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Remote Monitoring of Selected Ground-Water Dominated Lakes in the Nebraska Sand Hills

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Abstract:
The Landsat-Multispectral Scanner (MSS) data were used to measure lake area fluctuations (1972-1989) for 130 groundwater dominated lakes in the Western Lakes Region of the Nebraska Sand Hills. In general, the pattern shown in lake area hydrographs was similar to that for in-situ lake elevations. In-situ lake-elevation data verify that remote monitoring of surface-area fluctuations, even at relatively coarse spatial resolution, is not only practical and useful, but also it elucidates the hydrologic characteristics of groundwater-dominated lakes of the Sand Hills. The apparent differences in behavior between lakes in the northern and southern portions of the study area may be related to both their location in the regional ground water system and the substantial local hydrologic complexity.

Keywords: remote sensing, time series analysis, Landsat Multispectral Scanner, surface water hydrology, Sand Hills Lakes, wet lands.)

Introduction

Remote sensing is a documented tool for monitoring and analyzing inland aquatic environments (Work and Gilmer, 1976; Gilmer *et al.*, 1980; Rundquist *et al.*, 1987; Bobba *et al.*, 1992; Gitelson *et al.*, 1993; Yacobi *et al.*, 1995). Satellite data allow one to obtain information about the number, spatial distribution, size, productivity, and, in some cases, depth of inland waters. The Landsat Multispectral Scanner (MSS), in operation between 1972 and 1993, provides researchers with a potentially unique historical data archive that can be used to examine surface water resources where no other hydrologic data exist. It may be possible to use MSS data for comparing the impacts of long-term climate change with natural seasonal variations.

The objectives of this paper are to: (1) examine the practical utility of archived digital coarse resolution Landsat-MSS data for investigating the seasonal and/or interannual patterns of lake-size variability; and (2) determine whether the measured fluctuations allow one to make meaningful inferences about the hydrologic characteristics of ground-water dominated lakes. To accomplish these objectives we examined historical satellite data and hydrologic records.

Study Area

The Nebraska Sand Hills, encompassing nearly 50,000 km^2 or about one-fourth of the state, contain an estimated 450 km^2 of shallow lakes and ponds, 260 km^2 of marsh and 4,500 km^2 of subirrigated meadows (Rundquist, 1983). These lakes and wetlands, which exist in sharp contrast to the sparsely vegetated uplands, are the result of a dynamic interaction among climatic, hydrologic, chemical, and biological processes. Underlying the region is 500 to 1000 feet of geologic material that comprises the northern High Plains aquifer. Water-dominated landscape features occur where this vast ground water reservoir intersects the low-lying, flat valley floors. Its myriad of wetlands make the Sand Hills, which provide habitat for over 300 bird species, the second most productive waterfowl area in the United States (Labedz, 1990). In addition, the wet meadows are the primary source of hay for an industry responsible for a third of the beef cattle production in Nebraska. For both environmental and economic reasons, an understanding of the hydrologic processes associated with Sand Hills wetlands is important.

Previous studies (Buckwalter, 1983; Rundquist *et al.*, 1987) have examined the utility of Landsat-MSS data for monitoring Sand Hills lakes. Buckwalter (1983), who analyzed photo enlargements of three MSS scenes for each growing season 1973 to 1978 (18 total images) for seven lakes located in two widely spaced study areas, demonstrated that noticeable differences existed in the area-fluctuation patterns between the two test sites. Rundquist *et al.* (1987), using a total of 58 digital MSS subscenes for 13 lakes in the Crescent Lake and Valentine National Wildlife Refuges (located about 165 km from one another), examined the relationship between rainfall (timing and amount) and lake-area fluctuations and found that: (1) the patterns for the two locations were statistically different, and (2) lake-surface area at the Crescent site was highly correlated with precipitation occurring over the previous 45 days. While both studies provided useful results, they were constrained by the number of available Landsat-MSS images and a minimum of hydrologic data.

The focus for this paper is the "Western Lakes Region" (WLR) of the Sand Hills, which includes southern Sheridan County and northern Garden County (Figure 1). Ground water flow patterns for the region indicate that the WLR coincides with a "saddle" in the regional water table (Figure 2), and that the highest elevations of that surface are slightly north of the boundary between Sheridan and Garden counties. Based on their location in the regional water table, the lakes predominantly in Sheridan County (n = 51) are referred to henceforth as the "northern lakes." Those predominantly in Garden County are referred to as the "southern lakes."

