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A COMPUTERIZED ICE CONCENTRATION DATA BASE FOR THE GREAT LAKES

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A COMPUTERIZED ICE CONCENTRATION DATA BASE FOR THE GREAT LAKES

Raymond A. Assel

ABSTRACT. A 20-winter computerized ice concentration data base was established for the Great Lakes. This report describes the computerized data set and an ice concentration climatology developed from it. Data reduction and analysis procedures, computer file structure and record format, and availability of the data are given.

1. INTRODUCTION

A computerized ice concentration data base was established for the Great Lakes as part of a study to update the existing Great Lakes ice-cover climatology (Rondy, 1969). Great Lakes ice charts were produced by United States and Canadian government agencies during the 20 winters between 1960 and 1979. Many of these data have been published in reports describing the Great Lakes ice cover for each winter. (See selected bibliography.) The purpose of this report is to describe the digital ice concentration data set and to document its computer tape file structure and record format. The actual computer compatible magnetic tapes are available from The National Snow and Ice Data Center (NSIDC) located in Boulder, Colo.

These data will be useful to a broad spectrum of users in those fields of research, operations, and planning in which ice cover on the Great Lakes is a consideration. The fact that the data set is computerized facilitates its application to computer models and its manipulation for specific areas or time periods.

2. BASIC DATA AND DATA REDUCTION

Starting in the early 1960's and continuing through the present, observations of ice cover on the Great Lakes have been made primarily by the organizations given in Table 1. These organizations observed ice conditions by visual areal ice reconnaissance and by side looking airborne radar. Observations, including the boundaries of homogenous areas of ice concentration, ice age, and other ice characteristics, were recorded on ice charts. A typical ice chart, taken from Rondy (1968), is shown in Figure 1. Ice charts for the Great Lakes over the years have been produced in several different map projections, map scales, ice-cover symbols, and ice terminology. Over 2,800 of these historic ice charts have been used in this study.

TABLE 1.--Sources of historic Great Lakes ice charts

Source code	Organization name and address
1*	Environment Canada, Atmospheric Environment Service, Ice Branch, Ottawa, Ont., Canada K1A OH3.
2	Great Lakes Environmental Research Laboratory, 2300 Washtenaw Avenue, Ann Arbor, Mich. 48104. (This data set includes ice charts from the Lake Survey Center, National Ocean Survey, and the Lake Survey District, U.S. Army Corps of Engineers, Detroit, Mich.)
3-4	U.S. Coast Guard, Ninth Coast Guard District, 1240 East Ninth Street, Cleveland, Ohio 44199. (Code 3 is for visual aerial ice reconnaissance ice charts and code 4 is for ice charts based on side looking airborne radar imagery.)

*The majority of the ice charts came from source 1.
Copies of most of the historic ice charts are given in published reports included in the selected bibliography. They can also be obtained from NSIDC.

