order to investigate the matter on a manageable research scale, a smaller study area was selected in southcentral Nebraska (Fig. 1). The study area is bounded by section lines of the township and range Public Land Survey to include 559 square mile sections located within a 20-kilometer-wide zone spanning 10 kilometers north and 10 kilometers south of the Phelps and E65 irrigation canals in Gosper, Phelps, and Kearney Counties.

The study covers a total of 143,104 hectares. It encompasses all lateral distribution lines from the Phelps and E65 canals, and very likely contains most of the localized hydrologic effects produced by the canal system. Downstream effects of upstream diversion and evaporation are, of course, excluded from the present study.

The study area was topographically described by Condra (1939) as a Loess Plains Region. Average annual rainfall is 62 cm, with precipitation peaking propitiously for agriculture during June, July, and August. About 80% of the land surface is cultivated, with the major crops being corn, wheat and sorghum (USDA NRCS 1973).

The landscape is characterized by surface depressions and gently rolling upland plains. Holdrege silt loam is the dominant upland soil type, with Massie, Scott, Fillmore, and Butler soils predominating in depressional zones. Depressional soils associated with wetlands are formed by clay particles that move downward in the soil profile to form clay pans. Depressions receive water from rainfall, snowmelt and irrigation runoff. Semipermanently flooded wetlands are found in the deepest depressions (1 to 2 m), and offer the most temporally continuous surface water regime. Seasonally flooded wetlands occupy slightly shallower areas (0.5 to 1 m), and usually hold water for 3 to 5 months. Temporarily flooded wetlands occupy the most shallow depressions, and usually hold water for up to 2 months per year. Individual wetlands range in size from 0.1 to 400 hectares, with 98% being 4 hectares or smaller in surface extent.

Research Methods

Aerial photographs of the study area were found to be available for the years 1938, 1941, 1956, 1963, 1969, 1978, and 1981. Air photos at a nominal scale of 1:7,920 or eight inches to one mile were obtained for 1941 (U.S. Department of Defense), 1956, 1963, and 1969 (U.S. Department of Agriculture Natural Resources Conservation Service [USDA NRCS]). Somewhat smaller scale photos at a nominal scale of 1:15,840 or four inches to one mile were obtained for 1938 (U.S. Department of Defense) and 1978 (USDA NRCS). The larger scale eight inches to one mile photos were used as much as possible, because of their greater land-cover and land-use detail. In addition, maps from the 1981 National Wetlands Inventory at a scale of 1:15,840 were obtained from the U.S. Fish and Wildlife Service (1981).

The aerial photos of Gosper, Phelps, and Kearney counties were examined section by section in order to identify wetlands and to trace their fate over time. Individual wetlands were visually differentiated from other land-

cover and habitat types by the presence of water and hydrophilic vegetation. Once wetlands were differentiated from other landscape features, the number of observable wetlands was counted for the study region at each time. Also, the areal extent of each wetland was estimated to the nearest hectare by visual comparions to agricultural land-use features of ascertainable sizes. These size comparisons were facilitated by obvious land-use manifestations of the region's rectangular land survey.

The first of our analytical objectives pertained to wetland patterns for the entire study area. Thus, the initial set of null hypotheses posited that 1) the overall number and 2) the overall area of wetlands remained the same from year to year across the study area as a whole. We used chi-squared goodness of fit tests to determine if statistically significant differences occurred among the numerical and area frequencies of wetlands for different years. Non-significant findings would have meant that observed differences were within the limits of chance sampling variability, and therefore not plausibly attributable to systematic changes over time.

Attention also focused on more localized variations within the study region. In particular, we were interested in possible relationships that might exist between surface patterns of wetlands change evident from the air photos we examined, and changes in groundwater levels as measured by the Steele and Wigley (1992). In order to study the possible effects of shifting groundwater levels, the number of wetlands was counted and the areal extent of wetlands was estimated for different groundwater table height change contours (Fig. 2). To standardize for differences in the areas of each groundwater level change class, the observed measurements were divided by the surface area associated with each contour level. Chi-squared tests were used to test for variations in numbers and areas of wetlands over time in relation to each of four groundwater change contour classes. Measures taken from 1956 aerial photographs were excluded at this stage, because unusually low precipitation dramatically reduced visible wetlands in that year. Only 28 cm of precipitation fell in 1956, compared to a long-run mean annual precipitation level of 62 cm.

In order to examine patterns even more closely, 15 sample subareas, each composed of four mile-square sections with an overall area of 2,560 acres, were randomly selected from the larger study area. The methodology at this stage added the use of computer image processing techniques to supplement the visual interpretation techniques used in preparing data for the previous two tests. The aim was to monitor the fate of specific wetland types between 1938, 1941, 1956, 1963, 1969, 1978, and 1981. Five sample subareas were found to be devoid of wetlands for all observation periods,

