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DETECTION AND MAPPING PACKAGE

ANALYST'S GUIDE:

INTERPRETING IMPOUNDED SURFACE WATER

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DETECTION AND MAPPING PACKAGE

Analyst's Guide: Interpreting Impounded Surface Water

R. C. Carnes
E. H. Schlosser
R. G. Davis
Lockheed Electronics Company, Inc.
Systems and Services Division
1830 Nasa Road 1
Houston, Texas 77058

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16. Abstract

The Detection and Mapping package is an integrated set of manual procedures, computer programs, and graphic devices designed for efficient production of precisely registered, formatted, and interpreted maps from digital Landsat multispectral scanner data. The generation, transmission, and calibration of Landsat data, and the Detection and Mapping package processing required to produce maps of surface water are covered in referenced publications.

This report documents the manual interpretation procedure, applied to these computer-generated maps of surface water, which identifies bodies of impounded water. This procedure includes techniques for minimizing false alarms and for determining the locations of impounding structures.

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CONTENTS

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FIGURES

1. BACKGROUND

1.1 DEVELOPMENT OF THE DETECTION AND MAPPING (DAM) PACKAGE

The beginnings of the DAM concept in the Spring of 1973 were preceded by two events which occurred in the summer of 1972. The first was the launch of the Earth Resources Technology Satellite (ERTS) on July 25, 1972. The satellite, then called ERTS-1 and subsequently redesignated Landsat-1, was the first of a series of Earth-looking satellites which provide relatively high resolution multispectral scanner system (MSS) data to the general remote sensing community.

The second event was the passage of Public Law 92-367 by the Congress of the United States and its approval by the President on August 8, 1972, two weeks after the launch of ERTS-1. This law charged the Secretary of the Army, acting through the Chief of Engineers, "to ... carry out a national program for the inspection of impoundment dams for the purpose of protecting human life and property." Implicit in this charge was the requirement to maintain an inventory of dams at the national level, and to institute coordination or regulation, as required, of existing dam safety programs in the governments of all the states and territories. The initial effort at the inventory (1973-74) reported over 49 000 dams in the United States, each of which impounded enough water to constitute a significant potential threat to the safety of areas downstream from the dam. The inventory data was compiled from many sources. The need for an economical and timely means for updating the inventory was recognized in the beginning.

In December 1972, the Texas Water Rights Commission (now the Texas Department of Water Resources) under contract with the Southwest Division of the U.S. Army Corps of Engineers, submitted through the Office of the Governor of Texas, a request for assistance by the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center (JSC), Earth Observations Division (EOD) in the development of a procedure for using Landsat data in detecting and locating water impoundments. In January 1973, representatives from the Office of the Chief of Engineers and NASA/JSC/EOD defined the following performance specifications for the requested inventory procedure.

a. Landsat MSS to be the sole data source (no ground truth)

b. Procedure to detect water bodies equal to or greater than ten surface areas to these criteria:
   - o Correct identification equal to or greater than 90 percent
   - o False alarms equal to or less than 10 percent

c. Positional error less than 1000 feet

d. Cost effective with conventional inventory techniques.

The original research at NASA/JSC/EOD used existing general purpose multispectral pattern recognition computer programs. These systems, designed for research and development applications, were not suitable for operational use. The situation led to the development of a special purpose hybrid procedure (utilizing both computer processing and human analysis) named the Detection and Mapping package.

Periodic refinements have been made to the DAM package, which now consists of over ten main programs and more than 300 subroutines together with associated graphic devices and procedural manuals. The unique software is directly useable on any Univac 1100 series computer system under the standard EXEC-8 operating system. The system characteristics of specific interest to the user are detailed in sections 2.4 and 3.0 of this manual.

In 1974, an early operational version of the DAM package was transferred to the State of Texas. The timing was such that this version was not used in the initial national inventory reported to the Congress by the Corps of Engineers. The DAM package was evaluated by two Corps of Engineers districts (Seattle and Nashville) who recommended its use for inventory update. These same two districts will now manage regional processing centers, providing computer-generated maps of surface water from the DAM package software for Corps of Engineers districts to use in updating the inventory of dams.

1.2 NATIONAL PROGRAM OF INSPECTION OF DAMS (NPID)

This program is directed by Section 2 of Public Law 92-367 which states in part: "All dams in the United States shall be inspected by the Secretary except (1) dams under the jurisdiction of the Bureau of Reclamation, the Tennessee Valley Authority, or the International Boundary and Water Commission; (2) dams which have been constructed pursuant to licenses issued under the authority of the Federal Power Act; (3) dams which have been inspected within the 12-month period immediately prior to the enactment of this act by a state agency and which the governor of such state requests be excluded from inspection; and (4) dams which the Secretary of the Army determines do not pose any threat to human life or property." Of all these conditions, the last one opens the subject of priorities. Priorities are needed not only because of the enormity of the task, but also because of the wide ranges of risks and hazards and the very real constraints of budgets. In a 1975 report to the Secretary of the Army, the Chief of Engineers advised that the cost of conducting an initial inspection of a dam would vary from $5,000 to $10,000. The key element of all the coordination required with state agencies (in 1974, 37 states had their own laws for dam safety programs), and other federal agencies with jurisdiction over dams, is the dam inventory.

1.3 NATIONAL DAM INVENTORY

A sample page of the inventory published in 1975 is shown in figure 1-1 of this manual. It is important for the analyst who will interpret computer output from the DAM software to be aware of the essential elements of information required in the basic inventory. These include geographic, geometric, hazard, and ownership data. Because the analyst's functions are similar to those of aerial photointerpretation, the analyst will be alert to other factors of interest in the area of dams. The most important of these are the nature of developments within the downstream floodplain, and distances thereto. None of this information is contained in the computer output per se, but the analyst will inevitably ask questions about the area as soon as topographic maps of an area are used. In any particular Corps of Engineers district there are all kinds of area information in a variety of sources. It is reasonable to presume that the analyst, who is directly concerned only with the presence or absence of impounded water, will be involved with all of the data required to maintain the dam inventory.

1.4 UTILITY OF THE DAM PACKAGE

The maintenance of the National Dam Inventory (ideally in near real time) is clearly a formidable task. The special advantage of the DAM package is that it permits very rapid screening of large areas. The DAM computer processing discards all of the satellite data except detected surface water. The retained information is output by a computer line printer in map form, at any desired scale. It will be seen that these features will greatly accelerate the process of monitoring water impoundments on a nationwide basis.

INVENTORY OF DAMS IN THE UNITED STATES

TEXAS (CONT'D)
VAN ZANDT COUNTY (CONT'D)