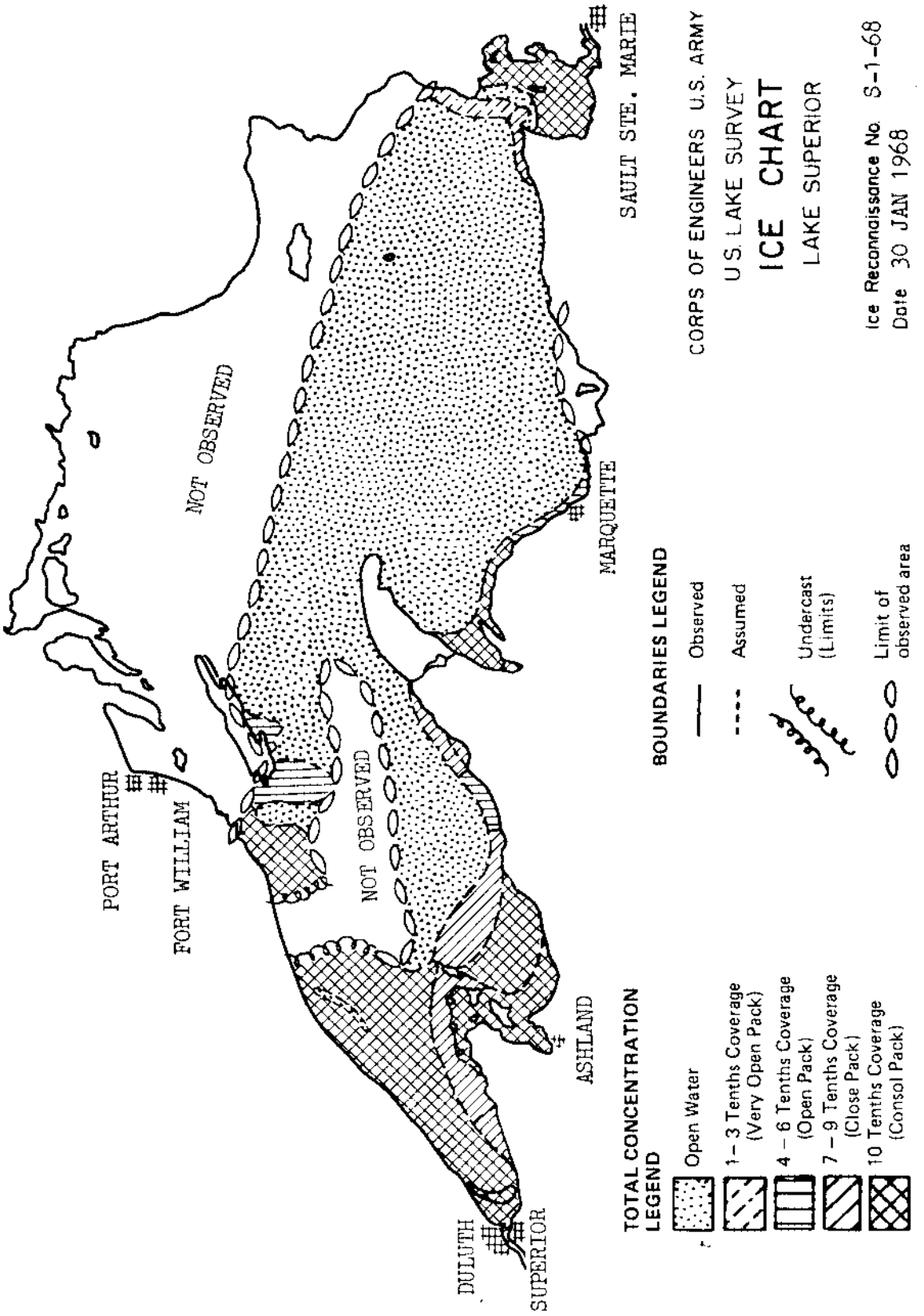

FIGURE 1.--Lake Superior ice chart, January 30, 1968.

Ice concentrations to the nearest 10 percent were abstracted from the original ice charts. Ice concentration is the percent of a unit surface area of the lake that is ice covered. An electronic digitizer coupled with a computer was used to abstract, code, and record the ice concentration from each ice chart. The digital data were then converted to a polyconic map projection of discrete 5 x 5-km grid cells in a rectangular cartesian coordinate system. A two-digit numeric code giving the ice concentration or a code for land is associated with each grid cell. A separate computer file was established for each ice chart digitized. The data set and ice concentration codes for each Great Lake are summarized in Table 2. The configuration of land and water grid cells is illustrated in Figure 2a-e. The latitude and longitude of the centroid of each grid cell for each Great Lake has been calculated and a separate geographic coordinate file established for each lake.

3. DATA ANALYSIS

The ice concentration data for each Great Lake were partitioned into half-month periods. This interval was selected because it is the smallest averaging period for which there were sufficient data for analysis. The time series of ice concentration for a given grid cell and half-month period was analyzed for its minimum and maximum value. Subperiod ice concentrations were then averaged for years with multiple observations and, because the number of years of observations varied from grid cell to grid cell for a given half-month period, this variable (called the observation density) was calculated for each cell for each half-month period. Then using the observation density, the average, median, and mode ice concentrations were calculated for each grid cell for a given half-month period. A lake-wide average value of each statistic was also calculated.

A series of five ice charts for each Great Lake was then produced to portray the maximum, minimum, median, average, and mode ice concentrations for each of nine half-month periods from the last half of December through the last half of April. This analysis is being published as a *NOAA Ice Atlas* (Assel et al., *1983)*. Charts of observation density were included in that atlas and, although not included here, they can easily be calculated from the original ice chart data given in this report. The average and mode ice concentration ice charts were not included in the atlas, but these two statistics are included in the ice climatology data base presented here. In addition, the atlas ice concentrations were grouped into five standard classes and the ice charts were color coded to show the distribution of the five classes. While this was desirable for the atlas in order to identify general patterns of ice-cover distribution, it also degraded the data. The ice concentration data given here are to the nearest 10-percent concentration. Thus, the climatological data given in this report are more detailed than those given in the atlas and they include two additional statistics not included in the atlas--the mode and average ice concentrations.

