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GEOLOGICAL SURVEY

DIGITAL DATA BASE OF LAKES ON THE NORTH SLOPE, ALASKA

By Kim-Marie Walker, James York, Dennis Murphy, and Charles E. Sloan

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WATER-RESOURCES INVESTIGATIONS REPORT 86-4143

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DIGITAL DATA BASE OF LAKES ON THE NORTH SLOPE, ALASKA

By Kim-Marie Walker[1], James York[2], Dennis Murphy[2], and Charles Sloan[3]

ABSTRACT

The National Mapping Division and Water Resources Division of the U.S. Geological Survey have produced a digital data base of approximately 23,330 lakes on the North Slope of Alaska. The inventoried region consists of the area north of the 69th parallel and is composed of sixteen 1° x 3° quadrangles. The data base includes (1) locations of lake centers in latitude and longitude, (2) a unique number for each lake within a quadrangle, and (3) acreage for water classes (deep, shallow or turbid, and ice) within each lake and lake total. The digital data base is an easily accessible storage and retrieval system that will allow for rapid identification of a particular lake or region of lakes and its characteristics. The data base is designed to accommodate field study data such as lake depth, water quality, volume of water, ice thickness, and other pertinent information.

INTRODUCTION

Because of permafrost, ground water is usually unavailable on the North Slope. Also, shallow lakes freeze to the bottom, prohibiting their use as a water source during the winter months. Therefore, the location and size of deep lakes are needed to identify potential year-round water resources for use during winter petroleum exploration and production activities.

In 1983, the National Mapping Division and Water Resources Division of the U.S. Geological Survey began a study to develop a digital data base of lakes on the North Slope. The specific objective of the study was to inventory the lakes to determine (1) the location of the lakes so that each could be assigned a unique label, (2) the classes of lakes (deep, shallow or turbid, and ice), and (3) the acreage for each class within a lake and lake total.

This report describes the data processing methodology applied to Landsat imagery and lake attribute data. In addition, the report provides examples of computer listings from the digital data base.

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[1] Technicolor Government Services, Inc. Work performed under U.S. Geological Survey contract 14-08-0001-20129.

[2] Previously employed by Technicolor Government Services, Inc. Work performed under U.S. Geological Survey contract 14-08-0001-20129.

[3] U.S. Geological Survey, Water Resources Division.

DATA-BASE DEVELOPMENT

Landsat Data Characteristics

Landsat multispectral scanner (MSS) data were used to classify the lakes as deep, shallow or turbid, and ice. The MSS data cannot distinguish between shallow and turbid water, hence the joint classification. The MSS averages the spectral brightness values within each picture element (pixel) representing a ground measurement of 56 x 79 m for the four spectral bands: 0.5 - 0.6 microns (band 4, green), 0.6 - 0.7 microns (band 5, red), 0.7 - 0.8 microns (band 6, near infrared), and 0.8 - 1.1 microns (band 7, near infrared).

Band 7 provided the best differentiation between water and land. Band 4 was used to separate shallow or turbid water from deep water. Field experience on the North Slope indicates that the depth threshold for distinguishing between areas of deep and shallow water is approximately 1 meter. Lake areas where the depth is less than 1 meter are classified as shallow. Clear shallow lakes that have a dark lake bottom could be classified as deep lakes; thus, lake-depth data obtained from the field will be an input to the data base for verification. Lake ice was classified by its high reflectance in all MSS bands.

Landsat Acquisition and Digital Processing

Images of a Landsat-MSS derived land-cover classification for the National Petroleum Reserve - Alaska (NPR-A), the Arctic National Wildlife Refuge, and most of the area between the reserve and the refuge were obtained from the Geological Survey offices at Moffett Field, California. These digital images were classified using the four MSS bands. Although they contained numerous vegetation classes, only the water classes (deep, shallow or turbid, and ice) were extracted and utilized in subsequent image processing.

The NPR-A land-cover classifications were registered to the Geological Survey 1:250,000-scale topographic maps by the Bureau of Land Management, Alaska. Landsat MSS data of the Point Lay quadrangle and part of the Umiat quadrangle were registered and classified (for water classes only) at the Geological Survey Earth Resources Observation Satellite (EROS) Data Center's Alaska Field Office (AFO). A threshold value in MSS band 7 was used to distinguish water from land. For the water areas, a threshold value from band 4 was used to differentiate deep and shallow water classes. No lake ice was present for these areas. For the Beechey Point quadrangle, the shallow water/very wet tundra class was split into two classes to match the classification used in the other coastal plain areas. All Landsat data were registered to a Universal Transverse Mercator projection and resampled to a 50-meter grid cell size.

