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DEVELOP A LAND USE – PEAK RUNOFF CLASSIFICATION SYSTEM FOR HIGHWAY ENGINEERING PURPOSES

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16. Abstract

The 101 square mile watershed of Sunkhaze Stream was studied in detail using standard airphoto interpretation techniques with ERTS imagery, U-2 RC 10 photography and MDOT airphotos. Stereo viewing of ERTS imagery was preferred throughout the study, for gaining detail. The sidelap area of adjacent orbits was studied stereoscopically as were various band and season combinations. Tracings of ERTS features were made from 1:125,000 scale projections for direct overlay on RC-10 transparencies. A variance of about six percent was computed for hydrologic studies prepared from standard USGS 15 minute quadrangle maps, U-2 9" photography and ERTS imagery. Comparable results were obtained from CIR RC 10 transparencies and simulated ERTS CIR products in preparing land use maps. Thirty-eight square miles of spring flooding in the Penobscot River valley were detected and measured on 23 April 1973 imagery, which is being utilized to study flooding problems in the town of Bradley. Repetitive ERTS coverage during all seasons is a necessity for obtaining accurate hydrologic and land use data. CIR ERTS imagery added significantly to the resolution of detail for hydrologic studies and land use mapping.

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PREFACE:

OBJECTIVES: The objectives of this report were to see if updated hydrological information could be gleaned from ERTS imagery, to develop a land use-peak runoff classification system tailored for hydrologic studies, and to monitor snow cover and flood conditions.

SCOPE OF WORK: Hydrologic work was concentrated on flooded areas within the Penobscot River Watershed. From the flood areas, Sunkhaze Stream Watershed was selected for detail study. Land use maps and drainage maps of the Sunkhaze basin were derived from ERTS imagery and U-2 UC-10 photography.

CONCLUSION: Based on the detail study of the Sunkhaze Stream Watershed, it is believed that good detailed drainage studies can be derived from repetitive ERTS-1 imagery. Land use maps tailored to a hydrologic study can be prepared from ERTS imagery. Significant changes in the Sunkhaze Stream and Otter Stream Watersheds at spring flood conditions have given important information on the causes for flooding in the town of Bradley.

RECOMMENDATIONS: Repetitive coverage is an absolute necessity to do accurate hydrologic and land use studies. Stereo viewing is better than monocular viewing of images. Color products are believed to be better than black and white.

Improvements in the image quality, speed in obtaining color products, closer repetitive cover and greater sidelap would greatly improve the information that can be obtained from satellite imagery.

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BACKGROUND

For over a decade the Airphoto Interpretation Section of the Maine Department of Transportation has conducted drainage studies using airphoto interpretation techniques. Hydrological information including watershed area, slope, channel characteristics, runoff factors, water storage areas, land use and other salient features is furnished to hydraulics engineers for culvert design purposes. These data have been provided for proposed culvert locations for nearly all new construction and reconstruction highway projects in Maine. Since the mid-fifties thousands of individual watersheds, ranging in size from a few acres to over a hundred square miles, have been evaluated using photo interpretation techniques with a minimum of field checking.

In Maine it is a standard procedure to acquire both black and white and color aerial photography of a five-mile wide band centered on a proposed construction project about two years prior to actual construction. This photography is used to provide a variety of data for different highway engineering purposes including soils, drainage, materials inventory, right of way and environmental information. These photo interpretation data are used by various departments for planning, location, design, preliminary engineering and actual construction of the roadway.

For drainage studies of watersheds less than 1000 acres in extent, the recently flown photography along a five-mile wide band is adequate for obtaining data on current land use and other dynamic factors which influence runoff rates, or criteria which are vital for culvert design purposes. For larger watersheds extending outside of the five-mile wide band covered by recent photography it is often necessary to use coverage which may be 10 to 20 years old. This photography is not suitable for acquiring accurate land use information.

OBJECTIVES

The major short term objectives were:

A. To determine if up-to-date hydrological information useful for the design of large drainage structures can be gleaned from satellite data. The imagery will be used:

1. To monitor and map high water levels during the spring break up period at the different climatic subdivisions of the State.

2. To locate and measure water storage areas.

3. To develop a land use classification system tailored to runoff characteristics associated with peak flow criteria required by culvert and bridge design engineers.

B. To monitor snow cover conditions, by climatic subdivisions, during the melting period.

C. To monitor major floods and prepare maps for damage assessment purposes.

Information of the type listed above will be of immediate value and can be incorporated in standard studies made for current construction projects. The location and extent of possible hazardous flooding conditions would be of definite interest to maintenance engineers.

TECHNIQUES USED

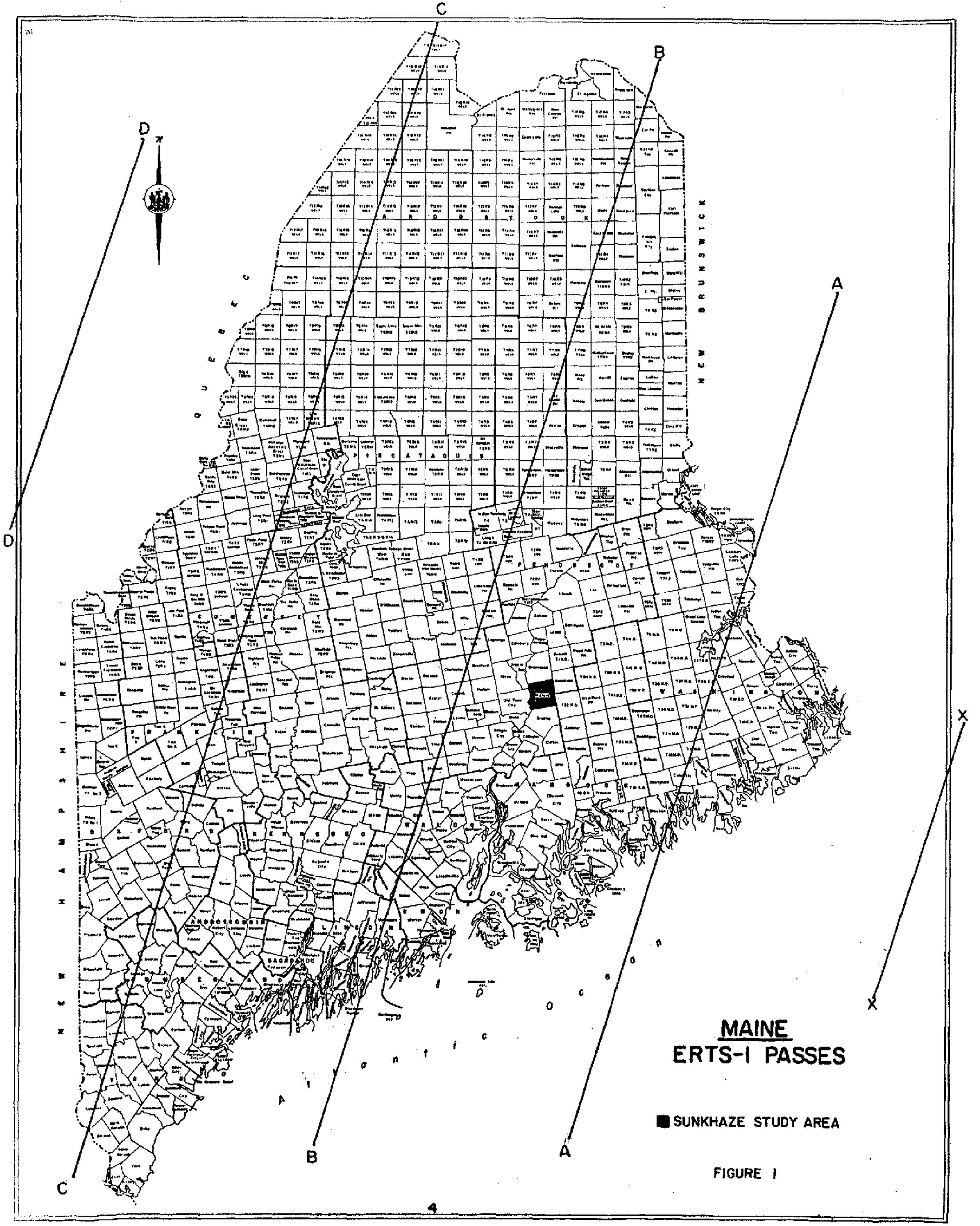
Standard photo interpretation techniques were employed wherever possible. Figure 1 shows the three major orbits (A, B, C) over Maine and the two supplementary orbits (X, D). There is about 40 percent sidelap of imagery for orbits on successive days. For three complete orbits the center image would lack about 15-20 percent stereo coverage. With the progressive shifts in orbits, most of the non-overlap area was reduced or totally eliminated, thus providing stereo viewing of almost 100 percent of the State on images obtained within one year.

Stereo viewing is greatly preferred to the viewing of a single image, and stereopairs of different bands such as 5 and 7, 4 and 6, etc., can be combined for enchanced data extraction. Of particular value was viewing stereopairs or similar images of the same location of different seasons. As examples, high water vs. low water (23 April vs. 22 July, Figures 2A through 2D), or winter snow cover vs. summer. This type of viewing made interpretation of the limits of flooding, type vegetation and height of vegetation possible to distinguish. This was of particular value when projections were made for enlargement and tracing. Only one image at a time could then be viewed, and frequently reference was made to the paired images for proper identification of tonal changes in the projection.

Stereo viewing was found to be most useful of black and white transparencies where these were available. The black and white prints were extensively used for recording information, tracing and for general display. A black and white print was often used in combination with a transparency, using the print to write on.

Projection of images was usually for tracing. The 9 X 9 inch (1:1,000,000) black and white and color composite transparencies were projected to scales of 1:62,500 and 1:125,000, using an overhead projector, or by extracting a 70mm slide of the area of interest. The best resolution was obtained at a scale of 1:125,000.

By far the most extensive projection was done of 70mm positive transparencies.



MAINE ERTS-I PASSES

FIGURE I

Both 35mm and 70mm slide projections were used. These images were enlarged to a scale of 1:125,000 with compatible results compared to the 9 X 9 projections at the same scale. Color composite prints and transparencies were also used. These were handled in the same manner as the black and white positive 9 X 9 products, and added greatly to the vegetation interpretation. The major disadvantage of color composites is the limited number available to date and the extreme delay in their arrival, some as much as a year and a half after the date of imagery.

LEVELS OF OBSERVATION:

Once a specific study area had been selected, the following method of observation was attempted:

1. The area of interest was studied in as many different image pairs as possible, using the methods above. The differences between bands, seasons, snow conditions and water conditions were noted. The images that showed the different qualities desired were projected and traced. All changes in tones and contrasts between bands were traced. Labeling was based upon only limited knowledge. Some tonal changes that could not be identified were left blank.

2. This tracing was checked against U-2 photography. Because the U-2 RC-10 photos are about the same scale (1:125,000) as most of the ERTS tracings, the tracing could be directly overlayed on the 9 X 9 CIR transparency. A U-2 map or tracing was also generated. We then went back to the ERTS image and tried to see any other changes not noted before, knowing better where to look. After referencing and relabeling the ERTS map, conventional airphoto coverage was studied.

3. The standard air photos used in most of this study are at the scales of 1:43,000 and 1:20,000, dated 1942 and 1958 respectively. The land use is, therefore, not up to date but fortunately this area has experienced little change in the land use pattern. Major changes are abandoned fields reverting to forest and scattered cutting operations in woodlands.

It should be noted that the larger scale black and white photos provided relatively little additional information over the U-2 CIR transparencies. Very large scale coverages of the study areas would be helpful, but are not available.

4. For the specific study phase of flooding, low altitude 35mm oblique color slides were obtained which provided excellent ground truth detail as in Figures 12 and 13, Page 37.

5. The final level of observation was actual "walkover" of points of interest, with detailed field checks. Vegetation cover and extent of high water were recorded and observations made of areas not covered by the low altitude photography. Ground surveys were made to determine spot elevations at critical points of interest.

SELECTION OF STUDY AREAS

Scenes imaged 23 April 73, ID 1274-14553 and 1274-14551, gave the first opportunity for selecting hydrologic study areas.

The 23 April images were compared with 1 September 72 images, ID 1040-14543 and 1040-14540, and 22 July 73, ID 1364-14544 and 1364-14541 (Figure 2, A through D), for comparison of flooded areas in the Penobscot River watershed. The 23 April 73 imagery is of importance because the flooding along the Penobscot River was the third highest level recorded since gauging stations were installed in 1918. Levels higher than the 118.91 foot mark on 1 May 1973, were on 1 May 1923, 126.7 feet, and 23 March 1936, 123.25 feet, recorded at the Sunkhaze gauging station.

Tables 1 and 2 list the changes in water elevation before and after the 1 May 73 flooding. The 23 April 73 imagery occurs 8 days before maximum high water on 1 May. The value of this imagery is that it presents a good picture of spring flooding by high runoff from snowmelt and normal spring rains. Snow on the lower Penobscot was gone by 12 April at Bangor, but in the uplands areas 2 feet of snow was still on the ground on 5 April and most was gone less than 2 weeks later on 22 April at Greenville. (Greenville is not in the Penobscot River watershed, but

SUNKHAZE GAUGE ELEVATIONS

U.S.G.S. DATUM

TABLE I

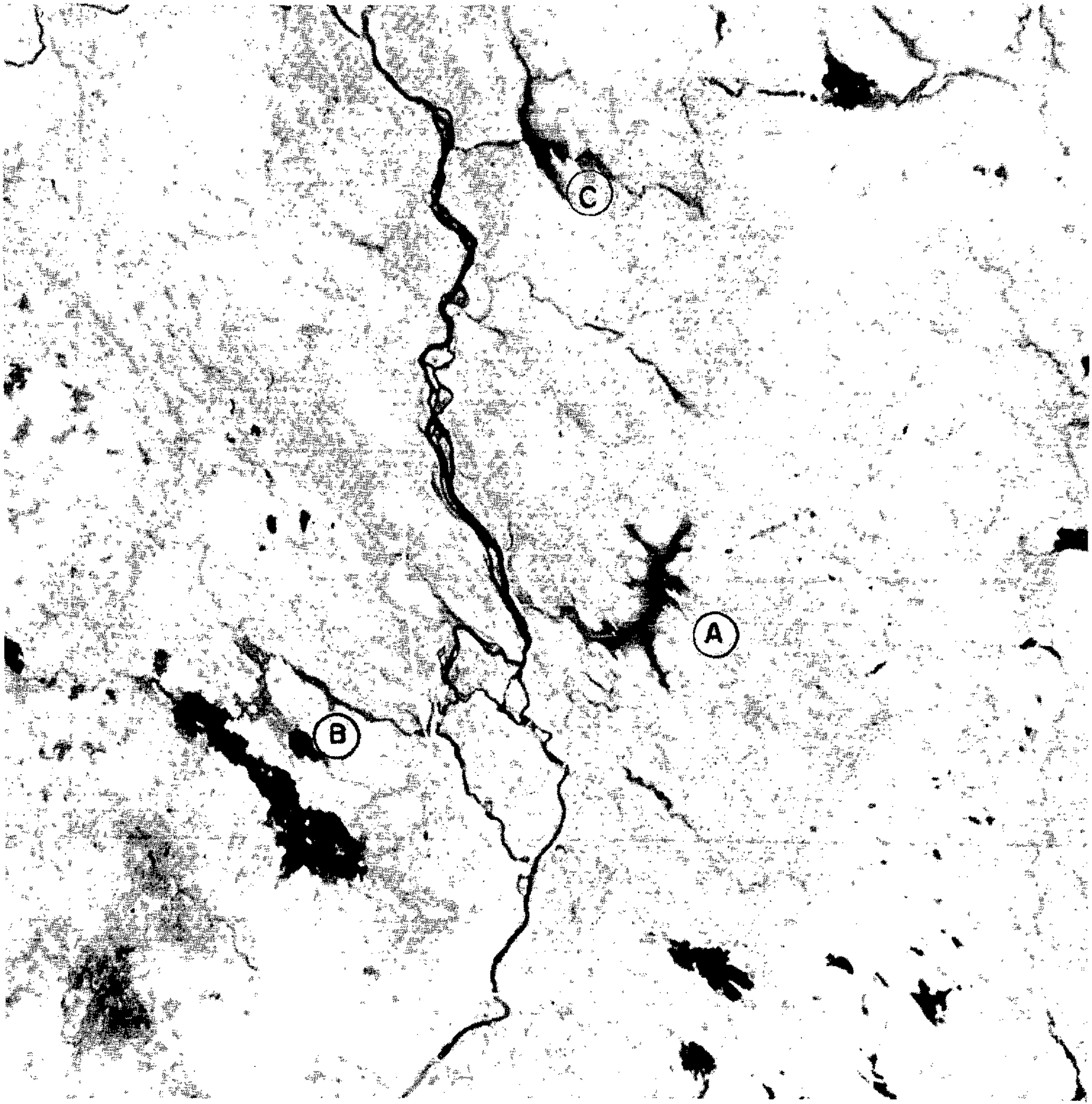
DATE	12 MID.	6 A.M.	12 NOON	6 P.M.
April 20	110.75	110.95	111.20	111.30
21	111.45	111.50	111.50	111.50
22	111.50	111.50	111.50	111.50
23	111.55	111.60	111.75 ERTS	111.95
24	112.20	112.45	112.75	112.95
25	113.15	113.30	113.35	113.35
26	113.35	113.35	113.30	113.20
27	113.15	113.05	112.95	112.90
28	112.85	112.85	113.05	113.65
29	114.55	114.95	115.25	115.50
30	115.50	115.50	118.76	118.76
May 1	118.76	118.91	118.91	118.41
2	118.41	118.41	118.61	116.96
3	116.96	116.41	116.41	115.86
4	115.86	115.86	115.56	115.56
5	115.56	115.56	115.01	114.81

TABLE 2

Changes in Water Elevation From 12 Midnight to 12 Midnight Sunkhaze Gauging Station in feet		Precipitation Millinocket (in inches)	Precipitation Bangor (in inches)
April 20	———	———	———
21	+0.70	———	0.02
22	+0.05	0.37	0.15
23	+0.05	0.15	0.14
24	+0.65	———	———
25	+0.95	———	———
26	+0.20	———	———
27	-0.20	———	0.83
28	-0.30	1.73	1.18
29	+1.70	1.75	0.02
30	+0.95	0.05	0.01
May 1	+3.26	0.01	———
2	-0.35	———	———
3	-1.45	———	———

Snow on ground. All snow at Bangor was gone by 12 April 73.