TABLE 2.--Computerized ice concentration data base and ice concentration codes.

			Lake image data matrix			
	Number of ice charts		Dimension		Grid cells	
Lake	Original	Climatic	Row	Column	Total	Overwater
Superior	618	45	71	121	8591	3195
Michigan	489	45	117	77	9009	2224
Huron	845	45	85	95	8075	2308
Erie-St. Clair	565	45	40	91	3640	1041
Ontario	307	45	34	73	2482	739

Ice concentration codes--0 = less than 10-percent ice cover; 1-10 = ice concentration from 10 to 100 percent, respectively, for ten-10 percent increments; 99 = no data; and 20 = land cell.

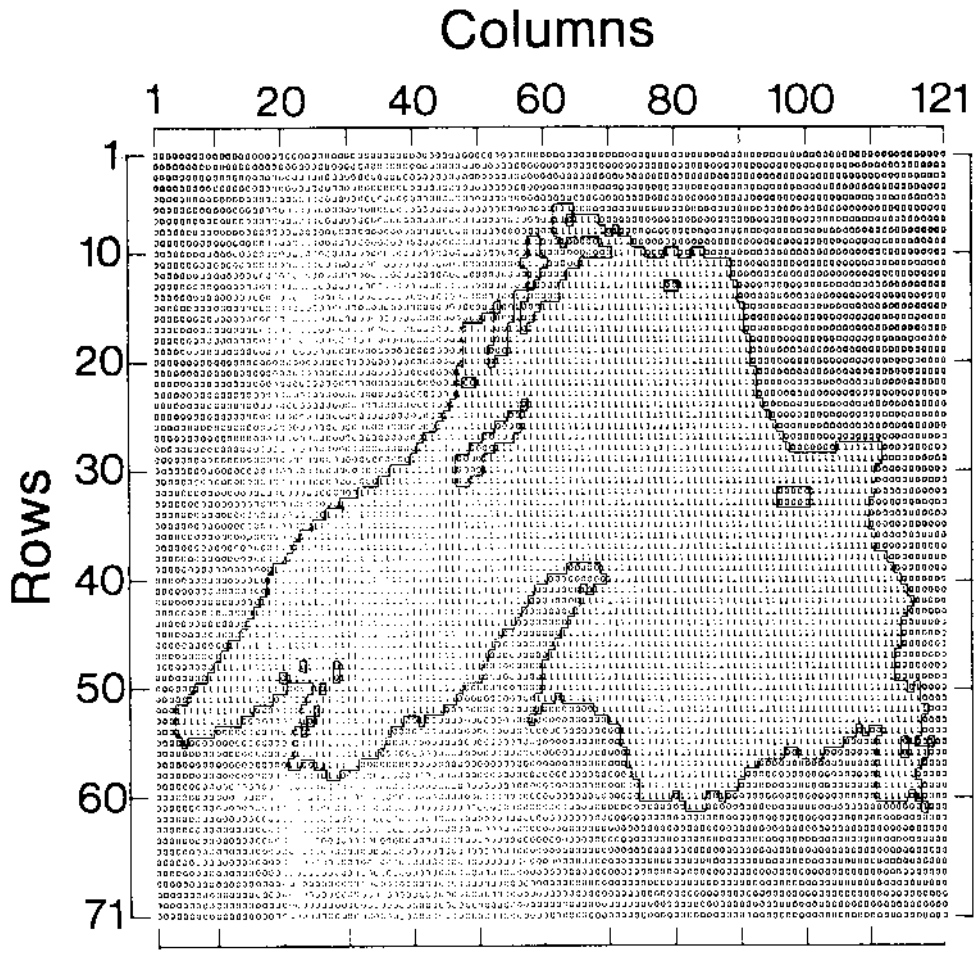

FIGURE 2a.--Configuration of Lake Superior digital lake image data matrix, consisting of 71 rows by 121 columns, making a total of 8,591 5 x 5-km grid cells, of which 3,195 (code 1) are overwater cells and 5,396 are land cells (code 0).

