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THE RELATIONSHIP OF LAKESHORE DEVELOPMENT TO LAKE MORPHOMETRY IN SOUTH CENTRAL MINNESOTA, AN EXAMINATION OF THE 1961 TO 1971 TRENDS AND THE PROJECTED EFFECTS ON THE 1970 STATE STANDARDS AND MODEL ORDINANCES

By

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The 1967 Minnesota Legislature funded a study entitled "Minnesota's Lakeshore, Resources, Development, Policy Needs" (Borchert, Orning, Stinchfield, Maki, 1970). This study served as the basis for Minnesota's state standards, and its model ordinances governing lakeshore development (Chapter Six: Conservation 70-84), adopted in 1970. The general policy statement declares, "The uncontrolled use of shorelands adversely affects the public health, safety and general welfare by contributing to pollution of public waters and by impairing the local tax base." It is further stated, "The Commissioner does hereby provide the counties of the state with minimum standards and criteria for the subdivision, use and development of the shorelands of public waters located in unincorporated areas, and thus preserve and enhance the quality of surface waters, conserve the economic and natural environmental values of shorelands, and provide for the wise utilization of water and related land resources of the state". Yanggen in his discussion of Wisconsin's shoreland protection program clearly indicates that the Minnesota state standards and model ordinance are among the best, if not the best, state standards in the nation (Goldman, McEvoy, Richerson, 1973). He further states that "regulations can be substantially strengthened both logically and legally by their underlying factual basis. Sound planning and scientific data can document the need for regulations, establish that

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the regulatory provisions are appropriate methods for dealing with the problem, and establish the extent to which private land use is impairing the public interest". It is the purpose of this study to question the logical and scientific basis of our present state standards and ordinances in order that they may be strengthened where necessary. The thrust of our study is first to investigate the relationship of lakeshore development and lake morphometry in South Central Minnesota, and then examine implications.

METHODS

The basic data for examining the relationship between lake shore development and lake morphometry was obtained from two source documents; Colakovic (1973), and Quade, Hill and Darley-Hill (1977). Forty-two lakes occurred in both documents. These are all the non-urban lakes in South Central Minnesota which are bathymetrically mapped and are considered fish management lakes by the Minnesota Department of Natural Resources. Initial study variables measuring lakeshore development were the number of permanent, seasonal, total non-farm, and farm homes, both in 1961 and 1971. In 1961 there were 77 permanent homes, 639 seasonal homes, and 183 farm homes on the forty-two lakes. In 1971 there were 138 permanent homes, 1093 seasonal, and 169 farm homes. Lake morphometry determinations utilized included area, volume, mean depth, shoreline length, shoreline development index, maximum depth and width.

Data were analyzed using the statistical package program SPSS on the UNIVAC 1106 Computer at Mankato State University. The principal thrust was to obtain descriptive statistics and to conduct investigations using correlation techniques. Besides the recorded variables pertaining to lake morphometry and development, additional variables were created through programming transformations. These were used to measure the ratios of permanent homes to total non-farm homes, seasonal to total non-farm homes, and farm homes to total development, and to gauge changes in development over the ten year span 1961 to 1971. Creation of a new variable was suppressed in the event of a zero divisor.

Descriptive statistics obtained for all variables were the mean, variance, standard deviation, standard error, minimum, maximum, range, skewness, and kurtosis. Frequency tables were constructed for all variables pertaining to numbers of homes. A breakdown analysis was done on each of the variables by analyzing it for stratifications of depth, volume, shore length, and shoreline development index. In each stratum the mean, standard deviation, variance and count was obtained for each type of development (e.g., number of seasonal homes on small lakes in 1961).

A matrix of correlation coefficients (Pearson's Product-Moment) was created, involving a match-up of all possible pairs of variables. Significance or non-significance was determined for each coefficient at the .05 level.

RESULTS

Figure 1 shows the locations of the lakes in South Central Minnesota which were utilized in this study. It is observed that most of the lakes are in Le Sueur, Blue Earth, and Martin Counties. The majority of these lakes were produced by irregular glacial deposition of till and are quite shallow by Minnesota standards.

Tables I, II, and III present the area, volume, and shoreline per non-farm home for each of the 42 lakes. The dashed lines in each table designate the strata arbitrarily selected for breakdown analysis.

In Figure 2 are displayed the signs and significances of Pearson's Product-moment Correlation Coefficient for every possible pair-wise match-up of the 24 variables. Many of these were included principally as a means of showing data validity, and also to view strength of known associations; e.g., we expected strong positive associations amongst morphometric variables such as area and volume. We also expected strong associations between morphometric variables and numbers of homes; e.g., area and number of farm homes. Hence, the correlations we were particularly interested in were not these, but those that relate to (1) the changes in number of homes versus morphometric variables, and, perhaps even more so, (2) the percentage change in number of homes over the 10 year span versus morphometric variables. These latter associations are probably the most meaningful, as percentage change eliminates the built-in associations we expect from magnitudes (e.g., number of homes is expected to be positively correlated with lake size). The percentage, however, is the gain (or loss) in number of homes over the 10 years, divided by the number present in 1961; this measure should be a good indicator of what has been happening with respect to development in housing of a certain type, irrespective of numbers present in 1961 or of the magnitude of morphometric values.

With respect to (1), changes in number of homes showed no statistical significance for any of the match-ups of the four change variables with the seven morphometric variables (VDI is not considered here due to the problems of interpretation of this parameter in shallow lakes). However, lack of statistical significance does not preclude investigating signs of the coefficients. In the case of change in number of farm homes, three of the seven signs were negative, showing us little trend. However, for each of the other three variables expressing change in numbers of homes, all seven signs were negative. This may suggest that the larger (deeper, wider) a lake is, the smaller the expected change in numbers of non-farm homes, and the smaller a lake is, the larger the change in numbers of non-farm homes.

