Spring runoff retention in prairie pothole wetlands

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ABSTRACT: The volume of water in 213 small wetlands on 648 ha of the Altamont moraine in northeastern South Dakota was measured in April 1982, immediately after the vernal thaw. Water depths were measured to the nearest cm at intervals along transects through each wetland. The surface area of each wetland was obtained from low-level, black-and-white aerial photographs obtained at the same time the water depth measurements were made. The 213 wetlands comprised 50% of the water surface area that occurred in the study area and contained an estimated 19.58 ha-m (158.7 acre-feet) of water. The data are discussed in relation to what is known about prairie wetland hydrology. Values of intact prairie wetlands should be given serious consideration in water resource planning and development in the glaciated prairie region.

THE glaciated prairie region of North America, which encompasses portions of Iowa, Minnesota, North and South Dakota, Montana, Alberta, Manitoba, and Saskatchewan, contains millions of depressional wetlands. Termed prairie potholes by biologists and closed depressions by geologists and soil scientists, these wetlands are extremely valuable to migratory waterfowl (2). Prairie potholes also provide important habitats for other marsh-dwelling wildlife species as well as upland species when the wetlands are frozen in winter or dry (*17*).

Unfortunately, prairie potholes are being drained to increase crop production and to eliminate the nuisance of having to maneuver large farm equipment around the "wet spots" in fields. Apparently, this nuisance factor plays a significant role in influencing landowners' drainage decisions (*15*). Drainage has been so extensive in Iowa, for example, that an estimated 95% of the state's wetlands have been destroyed (*5*). Based on the best available data, Weller (*38*) estimated that all of the privately owned prairie wetlands in the United States will be drained by the year 2050.

In addition to their ecological importance to wetland fauna, evidence suggests that prairie pothole wetlands are important to local and regional hydrology. Wetland drainage has been implicated as a cause for the doubling of flood frequencies since 1950 on the Red River in Manitoba (*29*) and the increasing streamflow over time on tributaries of the Red River in North Dakota (*6*). Hydrologic modeling studies have demonstrated that, under the right set of conditions, wetland drainage can increase small watershed discharges (*7, 8, 28*).

Retaining runoff in prairie potholes also may contribute to maintenance of water tables. Generally, recharge of the shallow groundwater aquifer, the top of which is the water table, does not occur over the entire soil surface in the glaciated prairie, but occurs in depressions, where water is ponded (*12, 19, 21*). Not all prairie pothole wetlands are groundwater recharge areas, however. Some are recharge areas; some are discharge areas; some are flow-through or transitional systems that recharge on one side and discharge on the other; and some change from one type to another depending on fluctuations in the water table (*19, 31, 40*).

An individual wetland or group of wet-

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lands may interact with local, intermediate, and/or regional groundwater flow systems (*19*, *40*). Which system or systems a wetland interacts with depends upon the topographic setting, position of the water table, thickness of the glacial drift, anisotropy of the drift, and the configuration of the underlying bedrock (*13*, *36*, *40*). Generally, prairie pothole wetlands with ephemeral, temporary, seasonal, or semipermanent water regimes tend to be groundwater recharge types; those with semipermanent or permanent regimes tend to be transitional or discharge types (*18*, *31*). Those wetland basins with net seepage outflow—recharge types—are fresh to brackish, while those with net seepage inflow—discharge types—are brackish to saline (*31*). The above water regime and water chemistry descriptors follow those described by Stewart and Kantrud (*33*) for prairie pothole wetlands.

Regardless of the direction of groundwater flow for a given wetland, wetlands on the glaciated prairies are hydraulically connected with the water table (*31*). Thus, drainage of prairie wetlands should, over the long term, contribute to eventual declines in the water table elevation. Maintenance of water tables is important to the agricultural economy of the prairies. An estimated 55,855 dugouts—excavations about 0.1 ha in size designed to intercept the water table—have been constructed in eastern South Dakota as sources of water for livestock (*22*). If water tables decline, new water sources for livestock will have to be developed.

Also, when the water table in glacial till soils is at moderate depth (1.2 to 2.7 m), it will recede an average of 1.5 m over the winter due to water movement from the water table up to the frozen soil zone above it in response to the thermal gradient (*3*, *21*, *30*, *39*). Malo showed this phenomenon was responsible for significant increases in soil moisture available for crop production on lower landscape positions (*21*). Indeed, in a hydrologic simulation of a watershed in central Iowa, Campbell and Johnson (*7*) predicted significantly higher soil moisture levels in the top 1.5 m of soil under corn throughout the growing season within an undrained watershed versus a completely drained watershed.