Landsat images dated from July 12 to August 25, between the years 1972 and 1980 were used in data processing. The short summer season span of imagery acquisition was necessary to minimize the effect of winter conditions (snow and lake ice) on the North Slope. Lake ice present in the summer represents lakes that did not freeze to the bottom; thus, lake ice presence indicates deep water. Landsat image coverage obtained during several years was needed to obtain good quality, cloud-free images for the entire study area. Figure 1 shows the geographic distribution of Landsat images in the inventoried area, the associated image dates, and scene identifications.

Digital procedures to create the data base were developed at the EROS AFO and the EROS Data Center. Processing was done on the AFO's Hewlett Packard* 3000 computer system using software from the Interactive Digital Image Manipulation System (IDIMS) for image processing and the Earth Resources Inventory System (ERIS), which contains 10 programs for text-file manipulation. Functions contributed to the IDIMS software by the Bureau of Reclamation, Denver, Colorado, were also incorporated into the procedures. Figure 2 illustrates the various digital processing steps.

Image Processing Steps

Step 1 -- Processing was performed on 1° x 3° quadrangle image subscenes. The land-cover values for each quadrangle image were assigned. The land was numerically designated 0 and the water classifications of deep, shallow, or ice as 1, 2, and 3, respectively. Thus, 16 images of water classes exist in the data base, each representing a 1° x 3° quadrangle area.

Step 2 -- Each image of water classes was reassigned values to allow for the labeling of a unique lake number to each distinct water body (as opposed to the labeling of water classes within a body of water). The resultant image was the water/land image, where all water classes were assigned values of 1 and land, 0.

Step 3 -- A smoothing algorithm was applied to the water/land image to eliminate lakes with areas less than approximately 5 acres. These small lakes do not contribute to the winter supply of water, yet they are numerous and would increase the computing costs if not eliminated. Two smoothing passes were made to eliminate the small lakes. The smoothing increased the area of most large lakes slightly, but this fact was accounted for in subsequent processing. For a test area in the Harrison Bay B-5, 1:63,360-scale quadrangle, the smoothing eliminated 70 percent of the lakes, but the total area of these eliminated lakes was only 5 percent of the total lake area. Thus, smoothing greatly reduces the number of lakes without appreciably affecting total lake area.

Step 4 -- Each lake within the smoothed water/land image was labeled as a polygon and assigned a unique number. A polygon is defined as a group of pixels with the same values that share edges, not just corners. The program assigned numbers to each lake, starting with 1, as it scanned the image line by line from top to bottom. While scanning, two portions of one lake might be assigned different numbers until the scanning process recognized that the two portions were joined; then, one number would be discarded and would not be reused in subsequent labeling. This labeled image was multiplied by the smoothed image to eliminate the islands found within lakes that would have been labeled as polygons.

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*Use of the trade name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