With respect to (2) (the percentage change is called "Ratio" in the Figure), the four ratio variables each have seven negative coefficients, except in one instance. Twelve of the 28 coefficients were found to be statistically significant for all four ratio variables. This may well indicate a strong negative association between lake depth and growth (in percentage) of all types of homes. The deeper the lake, the less growth in home numbers; the shallower the lake, the greater the growth.

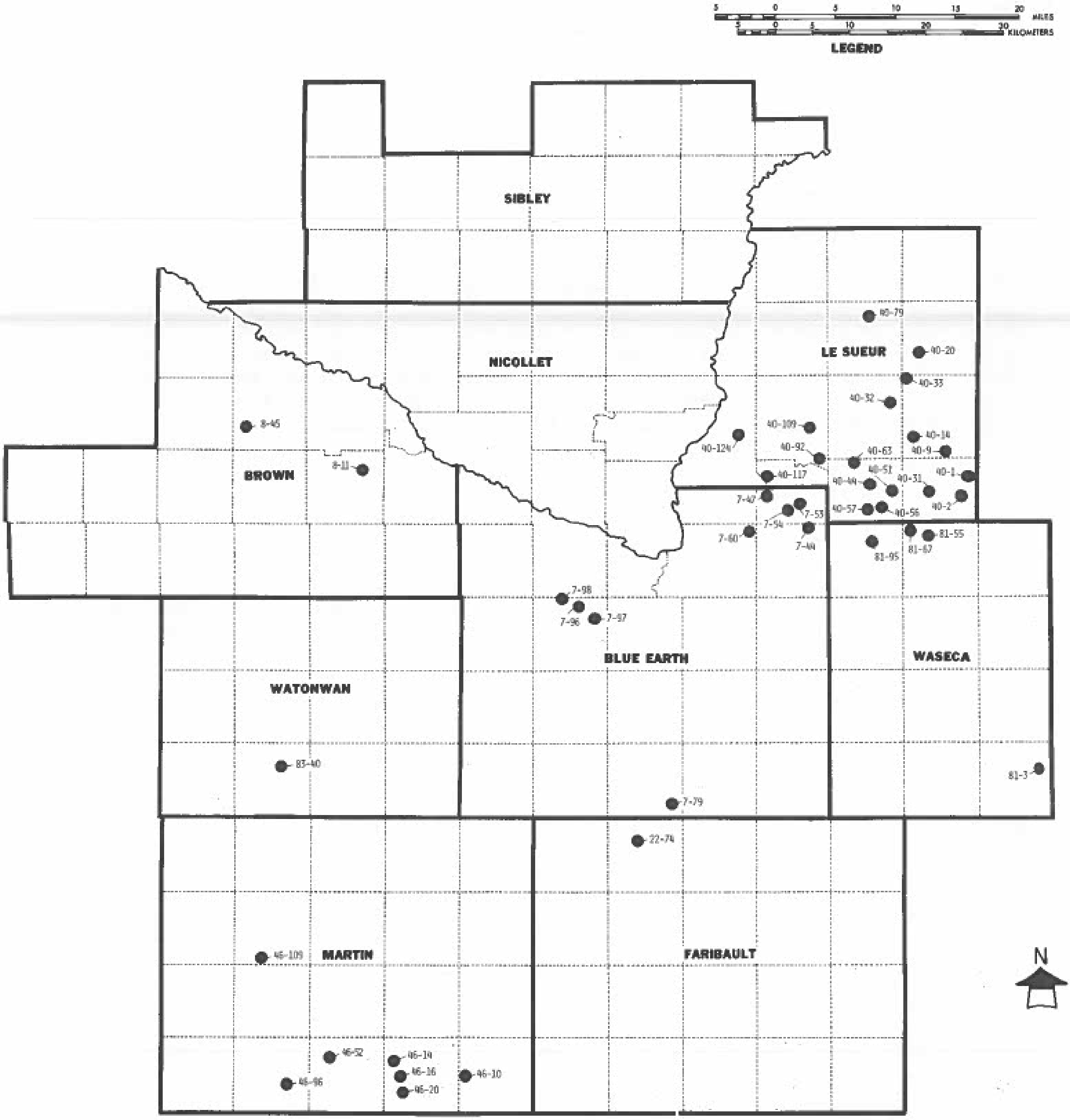

Figure 1. Location of mapped fish lakes in South Central Minnesota

Figure 2.
Significance or nonsignificance of associations as measured by Pearson's product-moment correlation coefficient.