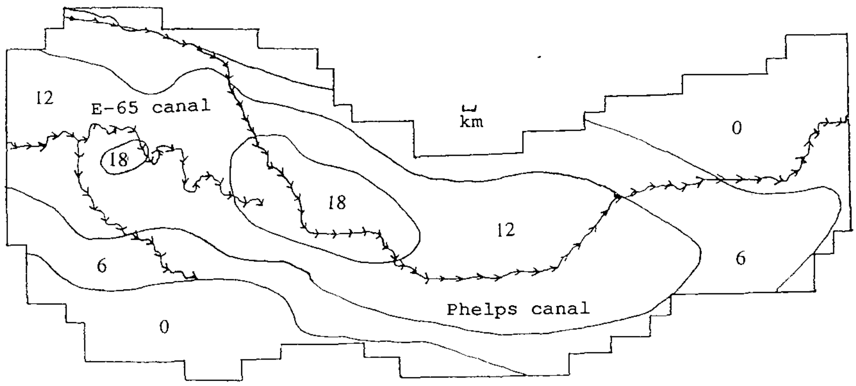

Figure 2. Contour areas of significant groundwater level increase (m) in Gosper, Phelps, and Kearney counties from 1940 to 1990 (Steele and Wigley 1992), relative to the Central Nebraska Irrigation canal system.

and were replaced by five additional randomly selected subareas. Aerial photos were scan digitized to produce computer data files for each sample subarea at each time. Frequency counts and areal extent measures of wetland were obtained using NIH-Image 1.43 (W. Rashand 1994) digital image processing software. This image processing system makes it possible to discriminate habitat types by image classification on a gray scale, and to determines area by counting pixels with each grey scale class. Again, chi-squared goodness of fit tests were used to test for differences between years.

Additional interest focused on wetlands differentiated by size. For this purpose, wetlands were classified into three size categories: "small" under 2 hectares, "medium" from 2 to 10 hectares, and "large" over 10 hectares. To begin this stage of investigation, wetlands were computer classified into these size groups from the 1938 aerial photos for each of the 15 sample subareas. The geographical site of each 1938 wetland was then traced from one study year to the next in later photographs to determine that wetland's fate. Some wetlands features visible in 1938 photos later were altered or drained to expand cropland, but most could be traced throughout the study period. Furthermore, additional wetlands which had not been observable in 1938 were classified from the 1981 photos. The geographical locations of 1981 wetlands were traced backwards year by year to 1938, to determine their times and circumstances of origin. NIH-Image 1.43 (W. Rashand 1994)

software was again used to calculate the areal extent of each wetland. Similarly, chi-squared goodness of fit tests were used to test for similarities between years.

More direct relationships with soil type variations were investigated by using NIH-Image 1.43 to computerize the locations and areas of hydric soils, as these had been recorded on old soil survey maps published at a scale of 1:63,360 or one inch to one mile. Early soil survey maps were obtained for each of the counties at dates that preceded the opening of the Phelps and E65 canals as follows: Gosper County (U.S. Department of Agriculture [USDA] 1938), Phelps County (USDA 1919) and Kearney County (USDA 1927) counties. For purposes of comparison, later soil survey maps at a scale of 1:15,840 or four inches to one mile also were obtained for recent dates as follows: Gosper County (USDA 1981), Phelps County (USDA 1973), and Kearney County (USDA 1984). Zones of hydric soils were also scan digitized and computerized from the later soils maps.

Once the pre-canal and post-canal soil surveys had been computerized, it was possible to overlay the old and new geographic images for each of the 15 sample subareas. The overlay procedure enabled comparisons of the locations and extent of hydric soils at each time for each sample subarea in order to further document the fate of wetlands over time. To reduce the effects of differences in map scale and changes in soil survey practices, threshold values of 100% increase and -50% decline were used to summarize differences in areas of wetland soils from the two time periods. For example, a change from 4 hectares to 8 hectares is a 100% increase, and a change from 4 hectares to 2 hectares is a -50% decline. Large differences were deemed needed for "significance," because wetlands soils have inherently indeterminate zonal boundaries (Kuzila et al. 1991).

Results and Discussion

As noted above, it has been estimated that as much as 90% of the original wetlands which once existed in the Rainwater Basin prior to EuroAmerican agricultural settlement were altered or destroyed by draining and filling between 1900 and 1980 (R. A. Gersib et al. 1992). Such evidence could be used to predict a steady diminution of wetlands in the Phelps and E65 canal study region during the period of investigation. To the contrary, however, our aerial photo interpretation based measures of the total number and aggregate area of wetlands in the study region as a whole do not show consistent decline in either the number or the areal extent of wetlands in the

vicinity of the Phelps and E65 canals since the late 1930s (Fig. 3). Instead, both increases and decreases can be found for sequential pairs of years during the overall study period.

To be sure, statistically significant differences do exist when comparisons are drawn, irrespective of temporal ordering, between study area wide values for the years 1941, 1956, 1963, 1969, and 1981. According to the chi-squared tests, there are significant differences in the total number (X^2 = 141.8, df = 4, $P < 0.001$) and area (X^2 = 3946.7, df = 4, $P < 0.001$) of wetlands for these years. But, no consistent pattern remains apparent once temporal ordering is noted. Numbers exhibit declines from 1941 to 1956 and 1963 to 1969, but increases from 1956 to 1963 and 1969 to 1981. Areas show declines from 1941 to 1956 and 1969 to 1981, but increases from 1956 to 1963 and 1963 to 1981. However, it can be noted that the lowest total area of wetlands was observed for 1981 at the end of the study period.

Various possible reasons can be conjectured for the diverse and nonmonotonic overall time trends. Among these reasons are fluctuations in annual rainfall, land-use changes, and differences in the time of year when the aerial photographs were taken.