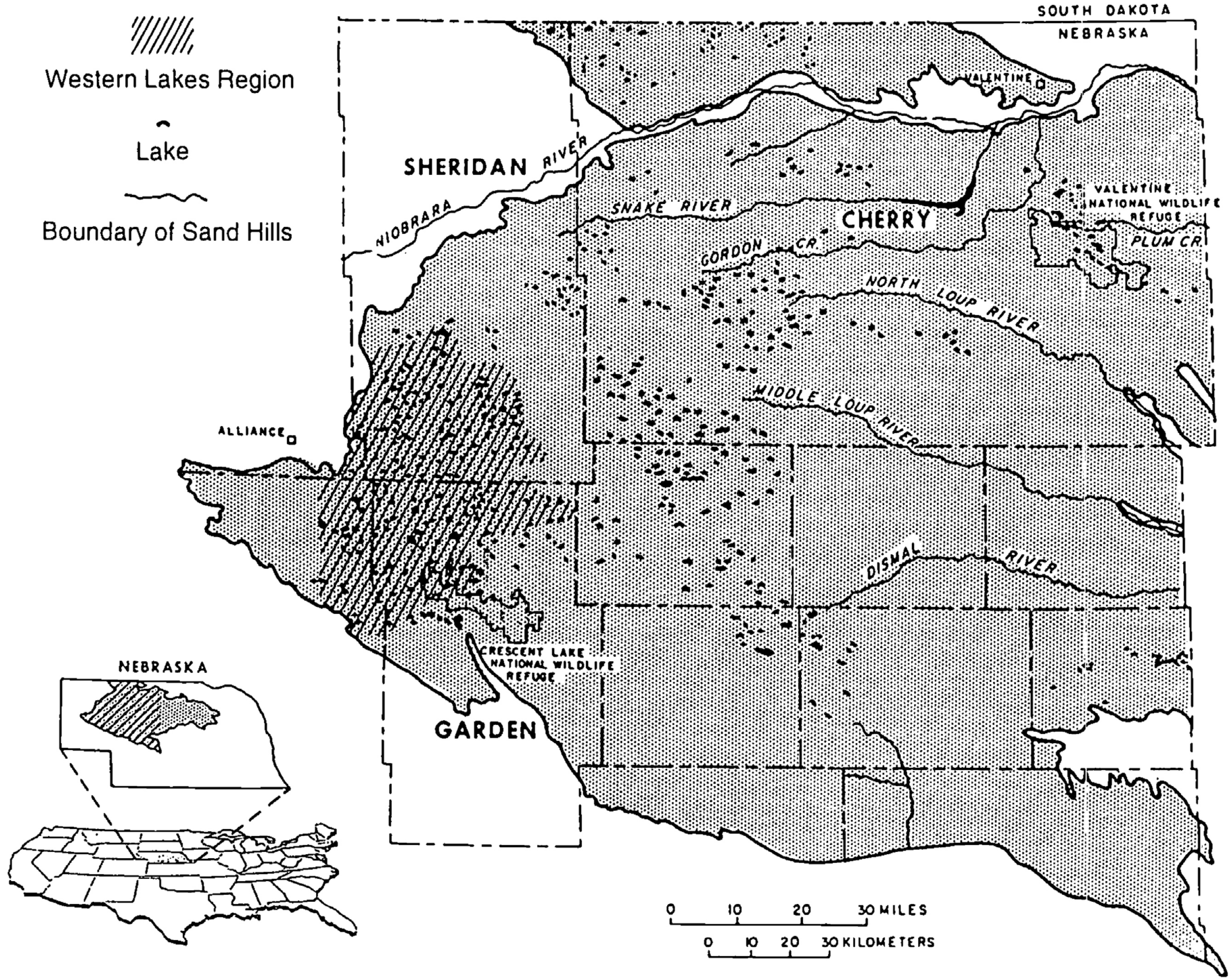

Figure 1. Map Showing Location of Western Sand Hills. The Western Lakes Region occupies the patterned area (modified from Keech and Bentall, 1971).

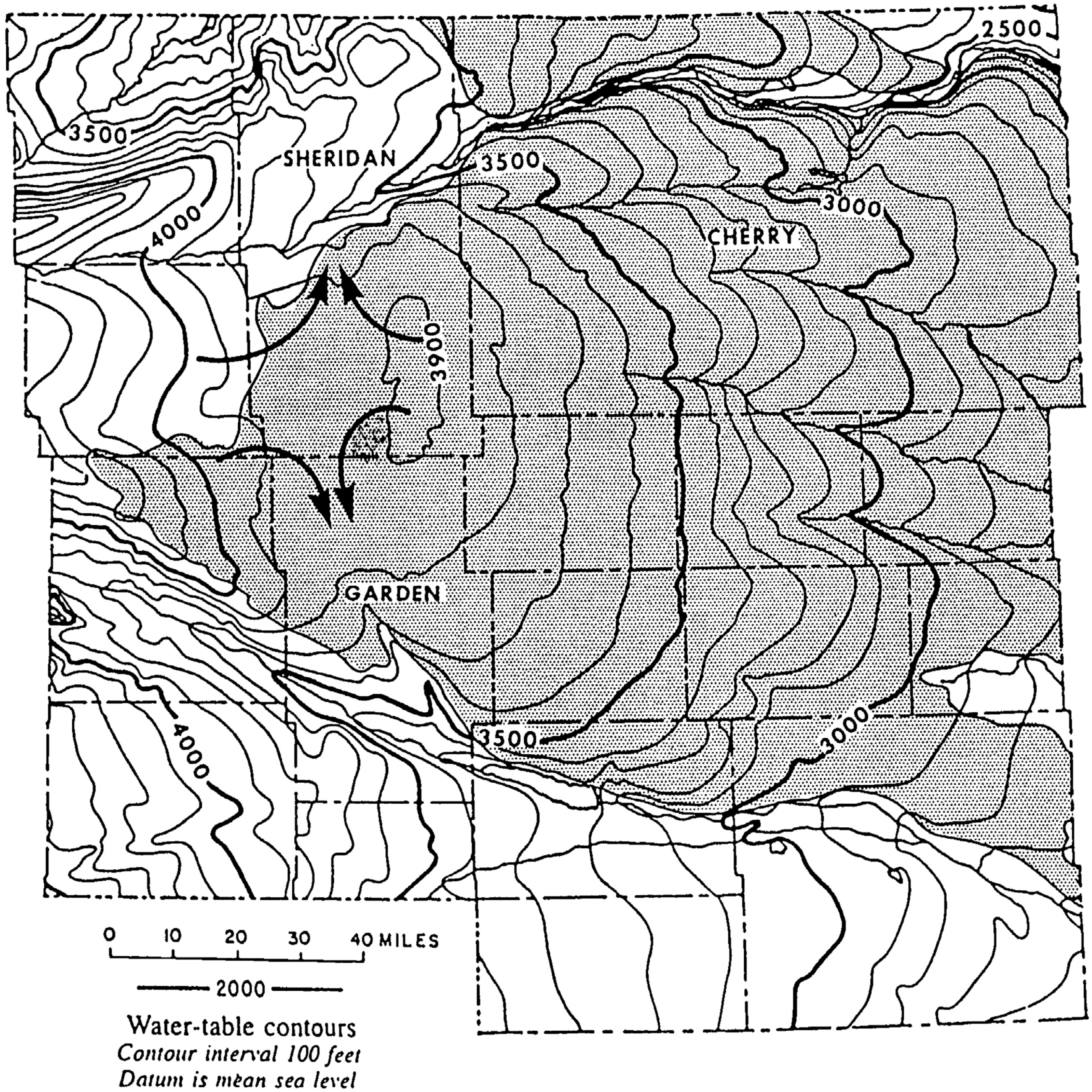

Figure 2. Configuration of the Regional Water Table (modified from *The Groundwater Atlas of Nebraska,* 1986). Arrows pointing north and south indicate the generalized direction of ground water flow, which suggests a "saddle" in the regional flow system.

Sheridan County contains about 521 lakes comprising 16,356 acres, but only 215 are permanent and larger than four acres. Maximum depths tend not to exceed 1.5 m (McCarraher, 1977). Gosselin *et al.* (1994), who visited 15 Sheridan County lakes during 1992 and 1993, measured depths between 2.5 cm to 60 cm, and several were dry between August and October. When the same lakes (and 17 others) were revisited in May, August, and October of 1993, depths ranged from 10 cm to nearly 2 meters. These results and the presence of (paleo) terraces up to 1.3 m above the current shorelines indicate that the lakes were once deeper and larger. Thus, it appears that some variability in lake sizes is common in the region.