	Farm chng	TNF chng	Permanent chng	Seasonal chng	Ratio F71	Ratio F61	Ratio P71	Ratio P61	VDI	Volume	Area	Width	SDI	Shoreline	Mean depth	Maximum depth	Farms 71	Farms 61	TNF 71	TNF 61	Permanent 71	Permanent 61	Seasonal 71
Seasonal 61	-	-	-	-	-**	-**	-*	-	-	+**	+**	+**	+**	+**	+	+*	+**	+**	+**	+**	+	+**	+**
Seasonal 71	-	+	-	-	-**	-**	-**	-*	-	+**	+**	+*	+**	+**	+*	+**	+**	+**	+**	+**	+	+**	
Permanent 61	+	-	-	-	-**	-**	-	+	-	+**	+**	+*	+**	+**	+	+*	+**	+**	+**	+**	+**		
Permanent 71	+	+	+**	+	-**	-	+	+	+	+*	+**	+	+**	+**	-	-	+**	+*	+	+			
TNF 61	-	-	-	-	-**	-**	-*	-	-	+**	+**	+**	+**	+**	+	+*	+**	+**	+**				
TNF 71	-	+	-	-	-**	-**	-**	-*	-	+**	+**	+**	+**	+**	+	+**	+**	+**					
Farms 61	-	-	-	-	-	-*	-	-*	+	+**	+**	+**	+**	+**	+	+	+**						
Farms 71	+**	-	+	-	-	-	-	+	+	+**	+**	+	+**	+**	-	-							
Maximum depth	-	-	-	-	-**	-**	-**	-*	-**	+*	+	+	+	+	+**								
Mean depth	-	-	-	-	-**	-**	-**	-*	-	+*	-	-	-	-									
Shoreline	+	-	-	-	-	-*	-	-	-	+**	+**	+**	+**										
SDI	+	-	-	-	-	-	-	-	-	+**	+**	+											
Width	-	-	-	-	-	-	+	-	-	+**	+**												
Area	+	-	-	-	-	-**	-	-	-	+**													
Volume	+	-	-	-	-**	-**	-	-	-														
VDI	+	+	+	+	+	+	+	+															
Ratio P61	+*	-	+	+	+**	+	+**																
Ratio P71	+	-	+	-	+**	+**																	
Ratio F61	+	+	+	+	+**																		
Ratio F71	+	-	-	-																			
Seasonal chng	+	+**	+																				
Permanent chng	+	+																					
TNF chng	-																						

+ or - Sign of the coefficient

* Probability less than or equal to .05 that this coefficient occurred due to chance alone

** Probability less than or equal to .01 that this coefficient occurred due to chance alone

Table I.
Lake acres per non-farm home, 1961 and 1971, with ranking for crowding.

Rank Ordered Lakes	Lake Number	Area (Acres)	TNF 1961	Acres/TNF 1961	TNF 1971	Acres/TNF 1971	Rank by Crowding 1961	Rank by Crowding 1971
Jefferson	40-92	2,318.0	147	15.7	157	14.7	7	13
Elysian	81-95	1,894.8	8	236.8	36	52.6	19	22
Washington	40-117	1,593.0	208	7.6	238	6.6	3	7
Tetonka	40-31	1,406.0	64	21.9	99	14.2	8	12
Lura	7-79	1,224.0						
Madison	7-44	1,113.0	13	85.6	37	30.0	17	18
Fox	46-109	936.3			53	17.6		14
Eagle	7-60	914.4			4	228.0		27
German	40-63	899.0	60	14.9	84	10.7	6	10
Upper Sakatah	40-2	888.1	22	40.3	27	32.8	12	19
Frances	40-57	797.0	72	11.0	123	6.4	5	5
Loon	7-96	754.0	1	754.0	5	150.8	21	26
Scotch	40-109	565.2			1	565.0		31
Bright	46-52	546.9						
Gorman	40-32	499.0	1	499.0			20	
Horseshoe	40-1	417.3	2	208.0	1	417.3	18	30
Crystal	7-98	396.0			6	66.0		24
East Chain	46-10	394.9						
Ballantyne	7-54	350.0	10	35.0	26	13.4	10	11
Wilmert	46-14	326.3						
Clear	8-11	313.3						
Greenleaf	40-20	293.0			1	293.0		29
Volney	40-33	283.0	5	56.0	11	25.7	15	16
Duck	7-53	281.8	7	40.2	92	3.06	11	2
Clear	40-79	263.8	8	32.9	12	21.9	9	15
Sabre	40-14	263.0						
Long	83-40	259.6			44	5.8		4
Clear	46-96	255.9	3	85.0	6	42.6	16	20
Sleepy Eye	8-45	250.9			1	250.9		28
South Silver	46-20	245.3	6	40.8	29	8.45	13	8
Emily	40-124	236.4	32	7.38	36	6.5	2	6
Mills	7-97	235.3			3	78.4		25
Bass	22-74	200.8	26	7.72	42	4.78	4	3
Reeds	81-55	191.0			5	38.0		20
North Silver	46-16	169.2			3	56.0		23
Rays	40-56	156.3	3	52.1	6	26.0	14	17
Sunfish	40-9	116.8						
St Olaf	81-3	100.4	16	6.27	33	3.04	1	1
George	7-47	80.4			9	8.9		9
Fish	40-51	78.0						
Steele	40-44	68.8						
Lily	81-67	59.2						

Table II. Lake volumes per non-farm home, 1961 and 1971, with rankings for crowding.