At Greenville snow went from 21 inches on 5 April 73 to none on 22 April 73.



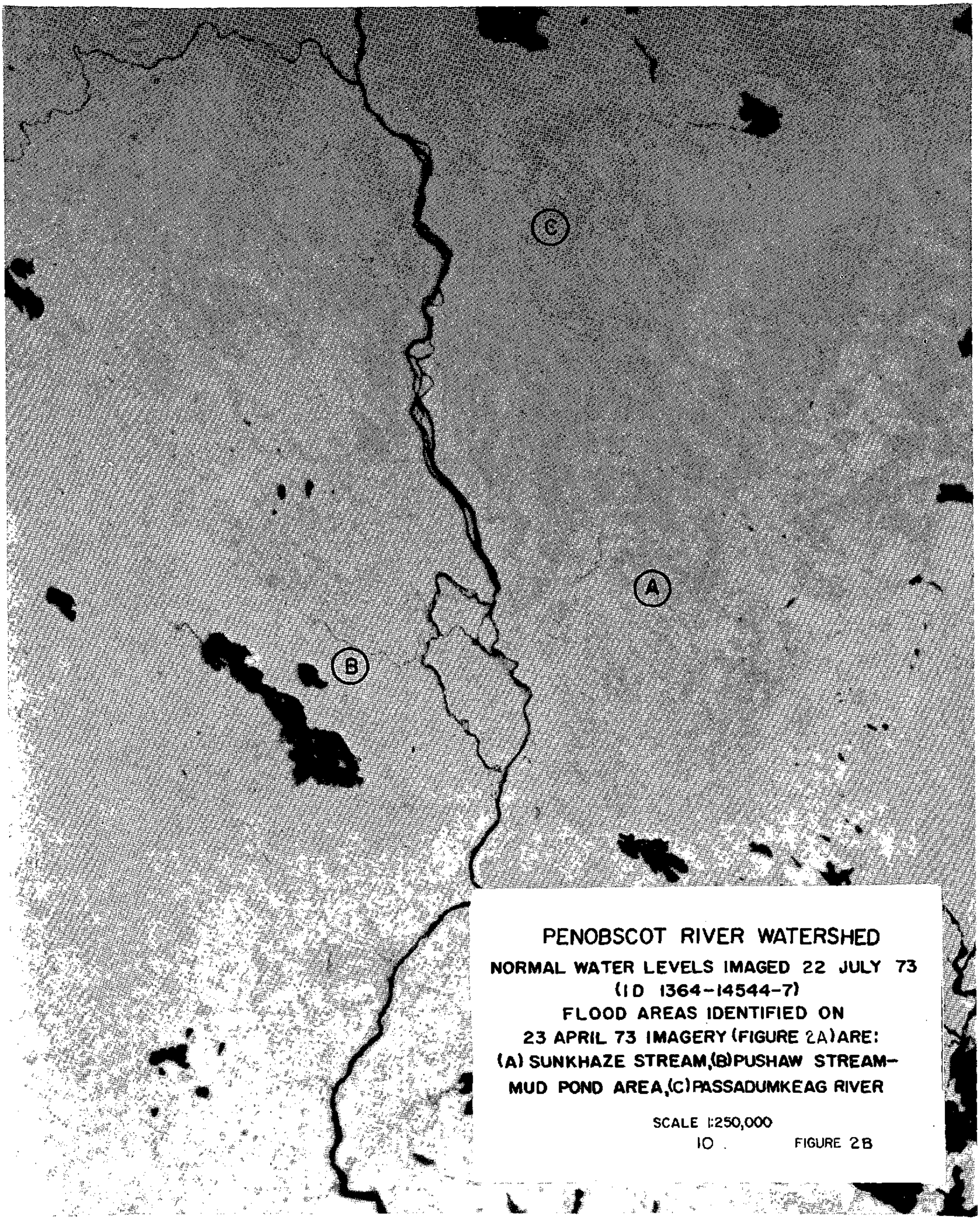
PENOBSCOT RIVER WATERSHED

FLOODING IMAGED 23 APRIL 73
(ID 1274-14553-6)
MAJOR FLOOD AREAS IDENTIFIED:
(A) SUNKHAZE STREAM, (B) PUSHAW STREAM-MUD POND AREA, (C) PASSADUMKEAG RIVER

COMPARE WITH NORMAL WATER LEVELS IMAGED 22 JULY (FIGURE 2B)

SCALE 1:250,000

FIGURE 2A

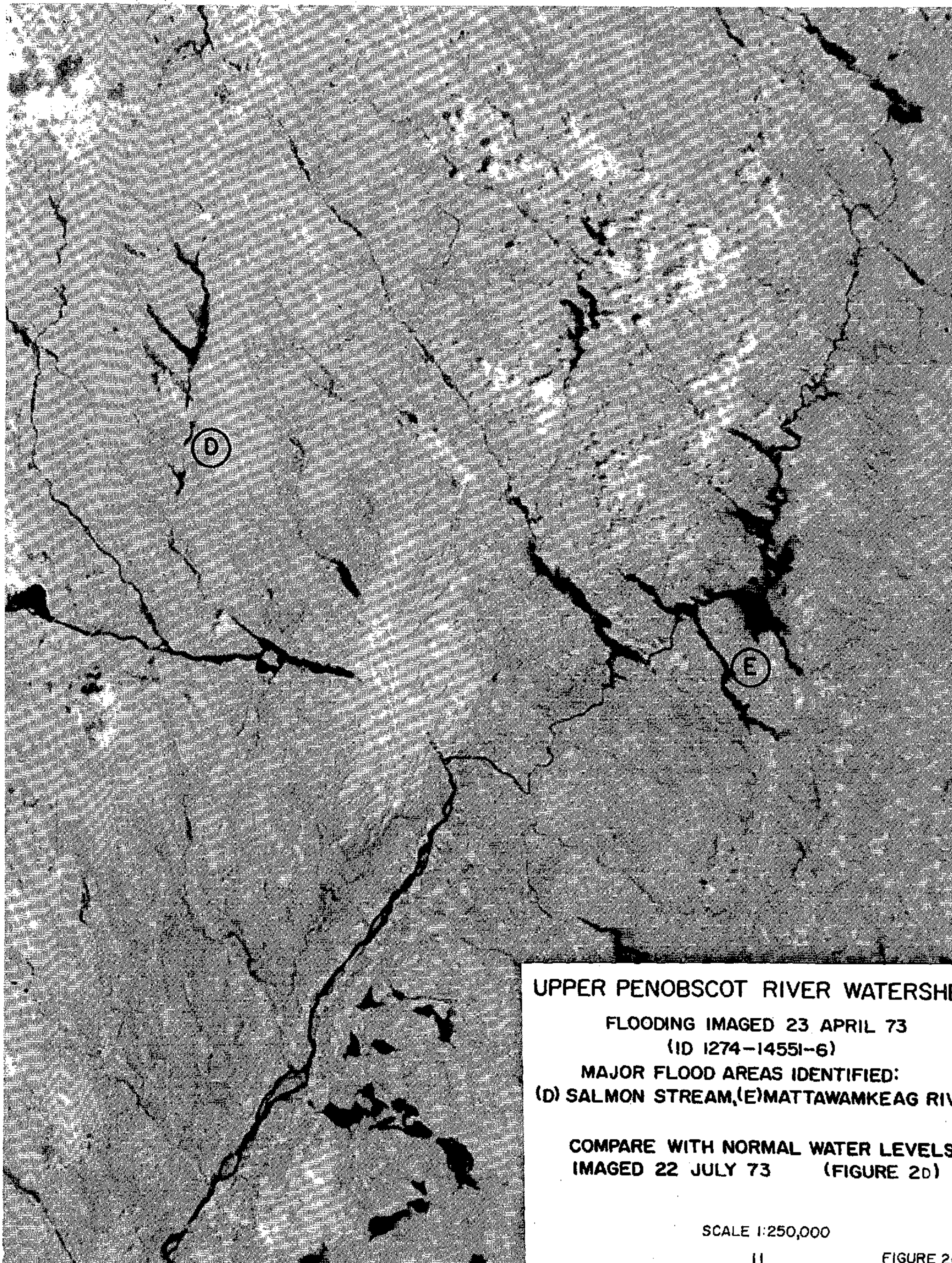


PENOBSCOT RIVER WATERSHED

NORMAL WATER LEVELS IMAGED 22 JULY 73
(ID 1364-14544-7)
FLOOD AREAS IDENTIFIED ON
23 APRIL 73 IMAGERY (FIGURE 2A) ARE:
(A) SUNKHAZE STREAM, (B) PUSHAW STREAM-MUD POND AREA, (C) PASSADUMKEAG RIVER

SCALE 1:250,000

FIGURE 2B



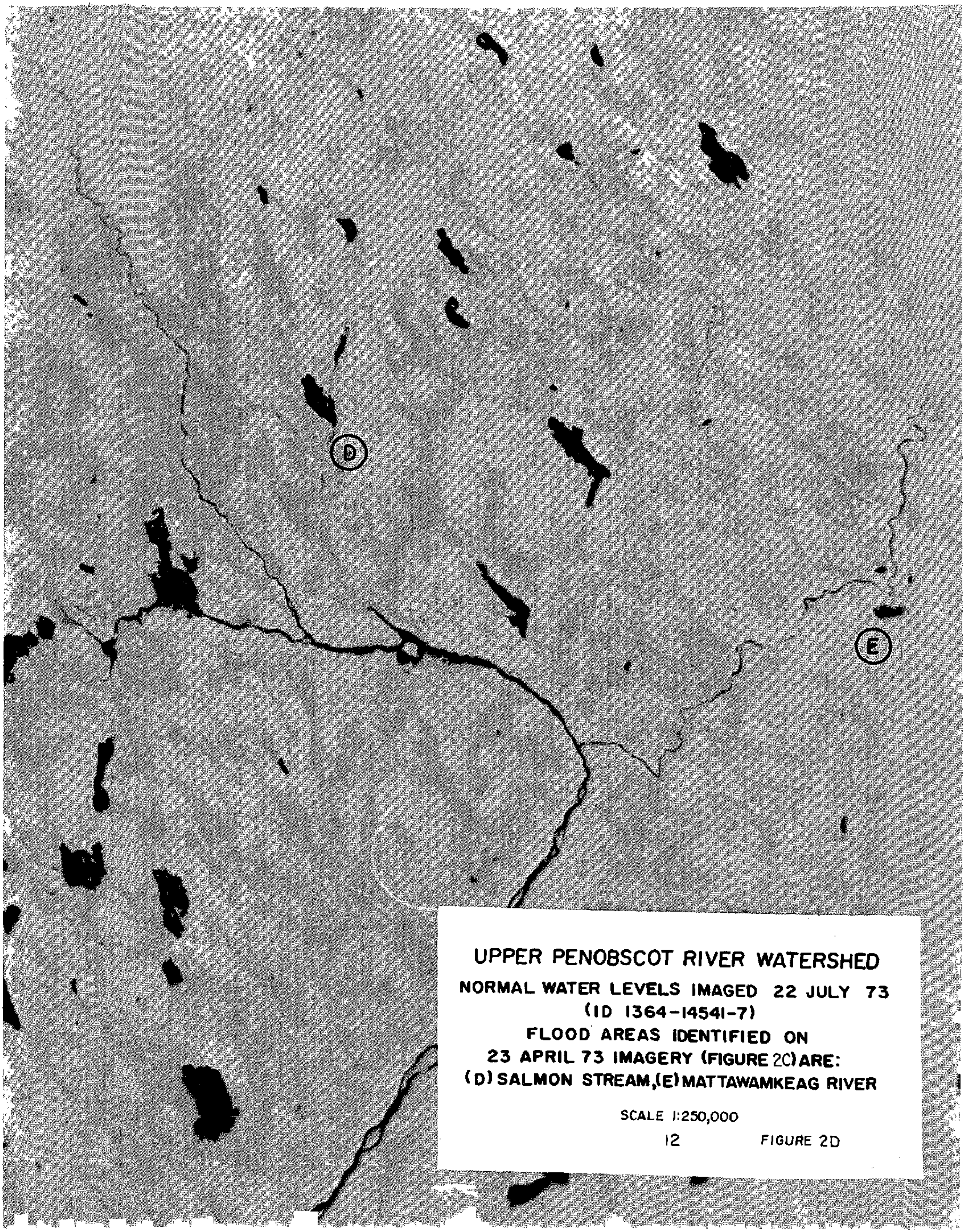
UPPER PENOBSCOT RIVER WATERSHED

FLOODING IMAGED 23 APRIL 73
(ID 1274-14551-6)
MAJOR FLOOD AREAS IDENTIFIED:
(D) SALMON STREAM, (E) MATTAWAMKEAG RIVER

COMPARE WITH NORMAL WATER LEVELS
IMAGED 22 JULY 73 (FIGURE 2D)

SCALE 1:250,000

FIGURE 2C



UPPER PENOBSCOT RIVER WATERSHED

NORMAL WATER LEVELS IMAGED 22 JULY 73
(ID 1364-14541-7)
FLOOD AREAS IDENTIFIED ON
23 APRIL 73 IMAGERY (FIGURE 2C) ARE:
(D) SALMON STREAM, (E) MATTAWAMKEAG RIVER

SCALE 1:250,000

FIGURE 2D

is the nearest station reporting snow on the ground in an upland area.) There is some indication on the 23 April imagery that the upland areas around Mt. Katahdin, within the Penobscot watershed, still had snow on the ground. A color composite of the scene might help answer this question, but is not available to date. That the flooding on April imagery is high water associated with spring runoff is suggested by the dropping of the river on April 27 and 28, shown in Tables 1 and 2. Within the Penobscot watershed five potential sites of flooding were selected. The areas of major flooding are noted on Figures 2A and 2C for 23 April 73, ID 1274-14553-6 and ID 1274-14551-6. The respective non-flooded areas are indicated on Figures 2B and 2D for 22 July 73, ID 1364-14547 and 1364-14541-7. The flooded sites are (A) Sunkhaze Stream, (B) Pushaw Stream-Mud Pond area, (C) Passadumkeag River, (D) Salmon Stream and (E) Mattawamkeag River.

WATER COVERAGE:

Each of the flooded areas was examined on the 9 X 9 inch black and white transparencies and prints of 22 July 73 and 23 April 73 imagery. It was determined that Band 6 is best for enlargement and closer study, due to the noise in the scan lines on Band 7 (23 April) and the ability to detect water better on Band 6 than on Bands 4 and 5. The 70mm transparencies were cut to 35mm slides and projected to the scale of approximately 1:125,000. The resulting tracings for flooding are shown in Figures 3, A through E.

Four categories of black-gray image could easily be detected in the projection as being water-covered terrain or flooded tracts. These grays and blacks are the darkest shades present in the images, as water has the least reflectance in the infrared wave lengths. The categories are (1) open water, darkest black probably deepest water, no vegetation showing at the water surface, (2) shallow water, mostly open water with no vegetation showing, (3) shallow water, with some brush and swamp hardwoods showing, and (4) water in hardwoods, with some softwoods.