4. FILE STRUCTURE AND RECORD SIZE

The computerized data base is composed of three classes of files--(l) original ice concentration files, (2) ice concentration climatology files, and (3) date index and map geographic coordinate index files. The record size of all files is standard 80-character card image and the records are blocked in groups of 50-card images, i.e., 4,000 characters. Each Great Lake has a separate file for each class of file, making a total of 15 files for the entire data base. Lake St. Clair, although not one of the five Great Lakes**,** is included in the data base because it is an important connecting link in the Great Lakes System. The Lake St. Clair data set is written as part of the Lake Erie data files.

The structure of all three file classes is similar. All are composed of two sections. The first section, one block in length, is a file identifier and gives pertinent information on the large data section that follows it**.** The data section is subdivided into what may be termed lake images of fixed block length. Each lake image is composed of a header record and one ice chart. Detailed descriptions of file blocks and record formats are given in the appendices.

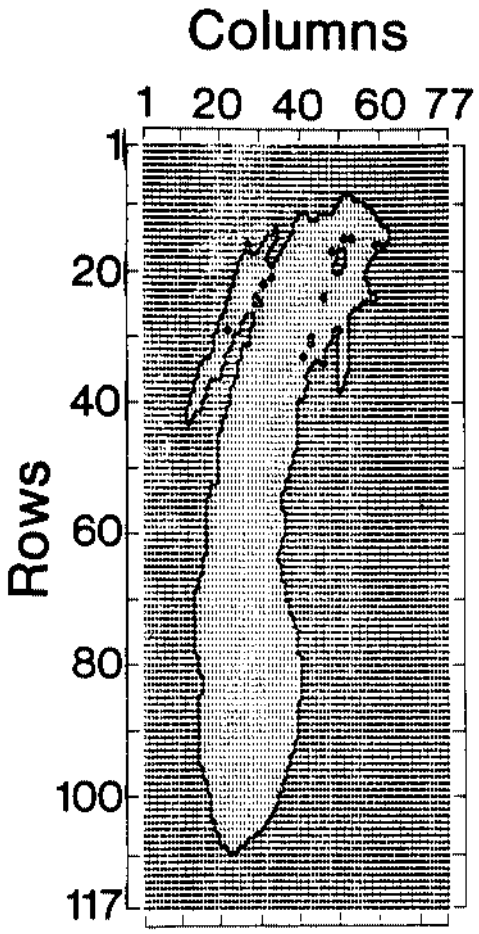

FIGURE 2b.--Configuration of Lake Michigan digital lake image data matrix, consisting of 117 rows by 77 columns, making a total of 9,009 5 x 5-km grid cells, of which 2,224 (code 1) are overwater cells and 6,785 are land cells (code 0).

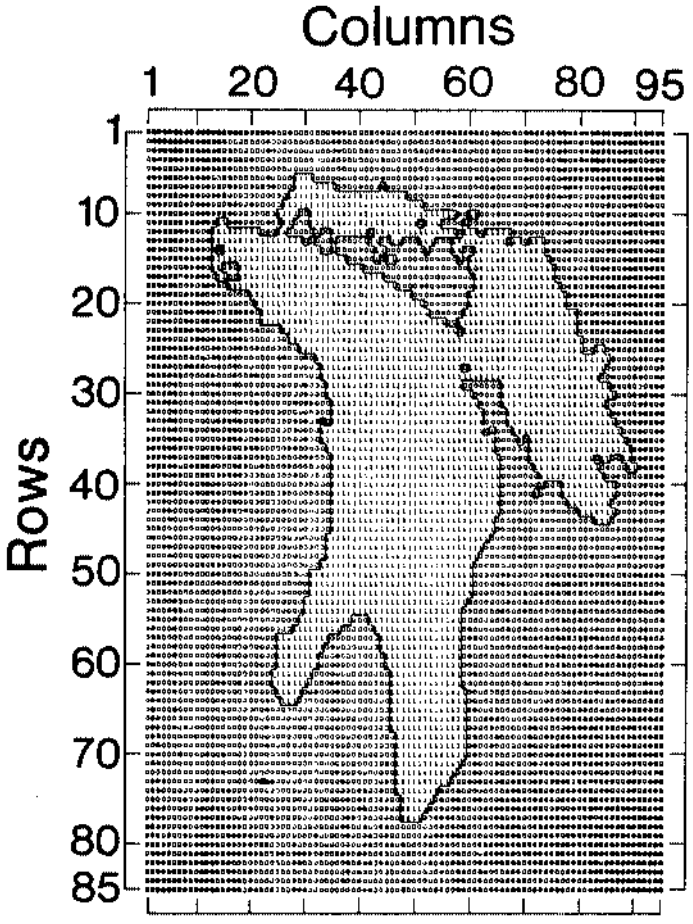

FIGURE 2c.--Configuration of Lake Huron digital lake image data matrix, consisting of 85 rows by 95 columns, making a total of 8,075 5 x 5-km grid cells, of which 2,308 (code 1) are overwater cells and 5,767 are land cells (code 0).