Examining patterns chronologically, a nearly average 62 cm of precipitation fell in the study area in 1941. The total number of individual wetlands observed for 1941 is comparatively high but total area is comparatively low, perhaps because much of that year's rainfall came early in the spring while the photo used in our investigation was taken in September. Total rainfall was only 28 cm in 1956, which helps to account for the low number and area of wetlands observed for that year.

The year 1963 again showed an average precipitation amount of 62 cm, which no doubt contributed to high values for the number and area of wetlands. In addition, there was a very notable four-fold or 400% increase in the use of irrigation water from 1941 to 1963 (D. Gersib et al. 1990). Expanded irrigation likely also prompted an increase in wetlands identifiable in the aerial photos.

The total area of wetlands observed for the study area in 1969 was augmented considerably by that year's unusually high annual precipitation amount of 84 cm. Throughout the entire study area in 1969, we observed small adjacent wetlands visually merging into larger wetlands. These fusions increased the aggregate area estimate but decreased the number of countable wetlands.

The wetlands observations for 1981 show a contrasting pattern. In 1981, counted wetlands were comparatively numerous, but their estimated

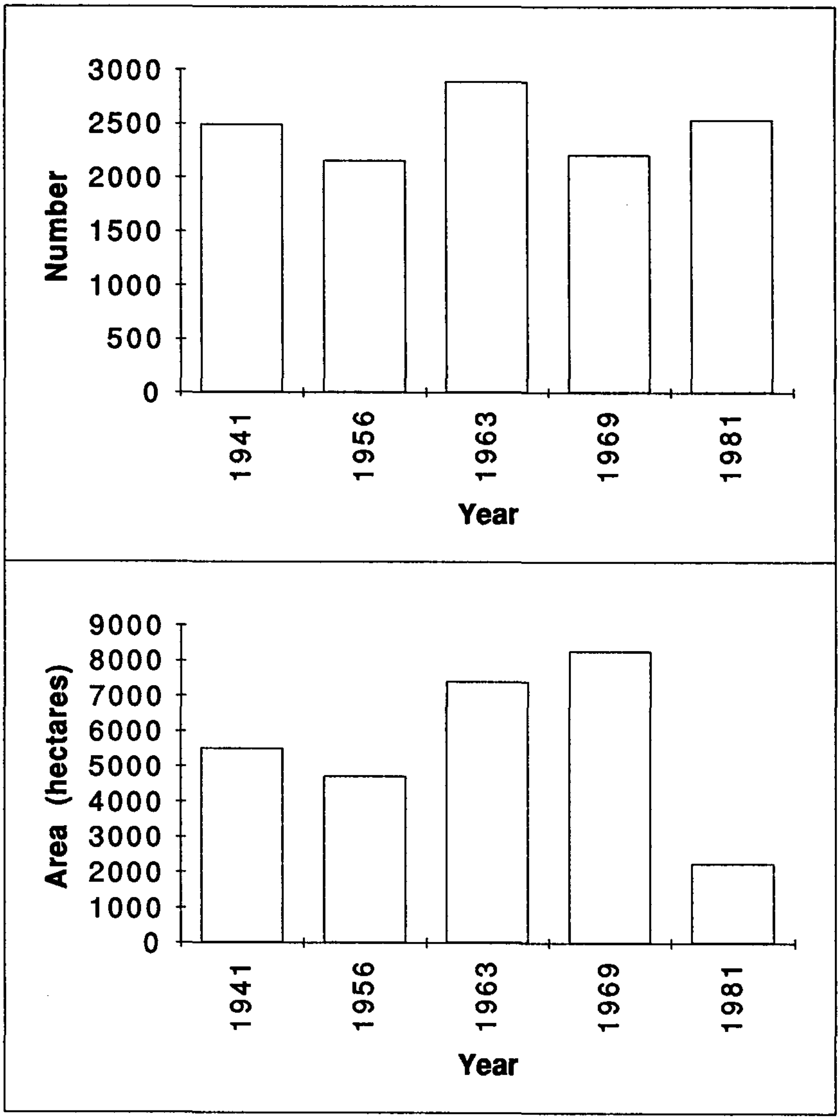

Figure 3. Total number and area (hectares) of wetlands in the study area from 1941 to 1981.

total area was the lowest of any of the study years. This may have been more attributable to precipitation variability than to land-use change, however. The aerial photos for the National Wetland Inventory photos were taken in May of 1981. Near normal precipitation during the winter and spring of 1980-1981 failed to offset a substantial accumulated moisture deficit, so that severe drought conditions prevailed at the time of the 1981 photos. Unusually heavy precipitation in June and August ended the drought later that year. The effects of the drought seem to have inflated the counted number of wetlands, since dryer conditions worked to divide normally merged wetlands into separately countable landscape units. Observed wetlands were most numerous near the canals, where elevated groundwater levels maintained wetlands which otherwise would have disappeared altogether in the drought.

At the other extreme, of course, flood conditions could inundate all land, and thus expand the measurable area of wetlands to the entire study region, while also reducing the countable number of wetlands to one. As moisture conditions tend toward either wet or dry extremes, the metrics employed of numbers and areas of wetlands cease to vary together and begin to vary in oppostion.