The 174 lakes in Garden County comprise 13,260 acres and average less than 1 meter in depth. Blue Lake is exceptional at 5 meters deep. Lakes range in size from less than 10 acres to nearly 970 acres (McCarraher, 1977).

Chemical data (McCarraher, 1977; LaBaugh, 1986; Gosselin, 1997; Gosselin *et al.*, 1994, 1997a) indicate that the lakes in the WLR are compositionally diverse, ranging from fresh to brine (total dissolved solids from less than 200 mg/l to more than 100,000).

Alkalinity (as $CaCO_3$) ranges from less than 200 mg/l to more than 100,000, and pH is usually greater than 8.0. Ground water, derived primarily from local precipitation, is the principal source of water and dissolved solids for the lakes. Inter-lake chemical differences are a function of local hydrologic variability, which is related to the magnitude of inflow and outflow of water from a lake as well as its age (Gosselin *et al.*, 1994; Gosselin, 1997).

Data and Methods

A search for all available Landsat MSS images was conducted, but cloud-cover and variations in areal coverage reduced the number of suitable full scenes to 59, with 17 additional subscenes used for analysis of Garden County (Table 1). All were employed to monitor 130 lakes from 1972 to 1989.

Raw Landsat-MSS digital numbers were converted to reflectance using standard procedures (Markham and Barker, 1986). All images were co-registered and resampled to a spatial resolution of 79 meters using a common nearest-neighbor algorithm.

Standing surficial water within each image scene was located by using MSS-4 (0.8 to 1.1 microns) (Work and Gilmer, 1976; White, 1978; Rundquist *et al.*, 1987). This simple procedure is based on the fact that water absorbs virtually all near-infrared energy, and land (especially vegetated) surfaces are highly reflective in the same wavelengths. Therefore, water appears very dark on the MSS-4 images, while land surfaces tend to be light in tone. The challenge is to determine what specific level of MS S-4 reflectivity marks the "threshold" between terrestrial (or aquatic) vegetation and standing surficial water. Thus, the process is one of "level thresholding" of the MSS-4 reflectance data to delineate water bodies.

Thresholds were determined for each MSS-4 scene for the study area, and water bodies were identified. If individual 79 m picture elements (pixels) were identified as water but were in topographic positions where water could not possibly accumulate, then the threshold for that scene was modified. The final step was to determine the areal extent of surface water for each lake in the study area on a per-image-acquisition basis by means of a simple pixel-counting algorithm.

Lake-elevation data, collected by standard staff-gage procedures, for Roundup, Island, Goose, and Hackberry lakes in the Crescent Lake National Wildlife Refuge (CLNWR) were provided by Dr. Tom Winter, United States Geological Survey. Unfortunately, elevations were not available for other lakes in the study area.

Table 1. Summary of Image Acquisition Dates Used in This Study. Dates having * indicate images available for lakes from the Crescent Lake National Wildlife Refuge only. These lakes include Island, Crescent, Blue, Hackberry, Goose, Roundup, Crane, Christ, Brewer, Gaff, Jones, Gimlet, and Hessey.

Year	Dates
1972	August 19; October 12
1973	May 15
1974	July 4; July 22; September 14; October 20
1975	May 14; July 7; August 22
1976	May 9; October 9
1977	October 13
1978	June 13; October 26
1979	June 25*; August 1; September 6; September 14*; October 2*
1980	June 2*; June 11*; June 29*, July 16*, August 4; August 22*; September 18*; September 27*; October 14*
1981	April 14*; May 1; May 19; June 6; June 24; July 11*; July 30; October 10*; October 16
1982	April 17*; June 28*; July 16; October 14* 1983 March 1; April 2; May 4; June 21; July 7; August 8; September 9; September 25; October 27
1984	April 12; May 14; May 30; June 15; July 17; August 10; September 3; September 19
1985	March 14; April 15; May 1; June 18; July 4; September 6; October 24
1986	May 4; September 25
1987	May 7; July 10; July 26; August 11; September 12; September 28
1989	April 18; May 20; July 23

Results And Discussion

The Utility of Landsat-MSS Data for Investigating the Seasonal and/or Interannual Patterns of Lake-Size Variability

The first objective for our research was to assess the use of Landsat-MSS data for examining seasonal and/or interannual patterns of lake-area fluctuation. To address this objective, one must consider the fact that most of the interdunal valleys in the region are broad and flat. Therefore, one would expect a close correspondence be-

tween surface-area and lake-elevation measurements. Basically, lake areas should increase as lake elevations increase, and vice-versa. We investigated the lake area changes over time for Crane, Island, Hackberry, and Roundup lakes in the CLNWR, based on 59 full or partial satellite scenes from 1979 to 1987 (Figure 3). We compared these areal fluctuations to *in-situ* ground water and surface water measurements at CLNWR (Winter, 1986, and unpublished data; Keen, 1992; Khisty, 1997). These are the only lakes that have staff gage measurements in the Western Lakes region and they have only been measured since 1982.

Figure 4 compares lake area and lake elevation measurements for one selected water body. The lake elevation hydrograph for Island Lake shows the characteristic increase in water levels from mid-September into early or late spring, followed by a progressive decrease from late spring until the first killing frost (Gosselin *et al.*, 1997b; Drda, 1998). In general, the lake area hydrographs have a pattern that is similar to the lake elevations, and the peak in lake area occurs within the same time frame that the lake elevation is within 0.20 feet of its maximum. In addition, the minimum elevations and areas generally coincide and occur in mid-to-late September. Combining the lake area measurements for 1982 to 1989 (Figure 3), for which we have ground-truth data (lake elevation), with those from 1972 to 1982 indicates that the seasonal and interannual variability has been fairly regular over the period of record with the exception of one data point for Island Lake in 1978. In this case, the lake was artificially lowered to modify the fish populations.