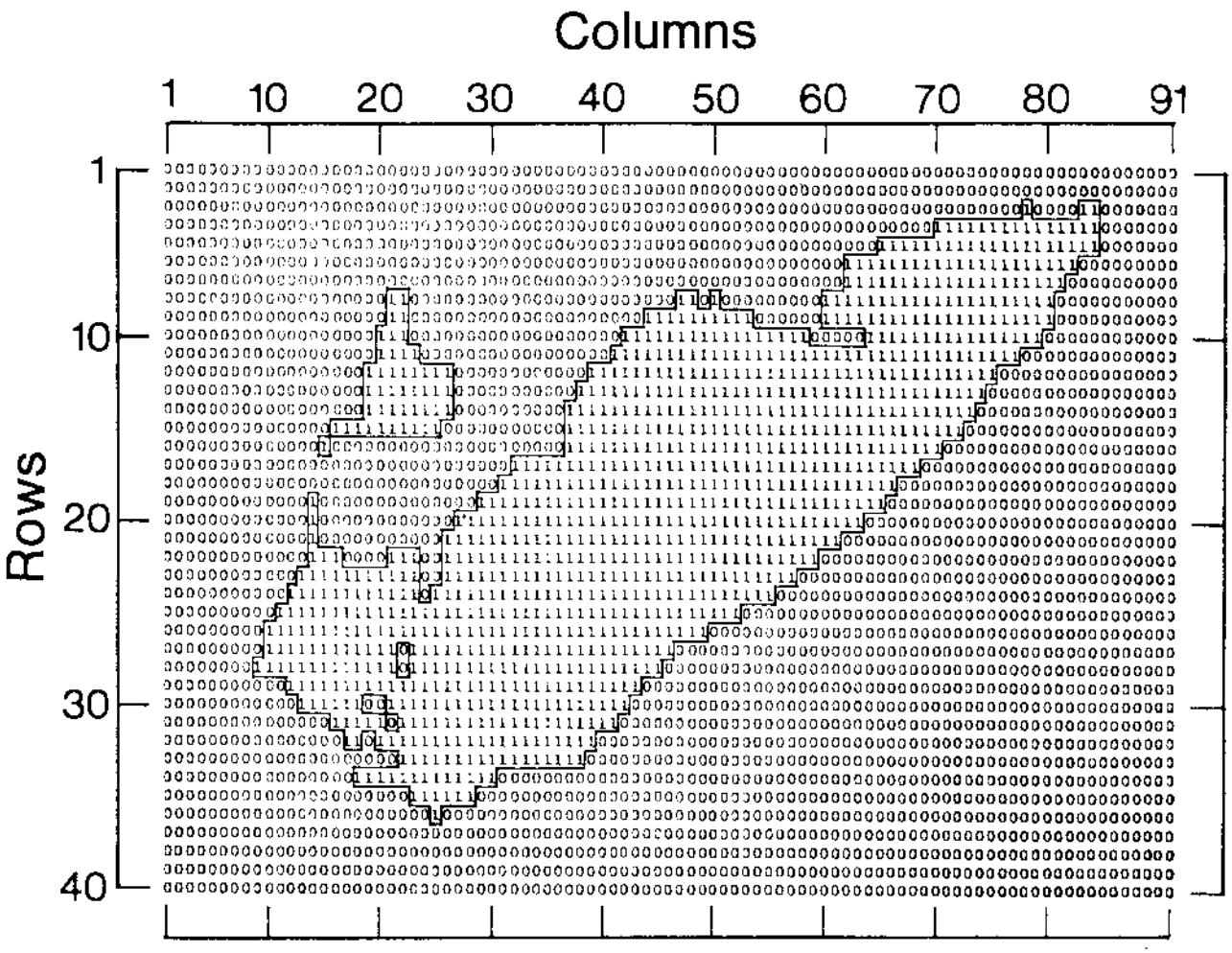

FIGURE 2d.--Configuration of Lake Erie and Lake St. Clair digital lake image data matrix, consisting of 40 rows by 91 columns, making a total of 3,640 5 x 5-km grid cells, of which 1.041 (code 1) are overwater cells and 2,599 are land cells (code 0).