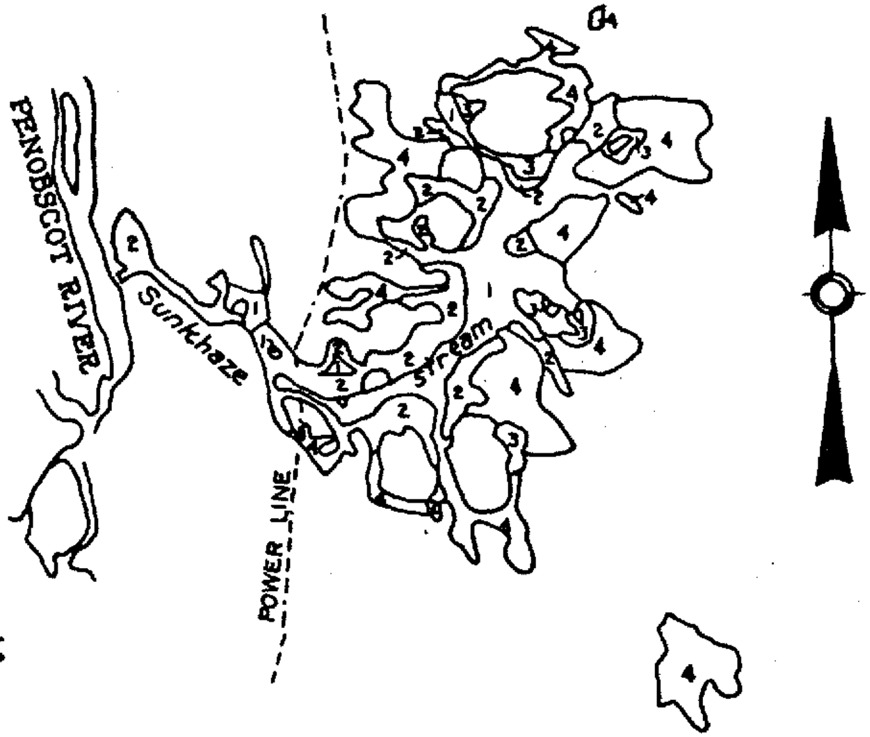


FIGURE 3A

DETAIL OF SUNKHAZE STREAM AND PUSHAW STREAM-MUD POND FLOOD AREAS

ENLARGED FROM ERTS-1 SCENE
IMAGED 23 APRIL 73, ID 1274-14553-6

APPROX SCALE 1:125,000

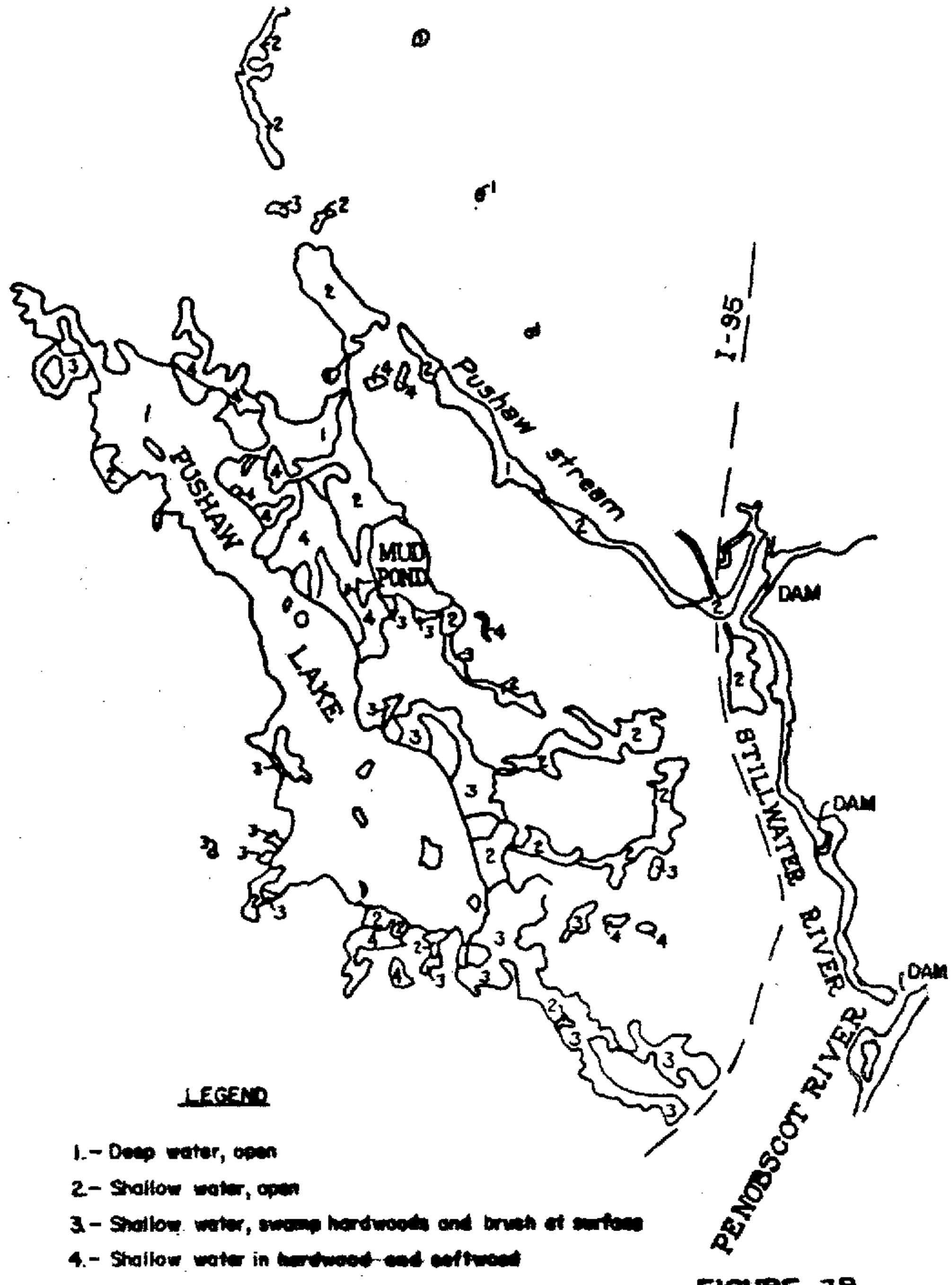
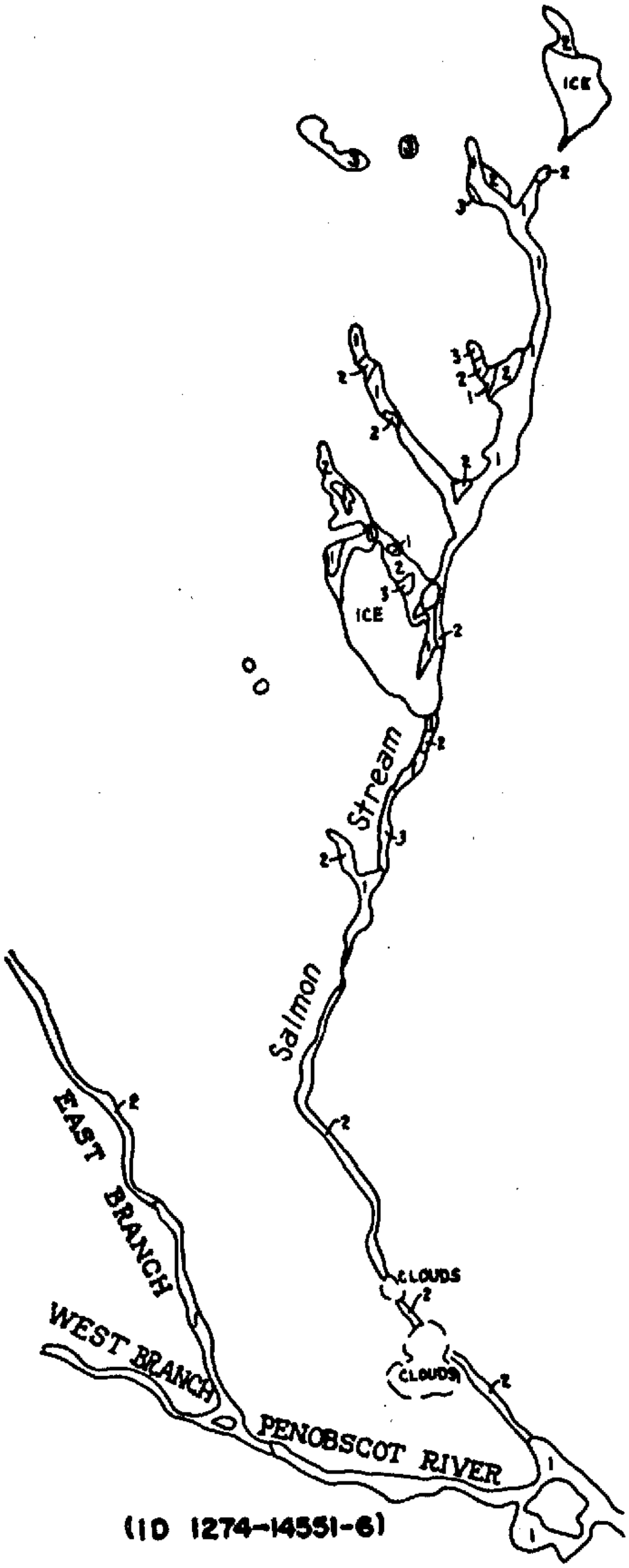
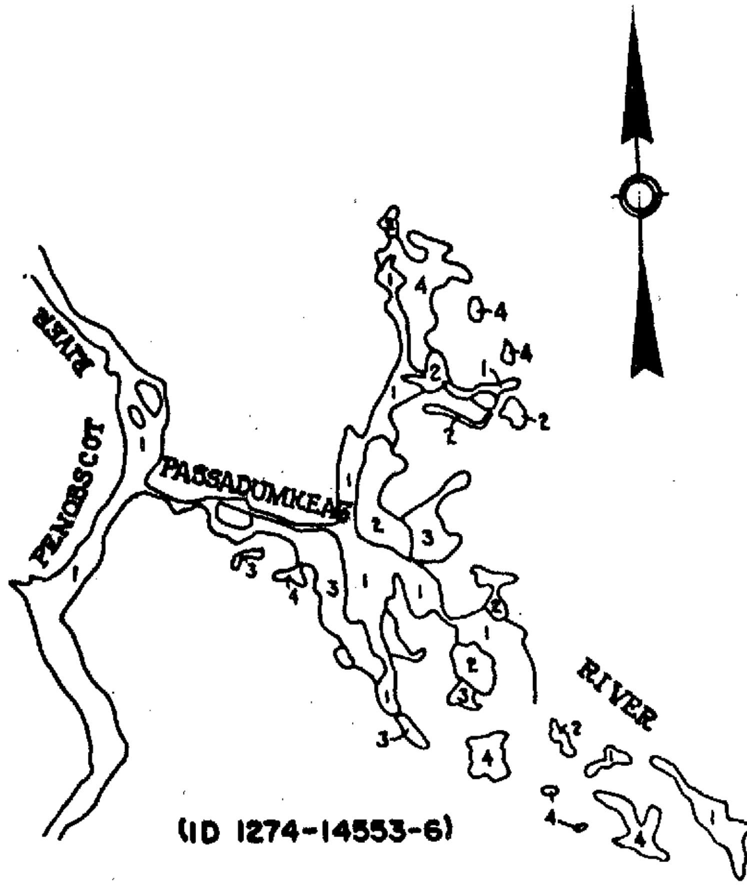


FIGURE 3B



(ID 1274-14551-6)

FIGURE 3D



(ID 1274-14553-6)

FIGURE 3C

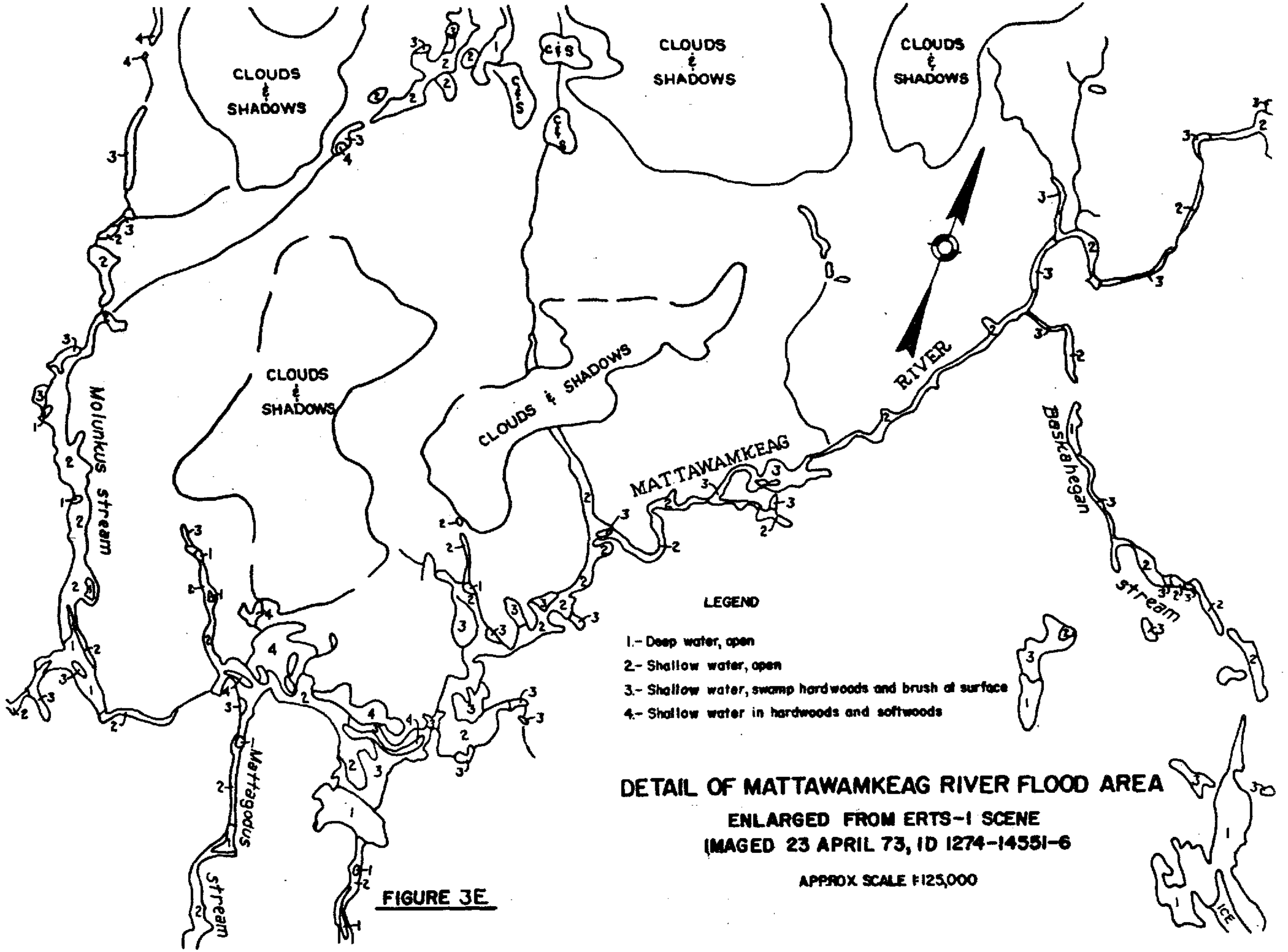
LEGEND

1. – Deep water, open
2. – Shallow water, open
3. – Shallow water, swamp hardwoods and brush at surface
4. – Shallow water in hardwood and softwood

DETAIL OF PASSADUMKEAG RIVER & SALMON STREAM FLOOD AREAS

ENLARGED FROM ERTS-1 SCENES IMAGED 23 APRIL 73

APPROX. SCALE 1:125,000



DETAIL OF MATTAWAMKEAG RIVER FLOOD AREA
ENLARGED FROM ERTS-1 SCENE
IMAGED 23 APRIL 73, ID 1274-14551-6
APPROX SCALE 1:125,000

FIGURE 3E

Tabulation of Water Cover in Figures 3, A through E

TABLE 3

FLOODED AREA	Types of Water Cover (Square Miles) 1	2	3	4	1 + 2	1+2+3	1+2+3+4	Normal	Increase Over Normal	% Increase
Sunkhaze Stream	2,273	2,727	0.130	1.753	4.999	5.128	6.881	0	6.881	———
Passadumkeag River	2.338	0.779	1.104	1.104	3.177	4.221	5.324	0	5.324	———
Pushaw Stream and Mud Pond	9.285	4.091	2.857	1.428	13.376	16.233	17.661	7.724	9.937	228%
Mattawamkeag River				1.862		14.371	16.233	3.084	13.149	528%
Salmon Stream						4.347	4.347	1.280	3.067	340%

TOTAL INCREASE: 38.3580 Sq. Miles

1. Deep water, open
2. Shallow water, open
3. Shallow water, swamp hardwood and brush at surface
4. Shallow water in hardwood and softwood

Table 3 gives the summary of flooded areas vs. normal water area. There is a 38.358 sq. mile total increase over normal water cover detected on the 23 April images for these five flooded areas. Examination of the two contrasting images in Figures 2A through 2D reveals there are several other rivers and streams that could also have been examined for increased water coverage.