Although there is a general coincidence of lake area and elevation, a comparison of 39 area and elevation measurements obtained within about 10 days of each other for Island, Crane, Hackberry, and Roundup lakes indicate that these two parameters are at best only weakly correlated when all data are considered (Table 2 and Figure 5). If we consider seasonal fluctuations, within which there are times when the amount of water in a lake is generally increasing (gaining) and corresponding periods when the amount is decreasing (losing), we find that the correlations are highly variable from 0.99 to -0.16 (Table 2). This apparent variability in correlation between the elevation and area is the result of several factors. First, lake elevation data are inherently more accurate than the 79 m spatial resolution of the satellite data as used for

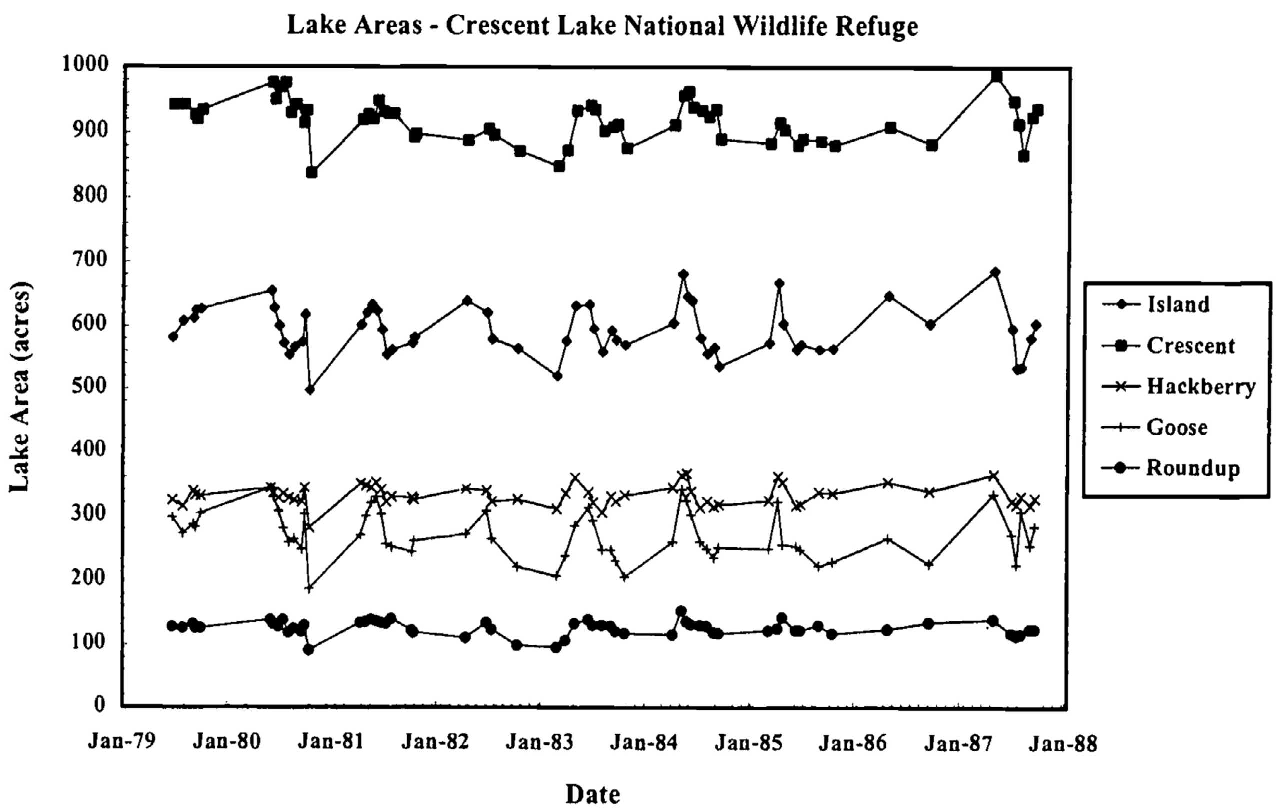

Figure 3. Lake Area Hydrographs for Island, Crescent, Hackberry, Goose, and Roundup Lakes in the Crescent Lake National Wildlife Refuge.

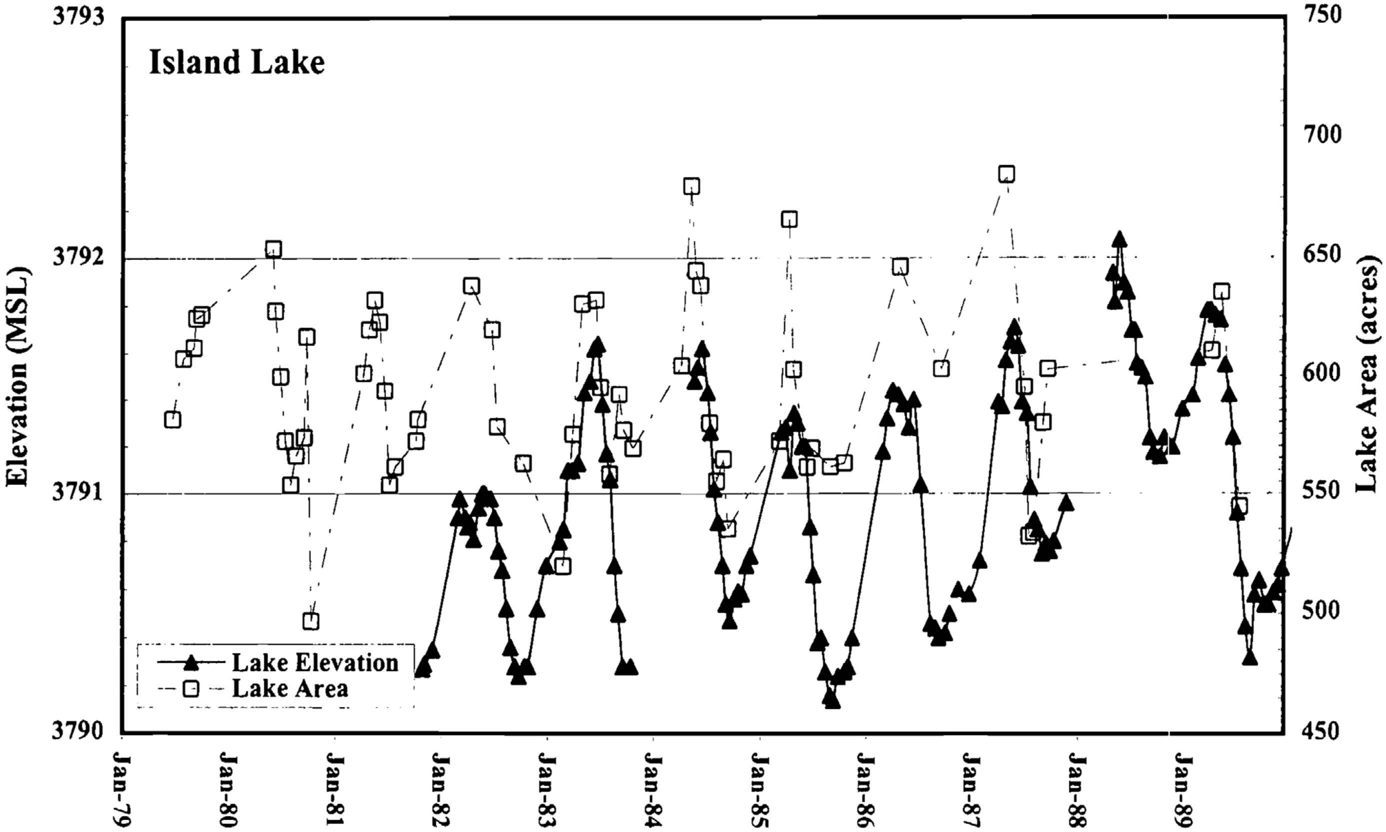

Figure 4. Comparison of Lake Area and Elevation Measurements for Island Lake from 1979 to 1989.