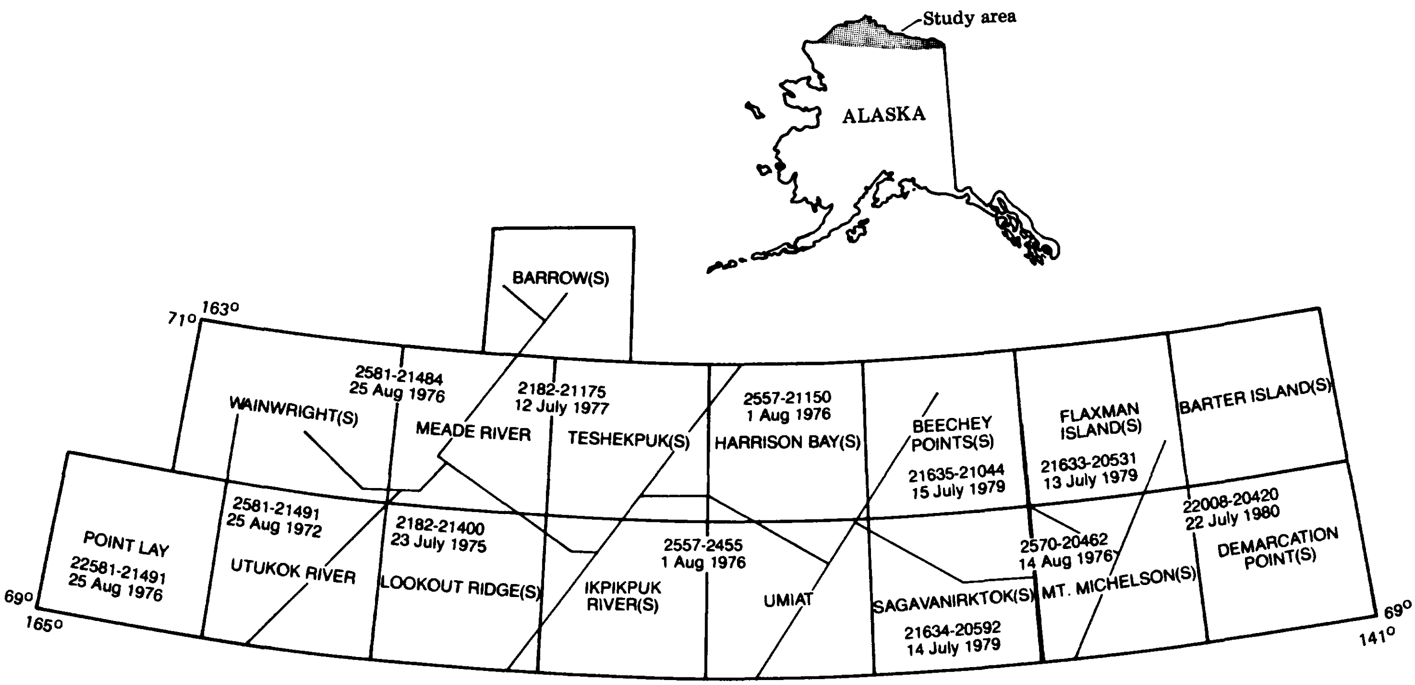


Figure 1.--Index of Landsat images covering the sixteen 1:250,000-scale quadrangles inventoried in the North Slope, Alaska lake data base. The 9 or 10 digit code refers to the Landsat scene identification number and the date refers to the Landsat multispectral scanner acquistion date. The thin black lines approximate the extent of image coverage.