5. DATA AVAILABILITY

The Great Lakes ice concentration data base is available in computer compatible magnetic tape through the National Environmental Satellite and Data and Information Service (NESDIS). Inquiries should be addressed to:

National Snow and Ice Data Center (NSIDC)
http://nsidc.org/index.html
CIRES, Campus Box 449
University of Colorado
Boulder, CO 80309
Telephone: (303) 492-5171
FTS 320-5311

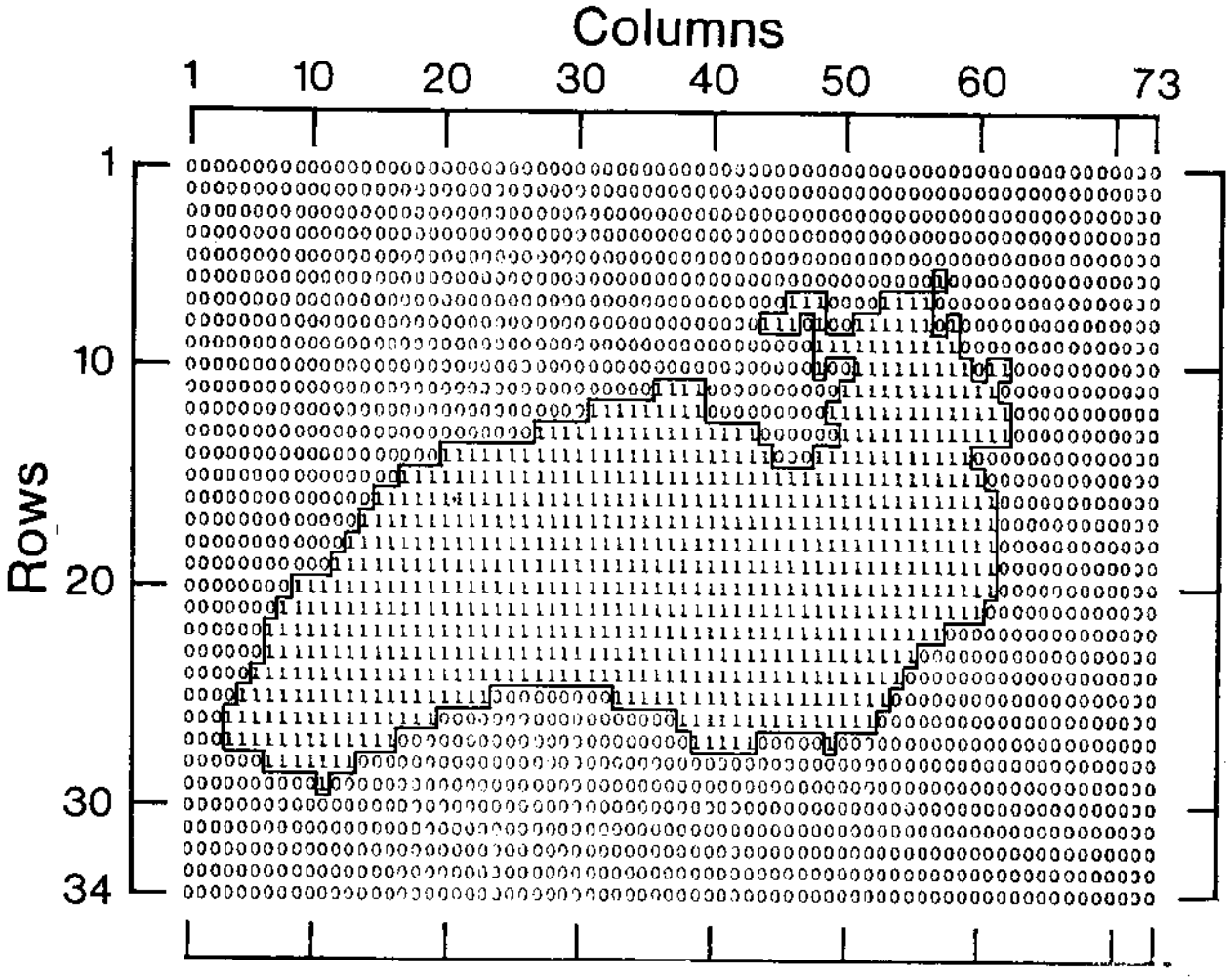

FIGURE 2e.--Configuration of Lake Ontario digital lake image data matrix, consisting of 34 rows by 73 columns, making a total of 2,482 5 x 5-km grid cells, of which 739 (code 1) are overwater cells and 1,743 are land cells (code 0).