Table 2. Lake Elevation and Lake Area Correlation Coefficients for Island, Crane, Hackberry, and Roundup Lakes in the Crescent Lake National Wildlife Refuge. Gaining periods represent the time that the amount of water in the lake is generally increasing. This period usually is from late September to mid-June. Declining period represents the time when the amount of water in the lake is generally decreasing. All data includes 39 images and water level measurements.

Lake Level Change	All Data	Island Lake		Crane Lake		Hackberry Lake		Roundup Lake
	1981–1989	0.58		0.71		0.39		0.35
Gaining	3/1/83 to 6/21/83	0.96	3/1/83 to 6/21/83	0.68	3/1/83 to 6/21/83	0.73	3/1183 to 6/21/83	0.98
Gaining	9/25/83 to 6/15/84	0.99	10/27/83 to 6/15/84	0.95	9/25/83 to 6/15/84	0.75		
Declining							6/15/84 to 9/19/84	0.91
Gaining	9/19/84 to 6/18/85	0.54	9/19/84 to 6/18/85	0.67	9/19/84 to 6/18/85	0.48	9/19/84 to 6/18/85	0.34
Declining	7/10/87 to 9/28/87	0.66	7/10/87 to 9/28/87	–0.16	7/10/87 to 9/28/87	–0.20	7/10/87 to 9/28/87	–0.87

lake area. With this coarse image resolution, it seems unreasonable to expect subtle changes in lake elevation to be detected in the lake area measurements. In fact, an important finding is that lake area usually begins to decrease earlier than lake elevation (Figure 4). The explanation for this finding is related to a second, even more important, factor. That is, during the time when the lake elevation is reaching its peak, the density of lake-margin vegetation is also increasing. Because of this increase in cover, the water beneath the canopy cannot be detected by the Landsat-MSS.

Nevertheless, even with these limitations, the MSS data record seasonal and interannual variations in lake area. Our analysis revealed a trend of increasing surface

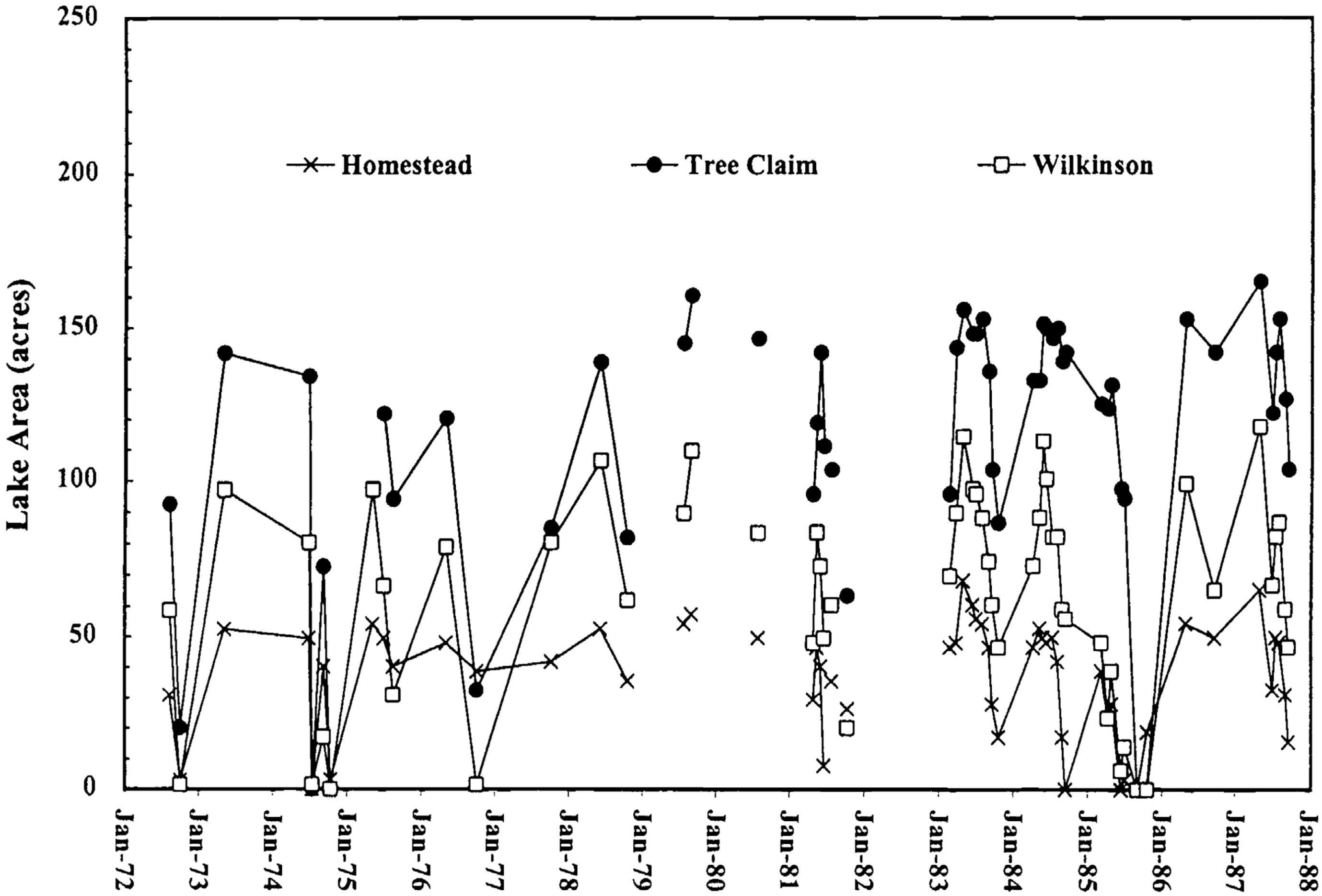

Figure 5. Lake Area *vs.* Lake Elevation for Island, Hackberry, Crane, and Roundup Lakes in the Crescent Lake National Wildlife Refuge. Values on the graph are correlation coefficients (see Table 2 for additional information).

area from mid-to-late September of a given year with maximum spatial extent occurring between late April and mid-June of the following year. The areal maximum was followed by a general decrease in lake size until the cycle began again.