The concentration of countable wetlands in the vicinity of the canals under the dry conditions of 1981 gave impetus to our investigation of relationships involving groundwater change levels. Regarding the increased groundwater table contours, we observed differences (Fig. 4) in the number of wetlands in the 12 m increase contour ($X^2 = 10.4$, df = 3, $P = 0.016$), but no differences in the 18 m increase contour ($X^2 = 3.8$, df = 3, $P = 0.288$), the 6 m increase contour ($X^2 = 1.4$, df = 3, $P = 0.708$), or the 0 m increase contour ($X^2 = 6.9$, df = 3, $P = 0.071$). The significant differences for the 12 m contour can be attributed to 40% of the study area and 49% of the canal being located within the 12 m contour. In addition, draining, filling and irrigation runoff likely added to the variability in numbers of wetlands in all contours. The number of wetlands in the 18 m contour was consistent only because 8% of the total area is contained within the contour. The number of wetlands in the 6 m and 0 m contours show no difference, indicating that groundwater recharge and irrigation runoff may have supplemented water to some depressions.

Differences in area are observed in all contour classes [18-m ($X^2 = 21.8$, df = 3, $P < 0.001$), 12 m ($X^2 = 682.9$, df = 3, $P < 0.001$), 6-m ($X^2 = 252.7$, df = 3, $P < 0.001$) and 0 m ($X^2 = 251.0$, df = 3, $P < 0.001$)]. The area of wetlands within the 18 m contour was stable until 1981. As noted above, 1981 photos were taken before summer rainfall and irrigation ended an

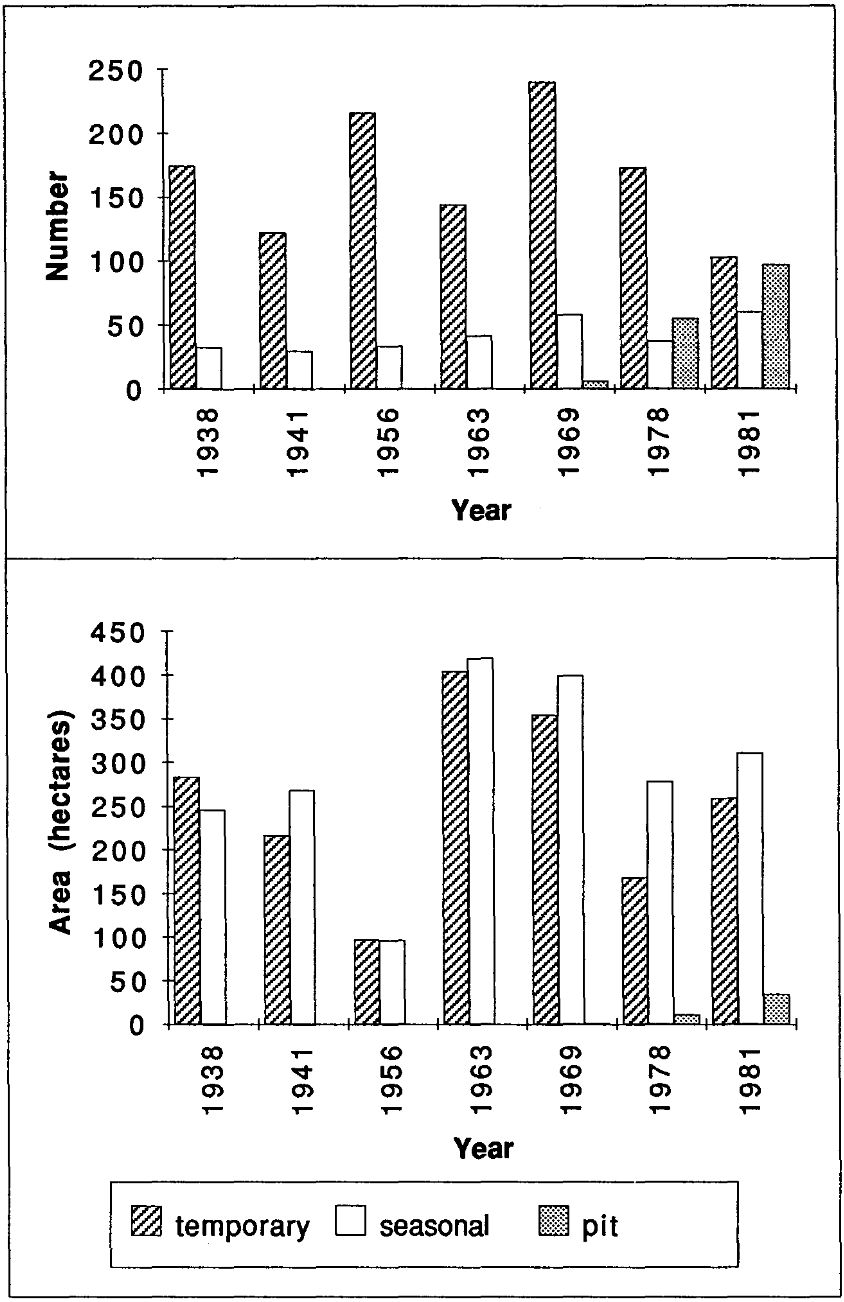

Figure 4. Total number and area (hectares) of wetlands in the study area from 1941 to 1981 relative to the change in the groundwater level over time.

accumulated moisture deficit, thus decreasing the area in all the contour classes and causing the difference in the 18 m contour. Area in the 6 m and 0 m contours increased across the years until the 1981 photos, due to irrigation runoff and groundwater recharge from the canal system. The 12 m contour had the largest increase in area in 1963. The large increase is an indication of surface water being supplemented from groundwater and the canals.