6. ACKNOWLEDGMENTS

The author wishes to thank all those agencies and individuals who over the 20-winter period 1960-79 helped to establish the historic ice chart data set. In addition, I would like to thank the present and past members of the GLERL staff who assisted in the large data reduction effort needed to establish the computerized ice concentration data base, including Mr. G. Leshkevich, Mr. D. Gaskill, Miss I. Proctor, Ms. D. Sellers, Mr. F. Nelson, and Mr. J. Lyden. The text was reviewed by Mr. L. Herche of GLERL's Computer Services Group and Mr. R. Weaver of NSIDC. The manuscript was typed by Mrs. B. Lawton and edited by Ms. J. Kelley.

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*App*endix A.--FILE STRUCTURE AND FORMAT FOR ORIGINAL ICE CONCENTRATION FILES

The block and record structure of original ice concentration files is given in Table 3. Records are 80-character card images with a blocking factor of 50. File variables, M, N, J, L, and others, are defined in Table 4. There are five separate original ice concentration files, one for each Great Lake. The first block of each file givea the lake name and value of file parameters. Blocks 2 through (N•M)+1 contain a total of N lake image ice concentration data sets. The first record of each lake image uniquely identifies that lake image. The lake image data sets are in time sequence by half-month period for nine half-month intervals from December 16-31 through April 16-30. Within each of these half-month intervals, the lake images are arranged by year and day of month, respectively. A summary of the number of ice charts per half-month period per lake is given as Table 5. The ice concentration data for each 1ake image as shown in Figure 2 is written by row; that is, all grid cells of row 1 columns 1 through C are written, followed by row 2 columns 1 through C, and so on to row R columns 1 through C. This same order is maintained in the lake images of the ice climatology and index files.

TABLE 3.--File structure and format for original ice concentration files.

Block	Record	Description	Format
1	1 to 50	A plain language description of lake name, row and column dimensions of lake image array, number of lake images, number of blocks per lake image, number of characters in last record with data in last block with data of each lake image, number of records with data in last block of each lake image, data contained in the first record of each lake image and its format, and ice concentration codes.	50(40A2)
2	1	Lake, year, month, day, source,map number, percent of lake observed .	(A1,3A2,2A1,I3,68X)
	2 to 50	Ice concentration data.	4012
M+l	1 to (L-1)	Last block of first lake image.	4012
	L	Last record of data--first lake images.	((J/2)12, (80-J)X)
	(L+1) to 50	Blank filled.	
M+2	1 to 50	Start of second lake image.	
2M+l	1 to 50	End of second lake image.	
(M-N)+1	1 to 50	Last block of last lake image.	

*Zero percent indicates less than l percent of the lake observed.

TABLE 4.--Variables for ice concentration files.

	Superior	Michigan	Huron	Erie-St.Clair	Ontario
Variable	Original ice files				
M	5	5	5	2	2
N	618	489	845	565	307
R	71	117	85	40	34
C	121	77	95	91	73
J	62	18	70	80	4
L	16	27	3	42	14
	Change in variable for climatology files				
N	45	45	45	45	45
	Change in variables for index files				
K	13	10	17	12	7
S	18	39	45	15	7
T	172	181	162	73	50
U	41	9	25	40	32

M = blocks per lake image.
N = number of lake images.
C = column dimension of lake image array.
R = row dimension of lake image array.
N = column dimension of lake image array.
J = number of characters of data in last record of last block of each lake image.
L = number of records with data in last block of each lake image.
K = number of blocks in date index.
S = number of records in last block of date index.
T = number of blocks in coordinate index.
U = number of records in last block of coordinate index.

TABLE 5.--Distribution of ice charts (1960-1979) over semi-monthly periods by lake.