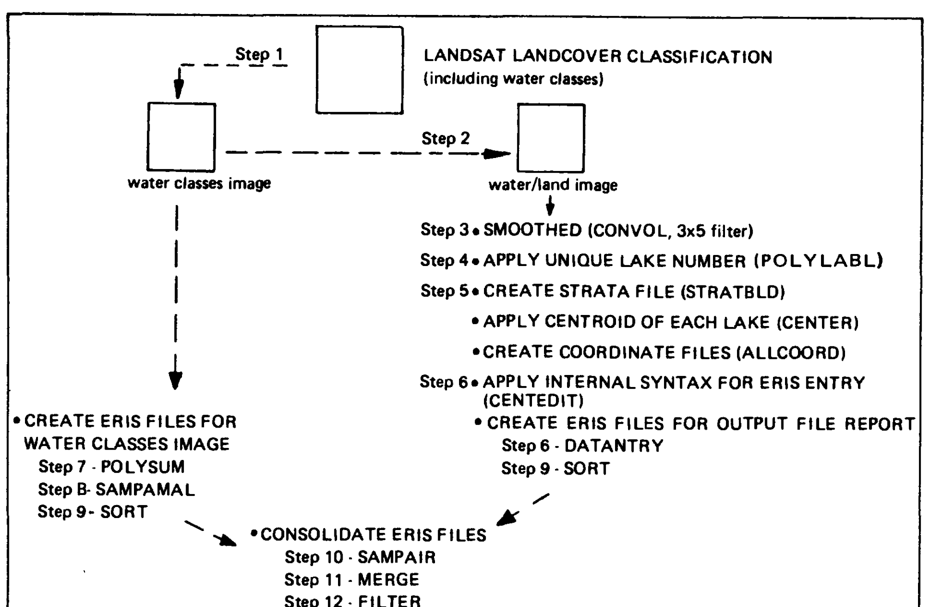
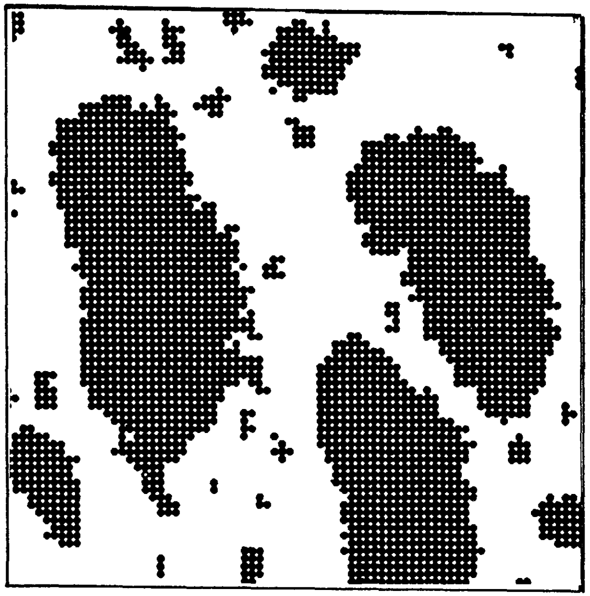
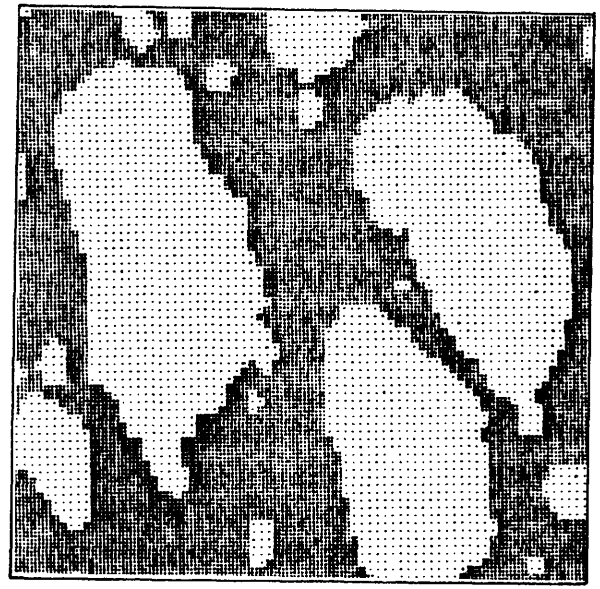


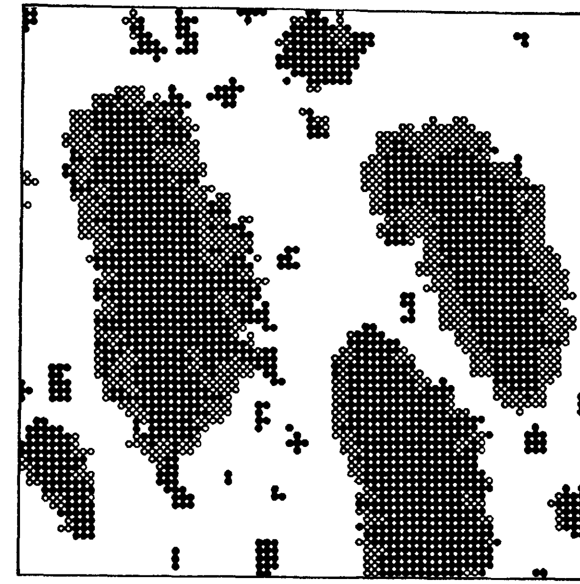
Figure 2.--North Slope, Alaska Lake Inventory digital image processing steps. Image processing function names from the IDIMS software package are shown in parentheses. ERIS text file functions are named in steps 6 and 8 through 12.



3a



3b



3c

Figure 3.--Determination of lake area.

3a -- Represents the initial image of water and land, where the black circles are the lake areas with each circle approximating an area of 64 m x 64 m. The white background (in 3a and 3c) represents land.

3b -- Shows the effect of a smoothed (filtered) image. Note the enlargement of water bodies as compared to 3a, and the elimination of small lakes present in 3a.

3c -- Shows two water classes (open circles, shallow or turbid water; black circles, deep water) of an unsmoothed image. Lake area for each water class was computed by counting the water class (deep, shallow or turbid, and ice) areas from the unsmoothed image which fell within the smoothed lake boundary.

Text File Generation Steps

Text files were produced to store lake variables in a tabular format. The text files are tables with each row representing a lake and each column representing a particular lake attribute.