Despite the evidence of the importance of wetlands to prairie hydrology, published studies quantifying the importance of natural wetlands to a specified region do not exist. A recent study of the Devils Lake Basin (976,000 ha) in North Dakota (*20*), however, found that small wetlands could contain 81,100 ha-m (657,000 acre-feet) of water, equivalent to about 72% of the total runoff volume from a 2-year frequency runoff and about 41% of the total runoff volume from a 100-year frequency runoff. Unfortunately, such data cannot be related easily to flood reduction potential because the amount of available storage varies depending upon the degree of fullness of the wetlands at the time of an individual runoff event (*34*). But such data do indicate the potential water storage that could be lost if all wetlands in the basin were drained. Such documentation is important in drawing attention to the wetland drainage problem.

Reported here are the results of a study documenting the amount of water in small prairie pothole wetlands shortly after the vernal thaw on several small tracts of land in northeastern South Dakota. The data are discussed in the context of what is known about prairie wetland hydrology in the hope that water resource scientists and managers, soil scientists, public officials, and public agency administrators will consider the values of prairie wetlands and initiate studies on their values.

Study area and methods

We analyzed four tracts of public land in northeastern South Dakota (Figure 1). Two were South Dakota Department of Game, Fish and Parks game production areas and two were U.S. Fish and Wildlife Service waterfowl production areas. The 178-ha (440-acre) Berwald waterfowl area, a 126-ha (311-acre) portion of the Summit Lake game area in southwestern Roberts County, the 65-ha (161-acre) Mezzeppa game area, and a 279-ha (690-acre) portion of the O'Farrell waterfowl area in northwestern Grant County were selected because of their similarities in soils, topography, and wetland densities.

The study area lies within the Altamont Moraine, which parallels and lies just interior to the northeastern edge of the Coteau des Prairies (*10*, *16*). This moraine approximates the divide between the Minnesota River drainage to the east and the Big Sioux River drainage to the west. Elevation ranges from 582 m to 619 m (1,867-1,986 feet). The area is a regional topographic high and as such is probably a regional groundwater recharge area (*36*). Soils, almost entirely glacial till with a few small patches of outwash over till, are of the Forman-Aastad, Forman-Buse, and Barnes-Buse associations (*26*, *27*).

The area has a typical continental climate. Average maximum temperatures in January and July are −6.7°C and 28.9°C, respectively. Average minimum temperatures are −17.8°C and 14.4°C in January and July, respectively. Average annual precipitation is 53 cm (20.8 inches). Mean lake evaporation is about 84 cm (33 inches) a year. Average seasonal snowfall is about 76 cm (30 inches) (*32*).

Vegetation is native grassland managed for wildlife habitat. The study area is within the bluestem prairie region (*Andropogon*, *Sorghastrum*, *Panicum*), but the upslope positions on the areas are occupied by mixed-grass prairie (*Andropogon*, *Stipa*, *Bouteloua*, *Agropyron*). East and west of the Altamont Moraine, most of the land is cultivated. About 64% of Roberts County and 68% of Grant County are cul-