NAME OF DAM OR IMPOUNDMENT	RIVER OR STREAM	TYPE OF DAM	YEAR COM PLETED	PUR POSE	HEIGHT (FT)	MAX CAPACITY (ACRE FT)	NEAREST DOWNSTREAM CITY TOWN VILLAGE	POPULATION	DIST. FROM DAM (MI.)	HAZARD	OWNER	CONG DIST
EDGEWOOD CITY LAKE DAM	TR-GILADON CREEK	EARTH	1952	S	25	680	NONE			3	EDGEWOOD WATERWORKS	04
FIN & FEATHERS CLUB LAKE DAM	TR-WILLS CREEK	EARTH	1962	R	35	840	NONE			3	FIN & FEATHERS CLUB	04
GARDEN LAKE DAM	TR-VILLAGE CREEK	EARTH	1959	S	35	672	NONE			3	IDA M COWDEN	04
GOETTSCHE DAM	TR-DUCK CREEK	EARTH	1965	S	21	150	NONE			3	DR H GOETTSCHE	04
HAMILTON DAM	TR-ALLEN CREEK	EARTH	1962	S	18	115	NONE			2	A D HAMILTON	04
HAND LAKE DAM	TR-MURCHISON CREEK	EARTH	1955	I	21	338	NONE			2	TED L HAND	04
KELLAM RESERVOIR NO 1 DAM	TR-GRAND SALINE CREEK	EARTH	1957	I	28	314	NONE			3	J C KELLAM	04
KELLAM RESERVOIR NO 2 DAM	TR-GRAND SALINE CREEK	EARTH	1957	I	26	418	NONE			3	J C KELLAM	04
LOWRIE DAM	COPPERS BRANCH	EARTH	1969	S	26	290	NONE			3	BRUCE W LOWRIE	04
METZGER DAM 1	TR-LITTLE SABINE CREEK	EARTH	1959	S	19	570	NONE			3	JACOB METZGER	04
METZGER DAM 2	TR-LITTLE SABINE CREEK	EARTH	1959	S	25	350	NONE			3	JACOB METZGER	04
METZGER DAM 3	TR-LITTLE SABINE CREEK	EARTH	1959	S	35	350	NONE			3	JACOB METZGER	04
MUSSLEWHITE LAKE DAM	ELLIOTT BRANCH TR-MILL CREEK	EARTH	1973	R	24	365	NONE			3	D C MUSSLEWHITE ET AL	04
OLD CITY LAKE DAM	HOARD BRANCH	EARTH	1962	S	25	380	NONE			2	CITY OF EDGEWOOD	04
OWEN DAM	TR-GRAND SALINE CREEK	EARTH	1962	S	29	209	NONE			3	ALEXANDER OWEN	04
PAYNE RANCH LAKE	TR-MURCHISON CREEK	EARTH	1969	I	15	150	NONE			2	RAYMOND D PAYNE	04
POCO CLUB DAM	TR-DAVIS CREEK	EARTH	1959	R	16	100	NONE			3	POCO CLUB	04
RHINES RESEVOIR DAM	NECHES RIVER	EARTH	1948	R O I	23	3,200	NONE			2	UNION OIL CO OF CALIF	04
RICHARDS DAM	TR-LACY FORK	EARTH	1962	S	18	115	NONE			3	M B RICHARDS	04
SPRING LAKE DAM	CHINGUAPIN BRANCH	EARTH	1962	S	28	560	CANTON	2,283	.4	2	UNKNOWN	04
T P LAKE DAM	WILLS CREEK	EARTH	1928	S	19	1,090	NONE			3	KENNETH L PFAFF ET UX	04
WILLIAMS DAM	TR-HORSLEY CREEK	EARTH	1948	S	15	180	NONE			2	W A WILLIAMS	04
WILLS POINT RESERVOIR DAM	MAGBY CREEK	EARTH	1962	S	20	568	NONE			3	CITY OF WILLS POINT	04
YOUNG LAKE DAM	TR-NECHES RIVER	EARTH	1967	S	25	140	NONE			3	DONALD C YOUNG	04
VICTORIA COUNTY												
DUPONT COOLING BASIN DAM	GUADALUPE RIVER-OFFSTREAM	EARTH	1948	O	11	1,056	NONE			3	E I DUPONT DE NEMOURS	14

PURPOSES I – IRRIGATION C – FLOOD CONTROL S – WATER SUPPLY D – DEBRIS CONTROL
H – HYDROELECTRIC N – NAVIGATION R – RECREATION O – OTHER

HAZARD POTENTIAL 1 – HIGH 2 – SIGNIFICANT 3 – LOW

F-44-159

Figure 1-1.– Sample page from Inventory of Dams in the United States published in 1975.

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2. AN OVERVIEW OF DAM COMPUTER PROCESSING

The basic purpose of the DAM package is the classification and mapping of surface water from remotely sensed MSS data acquired by NASA's Landsat satellites. The information that ultimately emerges from the DAM package in the form of precisely registered, formatted, and interpreted maps begins as energy reflected from the surface of the Earth. Small portions of this energy are detected and recorded high above the Earth by sensors aboard the orbiting Landsat satellites, as shown in figure 2-1. This data, now in digital or numerical form, is transmitted by the satellites to ground-based receiving stations where it is recorded, retransmitted or carried to a centralized processing facility, computer-processed to apply numerous calibration and geometric corrections, reformatted, and distributed to users. The DAM package takes this data, in the form of magnetic tapes and photographic film transparencies, and further processes it to detect and precisely locate surface water and to produce overlay maps depicting the surface water. These computer-generated maps are, in turn, interpreted by human analysts. This section presents a brief description of the chain of events that ultimately leads to the creation of DAM package classification maps.

2.1 LANDSAT MSS DATA

Landsat is a system designed by NASA to provide for the repetitive acquisition of high resolution MSS data of the Earth's surface on a global basis. This overall system is illustrated in figure 2-2. To date, three Landsat satellites have been placed in Earth-orbit. Landsat-1 (now inoperative) was launched in July 1972, Landsat-2 in February 1975, and Landsat-3 in March 1978. Two sensor systems have been employed to date on these Landsat satellites: a 4-channel (5-channel on Landsat-3) MSS and three-

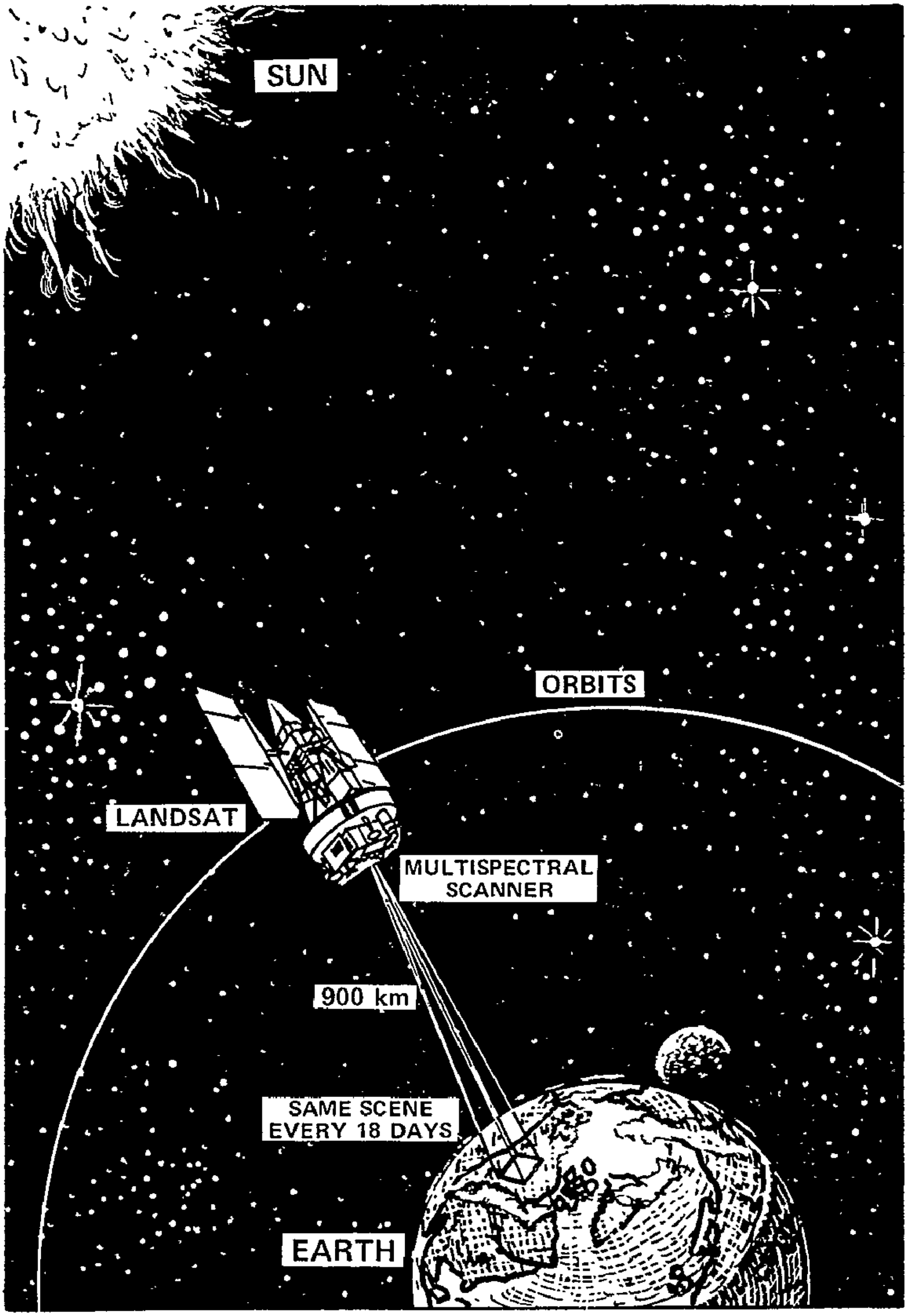

Figure 2-1.— Basic Landsat configuration.