The drop in 1969 may be attributed to an 83% increase in land leveling activity from 1963 to 1969 (R. A. Gersib et al. 1990). This activity drained and filled wetlands and shaped the landscape to increase irrigated cropland acreage. By this time, center pivot irrigation technology had appeared, and additional landscaping was done to allow adoption of full circle irrigation.

Detailed observations made on the 15 sample subareas (Fig. 5) indicate significant differences in the number of temporarily flooded ($X^2 = 86.4$, df = 6, $P < 0.001$) and seasonally flooded ($X^2 = 21.0$, df = 6, $P = 0.002$) palustrine wetlands in the study years from 1938 to 1981, and also a significant increase in concentration pits ($X^2 = 394.5$, df = 6, $P < 0.001$) from 1969 to 1981. The variability in the number of temporarily flooded wetlands across the years is expected. Temporarily flooded wetlands are unstable over time because they occupy very shallow depressions and are mainly dependent on rainfall and runoff for flooding. The decline in the number of wetlands which are temporarily flooded for 2 months or less seems to be a response to the increase in land leveling and the deepening concentration pits which can hold water year-round. Conversely, the increase in the number of wetlands which are seasonally flooded for 3 to 5 months per year was prompted by the advent of supplemental water from the canals, even with the implementation of concentration and reuse pits to drain wetlands and capture irrigation runoff.

Differences were also observed in the total area of temporarily flooded ($X^2 = 170.3$, df = 6, $P < 0.001$) and seasonally flooded ($X^2 = 239.5$, df = 6, $P < 0.001$) palustrine wetlands, with a significant increase in the total area of concentration pits ($X^2 = 146.1$, df = 6, $P < 0.001$). The total areas of temporarily and seasonally flooded wetlands fluctuated together, suggesting that each responded similarly to the effects of changes in land-use and environmental variability. While pits do supply surface water, they have altered the natural wetland hydrology and vegetation of surrounding wetlands (R. A. Gersib et al. 1992) by concentrating the water in the pits and stopping the flow of runoff into nearby depressional areas. After 1969, pits were located throughout the study area. Without these artificial pits, the number and size of naturally-occurring wetlands likely would have been greater.