Rank Ordered Lakes *	Lake Number	Volume (cu. ft.)	TNF 1961	Vol./TNF 1961	TNF 1971	Vol./TNF 1971	Rank by Crowding 1961	Rank by Crowding 1971
Tetonka	40-31	1,064,857,600	64	16,638,400	99	10,756,137	11	18
Jefferson	40-92	936,079,430	147	6,367,887	157	5,962,289	5	12
Washington	40-117	678,606,750	208	3,262,532	238	2,851,288	1	5
Elysian	81-95	545,586,950	8	68,198,368	36	15,155,193	18	22
German	40-63	493,227,380	60	8,220,456	84	5,871,754	7	11
Frances	40-57	469,793,970	72	6,524,916	123	3,819,463	6	9
Fox	46-103	438,765,550			53	8,278,595		14
Madison	7-44	414,783,700	13	31,906,438	37	11,210,370	16	19
Upper Sakatah	40-2	271,465,950	22	12,339,361	27	10,054,294	8	17
Volney	40-33	265,848,140	5	53,109,628	11	24,168,012	17	25
Lura	7-79	226,542,330						
Horseshoe	40-1	195,208,280	2	97,604,140	1	195,208,280	19	31
Ballantyne	7-54	172,010,520	10	17,201,052	26	6,615,789	14	13
Scotch	40-109	146,256,830			1	146,256,830		30
Gorman	40-32	143,617,510	1	143,617,510			21	
Emily	40-124	128,758,150	32	4,023,692	36	3,576,615	4	7
Loon	7-96	128,421,470	1	128,421,470	5	25,684,294	20	27
Reeds	81-55	121,229,050			5	24,245,810		26
Crystal	7-98	120,061,900			6	20,010,316		23
Clear	40-79	118,371,690	8	14,796,461	12	9,864,307	9	16
Duck	7-53	117,110,020	7	16,730,002	92	1,272,935	12	1
Bright	46-52	107,220,830						
Greenleaf	40-20	98,421,342			1	98,421,342		29
South Silver	46-20	94,001,049	6	15,666,841	29	3,241,415	10	6
Bass	22-74	88,926,374	26	3,420,245	42	2,117,294	2	4
Eagle	7-60	85,306,873			4	21,326,718		24
Sabre	40-14	81,788,761						
Long	83-40	80,552,588			44	1,830,740		2
Clear	46-96	78,616,796	3	26,205,598	6	13,102,799	15	20
East Chain	46-10	70,837,619						
Fish	40-51	62,777,935						
St. Olaf	81-3	61,875,139	16	3,867,196	33	1,875,004	3	3
Sunfish	40-9	61,469,233						
Rays	40-56	50,862,776	3	16,954,258	6	8,477,129	13	15
Mills	7-97	44,678,498			3	14,892,832		21
Sleepy Eye	8-45	44,164,413			1	44,164,413		28
Wilmert	46-14	37,652,917						
George	7-47	34,014,613			9	3,779,401		8
Clear	8-11	29,043,811						
Steele	40-44	28,382,043						
North Silver	46-16	15,723,850			3	5,241,283		10
Lily	81-67	14,646,588						

*dashed lines indicate the four strata arbitrarily selected for breakdown analysis

Table III. Lake shoreline lengths per non-farm home, 1961 and 1971, with rankings for crowding

Rank Ordered Lakes *	Lake Number	Shoreline (feet)	TNF 1961	Shoreline/TNF 1961	TNF 1971	Shoreline/TNF 1971	Rank by Crowding 1961	Rank by Crowding 1971
Jefferson	40-92	144,144.0	147	980.5	157	918.1	8	13
Elysian	81-95	75,570.0	8	9,446.2	36	2,099.1	18	20
Lura	7-79	69,168.0						
Washington	40-117	62,832.0	208	302.0	238	264.0	1	3
Fox	46-109	56,265.0			53	1,061.6		14
Eagle	7-60	54,384.0			4	13,596.0		29
Tetonka	40-31	52,387.5	64	818.5	99	529.1	7	7
Madison	7-44	51,744.0	13	3,980.3	37	1,398.4	16	17
Upper Sakatah	40-2	42,240.0	22	1,920.0	27	1,564.4	11	18
Frances	40-57	39,916.8	72	554.4	123	324.5	4	5
German	40-63	35,904.0	60	598.4	84	427.4	5	6
East Chain	46-10	28,957.3						
Crystal	7-98	28,545.0			6	4,757.5		25
Long	83-40	26,565.0			44	603.75		8
Horeshoe	40-1	26,482.2	2	13,241.0	1	26,482.2	19	31
Loon	7-96	26,400.0	1	26,400.0	5	5,280.0	21	26
Emily	40-124	24,997.6	32	781.0	36	694.3	6	10
Gorman	40-32	23,925.0	1	23,925.0			20	
Scotch	40-109	23,100.0			1	23,100.0		30
Clear	8-11	21,780.0						
Bright	46-52	21,615.0						
South Silver	46-20	20,625.0	6	3,437.5	29	711.1	14	11
Sunfish	40-9	20,460.0						
Ballantyne	7-54	17,424.0	10	1,742.4	26	670.1	9	9
Wilmert	46-14	17,160.0						
Greenleaf	40-20	15,840.0			1	15,840.0		27
Clear	40-79	14,685.0	8	1,835.6	12	1,223.0	10	16
Sabre	40-14	14,256.0						
Duck	7-53	14,025.0	7	2,003.0	92	152.4	12	1
Mills	7-97	13,728.0			3	4,576.0		24
Reeds	81-55	13,612.0			5	2,722.4		22
Clear	46-96	13,560.0	3	4,520.0	6	2,260.0	17	21
Volney	40-33	13,200.0	5	2,640.0	11	1,200.0	13	15
Sleepy Eye	8-45	12,672.0			1	12,672.0		28
North Silver	46-16	12,375.0			3	4,125.0		23
Bass	22-74	11,715.0	26	450.5	42	278.9	2	4
Rays	40-56	11,137.5	3	3,712.5	6	1,856.0	15	19
Fish	40-51	9,240.5						
St. Olaf	81-3	8,316.0	16	519.7	33	252.0	3	2
Lily	81-67	7,837.5						
George	7-47	7,392.0			9	821.3		12
Steele	40-44	6,336.0						

*dashed lines indicate the three strata arbitrarily selected for breakdown analysis

Area

The strong statistical correlation (Figure 2) between area and all forms of lakeshore development was examined by a breakdown according to an arbitrary stratification. The three strata chosen were from 1 to 275 acres, 276 to 600 acres, and 601 or more acres (Table I). The actual range for the 42 lakes was from 59 to 2,318 acres.