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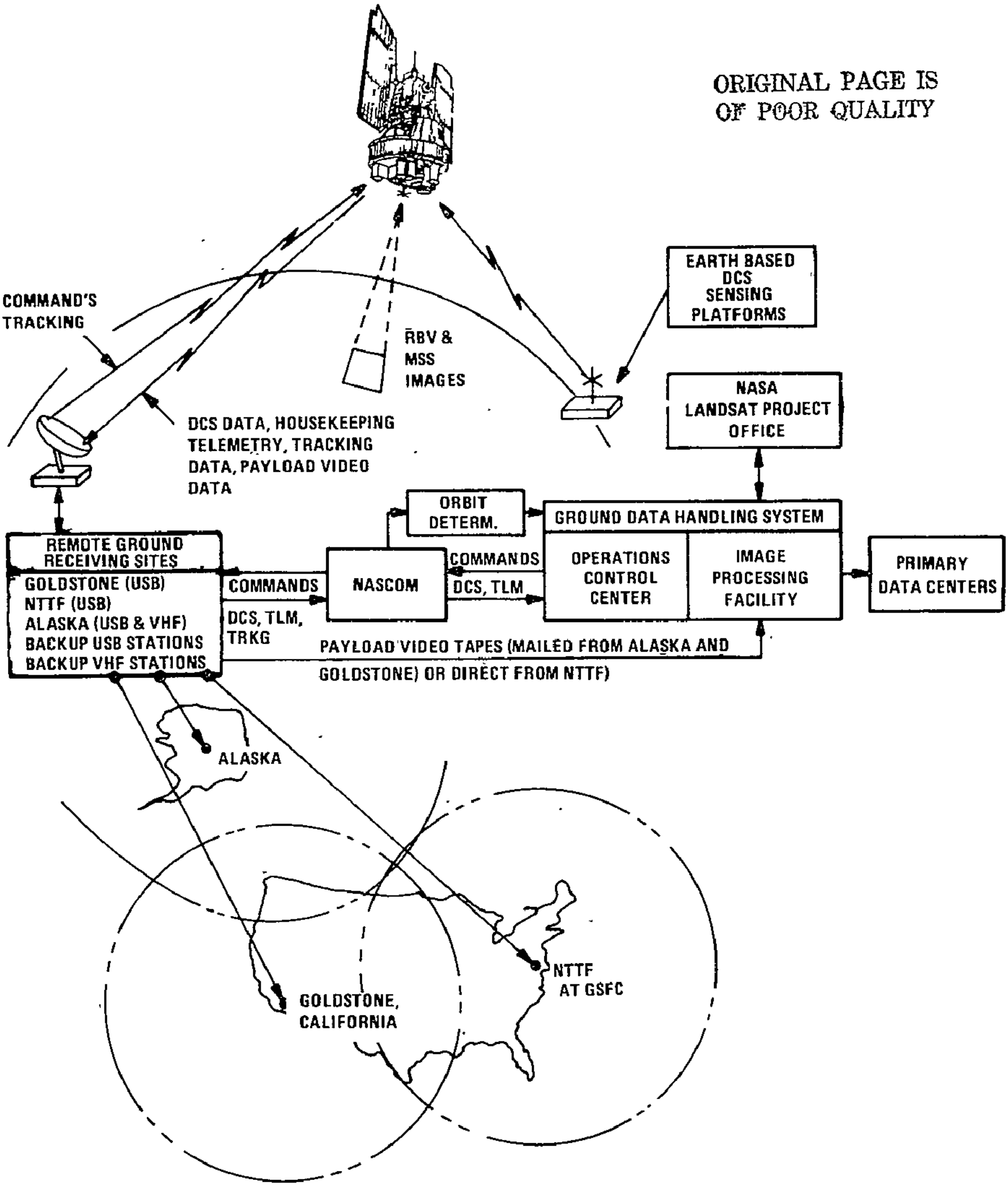

Figure 2-2.— Overall Landsat system.

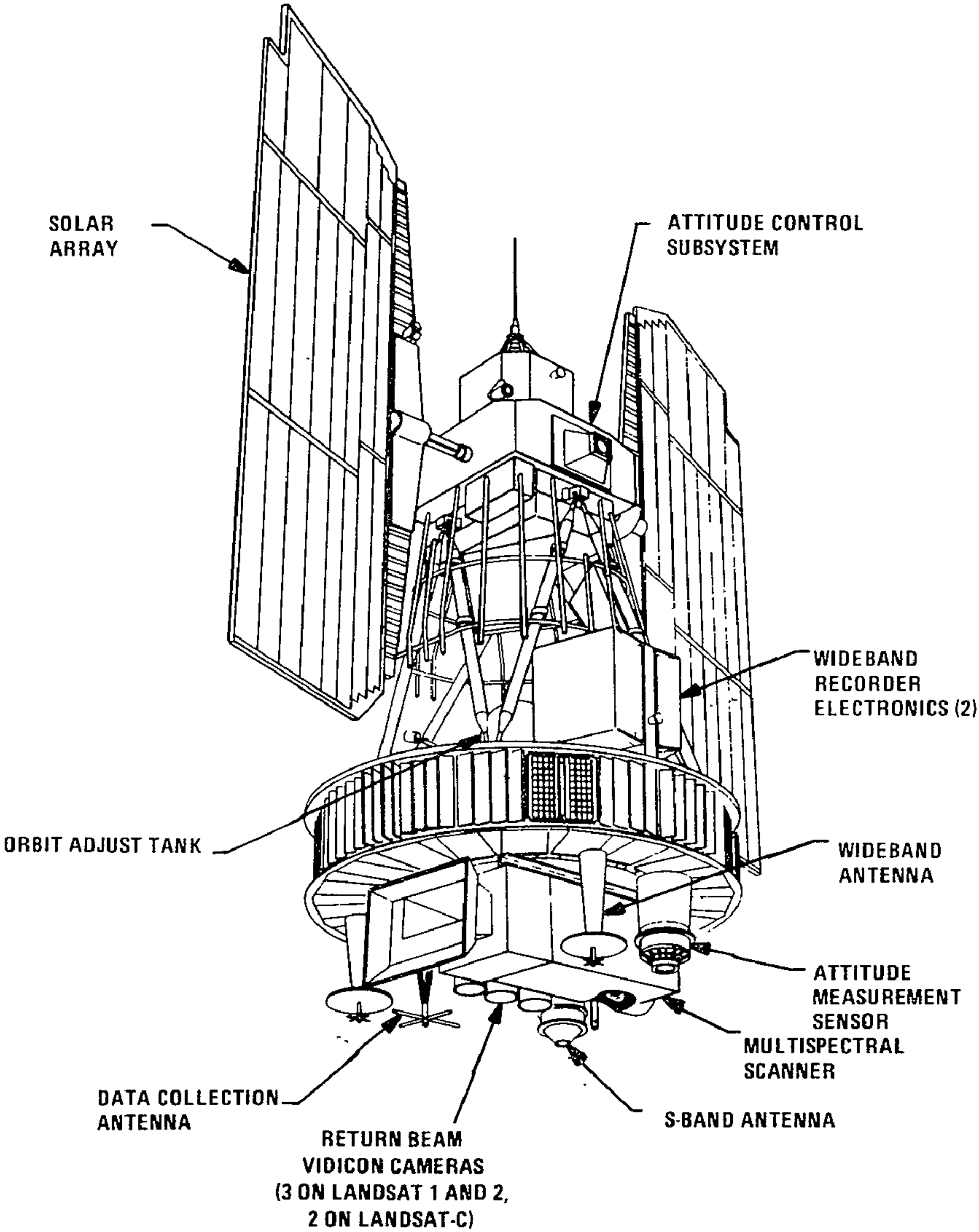

Figure 2-3.— Typical Landsat observatory.

camera (two-camera on Landsat-3) return beam vidicon (RBV) system. The elements of a typical Landsat observatory system are shown in figure 2-3. Since the DAM package utilizes only data from the MSS, the RBV system will be excluded from further consideration.

The Landsat-1 and -2 MSS* is a line scanning device that uses an oscillating mirror to continually scan perpendicular to the spacecraft direction of travel, as shown in figure 2-4. For each mirror sweep, six lines are scanned simultaneously in each of the following four spectral bands.

MSS channel	Landsat band**	Color	Wavelength (micrometers)
1	4	green	0.5 - 0.6
2	5	red	0.6 - 0.7
3	6	near infrared (IR)	0.7 - 0.8
4	7	near IR	0.8 - 1.1

The Landsat-1 and -2 satellites circle the Earth every 103 minutes in near-polar Sun-synchronous orbits at a nominal altitude of 917 km (495 n. mi.). They pass the Equator (southbound) at approximately 9:30 a.m. local time, complete approximately 14 orbits per day, and repeat the coverage of a given area once every 18 days. Figure 2-5 depicts some typical Landsat daylight ground traces.

The Landsat MSS acquires data along a swath approximately 185 km (100 n. mi.) wide as the satellite circles the Earth. During the active time of one sweep of the MSS mirror, each of the four channels for each of six consecutive scan lines are sampled

*Since the DAM package cannot presently accommodate Landsat-3 data, only Landsat-1 and -2 will be considered in the remainder of this manual.