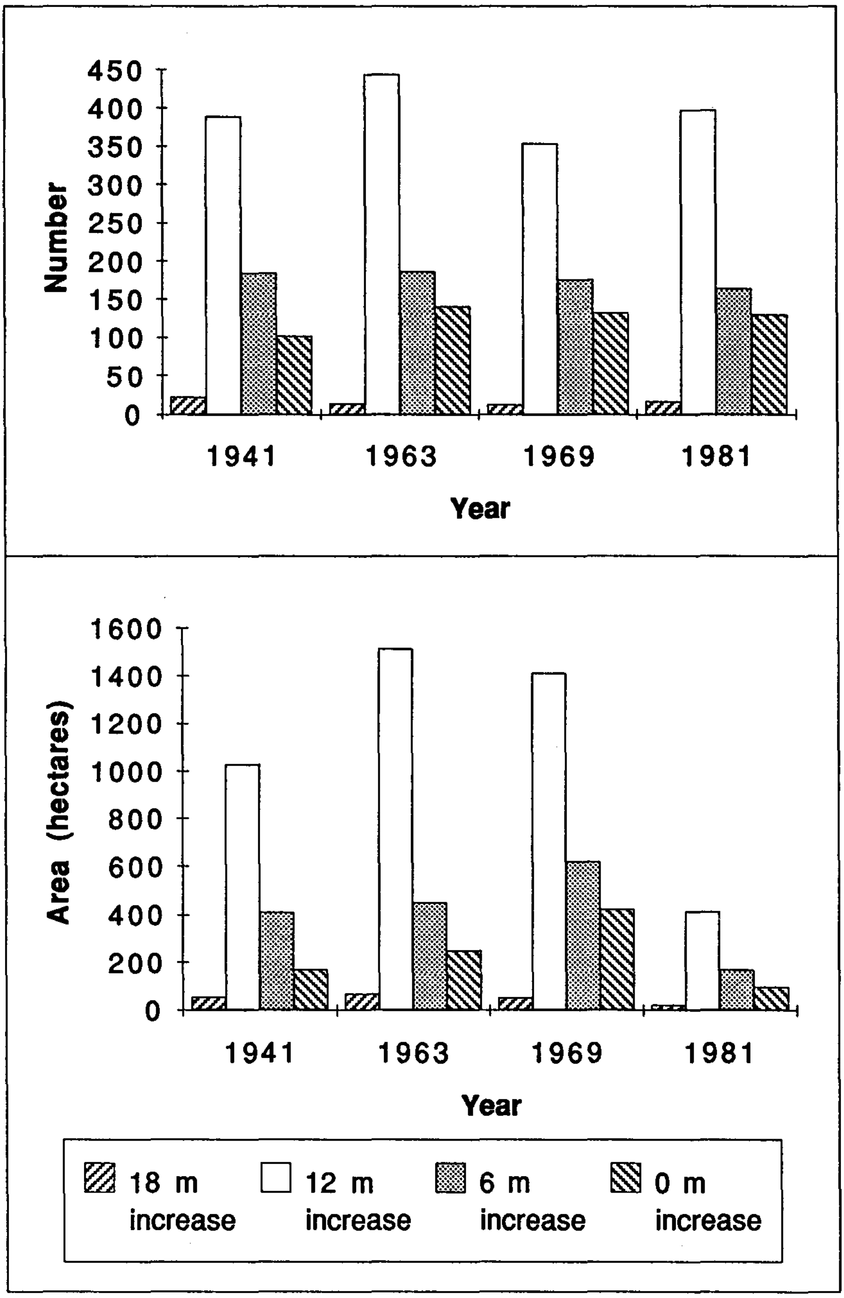

Figure 5. Total number and area (hectares) of palustrine wetland types from 1938 to 1981 in 15 sample subareas in Southcentral Nebraska.

We monitored 168 small, 30 medium and 11 large wetlands foreward through time from 1938 to 1981 (Fig. 6) in the 15 sample subareas to trace the fate of individual wetlands over time. In 1938, the 168 small wetlands ranged in size from 0.1 to 2.0 hectares. By 1941, 134 of the 168 wetlands had disappeared but the remaining 34 ranged in size from 0.1 to 18.2 hectares. By 1981, only 26 of the original 168 small wetlands remained. In 1938, 30 medium-sized wetlands ranged in size from 2 to 7.5 hectares. By 1941, 13 of the medium wetlands remained, which ranged in size from 0.1 to 24.2 hectares. In 1938, 11 large wetlands ranged in size from 10.4 to 78.0 hectares. By 1941, 8 large wetlands remained with a range of 0.1 to 95.7 hectares.

As individual wetlands disappeared, we observed the growth and decline of existing wetlands and the formation of new wetlands. The reduction in the number of small wetlands after 1938 is attributed to temporary wetlands only being present when conditions are favorable. While the number and size of small wetlands fluctuated, the mean area stabilized from 1963 to 1981, indicating that irrigation water from the canals supplemented depressions with water. However, the sizes of these wetlands decreased as wetland draining and filling continued. The number of medium-sized wetlands was relatively stable across the years, but their aggregate area fluctuated with annual rainfall. The end result is an increased stability in the number and area of medium-sized wetlands by 1981.

The number of large wetlands appeared to be stable across the years. However, 4 of the 11 original large wetlands shrank to less than 2 hectares by 1981. The other 7 original large wetlands grew in size, so the mean area remained relatively high. The 7 growing wetlands appear to have received supplemental water from the canal and groundwater. The 4 that shrank in size were drained or ditched.

In addition to studying 1938 wetlands foreward through time we also studied 1981 wetlands backward through time. After eliminating 1938 wetlands which persisted to 1981 in order to avoid reduncancy, we monitored an additional 165 small, 7 medium and 3 large wetlands from 1981 back to 1938 in the 15 sample subareas (Fig. 7). We hoped to determine if they were naturally occurring, or if they could have been the result of surplus groundwater from the canals. In 1981, the 165 small wetlands ranged in size from 0.1 to 2 hectares. In 1978, only 51 of the small 1981 wetlands existed, and ranged in size from 0.1 to 10.8 hectares. None of the small 1981 wetlands existed in 1938. In 1981, 7 medium-sized wetlands ranged in size from 2.6 to 8.6 hectares. In 1978, only 5 medium-sized 1981 wetlands existed and ranged in size from 1.4 to 4.6 hectares. All but one of these existed back to 1941, and none were present in 1938. Three large wetlands, ranging in size from 16.5 to 20.9 hectares were present from 1981 back through to 1963,