The Utility of Measured Lake-Area Fluctuations for Elucidating the Hydrologic Characteristics of Groundwater-Dominated Lakes

Our second objective was focused on determining whether or not the fluctuations in lake areas, as measured by means of Landsat-MSS data, are useful for elucidating the hydrologic characteristics of groundwater-dominated lakes. Landsat-MSS data provide an historical record back to 1972, so one can monitor lakes for which no site-specific staff-gage data have been collected. For the period and particular image-acquisition dates defined by the availability of suitable Landsat-MSS datasets (1972-1989), the 130 lakes examined in this study ranged in size from < 1.5 acres to > 910 acres, with a mean of 105 ± 22 acres and a 95 percent confidence interval (Table 2). A histogram of lake-area sizes (Figure 6) indicate that they are generally larger than 25 acres but less than 200 acres. The northern lakes, mainly in Sheridan County (n = 51), averaged 80 ± 17 acres in size. These southern lakes in Garden County (n = 79) averaged 122 ± 34 acres, which was statistically different (p < 0.5) than the average area for the northern lakes. Despite the relatively coarse resolution of Landsat-MSS data and the use of a simple level-threshold procedure, the data appear to be useful for monitoring and measuring lake areas over long periods of time.

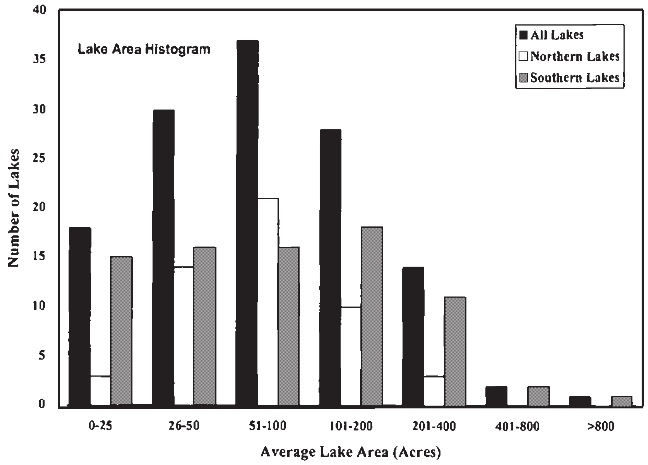

Figure 6. Histogram of Average Area for the 130 Lakes Examined in This Study. Histograms are also presented for the northern and southern lakes (date given in Table 1).

In addition to providing information about lake size, the measurements derived from analyses of Landsat-MSS data allow for meaningful inferences about the hydrologic variations of individual, relatively small lakes. This type of information is particularly useful because the hydrologic variations control, to varying degrees, the chemical and biological characteristics of individual lakes. To examine relative variability in size over geographic space, we calculated a coefficient of variation (CV) for each of the 130 lakes (Table 3), where CV = Standard Deviation/Lake Area Mean.

A cursory evaluation for the northern lakes indicates that the seasonal patterns in lake areas are similar to the southern lakes; however, several northern lakes, such as Homestead, Tree Claim, and Wilkinson, dried up at least five times during the period of record (Figure 5). Field observations confirm their ephemeral characteristics.

A comparison of the CVs for the southern versus northern lakes using an *F*-test ($p = 0.05$) indicated that there is a statistically significant difference in lake-size variability between the two regions. Thirty four percent of the lakes in the southern region have CVs less than 0.20 compared to 16 percent in the north. One possible explanation for the differences in variability may be that the southern and northern lakes are in different parts of the regional ground water flow system. The groundwater-fed lakes in the lower part of the southward flowing regional ground water system might be expected to be relatively more stable as recorded in the CVs of 0.06, 0.07, 0.10, and 0.11 for Hackberry, Island, Crane, and Roundup lakes, respectively. On the other hand, lakes in the upper (northern) parts of the ground water flow system would be expected to be more variable. However, the CVs in Table 1 indicate that there is substantial local hydrologic complexity throughout the WLR and the generalization about lakes in the lower and upper part of the ground water flow is too simplistic.

Evidence for complexity is consistent with previous interpretations related to lake chemistry (Gosselin *et al.*, 1994; Gosselin, 1997) that local differences in hydrology between lakes regulates the extent to which geochemical processes will proceed. Our current understanding of the factors that contribute to the development of local hydrologic regimes is limited. One factor that could influence the local regime is the distribution and thickness of geologic materials, which directly affects aquifer properties such as hydraulic conductivity and the extent to which the ground water and surface water interact. In the WLR, crescent-shaped barchan dunes are prevalent (Swinehart, 1990). They vary from closely spaced to widely spaced, have variable heights, and have interdunal valleys that occupy variable amounts of area ranging from 20 to 40 percent. Recent work in the central Sand Hills on the hydrology of interdunal valleys suggests that the topographic relationships between the interdunal areas and the adjacent dunes strongly influence the hydrologic characteristics of individual valleys and by inference the lakes that may occupy them (Gosselin *et al.*, 1999).

Six lakes in the study area (unnamed B, Eldred, Mellis, unnamed AD, Adams, and unnamed AA) had a CV exceeding 0.80, which indicates substantially greater variation than other lakes in the region. An examination of topographic maps and aerial photographs documented that these valleys are used for hay production and that their hydrology had been modified by either ditching or the pumping of water for irrigation. These data indicate that MSS data has the potential to be used to monitor land-use changes in these wetland and lake environments as well as documenting natural hydrologic variations.