**Bands 1, 2, and 3 are assigned to the RBV.

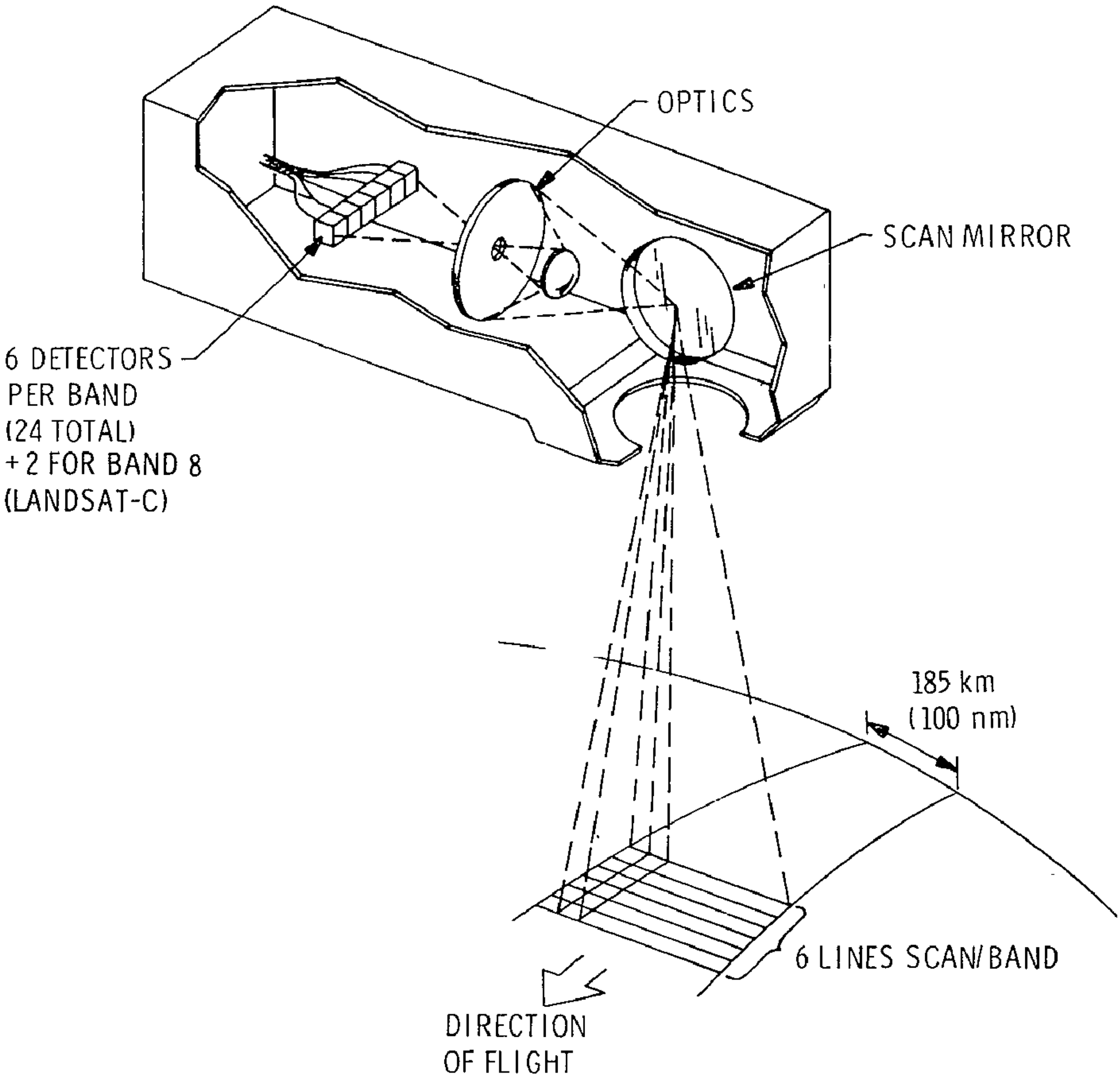

Figure 2-4.— Landsat MSS scanning arrangement.

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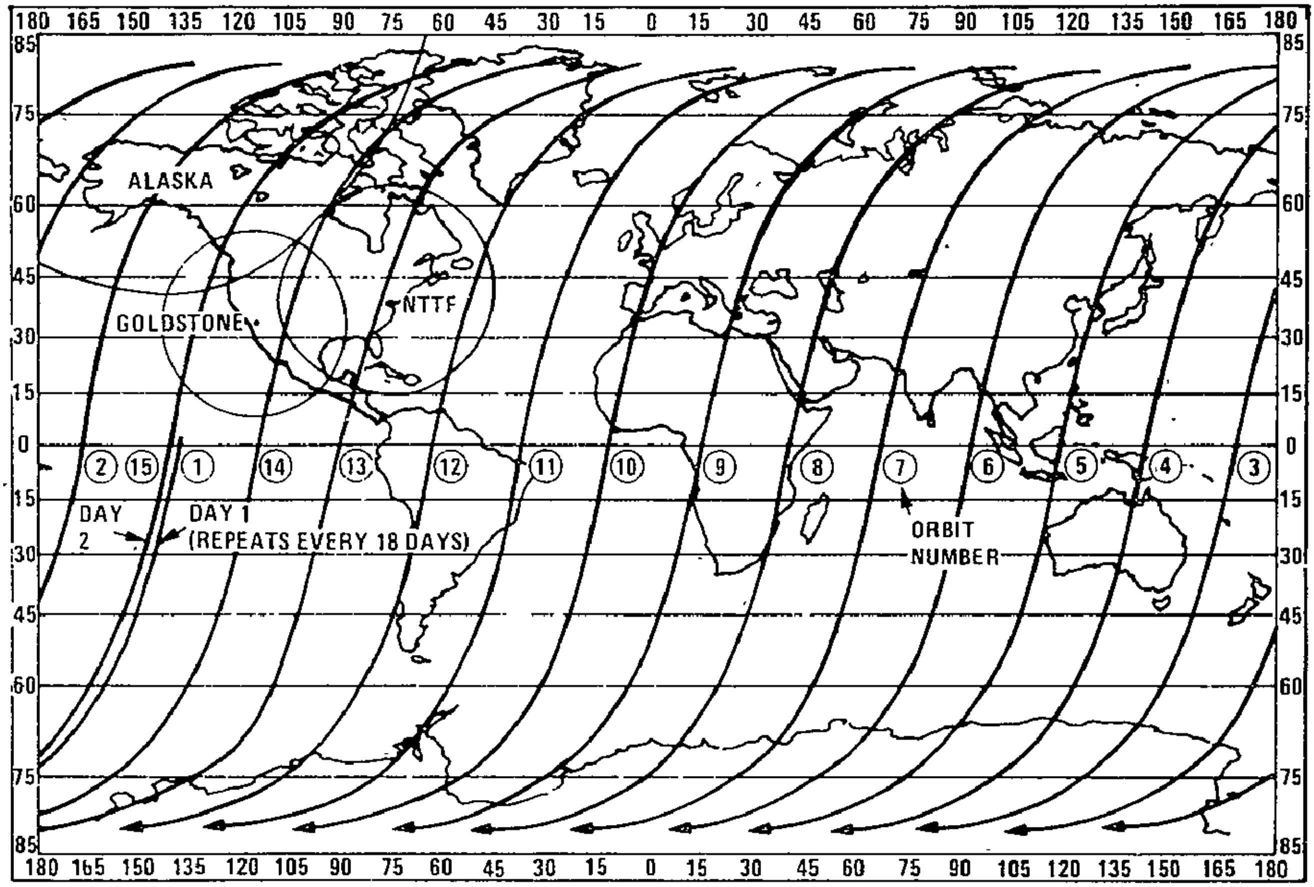

Figure 2-5.— Typical Landsat daily daylight pass ground traces.

approximately 3240 times and the analog detector signals for each of these small square picture elements (pixels) are converted to digital form. Spacecraft forward motion provides for along-track progression of the scan lines.