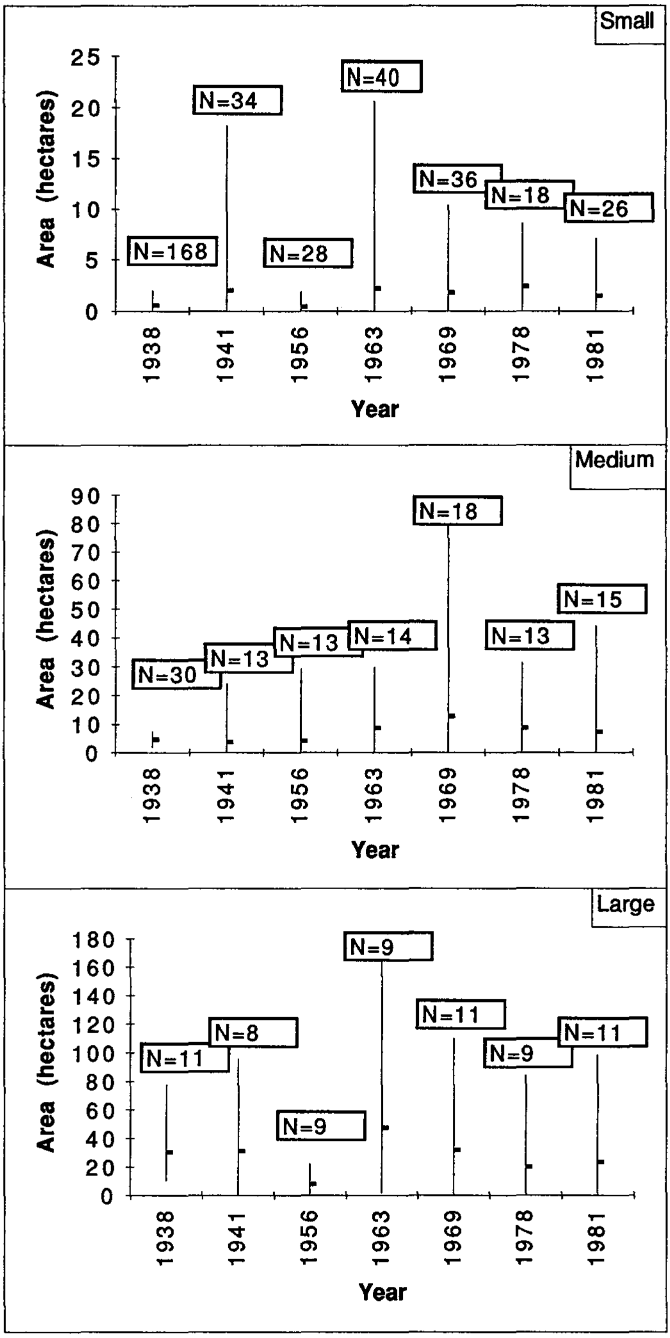

Figure 6. Total number and area (hectares) of small (< 2 hectares), medium (2 to 10 hectares) and large (> 10 hectares) wetlands within 15 sample subareas monitored forward from 1938 to 1981.

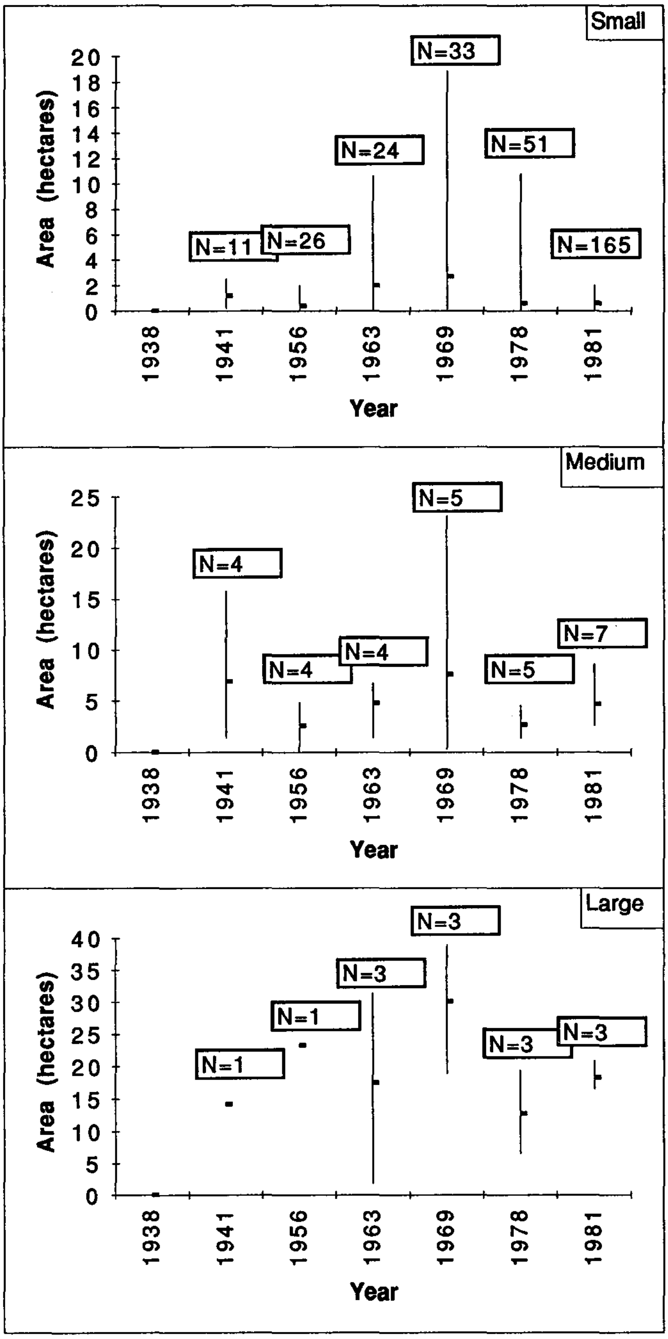

Figure 7. Total number and area (hectares) of small (< 2 hectares), medium (2 to 10 hectares) and large (> 10 hectares) wetlands within 15 sample subareas monitored backward from 1981 to 1938.

although the sizes of each varied considerably. Only one was present from 1956 back to 1941, and even that one was absent in 1938. Wetlands monitored from 1981 back to 1938 show that these wetlands formed subsequent to the development and use of the Central Nebraska Irrigation canal system. We hypothesize that the elevated groundwater table caused by the canals promoted the formation of several small, medium and large wetlands in the area.