Acknowledgments

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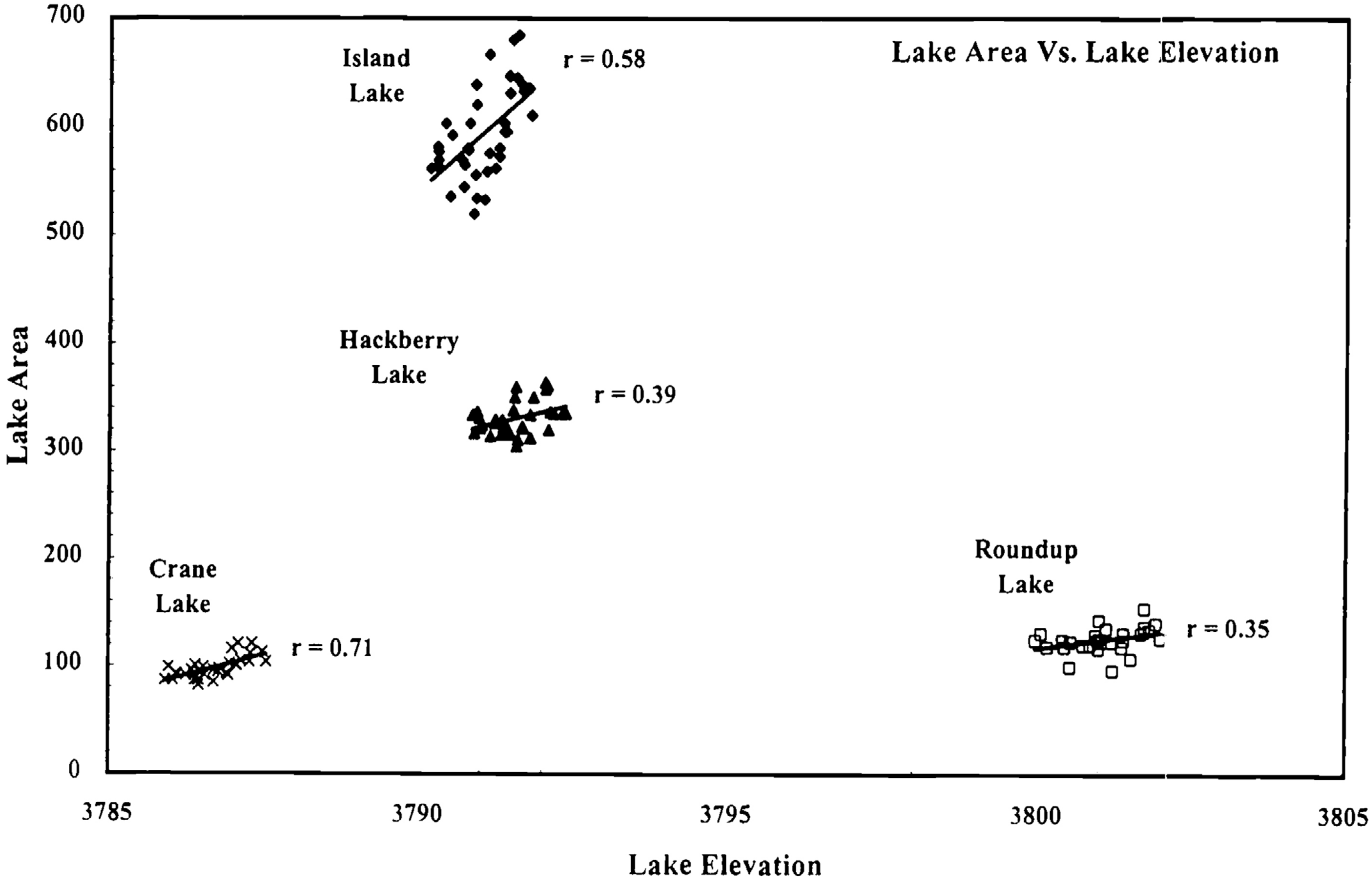

Figure 7. Lake Area Hydrographs for Northern Lakes. Data is from 1972 to 1987 for Homestead, Tree Claim, and Wilkinson Lakes.

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Table 3. Data (in acres) Estimated From 59 LANDSAT MSS Images for 130 Lakes From The Western Lakes Region, Sand Hills, Nebraska. For Dillings, School Island, and Tree Claim, data from May 14, 1975, were eliminated because the lakes were not on the image. One data point in 1978 was eliminated from Island lake because the lake was drained to manage game fish population.

Lake	UTM Coordinates Easting	UTM Coordinates Northing	Maximum Area	Minimum Area	Average Area	Coefficient of Variation
			Garden County			
Crescent	715511	4620231	989	791	913	0.0426
Twin Lakes	704838	4620315	227	29	82	0.5059
Blue	713315	4620893	321	256	279	0.0473
Swan	708290	4621585	464	281	382	0.0766
Jones	711290	4622047	37	<1.5	16	0.3977
Crane	718553	4622728	120	80	99	0.1014
Hackberry	713092	4623410	364	275	327	0.0557
Christ	719901	4623982	23	<1.5	15	0.3086
Island	716626	4623998	685	520	603	0.0681
Lower Harrison	706957	4624483	102	29	50	0.3174
Deer	723745	4624621	143	54	108	0.1957
"F"	713798	4625101	68	<1.5	18	0.5530
Charleys	705595	4625207	42	26	33	0.0951
Roundup	715272	4625273	153	62	124	0.1089
Upper Harrison	706912	4625336	77	8	22	0.4625
"A"	699815	4625839	102	11	70	0.2661
"B"	704088	4626314	39	<1.5	29	0.2055
"D"	695931	4626319	71	<1.5	16	1.3871
Black Steer	722712	4626508	242	139	196	0.1219
Gimlet	713700	4626565	83	17	55	0.2210
Bean	704815	4627278	353	177	280	0.1626
Gaff	715974	4627671	76	17	51	0.2065
Brewer	719249	4627866	56	20	39	0.2167
Goose	712222	4628414	339	205	262	0.1293
Sand	693731	4628982	173	88	133	0.1127
"C"	700151	4629038	51	<1.5	22	0.6462
Smith	705845	4629249	210	65	107	0.2701
Rush	709644	4629578	66	19	39	0.3322
Campbell	713566	4629688	31	<1.5	18	0.3606
"E"	722909	4629928	37	5	24	0.2676
Hessey	719379	4630082	171	42	106	0.2675
Moffit	695003	4631222	160	68	108	0.1579
Wolf	719941	4631322	299	173	218	0.1150
Gullet	715098	4631791	48	8	20	0.4316
Martin	705537	4631972	48	<1.5	16	0.7541
Eldred	702243	4632264	22	<1.5	0	6.0123
Alkalai	699561	4632412	230	<1.5	146	0.3518
"G"	712694	4632807	65	2	35	0.3872
"H"	719167	4633225	42	3	18	0.4715
Heskett	714496	4633252	85	34	50	0.1991
Maverick	716859	4633271	214	91	131	0.2093
Reno	709724	4633489	139	17	27	0.1456
Whitehead	707264	4633756	273	147	194	0.1442
Ashburger	712067	4634654	473	126	381	0.2157
Sage	709615	4635156	51	23	37	0.1957
Ramsay Lakes	711018	4636153	120	31	84	0.1873
"I"	704660	4637020	96	35	51	0.2131
Breman	709532	4637531	134	79	107	0.1254

Table 3 (continued). Data (in acres) Estimated From 59 LANDSAT MSS Images for 130 Lakes From The Western Lakes Region, Sand Hills, Nebraska. For Dillings, School Island, and Tree Claim, data from May 14, 1975, were eliminated because the lakes were not on the image. One data point in 1978 was eliminated from Island lake because the lake was drained to manage game fish population.