In 1961 the greatest proportion of seasonal homes was found on lakes with the largest surface area (Table IV). There was an average of 4.3 seasonal homes on small lakes (area category 1), 1.6 on medium lakes, and 45.2 on large lakes. The growth which occurred between 1961 and 1971 resulted in a somewhat more even distribution, although the large lakes still experienced the greatest development in actual numbers of homes. However, in proportionate growth, lakes in category 1 showed a change of 132 percent as compared to 537 percent in category 2 and only 44 percent in category 3.

Permanent home development showed some of the same trends as the seasonal homes with the greatest difference being that the smallest lakes saw the greatest increase by percentage, rather than the intermediate lakes. When looking at total non-farm home development the lakes in category 1 showed a change of 143 percent, those in category 2 increased by 456 percent (due partially to the small base in 1961) and development on lakes in category 3 changed by only 45 percent. Farm homes were evenly distributed amongst lakes in the three area categories, and all categories experienced approximately the same relative decrease during the period 1961 to 1971.

The ratio of permanent homes to total non-farm development increased slightly from 1961 to 1971 in small lakes, decreased substantially in medium-sized lakes and remained unchanged in large lakes. By 1971 it is clear that there is a significantly higher ratio of permanent homes on smaller lakes than on the other two categories. The ratio of farm homes to total homes showed a decrease in all three strata, with the greatest percentage decrease being in the middle category.

Volume

Volume showed strong statistical correlation to all forms of development. Breakdown analysis was based on four arbitrary strata; 1 to 50, 51 to 100, 101 to 400, and 401 or more million cubic feet. The actual range for the 42 lakes was from 15 to 1065 million cubic feet.

In 1961 the greatest number of seasonal homes was located on lakes with large volumes. Immediately above we saw this same phenomenon occur for area, which is to be expected due to high correlation of area and volume). Up until 1961, there had been no seasonal development on lakes in category 1. During the decade in study there was much development in categories 1 and 2, which resulted in smaller differences amongst the strata by 1971.

Table IV. Breakdown of numbers of homes by area, volume, shoreline and SDI.

		Category Number	# Lakes	SEASONAL 1961 Mean	SEASONAL 1961 Sum	SEASONAL 1971 Mean	SEASONAL 1971 Sum	SEASONAL % Chng	PERMANENT 1961 Mean	PERMANENT 1961 Sum	PERMANENT 1971 Mean	PERMANENT 1971 Sum	PERMANENT % Chng	TNF 1961 Mean	TNF 1961 Sum	TNF 1971 Mean	TNF 1971 Sum	TNF % Chng	PERM./TNF 1961 %	PERM./TNF 1971 %	FARMS 1961 Mean	FARMS 1961 Sum	FARMS 1971 Mean	FARMS 1971 Sum	FARMS % Chng	FARMS/TNF & FARMS 1961 %	FARMS/TNF & FARMS 1971 %
Area (acres)	1-275	1	18	4.3	77	9.9	179	132	0.9	17	2.8	50	194	5.2	94	12.7	229	143	18	22	2.7	48	2.4	43	-10	34	16
	276-600	2	12	1.6	19	10.7	128	573	0.5	6	0.9	11	83	2.0	25	11.6	139	156	24	8	3.9	47	3.7	44	-6	65	24
	601-up	3	12	45.2	543	65.5	786	44	4.5	54	6.4	77	42	49.5	595	71.9	863	45	9	9	7.3	88	6.8	82	-6	13	9
Volume (millions ft.)	1-50	1	8	0.0	0	1.1	9	--	0.0	0	0.9	7	--	0.0	0	2.0	16	--	--	44	2.5	20	2.0	16	-2	100	50
	51-100	2	11	3.4	38	10.9	120	215	1.2	13	3.6	40	207	4.6	51	14.5	160	213	25	25	3.7	41	3.4	38	-7	45	19
	101-400	3	14	5.1	72	14.2	199	176	1.1	16	1.6	23	43	6.3	88	15.8	222	152	18	10	3.8	53	3.6	40	-24	37	15
	401-up	4	9	58.7	529	85.0	765	44	5.3	48	7.5	68	41	63.9	575	92.5	833	44	8	8	7.7	69	7.2	65	-5	11	7
Shoreline (1000's ft.)	1-20	1	19	3.3	63	11.4	218	246	0.8	15	1.7	33	120	4.1	78	13.2	251	221	19	13	3.2	61	2.6	49	-19	44	16
	20.1-40	2	14	11.0	154	21.2	297	92	1.6	22	2.2	32	45	12.1	174	23.5	329	89	13	10	3.8	54	3.8	53	-1	24	14
	40.1-up	3	9	46.8	422	64.2	578	37	4.4	40	8.1	73	82	53.3	462	72.3	651	40	9	11	7.5	68	7.4	67	-1	13	9
SDI	1-1.25	1	15	4.2	63	14.1	212	235	1.0	15	2.0	31	106	5.2	78	162	243	215	19	13	3.4	51	2.9	43	-15	39	15
	1.26-1.50	2	8	0.1	1	1.2	10	900	0.1	1	0.5	4	300	0.2	2	1.7	14	600	50	28	2.9	23	2.3	19	-17	92	57
	1.51-2.00	3	9	22.0	198	38.0	342	72	3.3	30	3.0	27	-10	25.1	226	41.0	369	63	13	7	5.1	46	5.0	45	-2	17	11
	2.01-up	4	10	37.7	377	52.9	529	40	3.1	31	7.6	76	145	40.8	408	60.5	605	48	7	13	6.3	63	6.2	62	-1	13	9
	Totals		42 per Group	15.2	639	26.0	1093	71	1.8	77	3.2	138	79	17.0	714	29.3	1231	72	11	11	4.3	183	4.0	169	-7	20	12

There were no permanent homes on category 1 lakes in 1961. By 1971 permanent homes were found in all volume categories. The small-volume lakes experienced the greatest increase during the decade, resulting in a more even distribution of development. These trends can be easily seen by examining the total non-farm development. There was a 213 percent increase in category 2 lakes, a 152 percent increase in category 3 and a 44 percent increase in category 4.