2.2 PREPROCESSING OF LANDSAT DATA

The continuous-swath MSS data are transmitted to the ground where they are segmented into scenes comprised of exactly 2340 scan lines by approximately 3240 samples, which correspond to areas of approximately 100 by 100 nautical miles on the ground. Each scene is then further processed into various data products which are available to the public. The two such products utilized by the DAM package are listed below.

a. System-corrected images — Each image covers an entire scene except for 42 lines at the top and 42 lines at the bottom. The scenes are radiometrically calibrated and nominally corrected for scanner geometry, spacecraft attitude/altitude and Earth's rotation based on satellite tracking and telemetry information. One scene is comprised of approximately 7 500 000 individual pixels, each representing (by a density or shade of grey) the radiance reflected, for the particular spectral band from a 79- by 57-meter area of the Earth's surface. Figure 2-6 shows a typical system-corrected Landsat MSS image of MSS channel 4 (Landsat band 7).

b. System-corrected computer-compatible tapes (CCT's) — Digital MSS data for each 100- by 100-nautical mile Landsat scene are divided into four 25-mile wide strips. The data are radiometrically calibrated but are not corrected for scanner geometry, platform attitude variations, orbital altitude, or other perturbations. The data for the four strips of a scene are recorded on either one, two, or four reels of magnetic computer tape, depending on the format and recording density.

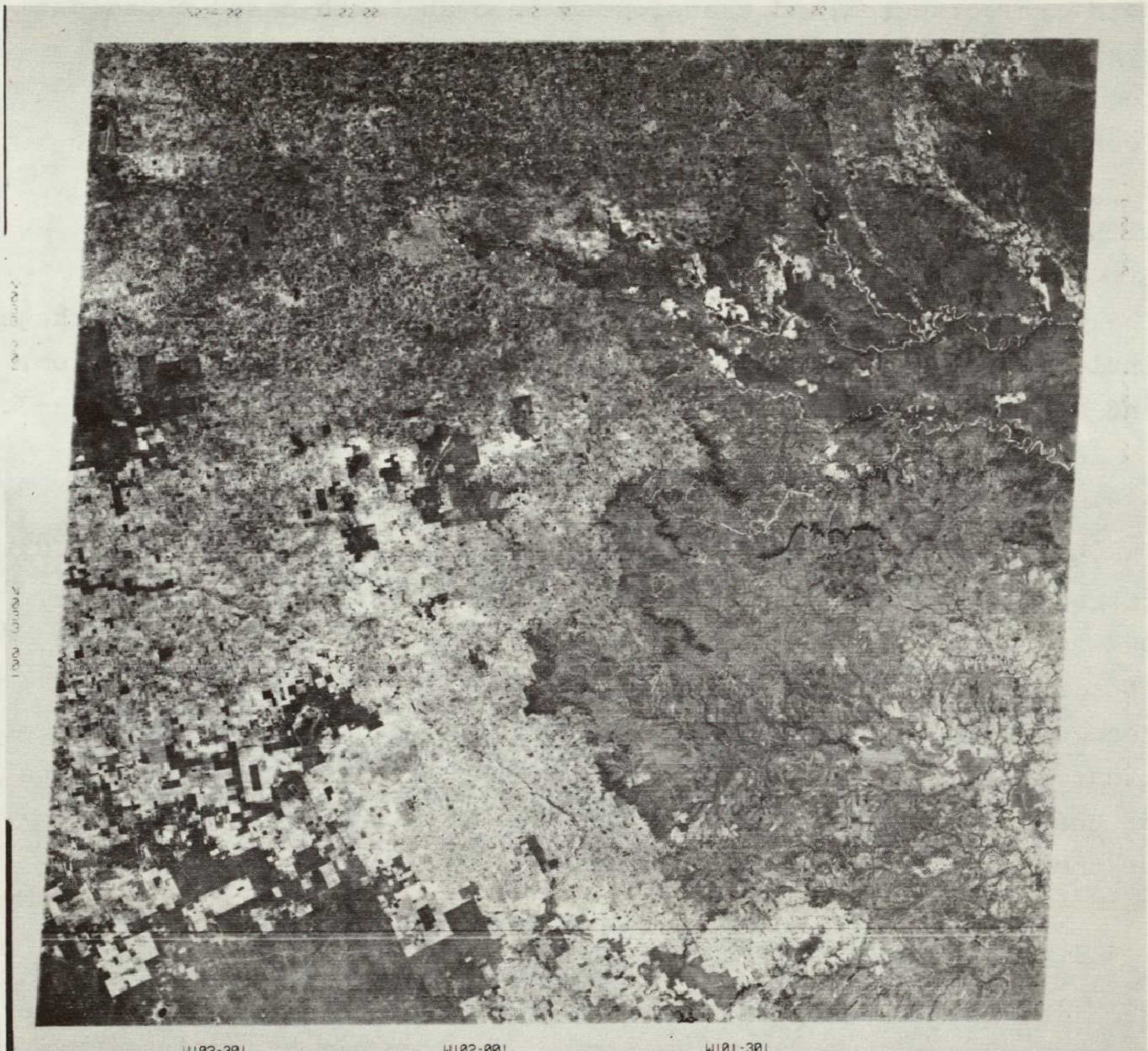

Figure 2-6.— Typical system-corrected
image of Landsat scene.

2.3 DAM PACKAGE DATA PROCESSING

The DAM software utilizes the surface radiance of Earth features, as recorded by the four Landsat MSS channels to classify or detect surface water. The digital data used to perform this classification are geometrically uncorrected and in a dynamic scanner-oriented coordinate system. After classification these data are corrected and transformed into an Earth-based coordinate system. The correction and transformation process, termed registration, utilizes parameters derived from a network of "control points", identified and measured on both maps and the MSS scene, to bring the classified data into registration with prescribed base maps.

The generalized flow of the data processing within the DAM package including control network establishment, surface water detection, and generation of surface water maps, is summarized in figure 2-7.

2.4 DAM PACKAGE OUTPUT DATA FORMAT

The standard DAM package output maps are produced by a conventional, 132-column, computer-driven line printer. Although the DAM software can output correctly scaled maps with a paper feed of six lines per inch (standard commercial), better map resolution is achieved when the printer feed is switched to eight lines per inch. This section discusses the general aspects of the output line-printer thematic maps. Specific elements of the maps are detailed in section 3.

2.4.1 LINE PRINTER MAPPING GEOMETRY

The line printer outputs one horizontal line of discrete characters at a time, and then advances the paper vertically before the next line is printed. At eight lines per inch and ten columns per inch, each print character effectively covers an area 0.125 inches

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DETECTION AND MAPPING (DAM) PACKAGE

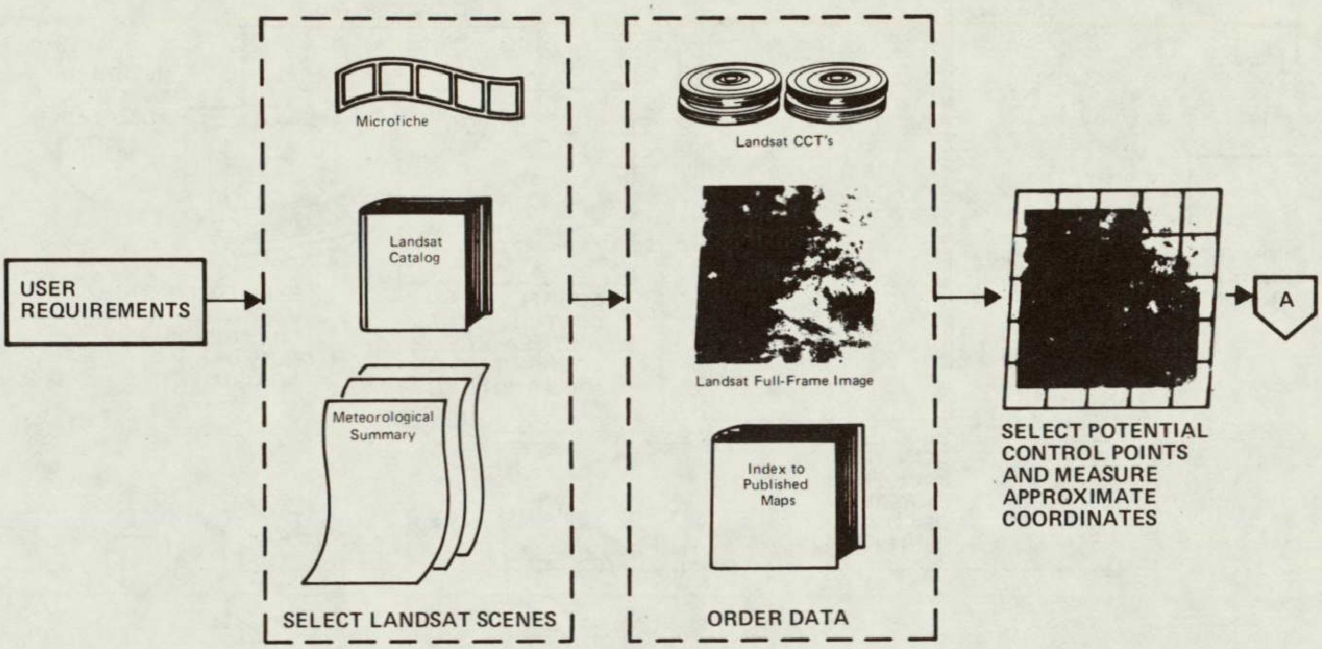

Figure 2-7.— Generalized DAM package data flow.