Step 5 -- A program was used to convert the numbered lake (labeled) image into a strata mask (a non-image run length encoded) file. Another program read the strata mask file and computed the geometric center of each lake in the mask. The resultant file contained the line and sample coordinates of the registered image and was altered to a compatible text file for conversion to latitude/longitude coordinates.

Step 6 -- This file, containing both lake numbers and center location was further manipulated to arrange the lake information in the proper format for entry into the ERIS. The resultant text file contained nine attributes: (1) Lake number; acreage for each water class of (2) deep, (3) shallow or turbid, and (4) ice; (5) degrees latitude/longitude; (6) minutes latitude/longitude; (7) seconds latitude/longitude; (8) null values for depth (which will be added later); and (9) comments.

Step 7 -- The initial water classes image (step 1) had to be restored into the process so that the water classes (deep, shallow, ice) and their respective size could become data-base attributes. The next program created another text file with the areas of each water class and their combined total for each numbered lake. Two digital images were used in this step. The image of smoothed labeled lakes defined the boundaries of each numbered polygon. Within these boundaries, the unsmoothed image of water classes (step 1) determined the area of each water class. Although the areas of the smoothed lakes were often slightly larger than the unsmoothed lakes, the area of each water class was accurate within 95 percent for lakes with areas greater than 10 acres. Figure 3 illustrates the determination of a lake area. The resultant text file contained three variables: lake number, total pixel count per lake (total lake area), and pixel count per water class (water class area).

Step 8 -- The pixel counts generated from step 7 were multiplied by a scale factor to convert from number of pixels to area in acres for each lake class. The total lake size was also computed by summing the acreages from the water classes.

Step 9 -- To combine the two text files generated in steps 5 and 6, both files were first sorted on the basis of lake number so that they could be easily matched. Because the labeling process (step 4) eliminated some numbers, the sequence of sorted lake numbers did not always increase by units of one.

Step 10 -- The two sorted files were then compared to ensure that lake numbers matched across files. The program produced a listing of unmatched lakes. The rare unmatched lake which could be traced to a problem in processing was eliminated.

Step 11 -- The resulting matched files were merged into a single attribute file with each lake represented by: a lake number; total area; area for deep, shallow, and ice classes; latitude and longitude of the lake center in degrees, minutes, and seconds; and spaces assigned for depth data and a comment entry.

Step 12 -- This file was filtered to eliminate any lakes with areas less than 5 acres.

The 16 filtered files, one for each quadrangle, are the final lake attribute files that constitute part of the lake inventory data base. Approximately 23,330 lakes were inventoried. The number of lakes in each quadrangle is listed in table 1. Figure 4 shows a partial computer listing of a lake file for the Teshekpuk 1:250,000-scale quadrangle.

DATA BASE ACCESS AND RETRIEVAL

Digital Data-Base Files

The digital data base stored on computer compatible tapes at the EROS AFO, consists of: (1) 16 lake attribute files, (2) 16 water class (deep, shallow or turbid, and ice) digital images, (3) 16 smoothed lake digital images, and (4) 16 lake center text files. The attribute files are used for online data retrieval and modification. The digital images and lake center text files can be used to generate map products showing water classes, smoothed lakes, or center locations with lake numbers. These map products can be used in conjunction with the lake files.

"Earth Resources Inventory System" Lake Files

The Earth Resources Inventory System (ERIS) attribute files can be accessed through the Hewlett Packard 3000 computer system at the EROS AFO, in either interactive or batch mode. Once online, the files can be searched by several Boolean expressions. A listing of lakes with any combination of attributes can be obtained. For instance, these attributes could be a given value (for example, a lake number), a range of values (for example, within a certain lake size range), or a logical combination of ranges (for example, within given latitude and longitude ranges and above a certain size). Data-base searches also can be made for lake centers within a given distance from a point. The listings of lakes can be output to the terminal screen or line printer. Because the attribute lake files have been processed on a 1° x 3° quadrangle basis, searches only will be effective within one quadrangle. Figure 5 shows the output for user-requested search parameters for the Harrison Bay 1:250,000-scale quadrangle.

If other data suggest that the area figures or even location of a lake should be changed, the data base can accommodate such changes. Field data on depths can be added. The "Comment" column is for indicating the existence of other data pertaining to the lake (for example, water quality).