The number of farm homes was evenly distributed amongst the volume categories in 1961 and 1971, with all categories experiencing a decline. The ratio of permanent homes to total non-farm development was substantially higher on lakes with smaller volume. In 1971, 43 percent of non-farm homes in category 1 lakes were permanent, as compared to 25 percent, 10 percent, and 8 percent on the category 2, 3, and 4 lakes, respectively. Likewise the ratio of farm homes to total development was highest on lakes with smaller volume.

Shoreline Length

Shore length showed strong positive statistical correlation to all forms of development. Breakdown analysis was based on three arbitrary strata; 1 to 20 (thousands of feet), 20.1 to 40, and 40.1 or more. The actual range for the 42 lakes studied was 6,336 to 144,144 feet.

In 1961 non-farm development was predominant on lakes with the longest shore lengths (mean number of non-farm homes was 53.3 in category 3, 12.1 in category 2, and 4.1 in category 1). The proportion of permanent homes to TNF development was highest on lakes with the shortest shoreline. By 1971 there was seen an increase in both seasonal and permanent homes on all lakes, with lakes having smaller shorelines (category 1) showing not only the greatest increase in total non-farm development, but also the greatest decrease in number of farm homes.

SDI Index

Shoreline Development Index (SDI) as a morphometric parameter was found to show a strong correlation to shoreline development. SDI is an index which attempts to compare the shape of a lake to a circle. The formula is: the shoreline length divided by two times the square-root of the area, multiplied by pi. If a lake were perfectly round the SDI would be 1.0, which is the minimum possible index value. SDI was arbitrarily divided into four strata for breakdown analysis; 1 to 1.25, 1.26 to 1.50, 1.51 to 2.0, and 2.01 or higher. SDI ranged for the 42 lakes from 1.02 to 4.05.

In 1961 a majority of seasonal homes were on high SDI lakes. It is important to note that the high SDI lakes were also the lakes with the largest shoreline. Permanent homes tended to be more evenly distributed in relation to SDI in 1961. Category 2 lakes showed the greatest increase for seasonal, permenent and total non-farm homes for the period 1961 to 1971.

For total non-farm homes the most irregular lakes (category 4) showed the smallest percentage change during the decade, perhaps indicating previous saturation. There was a significant decrease in farm homes in strata 1 and 2, which corresponded to growth of seasonal and permanent homes on these lakes.

The ratio of permanent homes to total non-farm was highest for both 1961 and 1971 in stratum 2. Further the ratio decreased during the decade for strata 1, 2 and 3 but increased in the most irregular lakes (stratum 4). In all four strata the ratio of farm homes to total development decreased during the decade.

Partitioning

Development on all 42 lakes combined showed a 71 percent increase in seasonal homes, a 79 percent increase in permanent homes, a 72 percent increase in total non-farm homes, and a 7 percent decline in farm homes during the period 1961 to 1971. There was little change in the percentage of permanent to total non-farm development and a major decrease in the percentage of farm homes (see totals, Table IV).

The data broken down by strata in Table IV can be examined from the point of view of units of morphometric parameter per development unit (home) (Table V). It is possible to divide area, volume and shoreline amongst development units, but this cannot be done with Shoreline Development Index.

The acres per development unit in both 1961 and 1971 were highest in the middle strata, but a great deal of the differences amongst strata was eliminated by 1971, due to a 69 percent decrease in acres per development unit during the decade. Volume showed the effect of the development of smaller lakes during the 10-year period by almost halving the cubic feet of water per TNF unit in the smaller lakes, while only showing a 24 percent change in the largest lakes. Shoreline showed a 60 percent decrease in shoreline length per development unit for the smaller lakes, 32 percent for the intermediate lakes, and only 10 percent for the largest lakes.

It is clear from our breakdown analysis (Table IV) that high development during the decade, though still greater in absolute numbers on larger lakes, had a much greater impact on the medium and smaller lakes (Table V). The result has been to somewhat equalize the acres, volume and shoreline available to lakeshore residents of all lake sizes. This equalization of morphometric parameter units per developmental unit may be the result of pure accident or of some other external parameter--economics, land availability, zoning, aesthetics, etc. Secondly, it is clear that the partitioning of the various morphometric parameters as a result of development has resulted in a very significant decrease in these qualities per developmental unit. The question arises as to how much further these should be partitioned.

Table V.

		1961	1971	% Chng
Area (acres)	1	18.2	11.6	-36%
	2	73.2	22.3	-69%
	3	19.6	15.6	-20%
Volume (cubic feet)	1	----	8,661,335	----
	2	6,931,150	3,870,078	-44%
	3	14,424,378	7,463,484	-48%
	4	8,047,090	6,096,374	-24%
Shoreline (feet)	1	1,795	718	-60%
	2	1,139	767	-32%
	3	928	828	-10%

To examine the question of partitioning in more detail we will take a closer look at Blue Earth County. Table VI shows the resulting area and volume per total non-farm development if the present shoreline limits are reached. The acres per TNF unit would range from 1.3 to 4.2 and the cubic feet of water from 314,785 to 1,482,849. The actual 1971 development was from 1.4 to 65.7 percent of shoreline saturation. In four out of the seven lakes, under present standards we could increase development over 10 times.