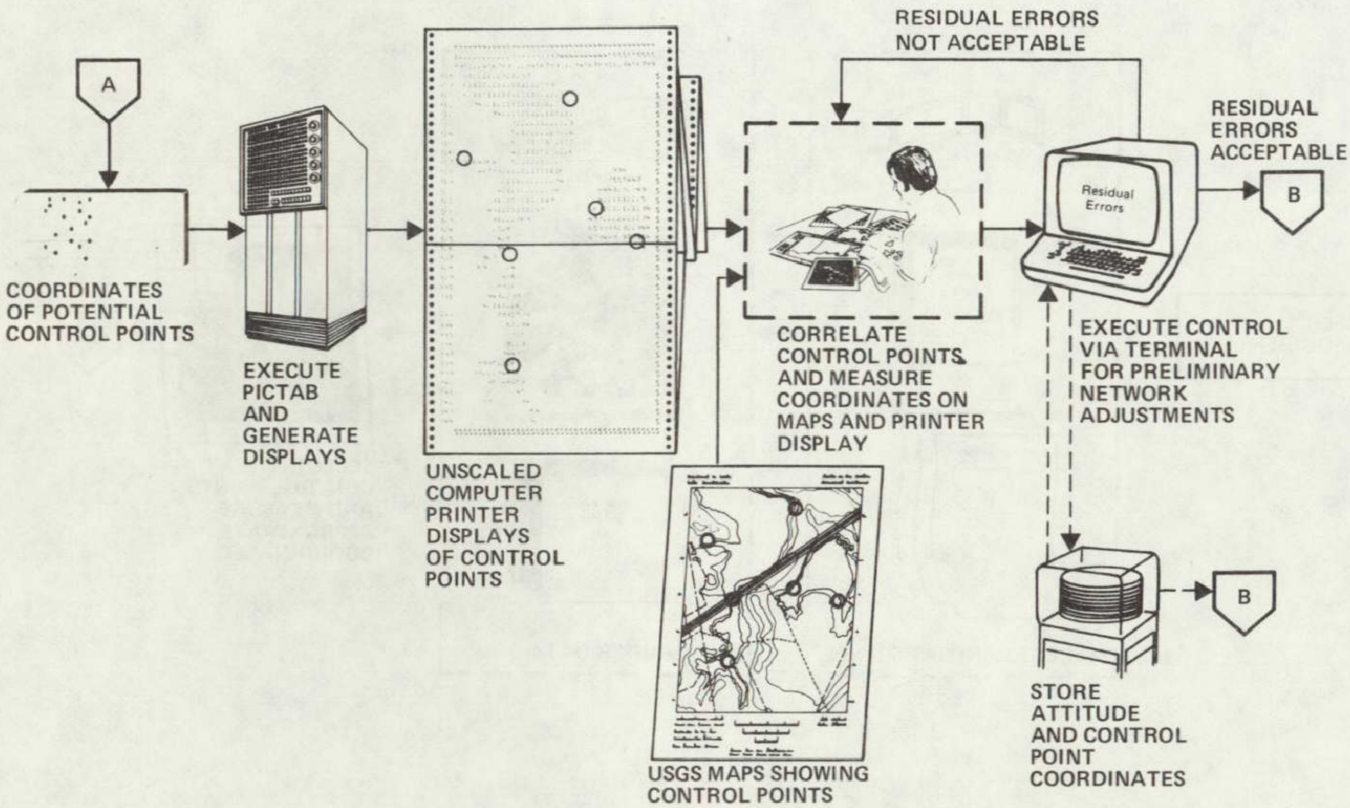

Figure 2-7.— Continued.

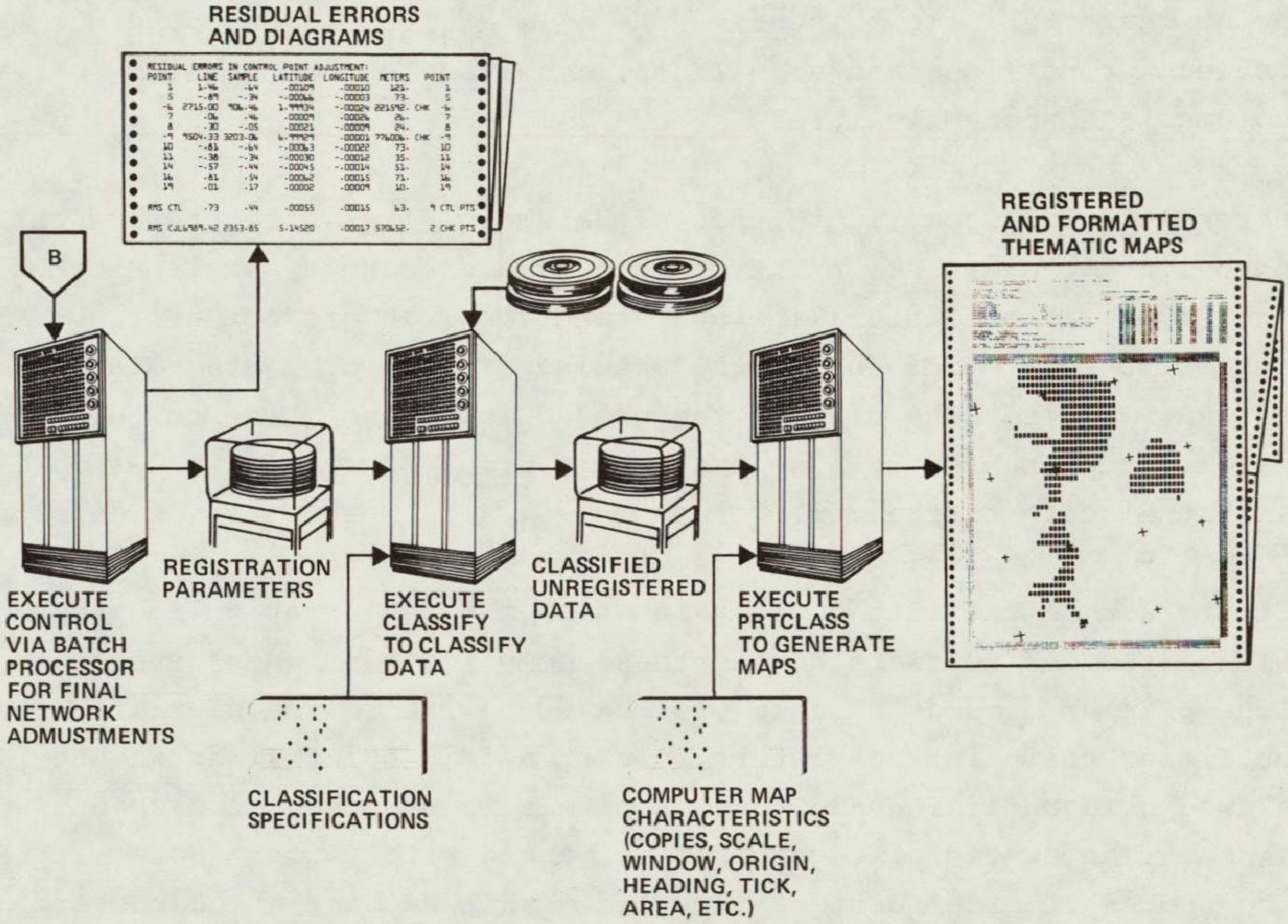

Figure 2-7.– Concluded.

high by 0.10 inches wide. Now recall that the Landsat MSS acquires data by sampling the reflected radiation for discrete pixels within scan lines, and that orbital motion advances the satellite to the south before subsequent scan lines are sampled. It is a relatively simple matter to assign each pixel to one print character. In this case, there is a direct correspondence between print lines and scan lines, and also between printer columns and scanner samples.

Several factors complicate this situation. First, the proportions of height to width for print characters and scanner pixels are not the same. Second, scan line and scanner sample are not at right angles to each other due to the skewing effects of Earth rotation and yaw. Third, the area on the ground (and hence, the number of pixels) represented by a constant-size print character varies with the scale of the map.