Lake	UTM Coordinates Easting	UTM Coordinates Northing	Maximum Area	Minimum Area	Average Area	Coefficient of Variation
			Garden County (cont'd.)			
Mellis	711897	4638131	116	<1.5	24	1.3551
"AD"	701890	4638384	150	8	46	0.7970
Sandbeach	712589	4640451	404	207	286	0.1512
Jordan	703502	4640671	105	22	73	0.2090
"J"	707983	4640972	72	2	47	0.3323
Merrill	705828	4641191	276	130	210	0.1483
Clough	701844	4642984	159	51	114	0.1838
Bluebaker	713846	4643489	211	<1.5	131	0.3378
Whitehead 2	706800	4643726	168	63	126	0.1828
"L"	710164	4644202	69	<1.5	46	0.3589
Mohall	717676	4644213	43	2	25	0.3204
Marys	711724	4644364	131	28	77	0.3218
Murphy	713829	4645049	86	<1.5	28	0.6803
"K"	716488	4645892	76	<1.5	39	0.4648
Beck	702640	4646072	310	177	235	0.1335
Ross	721606	4646227	57	<1.5	33	0.4058
Belle	711893	4647502	290	66	181	0.3026
Hills	702122	4648879	262	117	194	0.1700
Adams	720387	4649153	35	<1.5	10	1.1061
Schoonover	709870	4650337	697	481	625	0.0801
Stockholm S	716109	4650987	88	<1.5	39	0.6866
Roland	713701	4651180	93	2	61	0.3404
Herman	711233	4651425	140	2	84	0.4286
Stockholm N	715072	4651552	182	96	152	0.1076
Dennis	721719	4652657	37	<1.5	15	0.7169
"M"	716834	4653203	140	<1.5	70	0.4265
"N"	702340	4653564	46	<1.5	27	0.4544
			Sheridan County			
Nelson	706161	4653989	88	<1.5	50	0.4288
Patterson N	716221	4654200	71	22	51	0.2436
Strong	708907	4654726	187	28	100	0.3737
Floyd	712742	4654970	369	222	288	0.1035
Hiers	701698	4656201	114	35	82	0.1842
McFall	709059	4656208	60	9	44	0.1990
McFall 2	704966	4656527	116	23	78	0.2404
Ashburger 2	708232	4658599	80	6	45	0.4008
Hancock	711579	4659104	79	<1.5	40	0.4378
Lane	704502	4659269	72	22	53	0.2120
Harris	716056	4659736	82	9	60	0.2319
"O"	704917	4660230	51	<1.5	28	0.6387
Potash	700348	4660368	66	19	51	0.1759
Thompson	713275	4661932	185	134	164	0.0705
Palmer	698874	4662215	190	17	108	0.3225
Welsh	716234	4663005	91	28	55	0.2166
Lily	700723	4663308	86	<1.5	47	0.4419
Mulhull	708472	4663528	106	<1.5	60	0.4622
Bower	699748	4663709	153	51	102	0.2143

Table 3 (continued). Data (in acres) Estimated From 59 LANDSAT MSS Images for 130 Lakes From The Western Lakes Region, Sand Hills, Nebraska. For Dillings, School Island, and Tree Claim, data from May 14, 1975, were eliminated because the lakes were not on the image. One data point in 1978 was eliminated from Island lake because the lake was drained to manage game fish population.

Lake	UTM Coordinates Easting	UTM Coordinates Northing	Maximum Area	Minimum Area	Average Area	Coefficient of Variation
			Sheridan County (cont'd.)			
Williamson	719809	4665121	136	5	105	0.2422
Cody	707461	4665724	74	17	51	0.2550
"P"	699057	4665907	74	<1.5	46	0.4295
Simondson	708346	4666230	165	25	114	0.2879
Dennis 2	714871	4666862	79	40	62	0.1249
Jess	699402	4666897	40	<1.5	21	0.4392
"Q"	699954	4667572	100	<1.5	59	0.3259
Snow	710115	4667999	299	180	266	0.0752
"R"	700443	4668281	63	<1.5	29	0.4748
Tin Can	726642	4668426	123	9	80	0.1910
"AB"	718999	4669729	190	63	115	0.3160
Wickson	698771	4670053	170	<1.5	125	0.2755
O'Brien	723751	4671728	190	32 1	06	0.3635
White	718653	4671892	120	22	75	0.2095
T Briggs	704764	4672159	37	<1.5	25	0.3396
"X"	710401	4672511	79	<1.5	50	0.2796
"AC"	705323	4673223	72	<1.5	47	0.3792
"W"	713203	4673873	150	25	77	0.3188
Tree Claim	699290	4674070	165	0	110	0.4111
Bennet S	700783	4674509	86	<1.5	56	0.3688
"S"	702094	4674536	62	<1.5	39	0.4288
Bennett N	700063	4675027	134	<1.5	88	0.3130
"Y"	717143	4675095	196	<1.5	85	0.4400
Wilkinson	701540	4675618	80	<1.5	28	0.7555
Peter Long	708506	4676954	387	14	271	0.3131
"Z"	716871	4677132	99	45	71	0.1757
School Island	700745	4677895	109	<1.5	51	0.6724
Wilkinson 2	703808	4678046	117	<1.5	61	0.5543
"AA"	717608	4678923	139	<1.5	23	1.8599
"U"	701128	4680464	68	<1.5	37	0.5021
"V"	708242	4680566	228	<1.5	135	0.3561
Dillings	699698	4681024	80	15	60	0.1487
Goose 2	705944	4681501	69	5	48	0.2266
Diamond	708156	4684246	398	239	312	0.1056
Skunk	704279	4684429	99	17	68	0.2286
Albrecht	706441	4685405	119	<1.5	48	0.7439