On May 9, 1978, the Blue Earth County Board of Commissioners heard a request for preliminary plat approval of a 19 lot subdivision for Ballantyne lake (7-54). In 1971 Ballantyne Lake was at 22.4 percent saturation level, with 13.4 acres and 6,615,789 cubic feet of water per TNF development. State Shoreline Ordinance saturation levels would result in 3.0 acres and 1,482,849 cubic feet of water per TNF unit.

During the May 9 meeting the Commissioners questioned if Blue Earth County Planning Office had considered the environmental impact of the proposed development on the water quality of the lake. The representative of the Planning Office explained that the specific question of water quality had not been addressed, but stated that several members of the audience during hearings had voiced concern over the general impact the development would have on the environmental quality of the lake. Dan Masterpole asked if the County Commissioners had a policy concerning the density of development to be allowed on the lakes. Did they have a cut off point where no more development would be allowed? The representative of the Planning staff explained that the county had adopted the State Model Lakeshore Ordinance almost word for word. Mr. Masterpole asked the Board if the State had given them the authority to limit the density of lakeshore development. The Board did not know. Mr. Masterpole stated that it was then feasible for a lakeshore to be totally developed if the lake was zoned for residential use. The representative of the Planning Office agreed that as it now stood that was possible. A commissioner then stated that "the Board had no criteria on which to base an opinion concerning the density of future lakeshore development." The Board of Commissioners then unanimously passed the Preliminary Plat Request.

Discussion

The above subdivision request and disposition is an example of the decision making process with regards to lakeshore development. It is clear that the Blue Earth County Commissioners were concerned about the "environmental effects" of further lake development but that they "had no criteria on which to base an opinion concerning the density of future lakeshore development".

It is our contention that the spirit of the 1970 Minnesota Statewide Standards and Criteria for Management of Shoreline Areas was not to focus on how much shoreline each home should have but rather how much development an individual lake can effectively support while still maintaining its diverse values. It is our further contention that minimal shoreline length

Table VI. Present and potential partitioning of some Blue Earth County Lakes.

Lake	DNR Lake #	DNR Classification	Shoreline in feet	SDI	Area in acres	Volume in cubic feet	Development TNF 61	Development TNF 71	Shoreline/TNF in feet 61	Shoreline/TNF in feet 71	Sat. Level # of units*	71 % Sat. level	Area/TNF in acres 61	Area/TNF in acres 71	Sat. level** Acres/unit	Volume/TNF in cubic feet 61	Volume/TNF in cubic feet 71	Sat. level** cu. ft./unit
Lura	7-79	natural	69,168	2.66	1,224	226,542,330	ND	ND										
Eagle	7-60	natural	54,384	2.43	914	85,306,873	ND	4	54,384	13,596	271	1.4%	914	228	3.3	85,306,873	21,326,718	314,785
Madison	7-44	recreational	51,744	2.08	1,113	414,783,700	13	37	3,980	1,398	344	10.7%	85.6	30	3.2	31,906,438	11,210,370	1,205,706
Crystal	7-98	general	28,545	1.90	396	120,061,900	ND	6	28,545	4,757	285	2.1%	396	66	1.3	120,061,900	20,010,316	421,269
Loon	7-96	recreational	26,400	1.42	754	128,421,470	1	5	26,400	5,280	172	2.9%	754	150	4.2	128,421,470	25,684,470	729,667
Ballantyne	7-54	recreational	17,424	1.25	350	172,010,520	10	26	1,742	670	116	22.4%	35	13.4	3.0	17,201,052	6,615,789	1,482,849
Duck	7-53	general	14,025	1.12	281	117,110,020	7	92	2,003	152	140	65.7%	40.2	3.06	2.0	16,730,002	1,272,935	836,500
Mills	7-97	natural	13,728	1.20	235	44,678,498	ND	3	13,728	4,576	68	4.4%	235	78.4	3.4	44,678,498	14,892,832	657,036

* Saturation level calculations based on minimum lakeshore frontage requirements:
Natural = 200 feet
Recreational = 150 feet
General = 100 feet

** Volume and Area Saturation levels based on Shoreline length Saturation.

alone is not an adequate criterion. By extrapolating the shorelength criterion to the maximum development permitted, as seen in Table VI, the effect would be potential problems in water use and water quality, depending on the individual morphometry of each lake. Perhaps a series of cut-offs based on several criteria would be more effective.

Area

The lakes in our study ranged from 59 to 2,318 acres. The calculated acres per total non-farm development unit ranged from 11.6 to 22.3 (Table VI). A recommended cut-off for acres per development unit is not established at this date. Borchert, et al. (1970) state "The most crowded lakes (in Minnesota) have 15 acres of water or less per cabin." Threinan (1962) indicates studies have established that 20 acres of water are needed for each active water-ski boat on a lake, provided other boaters are excluded from the water. The Minnesota Water Resources Coordinating Committee (1970) states that:

> "Projections of boating demand can be forecasted on the basis of population increases, boating industry growth experience, and other factors. In general boat ownership as a function of population will vary from 1 to 5 percent based on availability of water. The attitude of government toward the need for recreation boating will to a major extent determine the level of boating participation in the projection period. The demand for boating facilities is increasing at the rate of 3 percent per year."

They use a system of space standards for calculating lake load. Each fishing boat is calculated as requiring 8 acres of water; 7.5 acres of water is necessary per person for boating, and 20 acres per boat for water skiing.

McKee and Wolf (1963) state that it is difficult to draw a sharp distinction between waters that are used for boating and aesthetic enjoyment, from those that are used for swimming, bathing, and water contact sports, or from those used for fishing and wildlife. This creates further problems, since the above Minnesota Water Resources Coordinating Committee space standards are additive for multiple use. It is clear that the lakes in our study group are presently in conflict with the space standards.