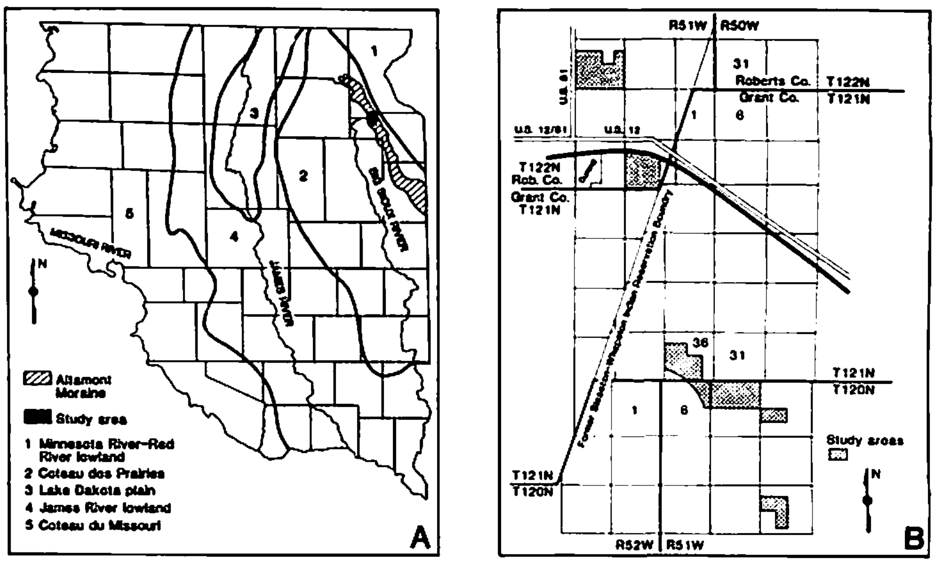

Figure 1. (A) The major physiographic regions, the Altamont Moraine, and approximate location of study area (*10*). (B) Location of areas used in this study; the town of Summit; railroad and major highways; and township, range, and section numbers.

tivated (*26, 27*). Principle crops are corn, soybeans, oats, alfalfa, and flax.

Small, unmodified, shallow wetlands containing ponded water were located on foot by several two-person teams in April 1982. Water depth in each wetland was measured to the nearest centimeter at intervals along a transect oriented across the longest axis of the pond. For irregularly shaped ponds, more than one transect was obtained. Intervals between depth measurements were determined by pacing. Intervals from 1 to 5 paces were used, depending on pond size and slope. The length of each observer's pace was individually determined. Black-and-white enlargements of high-altitude, color-infrared aerial photographs were used as field maps for recording the location of each wetland.

Low-altitude, black-and-white photographs of the area were taken on April 22, 1982, using a 70-mm Hasselblad camera and an exterior sidemount on a small, high-wing aircraft (*4*). Photos were taken about 762 m (2,445 feet) above ground level; scale was about 1:10,000. Enlarged (8.4x), composite maps of the ponds on each of the four tracts were drawn with the aid of a zoom transfer scope. Due to variations in aircraft altitude when the shutter was snapped, slight variations in scale occurred both within a photo and between photos. Therefore, the scale for each pond was determined from the paced distance of the transects traversing them.

We used depth measurements from the paced transects to determine contours of each pond bottom. Contour intervals of 0.2 m (0.6 foot) were most commonly used. Pond and contour surface areas were measured planimetricly. Volumes between two contours were calculated with the formula:

$$V = \frac{h}{3}\ (a_1 + a_2 + \sqrt{a_1\ a_2})$$

where h is the vertical distance between contours and a_1 and a_2 are the surface areas of the upper and lower contours (*37*). We calculated pond volumes as the summation of volumes between contours.

We also estimated the surface area of water not included in our study. This area was determined planimetricly from the enlarged maps using the average of the scales on adjacent measured ponds. These water bodies included large or deep wetlands, an intermittent stream, wetlands modified by road ditches, wetlands modified by the U.S. Fish and Wildlife Service to increase their water storage capacity, and small wetlands inadvertently missed by the field crews.

Results and discussion

We measured a total of 213 wetlands and determined pond volumes on the 648-ha (1,600-acre) study area. All of the ponds were small and shallow, averaging 0.27 ha (.67 acre) in size and only 0.44 m (1.4 feet) in maximum depth (Table 1). In total surface area, these 213 small ponds comprised 50% of the total water surface and 88% of the total number of water areas on the study area (Table 2). Seven large wetlands accounted for 43% of the total water surface area but only 3% of the number of water areas (Table 2). Small wetlands typically comprise most of the glaciated prairie wetlands in high-density wetland topography, but they usually comprise only about 50% of the wetland water surface area (*9, 24, 35*).

The ponds contained an estimated 19.58 ha-m (158.7 acre-feet) of water during the week of measurement (Table 1). Much of this water probably came from snowmelt runoff and spring precipitation. Visits to the site prior to the vernal thaw revealed that many of the wetlands had little or no ponded water beneath the snow cover.

If these wetlands had been artificially drained via surface ditches (the most common method of drainage in south Dakota), that volume of water would have been relocated elsewhere in the watershed. Under the right conditions, this water would contribute to flooding at lower elevations in the watershed. Many of the depressions containing the wetlands measured in our study were not filled to capacity. More water could have been stored.