Since all five watersheds could not be examined in detail, the Sunkhaze Stream area was selected for detailed data collection and examination because of its close proximity to the soils office and relative ease of access. This site has repetitive stereo coverage by ERTS-1 images (Table 4), and is known to have undergone repeated flooding. In 1973 there was high water on 1 May and 25 December. There is also a need to understand the repeated flooding of the town of Bradley by Otter Stream and the Penobscot River. Otter Stream receives a portion of the Sunkhaze overflow due to backwater flooding by the River. A gauging station at the confluence of Sunkhaze Stream and the Penobscot River, operated by Bangor Hydro Electric Company, allows accurate correlation of water elevations at the mouth of the stream with conditions upstream.

Scenes Imaging the Sunkhaze Stream Watershed

TABLE 4

ORBIT A		ORBIT B	
18 September 72	1057-14484	1 September 72	1040-14543
17 December 72	1147-14493	5 January 73	1166-14550
22 January 73	1183-14491	10 February 73	1202-14552
27 February 73	1219-14495	28 February 73	1220-14553
13 September 73	1417-14480	23 April 73	1274-14553
1 October 73	1435-14473	22 July 73	1364-14544
19 October 73	1453-14470	7 November 73	1472-14523
24 November 73	1489-14464	13 December 73	1508-14521

DATA COLLECTED

Tables 1 and 5 are the records of the water elevations at the Sunkhaze gauging station for 1 April to 5 May 1973 and for 1 December to 21 December 1973. It can be

SUNKHAZE ELEVATION

December 1, 1973, to December 31, 1973

TABLE 5

Date	12 Mid.	6 A.M.	12 Noon	6 P.M.
Dec. 1	105.30	105.35	105.40	105.40
2	105.30	105.25	105.20	105.10
3	105.05	104.95	104.85	104.80
4	104.75	104.75	104.70	104.60
5	104.35	104.50	104.50	104.65
6	104.75	104.90	105.10	105.60
7	106.20	107.00	107.45	107.75
8	107.80	107.85	107.80	107.70
9	107.50	107.35	107.05	106.90
10	106.80	106.90	107.15	107.55
11	108.30	108.90	109.30	109.50
12	109.50	109.35	109.25	109.10
13	108.95	108.75	108.45 ERTS	107.95
14	107.80	107.65	107.65	107.65
15	107.65	107.65	107.70	108.15
16	108.80	109.20	109.45	109.45
17	109.45	109.20	109.10	109.00
18	109.25	110.25	111.60	112.85
19	113.95	114.75	114.85	114.85
20	114.85	114.50	114.15	113.95
21	113.50	113.10	112.80	112.70
22	113.20	114.05	114.80	115.10
23	115.20	115.20	115.20	115.25
24	115.55	115.75	115.75	118.85*
25	118.85*	118.85*	113.80	113.35
26	113.00	112.65	112.50	112.45
27	112.45	112.25	112.10	111.90
28	111.80	111.60	111.35	111.10
29	110.85	110.65	110.45	110.35
30	110.20	110.10	109.95	109.75
31	109.60	109.20	109.05	109.00

* 118.85 using different datum for which there is an unknown conversion factor to USGS datum.

seen from the April-May elevations that two peaks were reached, one on 25-26 April and a higher one on 1 May. The December elevations show an increase from 105 feet on 1 December to 115 feet (±) on 25 December 1973.

Table 2 shows the rainfall at Bangor and Millinocket for 20 April and 5 May. Table 6 is the snow on the ground at Greenville and Bangor from 1 to 25 April. Table 7 is the rainfall at Bangor and Millinocket for December 73. Bangor is located on the Penobscot River 15 miles south of Sunkhaze Meadows, and Millinocket is located on the west branch of the Penobscot about 55 miles up-stream from Sunkhaze Meadows. Shown on these tables is the date of ERTS-1 imagery.

Figure 4 is a graph of the normal river gradient between the mouth of Sunkhaze Stream and the County Road crossing at Baker Stream (See Figure 5). The normal elevation is 104.6 feet at the mouth and 111.1 feet at the County Road Bridge. The slope is 0.95 feet/mile down to the Sunkhaze Stream Bridge.

Figure 6 is a profile of the southeast meadow (See Figure 5 for location) traversing east to west from the east edge of the meadow to the first definite sign of high water. The signs for high water were sticks and branches lodged in the tops of the low meadow brush. The highest point in this meadow is over 121 feet. The highest elevation of the first sign of flooding is about 119.6 feet, at the top of a hummock where the branches were lodged. The lower elevation at this point is 118.1 feet, measured by transit survey. The water elevation of 119.6 is in good agreement with the high water level of 118.91 feet measured at the Sunkhaze gauging station. It can be seen from the cross section of the bog that the two previously recorded floods were higher than that of 1973 and covered the entire meadow surface; 1 May 1923 (126.7) and 23 March 1936 (123.25).

Flow directions were noted from debris caught in trees on the Sunkhaze River levee. These directions were reverse flow parallel with the stream. The debris

SNOW ON GROUND
(inches)

TABLE 6

	Greenville	Bangor
April 1 1973	9	—
2	7	T
3	15	T
4	17	T
5	21	3
6	17	T
7	15	—
8	14	—
9	13	—
10	12	—
11	16	T
12	15	—
13	15	—
14	14	—
15	13	—
16	11	—
17	6	—
18	1	—
19	T	—
20	T	—
21	T	—
22	T	—
23	— ERTS	— ERTS
24	—	—
25	—	—

DECEMBER 73 PRECIPITATION

TABLE 7

	Millinocket (Total 10.41)		Bangor (Total 8.44)	
Dec. 1	—		—	
2	—		—	
3	—		T	
4	.20		T	
5	.10		0.39	
6	1.00		0.32	
7	—		—	
8	—		—	
9	—		1.12	
10	1.35		0.02	
11	0.05		0.35	
12	.23		T	
13	—	ERTS	—	ERTS
14	—		0.64	
15	.78		0.07	
16	—		0.27	
17	.60		2.93	
18	3.48		T	
19	—		—	
20	—		0.09	
21	.68		1.43	
22	1.34		—	
23	—		T	
24	T		—	
25	—		0.03	
26	0.15		0.10	
27	—		0.19	
28	0.25		0.35	
29	0.17		T	
30	0.03		0.04	
31	—		0.10	

There were only trace amounts of snow anywhere in Maine in December.

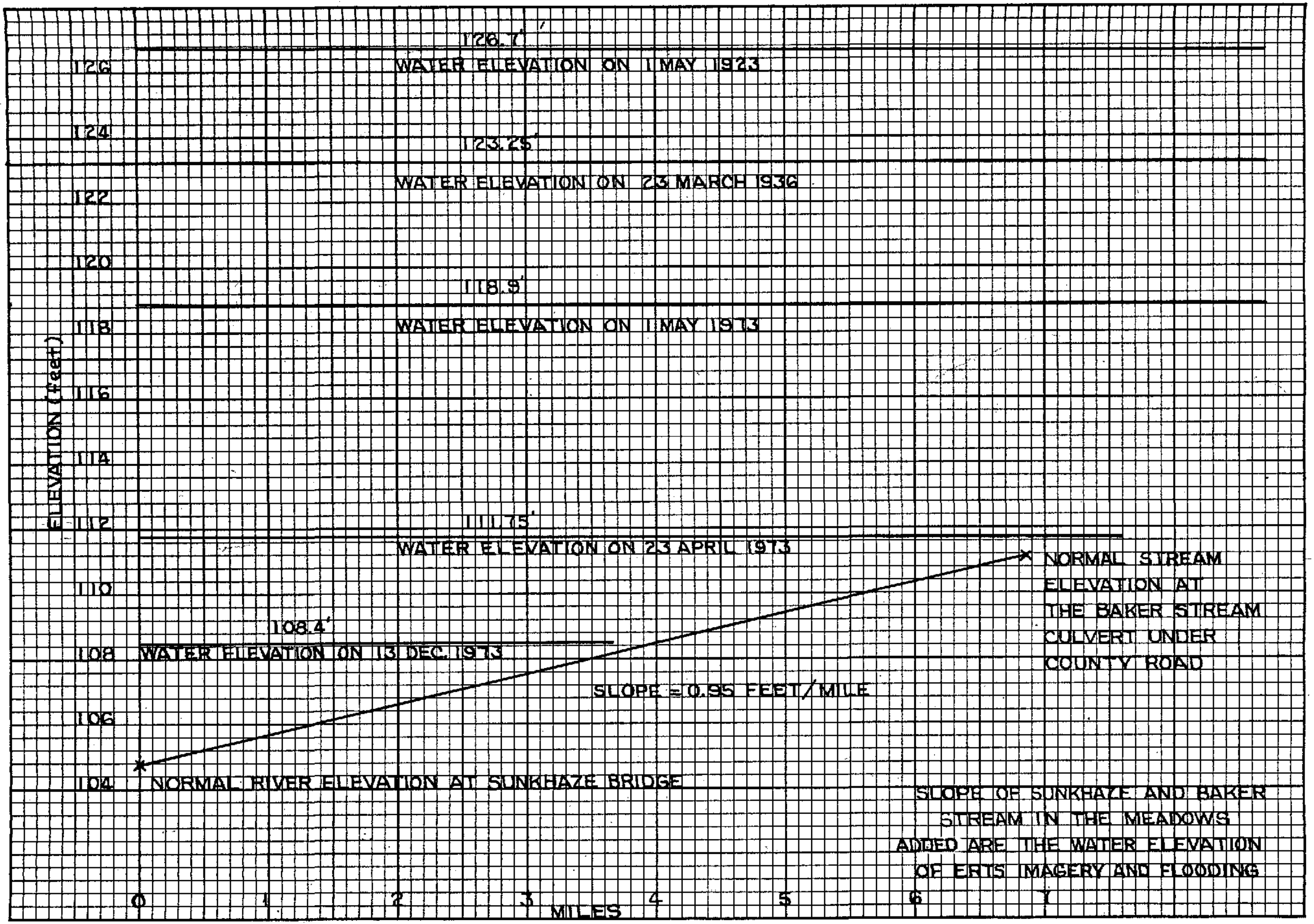

126.7'
WATER ELEVATION ON 1 MAY 1923
123.25'
WATER ELEVATION ON 23 MARCH 1936
118.9'
WATER ELEVATION ON 1 MAY 1973
111.75'
WATER ELEVATION ON 23 APRIL 1973
108.4'
WATER ELEVATION ON 13 DEC. 1973
SLOPE = 0.95 FEET/MILE
NORMAL STREAM ELEVATION AT THE BAKER STREAM CULVERT UNDER COUNTY ROAD
NORMAL RIVER ELEVATION AT SUNKHAZE BRIDGE
SLOPE OF SUNKHAZE AND BAKER STREAM IN THE MEADOWS
ADDED ARE THE WATER ELEVATION OF ERTS IMAGERY AND FLOODING
ELEVATION (feet)
126
124
122
120
118
116
114
112
110
108
106
104
0
1
2
3
4
5
6
7
MILES