	Half-month period								
Lake	D2	J1	J2	F1	F2	M1	M2	A1	A2
Superior	33	43	88	82	65	83	93	87	44
Michigan	25	35	67	70	59	79	75	63	16
Huron	36	64	124	116	111	134	133	94	33
Erie-St. Clair	28	50	. 86	76	81	87	77	61	19
Ontario	16	26	52	38	40	41	39	42	13

D2 = December 16-31
J1 = January 1-15
J2 = January 16-31
F1 = February 1-14
F2 = February 15-28
M1 = March 1-15
M2 - March 16-31
A1 = April 1-15
A2 = April 16-30

Appendix B.--FILE STRUCTURE AND FORMAT FOR ICE CLIMATOLOGY FILES

With two exceptions, shown on Table 6, the ice climatology files have the same structure and format as the original ice concentration files: (l) the first record in each lake image now identifies a statistic of ice concentration and (2) there are 45 lake images for each Great Lake ice climatology file. The statistics are defined and the order in which they appear on the file is given in Table 7. File variables for the ice concentration climatology files are defined in Table 4.

TABLE 6.--File structure and format for ice climatology files.

Block	Record	Description	Format
1	1 to 50	Same as shown on table 3.	
2	1	Statistic identifier, half-month period	(5x,I2,5X, I1,5X,I3,59X)
		identifier, and lake-averaged value of statistic.	
	2 to 50	Ice concentration data.	(40I2)
M+I	I to (L-I)	Ice concentration data.	(40I2)
	L	Last record of data -- first lake image	((J/2)I2, (80-J)X)
	(L+1) to 50	Blank filled.	
M+2	1 t0 50	Start of second lake image.	
2M+1	1 to 50	End of second lake image	
(M •N)+1	1 to 50	Last block of last lake image.	

TABLE 7.--Definition of numeric codes and order of statistics in climatology ice files.

	Half-month period code								
Ice concentration statistics	1 D2	2 J1	3 J2	4 F1	5 F2	6 M1	7 M2	8 A1	9 A2
1 Maximum	1	2	3	4	5	6	7	8	9
2 Minimum	10	11	12	13	14	15	16	17	18
3 Median	19	20	21	22	23	24	25	26	27
4 Average	28	29	30	31	32	33	34	35	36
5 Mode	37	38	39	40	41	42	43	44	45

Half-month period codes--1 - December 16-31, 2 - January 1-15, 3 - January 16-31, 4 - February 1-14, 5 - February 15-28, 6 - March 1-15, 7 - March 16-31, 8 - April 1-15, and 9 - April 16-30.

As shown above, the first lake image is for maximum ice concentration for December 16-31 and the last lake image (45) is for the mode ice cover for April 16-30.

Appendix C--FILE STRUCTURE AND FORMAT FOR DATE INDEX AND GRID CELL COORDINATE INDEX FILES

The detailed structure of the date index and coordinate index file is given as Table 8. File variables are given in Table 4. Each record in the date index corresponds to one date for one original ice chart lake image data set. The order of dates on the index is the same order as on the original ice concentration file. The grid cell coordinate index follows the date index.

Only one coordinate pair is written for each record on the coordinate index. The coordinate is written as the latitude and longitude of the centroid of the grid cell and as the lake image row and column array element of the grid cell. An additional code indicating whether that cell is a land cell (code O) or overlake cell (code 1) is also included on each record. The date index is useful for making temporal searches through the ice cover data base, while the grid coordinate index is useful for making spatial searches through the ice data base. In addition, the coordinate index can be used to generate a “mask” lake image that is useful to decompose the icecover data base into an ice-cover concentration subset of the data. Decomposition into the ice concentration subset before performing any analysis on the ice concentration data results in considerable cost savings in computer storage.

TABLE 8.--File structure and format for date index and grid cell coordinate index files.

Block	Record	Description	Format
1	1 to 50	A plain language description of lake name, number of blocks in date index, number or blocks in coordinate index, number of records with data in last block of date index, number of records with data in last block of coordinate index.	50(8A10)
2	1	Lake, year, month, day, source, map, number, and percent of lake observed.	(5X,6I2,I3,60X)
	2 to 50	Same as record 1, above.	
3	1 to 50	Same as block 2.	
K+1	1 to S	Same as record 1, block 2.	
	(S+1) to 50	Blank filled (last block of date index).	
K+2	1	Latitude and longitude, row, column of grid cell, and code for land or water.	(1X, 2F12.7, 5X,3I5,35X)
	2 to 50	Same as record 1, above.	
K+3	1 to 50	Same as block (K+2).	
(K+T)+1	1 to U	Same as record 1, block (K+2).	
	(U+1) to 50	Blank filled (last block of coordinate index).	