Figure 2-8 illustrates the way in which the registration routines within the DAM software handle these complications when generating line-printer maps at a scale of 1:24 000. The rectangular grid outlining the print characters is sketched in solid lines and the skewed grid outlining the scanner pixels is sketched in dashed lines. The center of each pixel is marked with a dot. Note the number of pixel centers that lie within each print character: some characters have no pixel centers, most have one, and some have two. Clearly, this results from the proportion differences, skewing, and scaling described in the previous paragraph. By holding figure 2-8 up to the light you will see the symbols that the registration software would assign to these print characters if all the pixels were classified as water.

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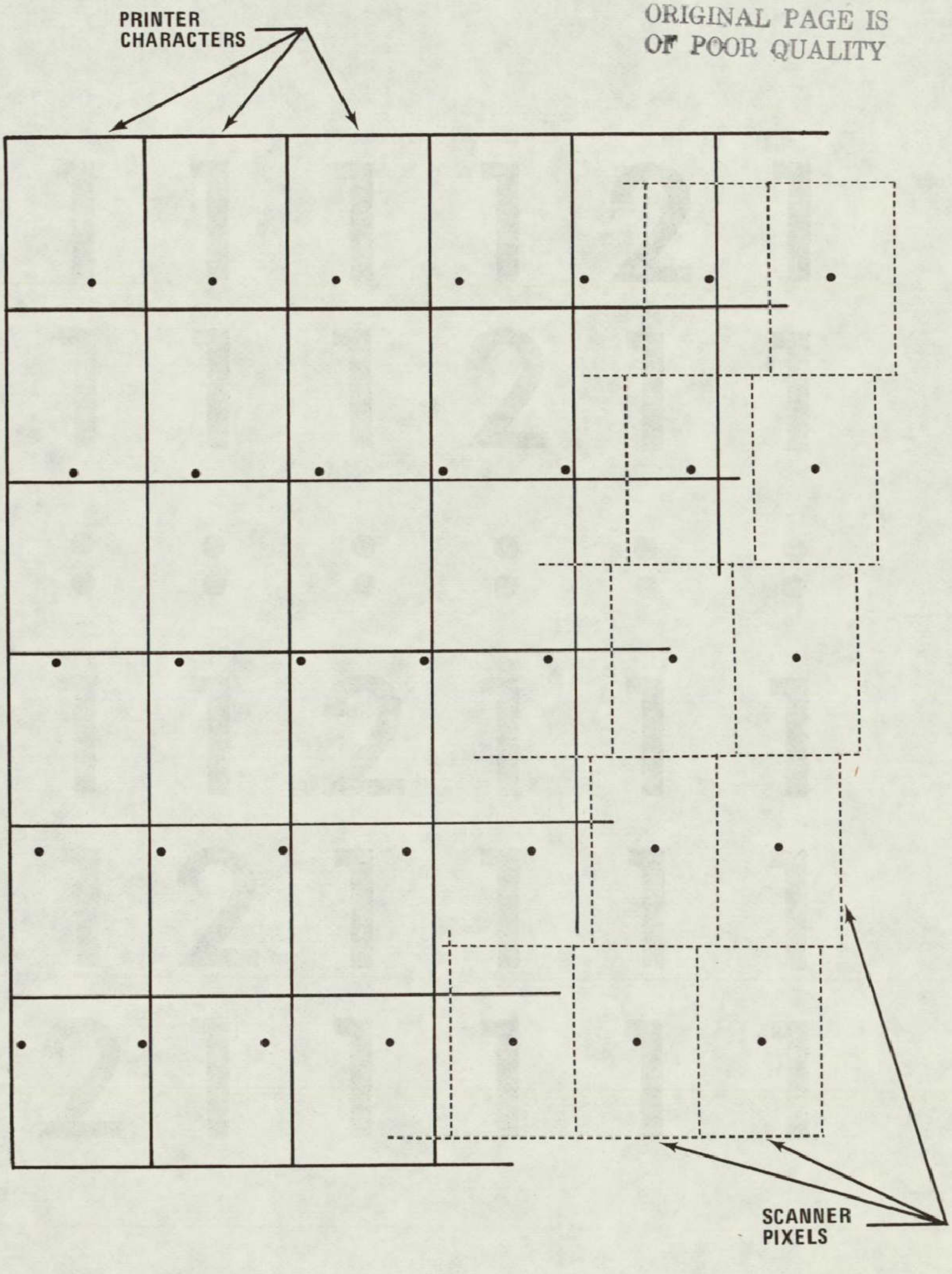

Figure 2-8.— Locations of Landsat pixel centers relative to line printer character locations for 1:24 000-scale computer-generated maps.

$$
\begin{matrix}
1 & 1 & 1 & 1 & 2 & 1 \\
1 & 1 & 1 & 2 & 1 & 1 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
1 & 1 & 2 & 1 & 1 & 1 \\
1 & 2 & 1 & 1 & 1 & 1 \\
2 & 1 & 1 & 1 & 1 & 1
\end{matrix}
$$

The meaning of these symbols is as follows:

Symbol	Meaning
:	0 pixel centers (no data)
1	1 pixel center
2	2 pixel centers

Because (at 1:24 000) a print character is shorter than a pixel, periodically a line of print characters will occur for which there are no corresponding pixel centers. Any of these print characters below pixels classified as water will then be printed as a colon (:) and any not below water pixels will be printed as a blank. Conversely, (at 1:24 000) a print character is wider than a pixel, resulting in the periodic occurrence of print characters with two pixel centers, symbolized by an arabic numeral 2. Note that these 2's occur on the diagonal as a result of the previously described skew in the placement of pixels.

The net result of these registration techniques is that pixels classified as water are never duplicated (a no-data symbol is printed instead) nor are they lost (an arabic numeral 2 is printed instead). Hence, an exact count of pixels classified as water can always be determined from the registered output maps.

At scales other than 1:24 000, the same techniques are used. Each print character contains a symbol indicating the number of pixels classified as water whose centers lie within the character.