FIGURE 4

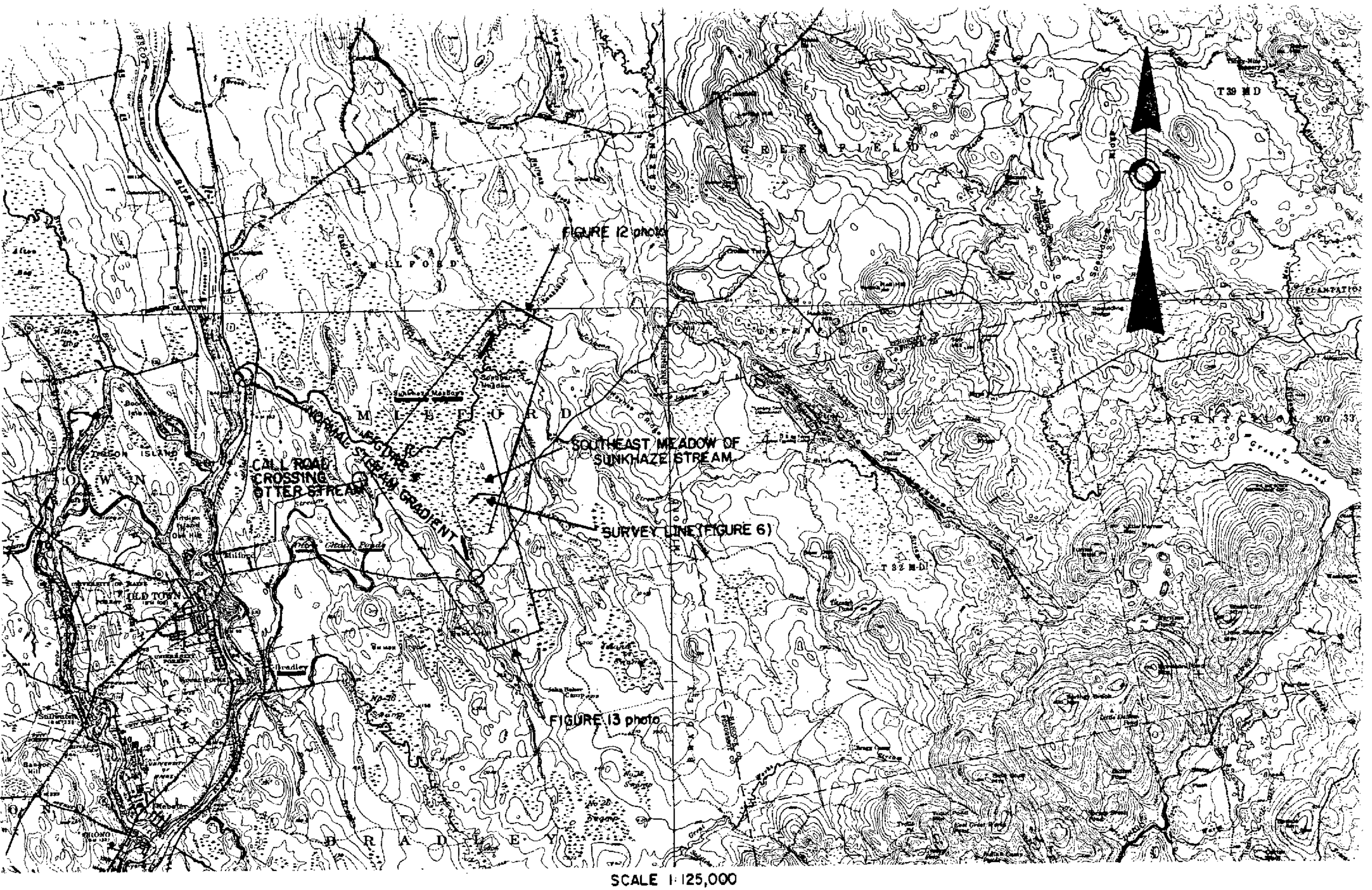


FIGURE 5 LOCATION MAP SUNKHAZE STREAM DATA

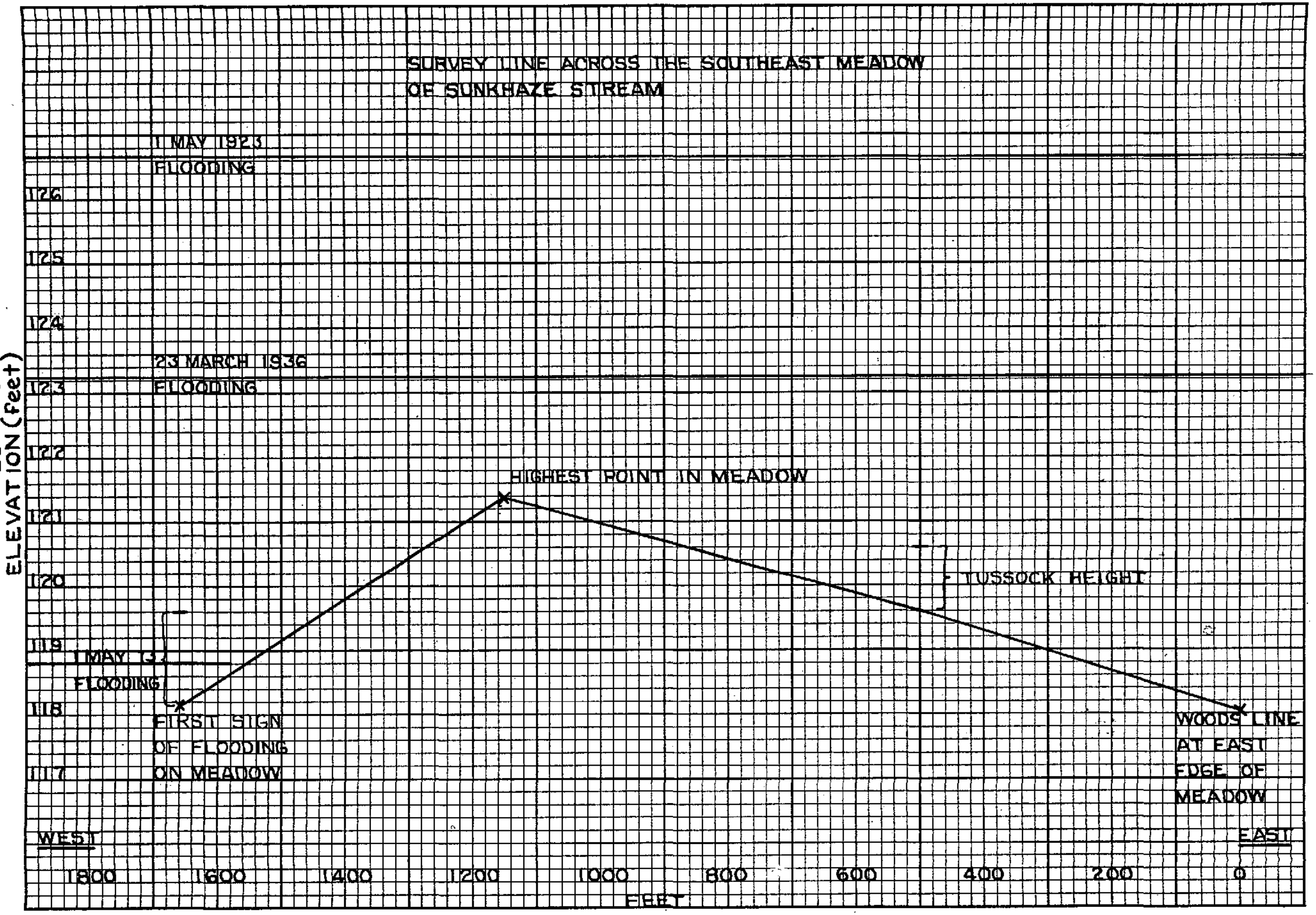

SURVEY LINE ACROSS THE SOUTHEAST MEADOW
OF SUNKHAZE STREAM
1 MAY 1923
FLOODING
23 MARCH 1936
FLOODING
HIGHEST POINT IN MEADOW
TUSSOCK HEIGHT
1 MAY
FLOODING
FIRST SIGN
OF FLOODING
ON MEADOW
WOODS LINE
AT EAST
EDGE OF
MEADOW
WEST
EAST
ELEVATION (Feet)
126
125
124
123
122
121
120
119
118
117
1800
1600
1400
1200
1000
800
600
400
200
0
FEET

FIGURE 6

consisted mostly of twigs, leaves and small branches in the tops of small trees 8-10 feet high. The exception to this was a larger pile of logs, sticks and leaves against the downstream side of a tree. From personal observation of Sunkhaze River where it passes under Route 2, it has been seen that the reverse flow of water from the Penobscot is very rapid and of very large volume into the meadows during flood stage.

On 18 December 73 there was little flow in Otter Stream through the culverts at Call Road. On 22 December 73 water flowed over the road 3 feet deep and 50 yards wide. The water elevation at Sunkhaze gauging station was 111.6 feet on 18 December 73 and 114.8 feet on 22 December 73. Between these two dates, backflow from the Penobscot River breached this divide between Otter Stream watershed and the Sunkhaze Stream watershed. The difference in water elevation between the two dates was 3.2 feet. Therefore, when the Penobscot rises above 113 feet at the Sunkhaze confluence it will backflow up the Sunkhaze drainageway into the Otter Stream watershed, compounding the flood problem at the Town of Bradley.

DRAINAGE STUDY OF SUNKHAZE WATERSHED AT NORMAL WATER ELEVATIONS

Three different methods of drainage studies are attempted. These are by USGS topography map (scale 1:62,500), RC-10 U-2 photography (scale 1:125,000) and ERTS-1 images (enlarged to 1:125,000). The USGS base maps were half-sized for ease of comparison with U-2 and ERTS maps drawn to approximately the same scale.

In all the studies the area of the total watershed, area covered by swamps and area covered by lakes were measured. Since the main stream channel lengths in the different maps were about the same, that derived from the USGS maps is used. (24 miles from the mouth of Sunkhaze to the ridge line). The slope of the watershed main channel was also derived solely from the topographic maps (9.5 feet/mile measured from 2.4 miles above the mouth of the stream and 3.6 miles from the ridge line, using the Benson formula). The resulting data is summarized in Table 8.

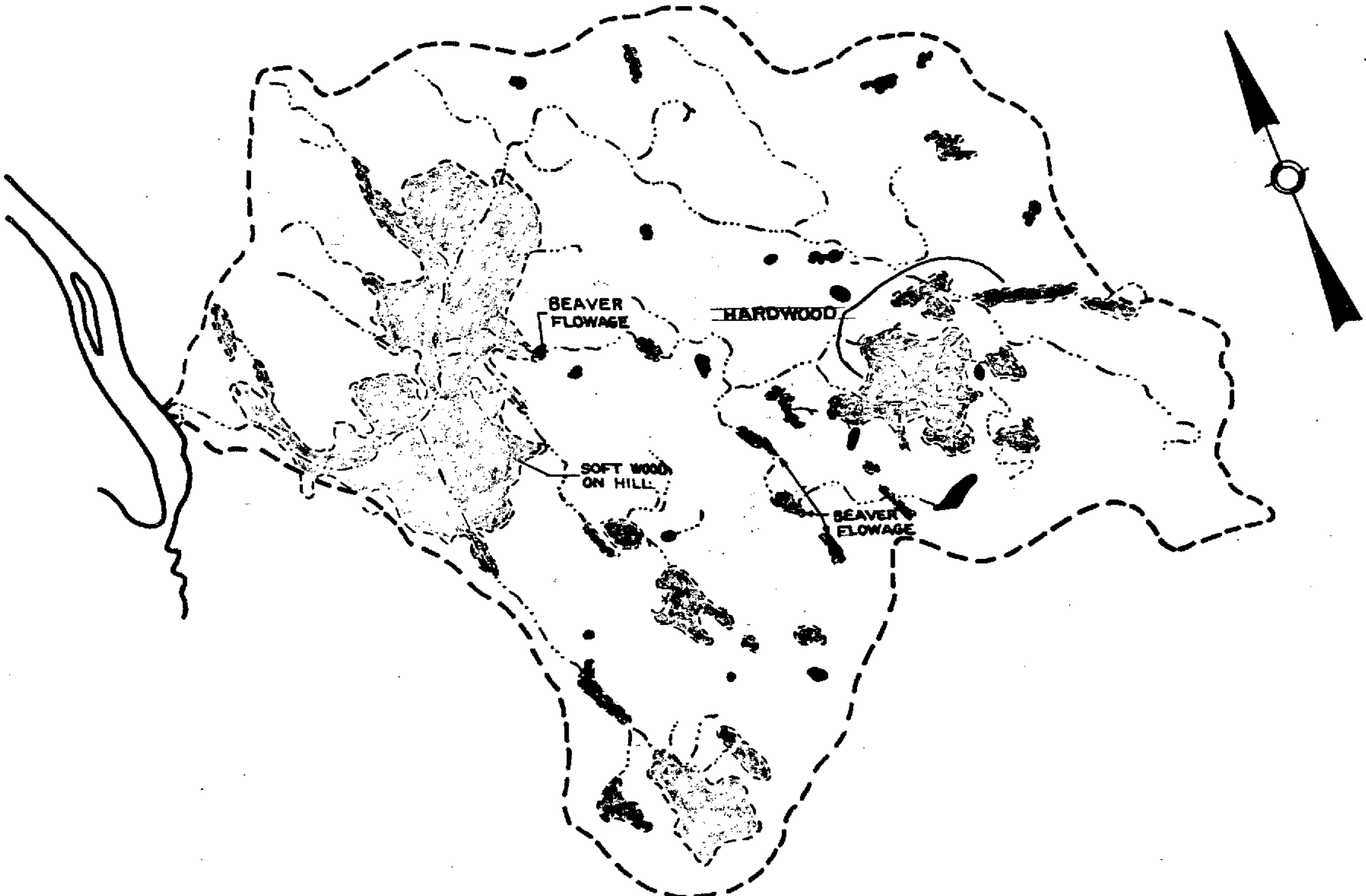
TABLE 8

	Area - Square Miles				Percent of total area			Slope feet/ mile
	Total	Swamp	Lake	Total Storage	Swamp	Lakes	Total Storage	
USGS Map Sunkhaze Stream	101.68	16.24	0.12	16.35	16.0%	0.119%	16.11%	9.5
U-2 (RC-10) Sunkhaze Stream	95.26	15.46	0.13	15.58	16.33%	0.13%	16.37%	——
ERTS-1 Imagery Sunkhaze Stream	98.70	15.73	0.31	16.03	15.93%	0.31%	16.25%	——
USGS Map Otter Stream	10.64	1.22	0.24	1.46	11.43%	2.28%	13.71%	36.6

Land use maps of the watershed were also derived from the U-2 photographs and the ERTS images. The relationship between peak runoff and the land use pattern in a drainage basin is at present only vaguely understood. Enger (et al, 1972) briefly mentions a composite land cover parameter but does not use this factor in the final set of recommended equations for an estimated peak runoff. The probable reasons for not using a land use or land cover parameter in most hydrological equations at present is the difficulty in measuring the parameter, and the difficulty in proper weighting of the data in the final analysis of the watershed. This study attempts to determine the measurability of land use factors from the various scales and types of imagery and photography, not the weight or importance to be attributed to this parameter.

DRAINAGE STUDIES:

Figures 7, 8 and 9 are drainage maps derived from ERTS images, U-2 photos and topographic maps respectively. The black areas on these maps are open water and the lighter shades are swamp areas. Data derived from the different maps is given on Table 8. Areal measurements from the three maps are surprisingly close, the greatest error being about 6 percent, for total area and for water storage areas.

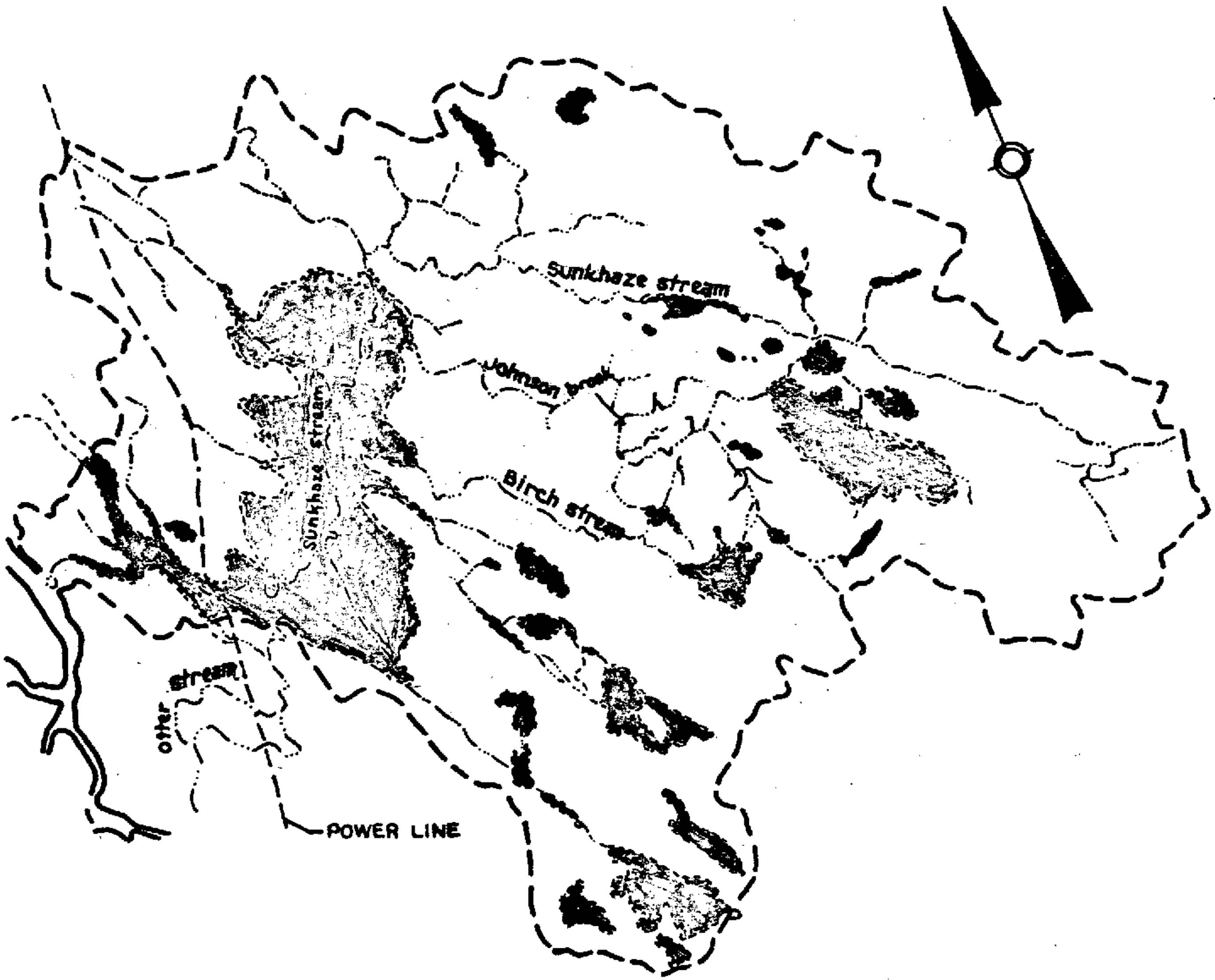


LEGEND
LAKES
SWAMPS

IMAGES: 10 FEB. 73 (1202 - 14552)
23 APR. 73 (1274 - 14553)
1 SEPT. 73 (1040 - 14543)