Volume

The volume of the lakes in our study ranged from 15 to 1065 million cubic feet. The calculated volume per development unit for the four breakdown strata (Table V) ranged from 3,870,078 to 8,661,335 cubic feet in 1971. From the point of view of development cut-off criteria the volume of the lake is treated in the sense of potential dilution capability. It is clear that the 1970 Standards and Criteria recognize the problem of the input of pollution to our waters associated with development. However, even with the best regulations to prevent input it is known that increased development will lead to increased input. The Minnesota Water Resources Coordinating Committee (1969) stated that studies of various communities in Minnesota have shown that raw sewage contained from 1.5 to 3.7 grams of phosphate per capita per day. Inadequate sewage treatment by septic systems almost invariably degrades lakes, particularly in areas of high density, and where second homes are being converted to permanent residences (C.E.Q., H.U.D., A.R.C., 1976). A 1968 study showed that 125 defective disposal facilities contributed as much phosphorous to Cormorant Lake, Minnesota, as came from natural sources. And the effects of septic tank leeching over 10 years changed Cochran Lake in Northern Wisconsin from a pristine lake to a "300-acre algal pond" (C.E.Q., H.U.D., A.R.C., 1976).

Even with strict sanitary codes and enforcement, other effects of increased development and lake use exist. An example is given by Smith (1977).

> "Adding to the eutrophication already discussed and destroying the floating and emergent vegetation around lakes is the prolification of permanent and summer homes and marinas on the shores. Such developments and accompanying activities ruin both fisheries and wetlands habitats. Oil pollution from motor boats is a major environmental problem on lakes. Wasting 10 to 40 percent of their fuel, motor boats discharge an oily mixture with gas exhausts beneath the surface of the water, where it escapes immediate detection. One gallon of oil per million of water imparts an odor to lake waters; eight gallons per million taint the flesh of fish. A mixture of 50 parts water to one of oil requires 30 million gallons of lake water for the decomposition of hydrocarbons. Such oily discharges can lower oxygen levels and have an adverse effect on the growth and longevity of fish."

Because lakes in South Central Minnesota are shallow relative to the state average, volume is an even more critical factor for this area of the state.

CONCLUSION

Pereira (1973) states that water resources are belatedly receiving a due measure of research attention in most countries of advanced technology, but the current fashionable enthusiasm for ecological protection frequently confuses the issues. He states that "in temperate climates the general public of the Western World are newly awakening to the realization that our technical progress already outruns our ability to protect vital natural resources. Many decisions on land use must be made on the fragmentary evidence which we now have."

Kneese and Bower (1968) state that the contemporary problems of water quality management raises three main issues: First, how do we determine the quality of water we want to maintain? Second, what is the "best" system of management measures for achieving the specified pattern of water quality? Third, what are the best institutional or organizational arrangements for managing water quality? It is our feeling that the 1969 Minnesota Shoreland Management Act needs to be assessed and evaluated in relation to these three issues especially in light of additional evidence which can now be brought to bear.

In 1974, Governor Anderson stated, "It is presently very difficult to obtain qualified personnel to effectively administer and enforce this program (Minnesota Shoreline Ordinance) at the state and local levels". He went on to say that "they (shoreland standards) will reduce the possibility of overcrowding and curb poorly planned development of shoreland areas, and thus stabilize property values." Many studies have established the increased benefit of water pollution control in increasing property values, after the fact. Dornbusch and Barragen (1973) found that "effective pollution abatement on badly polluted water bodies would increase the value of single-family homes situated on waterfront lots by 8-25 percent." Our concern is whether the present shoreline ordinance as applied in South Central Minnesota will lead to environmental degradation (real or perceived) and result in lake property devaluations.

C.E.Q., H.U.D., A.R.D. (1976) states "because of their tendency to locate in more sensitive environmental areas, recreational subdivisions result in environmental impacts which are more difficult to ameliorate." The subdividing of rural America into recreational lots and second home development has reached an estimated 10 million lots in the United States with the highest concentrations of second homes occurring in the Great Lakes Region and New England. In these regions lakeshore sites are preferred.

As a response to their unique problems many lakeshore home owners are forming various types of lakeshore property owners' associations (LPOA). Klessig and Yanggen (1972), in their study of 136 of these Wisconsin associations found from a questionnaire containing a list of 22 common problems that more associations were concerned with water pollution than with any other problems (80 percent). Enforcing building codes was the problem ranked fourth while planning development was ranked ninth. They found that voluntary associations and associations on lakes of over 300 acres are more likely than are mandatory associations or associations on small lakes, to recognize a need for further planning. Michigan associations considered the regulation of water skiing and/or boating to be the second greatest LPOA concern. The regulation of the uses of the lakes and the regulation of the number of users are two common approaches utilized to ameliorate problems. Klessig and Yanggen conclude, "A wide range of public and private interests are involved in decisions affecting the use of our lakes. Appropriate institutional mechanisms involving both the public and private sectors are needed to carry out long-range lake management."

A possible model for lake management could come out of the many reservoir management programs. The authors are presently investigating this.

Finally, Gleason and Adams (1975), in their discussion of the planning process and local land use control systems, emphasize that "an effective land use control system for Minnesota will emphasize directions rather than end-products. It will state where we want to go in terms of reduced rates of growth and change, rather than where we want to get in terms of describing the map of the state for the year 2000!" It is our contention that the Minnesota State Standards and Model Ordinance is being used as end-product planning and will, for lakes in South-Central Minensota, result in the deterioration of the very resource the legislature set out to protect.

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