PLOT PRODUCTS

The map products produced for the lake inventory include: (a) approximately 255 pen plots of lake center locations (marked "X" with a lake number) at a scale of 1:63,360, and (b) 16 electrostatic plots of the water class images and the smoothed water/land images at a scale of 1:250,000 (to register with the 1° x 3° Geological Survey topographic maps). The latter plots can be produced at a scale of 1:63,360 to match the 15-minute Geological Survey topographic maps.

Table 1.--Number of North Slope lakes inventoried for each 1:250,000-scale quadrangle

U.S. Geological Survey 1:250,000 quadrangle (fig. 1)	Number of inventoried lakes greater than 5 acres
Barrow	416
Barter Island	113
Beechey Point	1853
Demarcation Point	537
Flaxman Island	335
Harrison Bay	2782
Ikpikpuk River	2213
Lookout Ridge	410
Meade River	4166
Mt. Michelson	953
Point Lay	380
Sagavanirktok	1509
Teshekpuk	4108
Umiat	1770
Utukok River	381
Wainwright	1480

CASE	LAKENO	ACRES	DEEP	SHALLOW	ICE	DEPTH	DEGLAT	MINLAT	SECLAT	DELONG	MINLONG	SECLONG
1	2	473.204	254.517	218.687	.000000E+00	-1	70	59	28	155	49	33
2	3	88774.0	257.606	85022.3	3494.05	-1	70	53	57	155	41	19
3	5	12.3552	12.3552	.000000E+00	.000000E+00	-1	70	59	29	155	57	20
4	6	91.4285	1.23552	63.6293	26.5637	-1	70	59	52	155	16	37
5	7	10.5019	10.5019	.000000E+00	.000000E+00	-1	70	59	24	155	58	5
6	8	1297.30	.000000E+00	1297.30	.000000E+00	-1	70	59	28	155	11	27
7	9	18.5328	18.5328	.000000E+00	.000000E+00	-1	70	59	22	155	52	32
8	10	1828.57	64.2470	70.4246	1693.90	-1	70	59	4	155	5	17
9	11	5402.93	102.548	5257.75	42.6254	-1	70	57	39	154	53	37
10	12	15.4440	.000000E+00	15.4440	.000000E+00	-1	70	59	53	154	58	58
11	13	4369.42	584.401	1776.06	2008.96	-1	70	58	41	154	46	29
12	14	16.6795	16.6795	.000000E+00	.000000E+00	-1	70	59	32	155	18	47
13	15	43.8610	43.8610	.000000E+00	.000000E+00	-1	70	58	55	155	55	24
14	16	93.2817	.000000E+00	93.2817	.000000E+00	-1	70	59	52	154	38	39
15	17	23.4749	23.4749	.000000E+00	.000000E+00	-1	70	58	48	155	59	51
16	18	224254.	14473.5	72616.4	137164.	-1	70	55	23	153	56	29
17	19	516.447	.000000E+00	516.447	.000000E+00	-1	70	58	57	154	41	51
18	20	110.579	73.5134	37.0656	.000000E+00	-1	70	59	9	155	20	41
19	21	12.3552	12.3552	.000000E+00	.000000E+00	-1	70	59	21	155	16	31
20	23	163.089	163.089	.000000E+00	.000000E+00	-1	70	58	47	155	18	54
21	24	11.1197	11.1197	.000000E+00	.000000E+00	-1	70	58	32	155	57	7
22	25	47.5675	38.9189	8.64864	.000000E+00	-1	70	59	22	155	40	12
23	26	184.092	45.0965	16.0618	122.934	-1	70	58	51	155	16	6

[Explanation: CASE, internal enumeration of the lakes and not a lake attribute; LAKENO, lake number; ACRES, total acreage for the corresponding DEEP, SHALLOW, and ICE columns; DEEP, SHALLOW, ICE, lake surface acreage classified as deep, shallow, or ice; DEPTH, -1 is default value when data is not entered into the data base; DEGLAT, MINLAT, SECLAT, latitude; DEGLONG, MINLONG, SECLONG, longitude.]

Figure 4.--Partial computer listing showing all lake attributes (except COMMENT) of the Teshekpuk quadrangle.