ERTS DERIVED DRAINAGE STUDY
OF SUNKHAZE WATERSHED
APPROX. SCALE 1:125,000

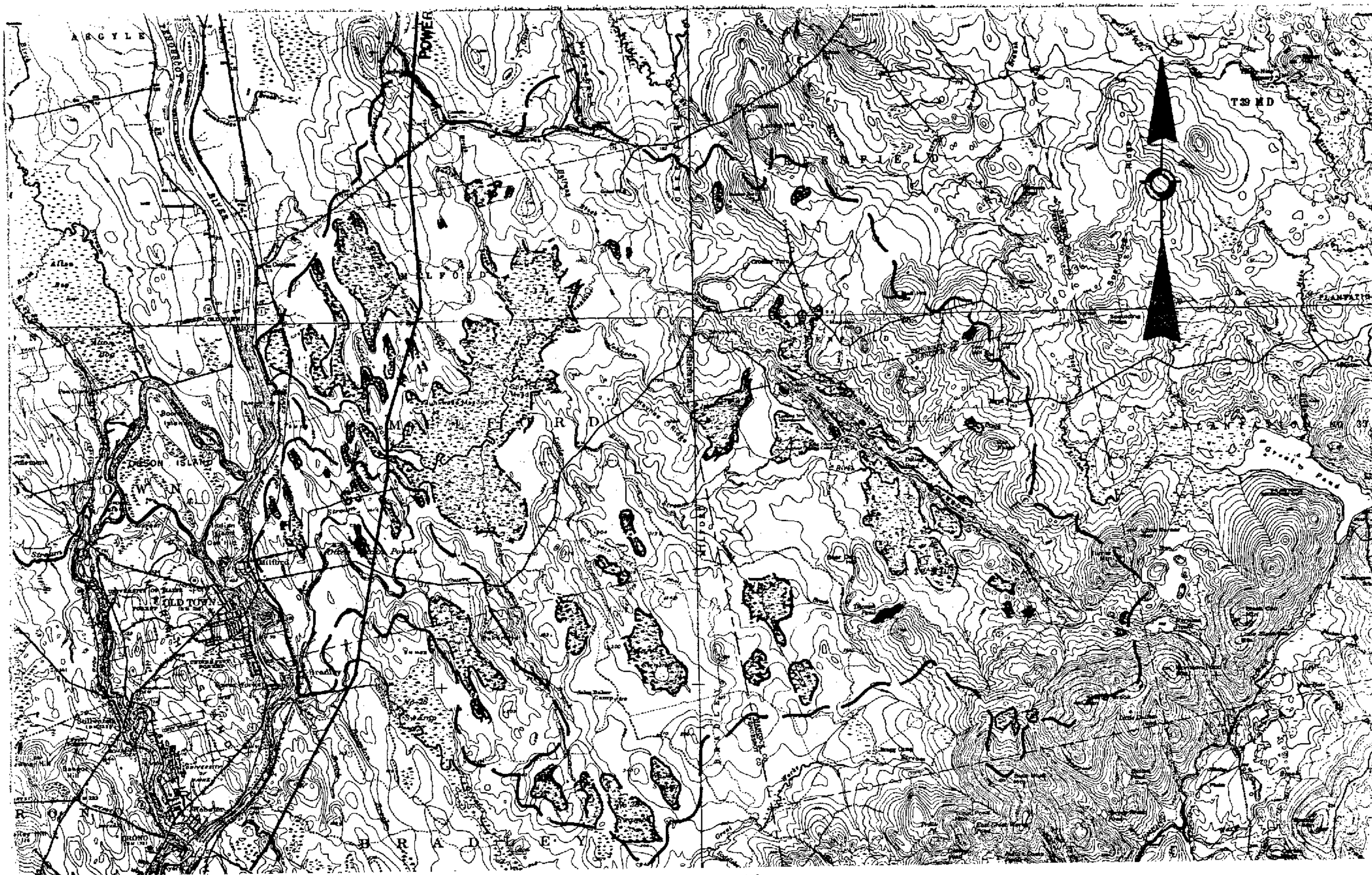
Figure 7



LEGEND
LAKES, PONDS
BOGS, SWAMPS
STREAMS

FIGURE 8

U-2 DERIVED DRAINAGE STUDY
OF SUNKHAZE WATERSHED
24 MARCH 1973
#9930, 9931, 9934
APPROX. SCALE 1:125,000



SCALE 1:125,000

LEGEND

SWAMP

LAKE

RIDGE LINE

DRAINAGE: SUNKHAZE STREAM AND OTTER STREAM WATERSHEDS

FIGURE 9

ERTS derived drainage map (Figure 7) is a combination of scenes imaged on three different dates. These are 10 February 72 color composite (4, 5, 7) and black and white, ID 1202-14352, and 23 April 73, ID 1274-14353, black and white transparencies, and 1 September 72 color composite (4, 5, 7) ID 1040-14543. On the 10 February 73 images cleared areas are outlined, as are features indicative of watercourses. The ridge line for the basin was delineated on the color composite of this date, supplemented by the stereo pair using 22 January 73, ID 1183-14491 imagery. This allowed fairly good definition of the ridge line in the mountainous area on the eastern end of the basin. To define the ridge line around the rest of the watershed required locating streams, channels and swamps, and observing their flow direction. If they flowed into different watersheds the ridge line was located between the ends of opposite flowing streams.

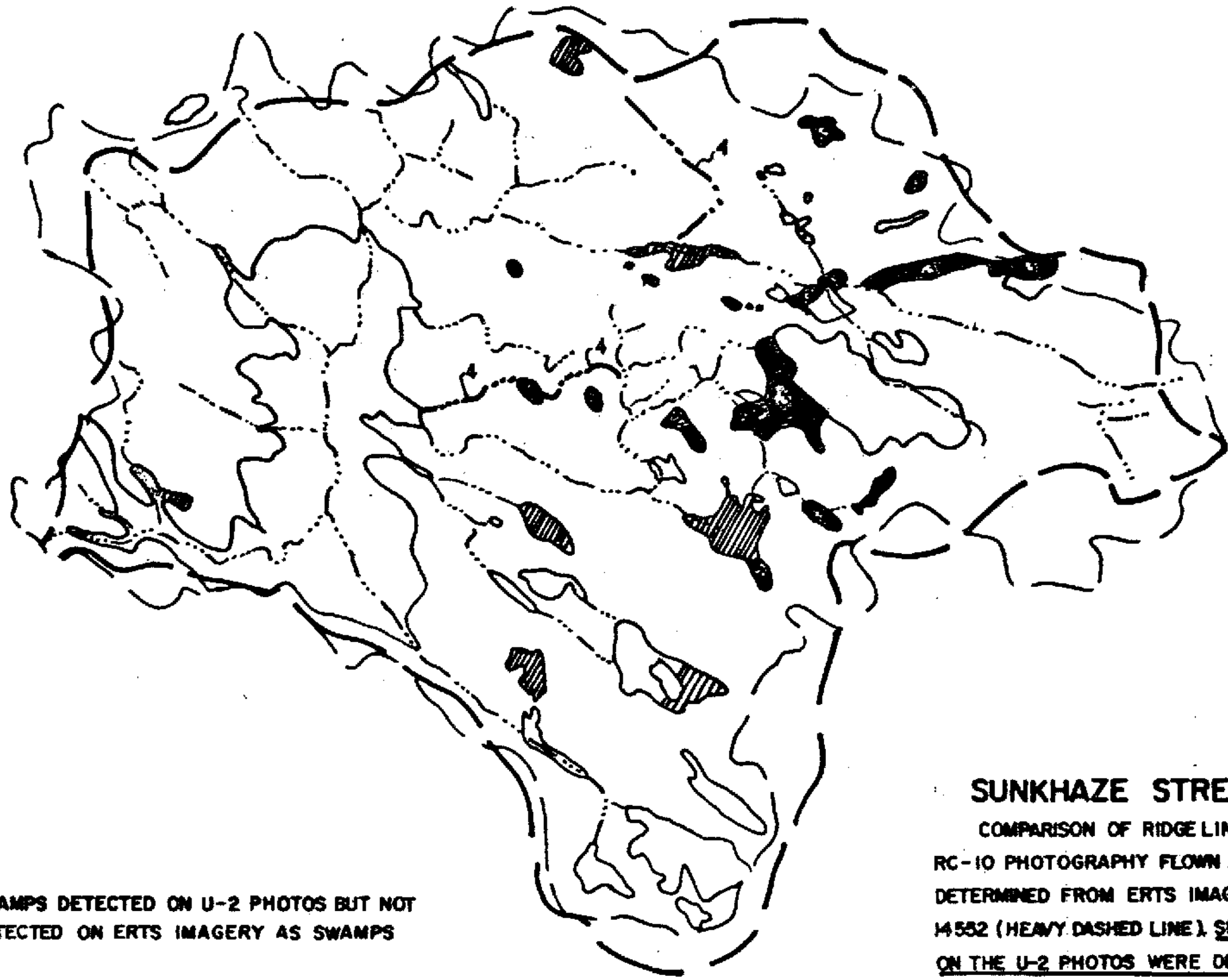
The 23 April imagery aided in the delineation of stream channels and any wet areas. This imagery also helped identify some softwood and hardwood-covered bogs, and some small wet areas subsequently identified as beaver flowages. One large area labeled "blueberry fields" on the U-2 land use map (Figure 16) was believed to be an open swamp on 10 February imagery. The vegetation was identified as low bush from the 1 September color composite. On the 23 April black and white transparencies this area showed no signs of being a raised bog, and thus was not included as a swamp storage area. The area was confirmed not to be swampy on U-2 photos.

Figure 8 is the map traced from U-2 RC-10 coverage flown 24 March 73 (Photos #9930, 9931, 9934) and 17 September 73 (Photos #4340, 4341, 4342, 4352, 4353). It was found that the 24 March 73 photos have better resolution of topographic features than the 17 September photos. This is primarily due to the lack of leaves and the effective snow enhancement in the March 24 photography. The 17 September photos were best for determining storage and stream patterns, particularly valuable in very flat areas with poorly defined drainageways. In these areas the hardwoods along the streams aided in stream delineation. The main problem with the 17 September photos was identification of softwood swamps, which are better determined on the 24 March coverage.

Figure 9 map was compiled from 1:62,500 USGS topographic maps reduced to an approximate scale of 1:125,000. The ridge line and storage areas of the topographic maps were checked against available large scale photography. The agreement between the topographic map and the photos was good.

COMPARISON OF ERTS AND U-2 DRAINAGE STUDIES:

Figure 10 is a composite of the U-2 and ERTS drainage studies. The outer lines are the different ridge lines, which become more generalized from the U-2 to ERTS. This is as expected because of the loss of detail with the progressively smaller scale of the various products. On Figure 10, only four of the larger storage areas (cross-hatched) and one major stream section have been completely omitted on the ERTS drainage. These are mostly softwood swamps. Areas that are shaded were believed to be storage areas on ERTS images but were not seen as storage areas on U-2. The major differences between U-2 photos and ERTS imagery are the areas adjacent to the storage areas delineated on U-2 (not coded, enclosed by fine line on Figure 10). Taking the locations of these areas and checking U-2 CIR and 1:43,000 black and white photos, most of these areas are hardwoods in low areas adjacent to the swamps. They are, in part, valleys and basins with drainage barely adequate to keep them from being swampy. The reasons the areas were seen in ERTS as storage areas and not on U-2 as storage areas appears to be seasonal variation. Most of the areas were identified on 23 April 73 images. This was near the time of peak runoff for this part of Maine. Areas that are nearly flat or have drainage retarded would be saturated and perhaps water-covered at this season. These extra areas may not be true storage areas except at highest runoff, as 23 April would be. There are considerably more ponds visible on the ERTS image than seen on U-2.



SWAMPS DETECTED ON U-2 PHOTOS BUT NOT DETECTED ON ERTS IMAGERY AS SWAMPS

SUNKHAZE STREAM WATERSHED

COMPARISON OF RIDGE LINE DELINEATION FROM U-2 RC-10 PHOTOGRAPHY FLOWN 24 MAR 73 WITH RIDGE LINE DETERMINED FROM ERTS IMAGE OF 10 FEB 73, ID 1202-14552 (HEAVY DASHED LINE). SHADED FEATURES, NOT SEEN ON THE U-2 PHOTOS WERE DETECTED ON ERTS SCENE IMAGED 23 APRIL 73, PROBABLY BECAUSE OF FLOODED CONDITIONS. (1) SWAMP SOFTWOOD AREAS, (2) BEAVER FLOWAGES, (3) HARDWOOD AREAS IN LOW TERRAIN, (4) ROADS IDENTIFIED AS STREAMS ON ERTS IMAGERY.

APPROX. SCALE 1:125,000

COMPARISON OF ERTS AND U-2 DRAINAGE STUDIES OF SUNKHAZE STREAM WATERSHED

FIGURE 10

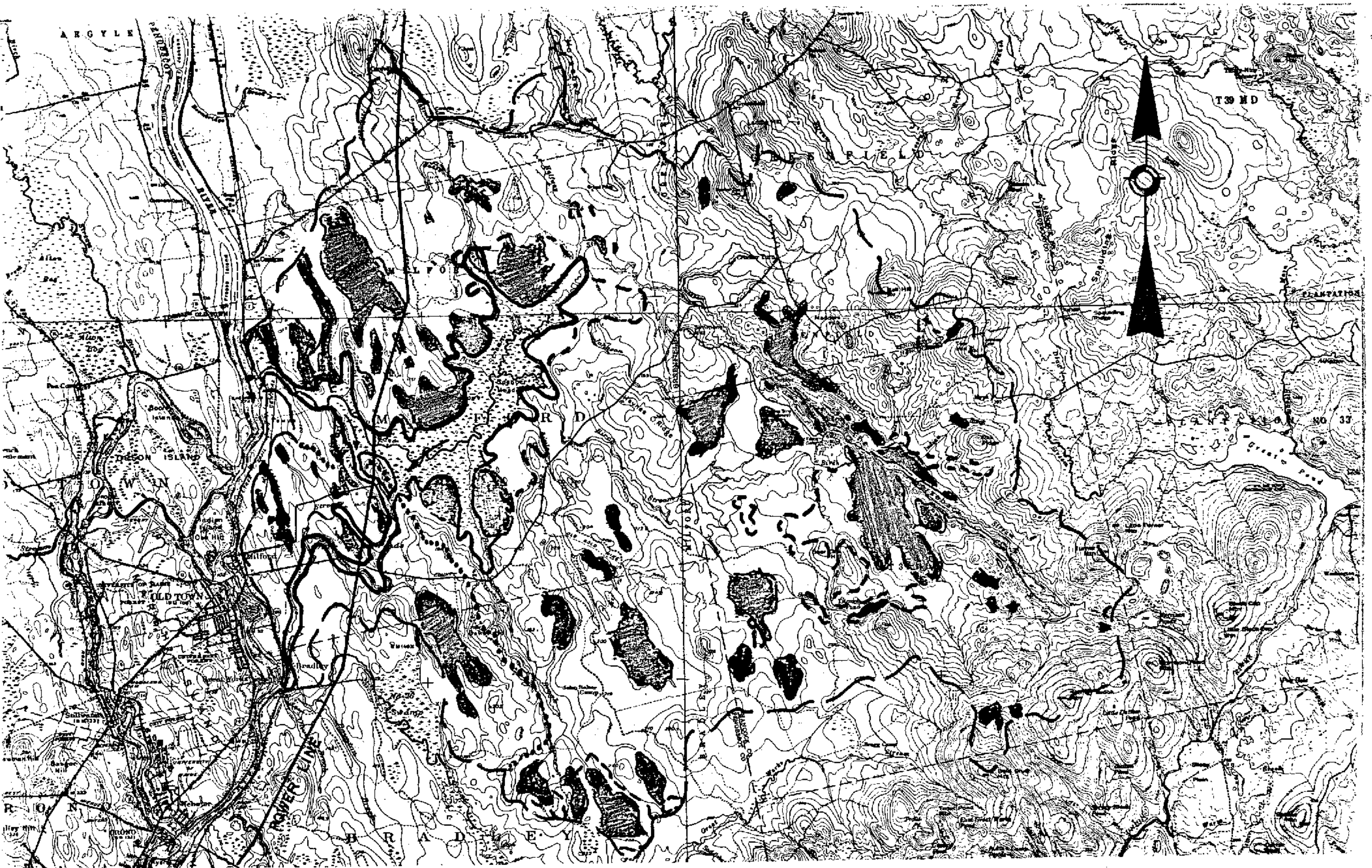
Wood-covered swamps cause the major problems for storage identification on ERTS images. They do not appear much different from other woods of the same type (softwood or hardwood) in the winter and summer imagery. On 23 April some softwood swamps have a darker tone than the woods around them because of increased water at the base of the trees. These softwood swamps that are identified on 23 April imagery have thin tree cover (spaces between trees large enough to see water below). The softwood swamps that have thick cover appear little different than normal softwood. Hardwood swamps could only be identified with certainty on spring images. All the hardwood storage areas seen on U-2 were detected on 23 April imagery in addition to other areas as mentioned before. It is felt that a color composite would have helped, but none has arrived to date.

In summary, it is felt that from ERTS alone, using good quality color images of winter, spring (high water), and summer (leaf on), that for a large watershed a respectable drainage study can be obtained. If this is supplemented by larger scale photography to aid in problem areas, such as areas of low relief or poorly developed drainage, these studies can be brought up to within acceptable limits for a hydrological study on this scale.

ERTS DETECTED CHANGES IN THE SUNKHAZE WATERSHED DUE TO FLOODING

At normal water elevations, Otter Stream and Sunkhaze Stream flow into the Penobscot River 5 miles apart, as shown in Figure 9. The area of Sunkhaze watershed is 101.68 square miles with 16.0 percent in swamp storage and 0.11 percent as open water storage (lakes and ponds). Otter Stream watershed is 10.69 sq. miles with 11.48 percent swamps and 2.28 percent pond storage (Table 8). The drainage studies discussed in previous sections are for normal water elevations.