Old soil survey maps at 1 inch to 1 mile showed the location of hydric soils prior to the canals, and new soil survey maps at 4 inches to 1 mile showed present hydric soil locations. After scandigitizing these maps we overlayed the old and new soil survey patterns in the 15 sample subarea using computer image processing methods. When comparing these areal delineations, we found a match of 716 hectares with hydric soils shown both before and after the advent of the canal system, a loss of 982 hectares with hydric soils on older but not newer maps, and a gain of 825 hectares with hydric soils on the newer but not the older maps. A survey of the Edgar Northwest quadrangle in nearby Clay County, Nebraska which was undertaken by other researchers similarly showed a match of 758 hectares, a loss of 1,147 hectares and a gain of 477 hectares (Kuzila et al. 1991). Four sample sites in our study area, which have been designated as sites 2, 3, 5, and 14, exhibited substantial increases in the areal extent of hydric soils (Fig. 8). Three sites, designated as sites 8, 9, and 10 showed substantial decreases. Sites 11, 12, and 13 showed less dramatically declining trends in hydric soils. And five sites, designated as 1, 4, 6, 7, and 15, showed relatively little change over time in area of hydric soils. As a caution, we hesitate to over interpret these locationally specific changes in areas of hydric soils. Although they may well have been due to the opening of the canal system and the consequent rise in groundwater levels, we cannot as yet clearly separate changes which were real from changes which were merely artifacts of differences in map scales and differences in soil survey practices.

Conclusions

Determination of the effects of the Central Nebraska Irrigation canal system on associated wetlands is complicated by variation in the environment and in land-use over time, and also by unavoidable diversity in the seasonal timing of aerial photographs available for research interpretation. Nevertheless, evidence of relative stability in the number and area of wetlands within the study area during the research period from 1938 to 1981 can be viewed as in stark contrast to the dramatic loss of wetlands reported by

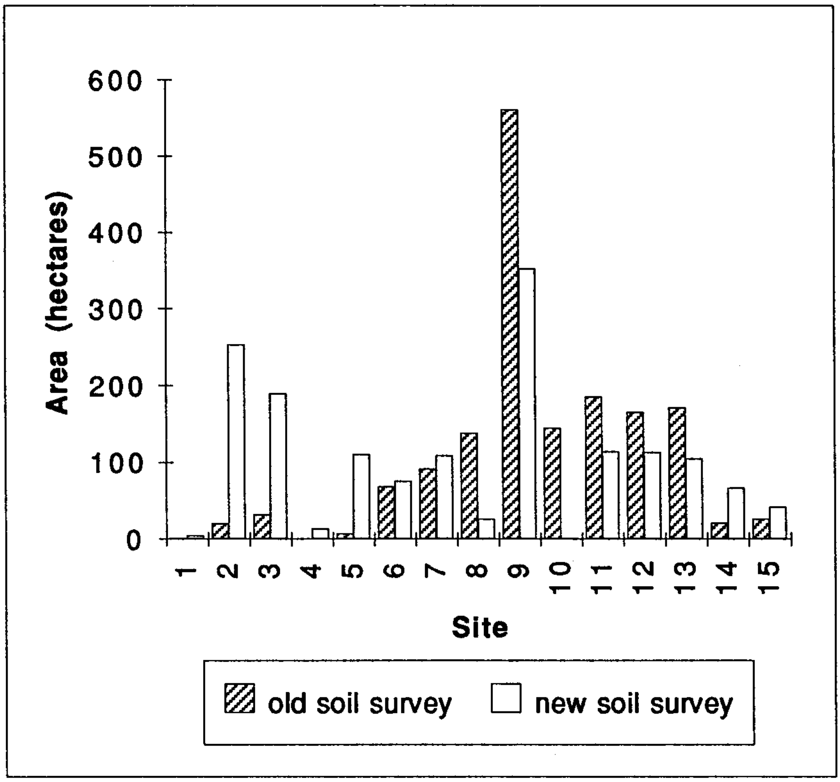

Figure 8. Area (hectares) of hydric soils shown in old (1917, 1927 and 1934) and new (1973, 1981 and 1984) soil survey maps in the 15 sample subareas in Southcentral Nebraska.

other researchers for other portions of the Rainwater Basin. As in other sections of the Rainwater Basis, widespread draining and filling of wetlands has occured in the area selected for study. Within our study zone which extends 10 kilometers to the north and 10 kilometers to the south of the Phelps and E65 canals operated by the Central Nebraska Public Power and Irrigation District, however, at least some of the effects of draining and leveling appear to have been offset by the effects of an elevated groundwater table which can be attributed to the development of the canal system. Nevertheless, important questions remain to be answered about whether the wetlands wildlife benefits of the canal system are comensurate with what

might be expected from naturally rather than artificially maintained wetland depressions.

Acknowledgments

We would like to acknowledge the U.S. Fish and Wildlife Service for providing support for this study from the Biodiversity Fund, secured by Nebraska's U. S. Senator Robert Kerrey. We would also like to thank Jon Kauffeld, Jay Maher, Mark Peyton, and two anonymous reviewers for helpful comments on the manuscript and the local Soil Conservation Service offices, Natural Resources District, Central Nebraska Public Power and Irrigation District and U.S. Fish and Wildlife Service for supplying aerial photos and assistance.

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