ESL *** EARTH RESOURCES INFORMATION SYSTEM *** THU, OCT 18, 1984, 2:43 PM LISTING: HARRLAK2
HARRISON BAY LAKES >700 ACRES AND <1000 ACRES

CASE	LAKENO	ACRES	DEGLAT	MINLAT	SECLAT	DELONG	MINLONG	SECLONG
41	71	947.644	70	49	36	152	26	42
96	152	717.837	70	46	3	152	24	32
125	191	920.462	70	43	24	152	56	33
248	352	700.540	70	33	31	152	52	9
259	370	909.343	70	32	3	151	53	27
290	413	798.146	70	31	21	152	43	15
454	636	703.011	70	28	33	152	4	53
685	983	761.080	70	24	31	150	41	55
774	1103	880.308	70	25	4	152	38	54
831	1185	866.099	70	23	51	151	28	25
915	1296	853.126	70	22	21	150	25	46
1014	1423	714.748	70	21	56	151	23	56
1041	1451	826.563	70	22	8	152	27	2
1073	1503	714.130	70	21	45	151	44	20
1117	1560	755.520	70	20	41	150	51	48
1124	1570	975.443	70	20	18	150	47	33
1184	1649	727.103	70	21	1	152	17	2
1230	1715	900.694	70	20	24	152	9	50
1309	1816	966.177	70	19	25	152	0	43
1354	1874	845.713	70	18	30	150	52	8
1530	2101	762.316	70	17	27	152	11	4
1573	2157	935.906	70	17	3	152	58	51
1645	2252	714.130	70	16	24	152	55	58
1784	2419	708.571	70	15	8	152	51	45
1908	2594	744.401	70	13	21	152	32	15
1967	2671	986.563	70	12	21	152	43	57
2048	2774	730.192	70	10	46	151	13	58
2258	3056	791.350	70	8	24	152	44	45
2316	3136	856.833	70	7	1	152	33	27
2388	3236	774.053	70	5	41	152	36	16
2396	3249	718.455	70	5	45	152	52	17
2397	3250	835.211	70	5	29	152	27	13
2403	3258	709.806	70	5	25	151	59	18
2467	3346	702.393	70	4	33	151	54	26
2525	3418	727.721	70	3	33	152	16	51
2577	3484	766.640	70	2	42	152	39	46
2732	3680	875.984	70	0	24	152	1	57

TOTAL NUMBER OF CASES LISTED = 37
TOTAL OF 8 VARIABLES LISTED

[Explanation: CASE, internal enumeration of the lakes and not a lake attribute; LAKENO, lake number; ACRES, surface area in acres; DEGLAT, MINLAT, SECLAT, latitude; DEGLONG, MINLONG, SECLONG, longitude.]

Figure 5.--Computer listing showing the result of a user-specified search locating all lakes within Harrison Bay quadrangle that are greater than 700 acres and less than 1,000 acres.

Lake Center Plot Characteristics

The lake center plot, when overlaid with the corresponding 15-minute topographic map, allows the user to determine the lake numbers for lakes seen on the topographic map. For example, if depth information is obtained for a particular lake, its lake number can be readily ascertained to make the depth entry into the data base. Similarly, if a search of particular lake parameters results in a list of lakes, the locations of those lakes on the topographic maps can then be verified by lake number as well as by latitude and longitude. Lake numbers are unique within each 1:250,000-scale quadrangle map. A lake that straddles a 1:250,000 quadrangle boundary is a separate and unique numbered lake within each quadrangle.

Because of the lake number labeling process described in step 4, some numbers are eliminated and will not appear on the plots or in the lake file. However, a few lake numbers may appear on the plots, but do not exist in the lake attribute file. This is true for lakes with areas less than 5 acres, since the lake center file did not contain area information, and hence, could not be filtered for eliminating lakes less than 5 acres.

Characteristics of Plots of Lake Classes and Smoothed Lakes

The plots of lake classes produced on an electrostatic plotter contain four symbols for deep water, shallow or turbid water, ice, and land. The plots of smoothed lakes show symbols for only water and land. Together, both map plots provide an overview of the lakes inventoried within a quadrangle. For quadrangles that include ocean, the ocean portions are shown as lakes. The ice class refers primarily to lake ice, except for those plots containing sea ice, and snow fields.