On 23 April 73 imagery, ID 1274-14553, major changes were detected in Sunkhaze and Otter Stream watersheds. Figure 11 shows these changes, transferred to a



SCALE 1:125,000

LEGEND

SWAMP

LAKE

RIDGE LINE

OPEN WATER STORAGE AREAS ON 23 APRIL 73 IMAGES

ADDITIONAL SWAMP STORAGE FROM 23 APRIL 73 IMAGES ERTS-1

NORMAL DIVIDE BETWEEN SUNKHAZE & OTTER STREAM WATERSHED

SUNKHAZE STREAM FLOW DIRECTION ON 23 APRIL 73

ERTS DETECTED CHANGES IN SUNKHAZE STREAM AND OTTER STREAM WATERSHEDS IMAGED 23 APRIL 73 (ID 1274-14553-6)

FIGURE 11

1:125,000 topographic map. The field data collected for these changes is on Pages 25-26 of the "Data Collected" section. The data is briefly, from personal observation:

1. The Penobscot does flow backwards up the Sunkhaze Stream.

2. That Otter Stream flows directly out of the Sunkhaze Stream watershed at high water conditions. From ERTS images on 23 April (1) Sunkhaze Meadow is flooded with 5.13 sq. miles of water, (2) Otter Stream watershed increased from 0.2 sq. miles of water cover to 0.85 sq. miles (3) Otter Stream could be seen to drain the Sunkhaze Meadows flooded area through two channels, and (4) there was a considerable increase in inundated wooded areas over those seen on U-2 photos and topographic maps. As was mentioned under the section on ERTS drainage studies, most of this increased inundation of wooded areas was in areas adjacent to swamps and was located in topographically low areas. These are water covered areas because of the increased runoff of spring melting.

Figure 11 is the resulting rearranged drainage of the Sunkhaze, Otter Streams and, in part, the Penobscot River watershed at spring runoff conditions. Otter Stream is draining all of the normal Otter Stream watershed, plus all of Sunkhaze Stream watershed and the Penobscot River water that is being pushed up Sunkhaze Stream. The backwater from the Penobscot River along with the runoff from the Sunkhaze watershed forms a large lake. Airphotos of this lake were taken on 3 May 73 (Figures 12, 13). These photos were taken when the Penobscot had receded some from its high on 1 May 73 (Table 1).

The result of this dramatic change in the size of Otter Stream watershed is periodic flooding of the Town of Bradley, located at the mouth of Otter Stream. The town was flooded on 1 May 73. This is felt to be partly the result of water backup behind a culvert designed for a normal Otter Stream watershed, aided by a rising Penobscot River.

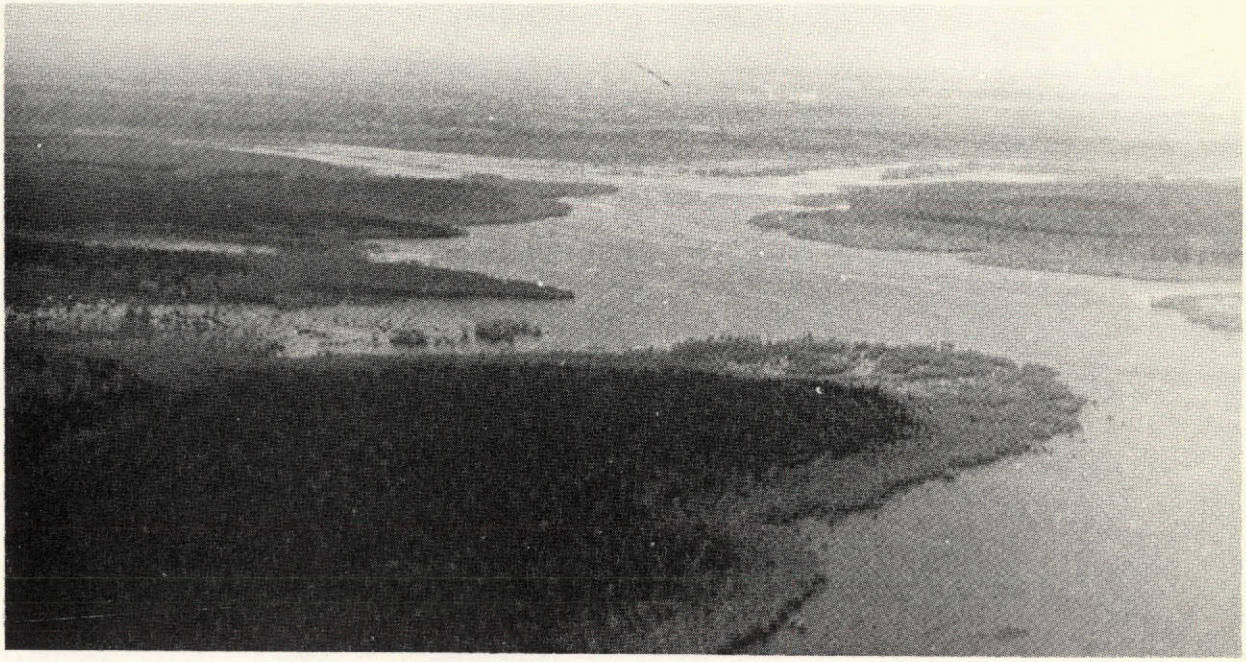


FIGURE 12
Sunkhaze Stream Flooding
3 May 1973
Looking S.S.W.; Milford and Old Town are in distance.

FIGURE 13
Sunkhaze Stream Flooding
3 May 73
Looking N.W. along Baker Stream
The County Road crossing of Baker Stream
is in the left foreground. Southeast
Meadow is in right center.

Conditions very similar to those of 1 May 73 recurred on 25 December 73. Ten inches of rain fell in December and again Bradley was flooded. The closest imagery to 25 December 73 is 13 December, ID 1508-14521, during a break in the heavy rains of December. Figure 14 is an enlargement to 1:250,000 which shows flooding in the Sunkhaze Stream watershed and Pushaw Stream and Mud Pond area. Compare this with Figure 2A, 23 April. The flooding on 13 December in the Sunkhaze watershed is not as extensive as on 23 April imagery, and Otter Stream has not yet started to drain through the divide between Sunkhaze and Otter watersheds.

It can be seen that fluctuations in the level of the Penobscot River are reflected by backwater flooding in the Sunkhaze Meadows. Because of the low divide between Otter Stream and Sunkhaze Stream, Otter Stream becomes the only drainageway for Sunkhaze and part of the Penobscot River's waters. The elevation where major flowing into Otter Stream takes place is around 113 feet. Before this, the flow can be seen across the divide, but from personal observation, there is not a significant amount of water until it has risen to 113 feet.

<u>LAND USE</u>

A land use parameter is currently used in the preparation of MDOT drainage studies, applicable to drainage areas of 1000 acres and smaller. This <u>LAND USE and SLOPE FACTOR (LF)</u> is a judgment factor determined from aerial photographic coverage of the area of interest by experienced photo interpreters, and is included in the data supplied to design engineers for use in "method B", the "B.P.R. 1021 Series" formula for the determination of peak rates of runoff. The LF factor is based upon the vegetation characteristics within the basin of interest, as seen on reasonably timely airphoto coverage, and the general slope of the major watercourse, as estimated from airphoto inspection or as determined from a topographic map. For example, a watershed having mostly forest cover and a slope of less than

PENOBSCOT RIVER WATERSHED

FLOODING IMAGED 13 DECEMBER 1973
(ID 1508–14531–7)
COMPARE WITH FIGURE 2A&B

SCALE 1:250,000

FIGURE 14

2 percent would rate an LF of 0.2. Conversely, pastureland combined with fairly steep slopes would be assigned a higher LF of about 0.6. An extreme example would be a small steep watershed in which a large percentage of area is occupied by bare soil, ledge outcrop and/or pavement, which would justify the maximum LF of 1.2. The interpreter's judgment and acuity plays an important role in weighing the significance of variables of vegetation, slope, soil type and storage areas within a watershed relative to their size and location.

The effect of land use apparently decreases as the size of the watershed increases beyond 1000 acres, although major progressive changes over a period of years, such as large clear cut woods operations, may ultimately have an effect on watersheds of several square miles. Current research within the State of Maine and several other locales is aimed towards gathering data for a better understanding of the interaction of land use and hydrographic properties. The long range study of repetitive and synoptic ERTS-1 imagery will eventually provide valuable information toward this end.

Three similar land use classification systems are discussed: (1) Land Use Classification System For Use With Remote Sensor Data (USGS CIR 671, 1972), (2) a land use classification system developed by the Maine Planning Commission, and (3) a Land Use Peak Runoff Classification System being developed by Ernest G. Stoeckeler (Maine Department of Transportation). These are listed in Tables 9, 10 and 11, Table 11 being a revised copy of the original USGS classification published in 1972. The other proposed systems were derived for use in Maine. The USGS system will be discussed only pertaining to those features relevent to Maine.

The system on Table 9, by Stoeckeler, was derived to be used specifically for hydrologic studies. The other two are general purpose classifications that give enough categories for almost all users, specifically for area planners who

LAND USE-PEAK RUNOFF CLASSIFICATION SYSTEM

Revised Stoeckeler

TABLE 9

A. Forest Areas

1. Softwood forests

2. Mixwood forests

3. Hardwood forests

4. Recently cut over areas

B. Non-forested areas

1. Tilled fields

2. Permanent pasture

3. Abandoned agriculture land

4. Built-up areas

C. Water storage areas

1. Lakes and ponds

2. Non-wooded swamps

3. Wooded swamps

need a general overview of a given area. The Stoeckeler classification does not go into as much detail about built up areas, and recent cut over areas are included as a separate category, making no distinction of forest type. Forested and non-forested wetlands are included with lakes and ponds as a water storage area classification. From working with the ERTS imagery, particularly color, it is possible to distinguish different types of bogs and swamps, especially non-wooded bogs. Sedge and low brush bogs have distinctly different colors on ERTS CIR images and are combined as non-forested swamps for hydrologic studies.

The classification system listed in Table 10 includes all of the categories of the USGS and Stoeckeler systems, and additional categories that can be added only by overlay from other maps sources, namely State land, Federal land, and public lots. The system is particularly derived for use with U-2 CIR photographs at the scale of 1:125,000.

The USGS system has the most general application. Some Level II classifications can be identified on ERTS in most areas, if supplemented by topographic maps.

The system does lack an additional category for recently cut over areas. It is possible to see these areas, particularly areas of clear cutting, on summer images, where dead vegetation (slash) that is left has distinctive "killed" or bare earth appearance. In areas of large woods operations the terrain has a striped appearance. In areas that have small scale operations, either by small private land owners or on a limited scale by larger companies, it is not possible to differentiate these areas from mixwood, because of the lack of planned patterns in the logging road systems and the small scale of cutting is not as thorough. This type of cutting has occurred in the Sunkhaze watershed. Considerable amounts of the area have been cut over to a moderate degree, but the rate of cutting is slow enough to allow new growth to start before large strips are cleared.

TABLE 10

Land Use Classification — By: Maine State Planning Office

LEVEL I	LEVEL II	
Urban and Built-up Land	Residential	R
	Commercial and Services	C
	Industrial	I
	Extractive	
	Transportation	
	Communication	
	Utilities	
	Institutional	
	Dumps	
	Recreational	Rc
	Cemetary	+
	State Land	
	Federal Land	
Agricultural Land	II	
	Cropland and Pasture	
	Orchards, Tree farms	
	Abandoned field	
	Berryland	
Forest Land	Softwood Land	
	Hardwood Land	
	Softwood - hardwood land	
	Hardwood - softwood land	
	Recently cut-over land	
	Public lots - town forests	
Water	Streams and waterways	
	Lakes	
	Reservoirs	
	Bays and estuaries	
Non-forested Wetland	Vegetated	
	Bare	
Barren Land	Beaches	
	Bare exposed rock	

TABLE II

TENTATIVELY PROPOSED REVISIONS
FOR
A LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA
(USGS CIRCULAR 671)

Prepared by: James R. Anderson, Chief Geographer, U.S. Geological Survey
October 1973

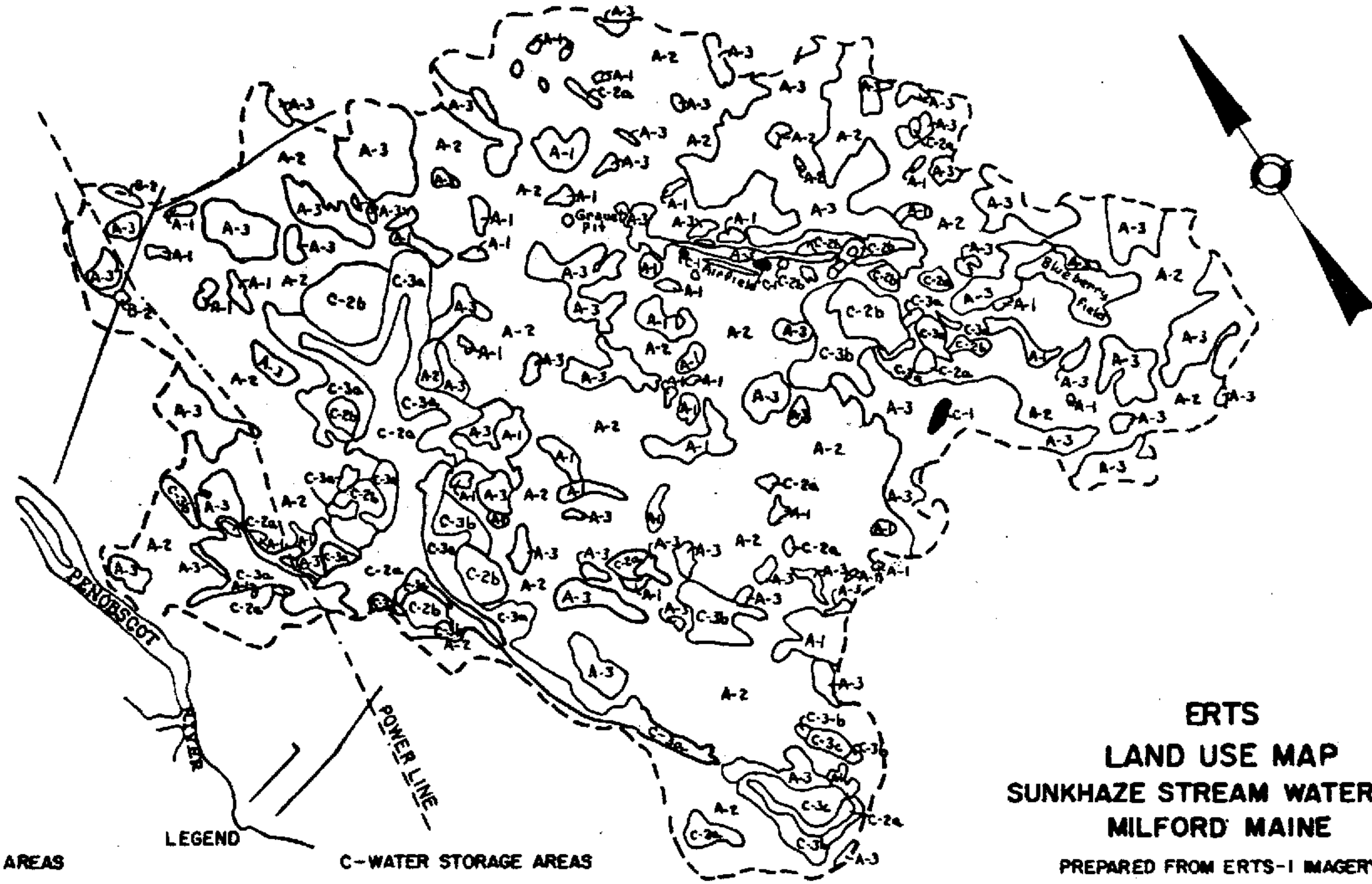
LEVEL I	LEVEL II
1 Urban and Built-up Land	
	1 Residential
	2 Commercial and Services (Including Institutional)
	3 Industrial
	4 Extractive (Excluding strip mining, quarries, and gravel pits, etc.)
	5 Transportation, Communications, and Utilities
	6 Mixed (Including Strip and Clustered Settlement)
	7 Open and Other
2 Agricultural Land	
	1 Cropland and Pasture
	2 Orchards, Groves, Vineyards, and Ornamental Horticultural Areas
	3 Confined Feeding Operations
	4 Other
3 Forestland	
	1 Deciduous
	2 Evergreen (Coniferous and Other)
	3 Mixed
4 Wetland	
	1 Forested
	2 Non-forested
5 Rangeland	
	1 Herbaceous Range
	2 Shrub-Brushland Range
	3 Mixed
6 Water	
	1 Streams
	2 Lakes
	3 Reservoirs
	4 Bays and Estuaries
	5 Other
7 Tundra	(Proposed Level II categories are currently under study in Alaska and will be reported separately.)
8 Permanent Snow, Icefields, and Glaciers	" "
9 Barren Land	
	1 Salt Flats
	2 Beaches (Including Mudflats)
	3 Sandy Areas other than Beaches
	4 Bare Exposed Rock
	5 Strip mines, quarries and gravel pits
	6 Transitional Areas
	7 Other

The Level II categories of berryland, orchards and abandoned fields are difficult to impossible to distinguish on ERTS imagery. In the watershed studied in this report there is a considerable expanse of blueberry barrens in the eastern portion of the watershed. These fields were traced as cleared areas on 10 February imagery, as low bush bogs on 1 September 72 images and as being non-wet from 23 April 73 images. A quick check of the topographic map reveals that this area is probably a sandy deltaic outwash area formed as part of an esker system, and as such has excessively drained soils. The crop that fits such an area in Maine is blueberry. An abandoned farm might have a similar appearance of low brush, but few farm fields in this area exceed more than several acres of cleared land and even fewer are located on esker delta systems. Only blueberry barrens are consistent with the size and location of the fields. It is possible to narrow some of the categories if conditions and coverage are optimum. Orchards of the size of those in Maine cannot be distinguished from wooded areas. Abandoned fields present similar problems, and these features can be identified with certainty only on larger scale photography.