Although small, shallow wetlands are the easiest and usually the first to be drained artificially, large wetlands also are drained frequently. Because large wetlands were not included in our study, our volume estimate should be viewed as the low end of the range of water volumes that could be retained and possibly released by artificial drainage.

The Altamont Moraine in South Dakota covers an estimated 645 km² (249 square miles) (*10*). Extrapolating our water volume results over the entire moraine shows that the amount of water held in small wetlands in April 1982 would have been about 1,949 ha-m (15,800 acre-feet). This extrapolation assumes, of course, that the density of small wetlands and the water conditions throughout the moraine were similar to those in the study area. Though these assumptions have not been verified, the extrapolation illustrates that over a large region small wetlands can store vast amounts of runoff.

As mentioned, prairie pothole wetlands may be important sites for recharge to surficial groundwater aquifers. Sloan (*31*) suggested that prairie wetlands with net seepage outflow tend to be ephemeral, temporary, seasonal, or semipermanent wetlands. However, semipermanent wetlands also may be transitional or discharge types. Of the 213 wetlands we measured, 2 (<1%) were ephemeral, 16 (8%) were temporary, 110 (52%) were seasonal, and 85 (40%) were semipermanent.

For simplicity, assume that all of these wetlands functioned as groundwater recharge sites at the time of measurement. This assumption is probably valid because most of the small wetlands in the area have been dry for several years due to drought. Hence, the water table was probably below the bottom elevation of most of the

Table 1. Summary of morphometrical measurements of 213 small ponds in prairie wetlands on 648 ha (1,600 acres) of the Altamont Moraine.

Variable	*Range*		*Mean*	*Sum*
	Minimum	*Maximum*		
Surface area (ha)	0.001	2.92	0.27	58.04
Maximum depth (m)	0.09	1.00	0.44	-
Volume (ha-m)	0.0002	1.73	0.09	19.58

Table 2. Amount of surface water and number of water areas occurring on four tracts of public land in northeastern South Dakota.

Category	*Surface Area*		*Water Areas*	
	Hectares	*Percent of Total*	*Number*	*Percent of Total*
Study ponds (small wetlands)	58.04	50	213	88
Other water areas:				
Large or deep wetlands	50.60	43	7	3
Small wetlands missed	0.57	<1	10	4
Modified wetlands	4.32	4	12	5
Intermittent stream	3.43	3	1	<1
Subtotal	58.92	50	30	12
Total	116.96	100	243	100

wetlands. A 12% water loss from these wetlands to groundwater over the course of the annual cycle would be conservative (*1, 25*). If 12% of the 19.58 ha-m of water retained in the small wetlands we measured seeped into the groundwater, total recharge would amount to about 2.35 ha-m (12 acre-feet). That is enough water to supply an irrigator with 3.6 cm (1.4 inches) on 64.8 ha (160 acres) or to supply 1,699 head of cattle for 1 year. These figures are based on a single-point-in-time measurement. They do not take into account further water inputs to the wetlands for the remainder of the season. The recharge estimate should thus be viewed as minimal.

If the estimated groundwater recharge of 2.35 ha-m were spread out over the entire study area, then accretion to the water table would amount to 0.36 cm. This figure compares favorably with published recharge values obtained in other portions of the glaciated prairies and parklands.

A year-long study of a single, small wetland in the glaciated aspen parkland region in south central Saskatchewan found that the net groundwater recharge from the wetland amounted to 1.07 cm (.42 inch) over the 0.81-ha (2-acre) watershed (23). Most of that recharge occurred during the spring and early summer, before evapotranspiration demands intercepted the seepage outflow from the pond.

In calculating the water balance for a drainage basin in east central Saskatchewan, Freeze (*11*) estimated that recharge rates on the till portion of the basin were less than 0.25 cm (.10 inch) per year, and usually less than 0.025 cm per year. That study was conducted in an area receiving, on average, 11 cm (4.3 inches) less precipitation per year than our study area.

Immense quantities of water can be held in prairie wetlands collectively—water that is kept out of rivers and streams where it could cause or aggravate flooding problems and water that is allowed to slowly seep into the ground to recharge groundwater supplies. On the subhumid and semiarid glaciated prairies, water conservation is extremely important to the maintenance of agricultural and biological productivity. Water conservation should dictate that the values of remaining prairie wetlands be given serious consideration in the development of water resources.

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