The boundaries of lakes are affected in four ways before being represented on the electrostatic paper maps: (1) by the date of Landsat coverage, (2) by the resolution of the Landsat MSS system and the choice of a classification scheme to separate land and water, (3) by the smoothing algorithms employed to eliminate lakes with areas less than 5 acres (for the maps of smoothed lakes only), and (4) by the resampling of pixels done to make the electrostatic image maps. Each of these effects is discussed below.

(1) The environment of North Slope lakes is known to be dynamic, in large part because wind and the freezing and thawing of the near surface ground layer modify lake boundaries. Thus, there have been occasional major changes in lake boundaries in the 25-30 year period between the acquisition of aerial photography used to produce Geological Survey topographic maps and the acquisition of Landsat images used in the data base. Comparisons between the topographic map and Landsat water class maps are generally good. However, changes in boundaries, lake disappearances, or new appearances of lakes can be found. Most changes occur in the shallow parts of the lake. Areas of deep water and summer ice (which usually indicate the presence of deep water) are less likely to change. These temporal changes indicate a need to update the lake attribute file and to utilize the data base as a source for revision of topographic maps.

(2) For the production of the lake class plots, the lake boundaries were defined by Landsat MSS data and the water classification schemes used initially. Generally,

the lake boundaries are located within one pixel when comparing the image maps to the Geological Survey topographic maps.

In parts of the North Slope where the lake boundaries are gradational between open water and very wet tundra, determining boundaries may be subjective both in the field and with Landsat imagery. Open water on the topographic maps was classified as water from Landsat images, and very wet tundra (the "marsh" symbol) on the maps was classified as land from Landsat.

(3) As discussed in processing step 3, the smoothing algorithms eliminated most of the lakes with areas less than about 5 acres. Smoothing also slightly enlarged the boundaries of lakes that are several tens of acres in size or larger. This did not affect the computation of lake area of the water classes (see processing step 7). Other effects of the smoothing are: (a) joining of closely spaced lakes, (b) separation of two portions of a lake joined by a thin neck, and (c) modification of lake boundaries with sizes around 10 acres or less. Comparisons of an area before and after smoothing are shown in figure 3. These image maps were produced at a scale of 1:63,360 to match the 15-minute Geological Survey topographic quadrangle maps.

The most undesirable effect of the smoothing is the occasional joining of two lakes originally separated by one or two pixels. For the data base, the joined lakes are considered one lake, with a center point that will fall between the actual midpoint of the two lakes and with an area that is the combined area. The splitting of one lake into two is very rare, but the same type of effect is seen as the smoothing process breaks a river into numerous small segments. For lakes less than 10 acres and similarly sized protuberances of larger lakes, their boundaries may be modified if their shape is not square or circular. If the smoothed lake then does not overlay well with the original water classes image, the area computation may be inaccurate. Thus, for narrow, sinuous lakes less than 10 acres, the area computation may be decreased by 50 percent or more. The smoothing effect on the total area for protuberances of lakes larger than 10 acres will not be significant.

(4) Because of the small limitation of plotting symbols on the electrostatic plotter, the grid cell size for the image maps is larger than the pixel size used in image processing. Approximately ten 50-meter pixels from the digital image maps were used to create one pixel (plot symbol) on the 1:250,000-scale plots. For the 1:63,360-scale plots, 10 digital image pixels were resampled to 6 pixels on the plot. The plot symbol corresponds to the class of the digital image pixel which is located closest to the plot pixel. This resampling generally causes a smoothing on the image maps. As an example, isolated islands that each consist of one 50-meter pixel found in the middle of large lakes will not appear on the 1:250,000-scale electrostatic map on the average of 9 times out of 10. The resampling effect thus tends to eliminate small lakes and join closely spaced large lakes. Note that this resampling affects only 1:250,000-scale map plots and does not affect the lake attribute file or plots.

SUMMARY

The digital data base of lakes on the North Slope contains information on about 23,330 lakes in sixteen 1:250,000-scale quadrangles that can be accessed by reference to quadrangle name and lake number, or latitude and longitude. Using a smoothing algorithm, lakes with areas less than 5 acres were eliminated from the data base. Using Geological Survey topographic maps in conjunction with paper plots of lake center locations, the user can locate particular lakes or regions of lakes and access the lake attributes in the data base. The data base can be searched on values of any of the lake attributes. Statistical summaries of lake areas also can be obtained. These attributes can be reported in a variety of formats. This data base is a flexible interactive system because additional attribute data can be easily entered and the data can be readily modified in response to detected changes in lake attributes.

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