Land Use Maps from ERTS and U-2: Figure 15 is a land use map derived from ERTS images 1040-14543, 1202-14552 and 1274-14553, typed using the classification system proposed by Stoeckeler. For this particular watershed, at the scale of ERTS, there would have been little significant difference between the classification on the map no matter which of the three systems had been used.

Where more detail can be seen on ERTS than categories given in the classification system (hardwood vs. softwood swamps) they will be labeled on the area of interest rather than as a separate category.

Figure 16 is a land use map derived from U-2 photos. The map was drawn by overlaying tracing paper on the U-2 photos and tracing the delineations by stereo viewing. The same classification system was used as for the ERTS map. The annotation was placed directly on the map.



ERTS

LAND USE MAP

SUNKHAZE STREAM WATERSHED

MILFORD MAINE

PREPARED FROM ERTS-I IMAGERY

I SEPT. 72 COLOR COMPOSITE, ID 1040-14543, BAND 4,5,7

10 FEB. 73 COLOR COMPOSITE, ID 1202-14552, BAND 4,5,7

23 ARPIL 73, ID 1274-14553

22 JULY 73, ID 1364-14544

ENLARGED TO APPROX SCALE 1:125,000

LEGEND

A-FOREST AREAS

- A-1 Softwood
- A-2 Mixed wood
- A-3 Hardwood

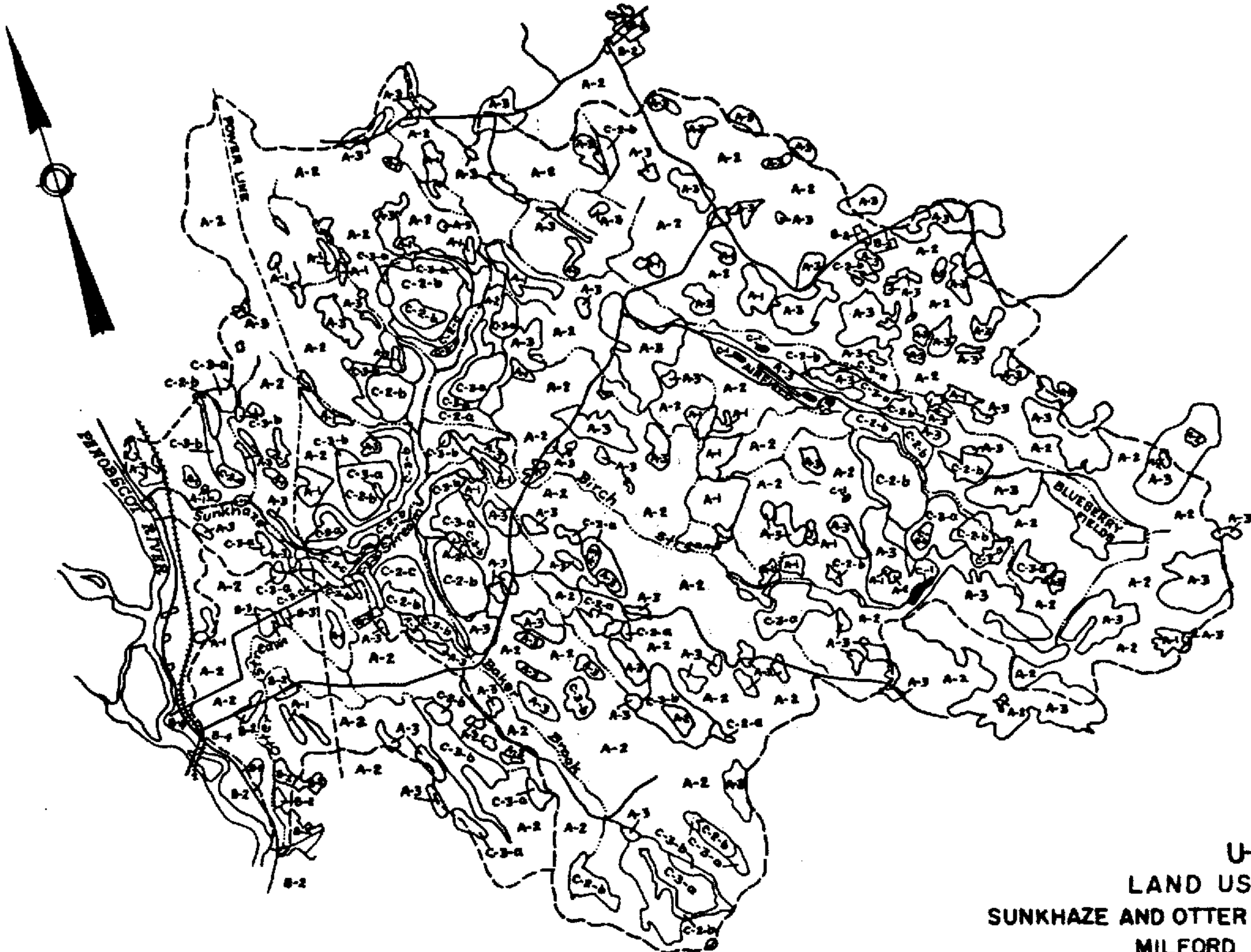
B-NON-FORESTED AREAS

- B-2 Permanent pasture

C-WATER STORAGE AREAS

- C-1 Water
- C-2 Non forest swamps
  - C-2a grass swamps
  - C-2b bush cover swamps
- C-3 Wooded swamps
  - C-3a hardwood swamps
  - C-3b mixed wood swamps
  - C-3c softwood swamps

Figure 15



U-2
LAND USE MAP
SUNKHAZE AND OTTER STREAM WATERSHEDS
MILFORD MAINE

PREPARED FROM
U-2 RC-10 (C.I.R.) PHOTOGRAPHY
FLOWN 17 SEPT. 73
FRAMES 4341 & 4342
APPROX. SCALE 1:125,000

LEGEND

A-1 Softwood
A-2 Mixed wood
A-3 Hardwood

B-2 Permanent pasture
B-3 Abandoned agriculture land
B-4 Built-up areas

C-1 Water
C-2 Non-wooded swamps
- C-2-a grass covered, some lower alder brush
- C-2-b lowbush meadows, some softwoods
- C-2-c high brush

C-3 Wooded swamps
- C-3-a softwood swamps
- C-3-b hardwood swamps

Figure 16

To type a small area such as the Sunkhaze watershed is not difficult from ERTS color imagery. For this land use mapping, "leaf on" imagery seems to be the best from what we received to date. At present, winter imagery is the only available alternative.

CONCLUSIONS

Limitation:

One of the basic limitations of ERTS imagery is the ultra small scale. Scan lines in the images require information to be of certain dimensions to be seen on the imagery. Because of this, much detail is lost. The high altitude of imagery causes stereo viewing to be limited. Relief differences less than about 200 feet cannot be resolved on ERTS images.

To do rapid land typing, an automatic scanning densitometer is a necessity. It is not felt that densitometers can detect more or subtler shades than the human eye, but they have a constancy for picking out one shade or tone and not forgetting it. The human eye, as used for land typing, tends to drift and forget exactly what shade was being viewed, and views shades relative to surrounding shades. The mind tends to interpret what is being viewed as it goes along, which can be of some help as well as hindrance.

Recommendations:

To improve and hasten productivity from satellite imagery, some recommendations are set forth for the future ERTS Programs which might materially improve the work.

Workers accustomed to viewing conventional aerial photography feel very limited when forced to do monocular interpretation from projections or single enlarged images. This problem can be lessened by viewing two bands of the same images, but the best viewing is in the sidelap area of scenes from adjacent orbits. In Maine, 40 percent sidelap is attained, providing stereo coverage of portions of the State. With progressive orbital shifts, some additional stereo coverage is possible by combining scenes from adjacent orbits and different passes. Stereo viewing of select seasonal coverage is usually limited because of weather obscuration of a large percentage of orbital passes.

Obvious improvements desired by investigators oriented to standard airphoto interpretation methods would be closer spaced orbits, to provide improved stereo coverage, and a greater number of passes to provide closely spaced data, especially for spring flood observations. It is realized, however, that factors considered optimum by all investigators are impossible or, at best, impractical to attain. Less time lapse in receiving imagery and standardized quality of color products would also aid in timely data extraction.

Future Work:

In working with ERTS images, a certain degree of confidence in the method used for imagery interpretation has been developed. This writer has used ERTS imagery in the field to locate expected strandlines in flooded areas, and in the office to predict vegetation types. Correlation has been good, but confidence has admittedly been bolstered by familiarity with many aspects of the Sunkhaze watershed. There is a need for future work in other areas, of the same type and by at least two observers, for comparison and accuracy checks. If the techniques outlined in this report are valid, at least for Maine, the results should be compatable for different individuals and with U-2 "ground truth". Other projects can be done from ERTS imagery which were far too ambitious for this proposal.

Estimation of snow depths can probably be made from ERTS imagery. The low brush of the southeast meadow of Sunkhaze Bog averages between 6 and 12 inches. About 300 yards from stream (traveling east to west), the brush becomes taller so that they are about 5.5 feet 75 yards from the stream. As snow accumulates, varying amounts of this brush is covered. As the brush becomes covered, the snow color changes from a greyish white to pure white. For example, on 10 February 73 image, ID 1202-14552, the Sunkhaze Meadows have a greyish white tinge and on 28 February 73 image, ID 1202-14553, the meadows are pure white, indicating that enough snow fell between the imagery dates to cover the brush to depths greater than 1 foot. A check of the precipitation records for February 73 shows that 12 inches of snow fell in the Bangor area between these dates.

Examination of scenes imaged 6 April 73, ID 1257-15012 and 1257-15015, and 23 April 73, ID 1274-14553 and 1274-14551, shows certain lakes that are frozen and others that have thawed, and snowline. With repetetive coverage, climatic lines based on snow retreat lines could be constructed. These can be compared to climatic data as in Figure 17, the plot of the freezing index in degree days for the coldest year in 10 (1958 - 1967).

Future work can be done from ERTS on areas of extensive cutting operations in northern and northwestern Maine. Limited study has shown that about 100 miles of new logging roads were built between 20 September 72, ID 1059-14595, and 22 July 73, ID 1364-14541, a period of 10 months. Also visible are extensive areas of cutting. It has been estimated by Stoeckeler that cut areas 10 years old or older can be identified on ERTS imagery.

Summary:

Useful information has been derived from ERTS imagery. For this report, a hydrologic study was preformed with results compatable to other methods. The area, major stream length and storage areas of the watershed were measured with good accuracy. This study area is not an ideal area suited to do a hydrologic study from ERTS, as significant relief was limited to the eastern portion of the basin. Mountainous watershed basins are obviously better suited to measurement from ERTS. In the study area, however, repetetive coverage, high spring water levels in the storage areas and some knowledge of local agriculture allowed good results to be obtained.

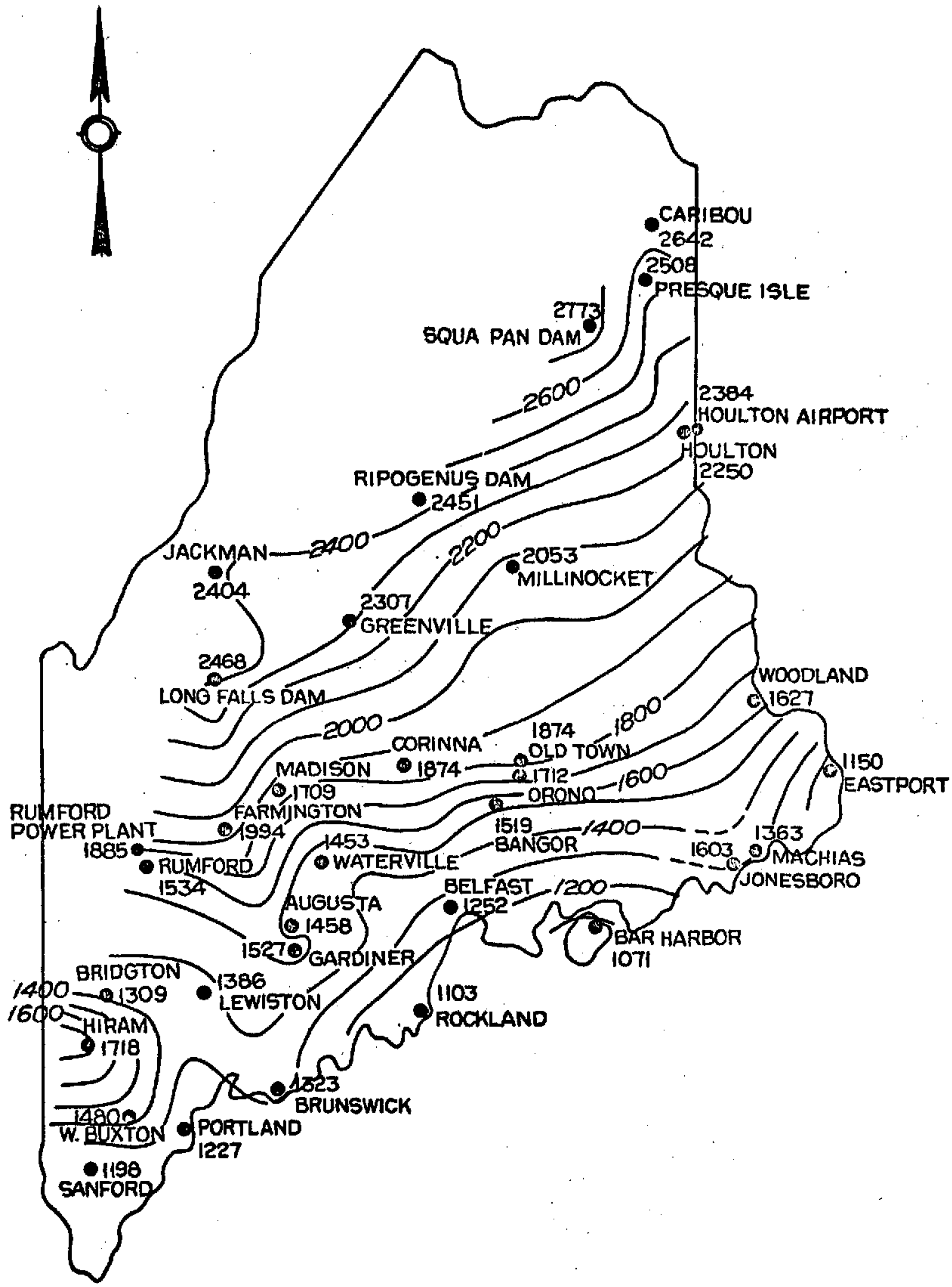


Figure 17

MAINE

COLDEST YEAR IN 10

1958-67

Useful data also obtained from this study are the maps of the flooded areas along the Penobscot River. A current study being conducted by the Maine Department of Transportation's Bridge Division will make use of this new information derived from ERTS.

Land use mapping from ERTS has been demonstrated to be feasible. ERTS repetetive coverage is an absolute necessity for proper classification of all major types of vegetation. This information is extremely useful to regional planners, and will be an aid to hydrologists when land use parameters and their relationship to runoff characteristics are further clarified and understood.

The time lapse involved in receiving clear imagery, especially retrospectively ordered color products, was a deterrent to the pursuits of the proposal. It is felt that the use of simulated infrared scenes of different seasons, had they been made available, would have added substantially to the land use investigation portion of this report.

U-2 aircraft underflight photography furnished by NASA as an adjunct to this proposal and the other two Maine ERTS proposals has been of extreme value for ground truth correlations. Coverage of about 95 percent of the State was acquired between August 20, 1972, and September 17, 1973, with some duplication of coastal areas. This photography, which includes the four 70mm format Vinten bands and 9-inch RC-10 CIR format, will constitute a valuable file for future multi-agency and multi-disciplinary use.

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INDEX OF SUBJECTS