An actual line printer example of these effects is shown in figure 2-9.

```
ORIGIN:   48:37:30.0 LAT,  122:15:00.0 LON

MAP SCALE:  1: 24000
PROJECTION:  TRANSVERSE MERCATOR
SPHEROID:  CLARKE 1866
CENTRAL MERIDIAN:    121.9400 DEGREES

CONTROL:  26 POINTS COVERING  55. PERCENT OF ERTS SCENE
ROOT MEAN SQUARE ERROR:    59. METERS

     111111111111111111111111111111111111111111111111111111111111111
     222222222222222222222222222222222222222223333333333333333333333
     566666666667777777777888888888899999999990000000000111111111122
     901234567890123456789012345678901234567890123456789012345678901
     :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
1644:
1645:
1646:
1647:
1648:
1649:
1650:
1651:
1652:
1653:
1654:
1655:
1656:
1657:
1658:
1659:           1111
1660:          111111
1661:          1111111111111
1662:           1111111111111
1663:         11111111111111
1664:        111111111111112
1665:        1111111111111211
1666:        11111111111121111
1667:        111111111112111111
1668:         111111111211111111
1669:         1111111211111111111
1670:         111111211111111111111        11111
1671:         1111121111111111111111   11111111111111
1672:         11112111111111111111121111111111111111121
1673:      11111121111111111111111211111111111111111211111111
1674:      11111211111111111111111121111111111111111121111111111111
1675:11*1111112111111111111111112111111111111111121111111111111111
1676:111111112111111111111111112111111111111111121111111111111111121
1677:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
1678: 111111211111111111111111121111111111111111211111111111111111211
1679:  11112111111111111111111121111111111111111211111111111111112111 1
1680:   1121111111111111111111121111111111111111211111111111111112111 11
1681:111121111111111111111112111111111111111121111111111111111211111 1
1682:112111111111111111111121111111111111111211111111111111111121111111
1683:121111111111111111111211111111111111112111111111111111111211111111
1684:211111111111111111121111111111111112111111111111111112111111111
1685:111111111111111112111111111111111121111111111111111211111111111
1686:1111111111      211111111111111112111111111111111121111111111111
1687:111111111111       111111111111211111111111111111211111111111111
1688:1111111111111          111111121111111111111111121111111111111111
1689:1111111111111            11112111111111111111112111111111111111
1690:      111                       11111111111112111111111111111111 1
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Figure 2-9.— Large water body at 1:24 000 showing line of NO DATA colons and periodic "2s".

2.4.2 MAP ORIENTATION AND TICK MARKS

Efficient computer implementation of the registration techniques explained in the previous section dictates that print lines on the line printer output maps must be parallel to scan lines in the MSS data. For this reason, individual line printer maps are oriented to the local orbital direction of the Landsat satellite. Because the Landsat orbital plane is inclined at 9.3 degrees to the Earth's axis (to achieve Sun-synchronous coverage) the MSS scan lines deviate by 9.3 degrees from true east-west at the Equator. This angle increases at higher latitudes. Figure 2-10 shows the typical orientation of DAM package computer-generated map relative to a standard USGS quadrangle map.

Not shown in the figure are the marginal data and the registration tick marks printed on the classification map. The DAM software computes the line printer location of all four corners of the base map. These are marked with asterisks (*) and designated primary tick marks. Secondary tick marks, marked by a plus sign (+), are plotted at even grid intervals on the map inside the four corners. The standard tick interval for the 7.5-minute USGS quadrangle map sheet is 2.5 minutes in both latitude and longitude. These tick marks assist the analyst in rotating and shifting a computer-generated map to match the corresponding conventional map.

2.4.3 MAP COVERAGE

The DAM mapping routines automatically calculate the number of line printer units that will be required to accommodate a particular map at the specified size and scale. For the standard USGS quadrangle map sheets, the size in the vertical (north-south) direction remains constant at 7.5 and 15.0 nautical miles (1852 meters/nautical mile) for the 7.5-minute and 15-minute quadrangle sheets, respectively, at their respective scales. Map length in the north-south direction is generally in the direction of the printer paper feed, except that as the latitude increases, the

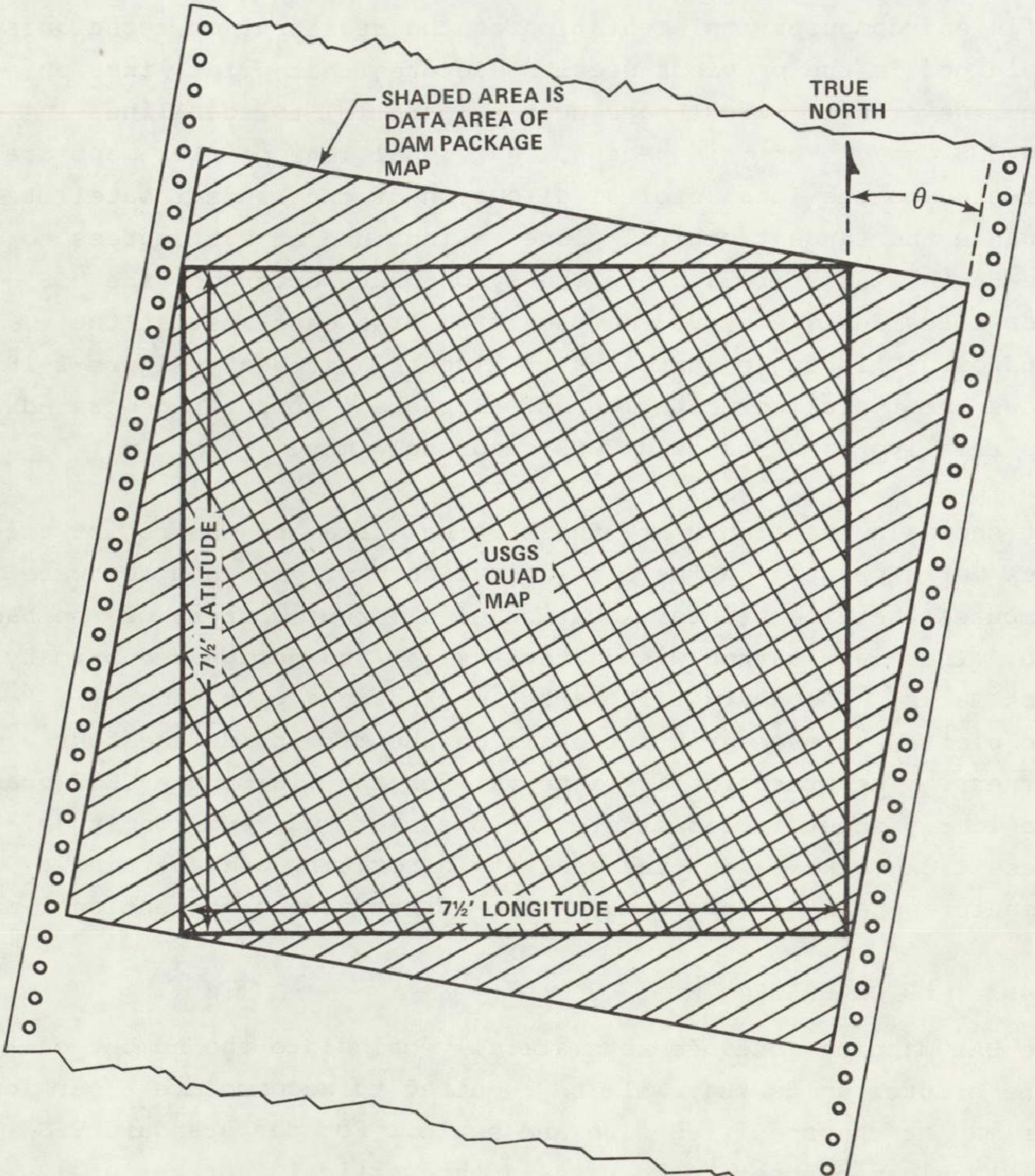


Figure 2-10.– Orientation of DAM package map data with standard USGS map sheet.

Landsat data orientation rotates with the changing spacecraft heading, in a westerly direction. For example, at the western border between the United States and Canada at 49° N latitude, the angle between the Landsat data and meridan lines on the map increases to nearly 14 degrees. On the other hand, the base map width has decreased in proportion to the cosine of the latitude. The two effects counteract each other. It is enough for the analyst to know how to determine how many computer printouts should have been prepared for each map overlay. This is explained in section 3.1.

2.4.4 LANDSAT DATA OVERLAP

The Landsat orbit progression and the field of view of its sensors have been designed so that, in the worst case at the Equator, the nominal data sidelap between longitudinally adjacent frames is 7.5 nautical miles. At all other latitudes sidelap is greater. It increases in inverse proportion to the cosine of the latitude. One minute of longitude is equivalent to one nautical mile at the Equator, therefore, the need to merge data from two or more scenes is reduced since one scene or another will usually contain all of a 7.5-minute quadrangle map sheet. Larger maps could present a problem, but it is unlikely the 15-minute quadrangle, for example, can do so in temperate latitudes and certainly not in extreme latitudes. As the satellite data overlap increases, the longitudinal distance of the ground covered by the map decreases.

3. PREPARATION OF COMPUTER-GENERATED MAPS

A recurring step throughout the actual interpretation and analysis of DAM package water classification maps will be the comparison of that information to the related topographic map. The simplest way to make these comparisons is by overlaying and registering the two maps, and plotting any other information on the overlay (or the map). When one line printer printout makes a complete map, this one map unit is easily registered to the base map for which it was constructed. In the more usual case, at least two separate computer printouts must be assembled to show water classification results over the entire base map area. When this occurs, the second (right most) unit must be carefully trimmed so that it can be joined in exact alignment with the first unit, with no loss of essential marginal data. This is called a mosaic. The mosaic may then be registered to the base map. The construction of a three-unit mosaic is not described in this manual. It will become obvious that the three-unit map is joined by simply repeating the process used to construct the two-unit map.

3.1 UNPACKING THE DATA

When data covering one Landsat scene arrives from the computer center it will be in the form of several stacks of computer printouts. The cover or header sheet of each DISPLAY/MAP PRINT FILE will be similar to the one shown at the top of figure 3-1. The top line of block symbols are computing system identifier codes. The next line identifies DAM PRTCLASS followed by a version number, (DAM PRTCLASS is the computer program which produces the registered maps on the line printer). Then follows the date and time of the processing; and finally, the file identifying numbers. The left block number identifies the number of the first file (0), while

```
ESL8X/ESL8X
DAMPRTCLASS(7802)
04/10/78 03:23

FIRST                 DISPLAY/MAP OUTPUT                 LAST
0                                                        3
FILE                                                     FILE

                      *** THIS ***
                           1
                      *** FILE ***

------------------------------------------------------------------------

ESL8X /ESL8X     DAM PRTCLASS(7802)     04/10/78   03:23     FILE *DAMPRT-1     * NO DECK *
10420-16303 / X00976 / USAED SEATTLE / EHS

???????????????????????????????????

DO YOU HAVE:

    1 COPY OF BASIC PRINT FILE FOR THIS RUN???
    1 COPIES OF ALL  4 DISPLAY/MAP PRINT FILES FOR THIS PROGRAM EXECUTION???

???????????????????????????????????
```


Figure 3-1.— Typical DAM package
DISPLAY/MAP PRINT FILE cover sheet.

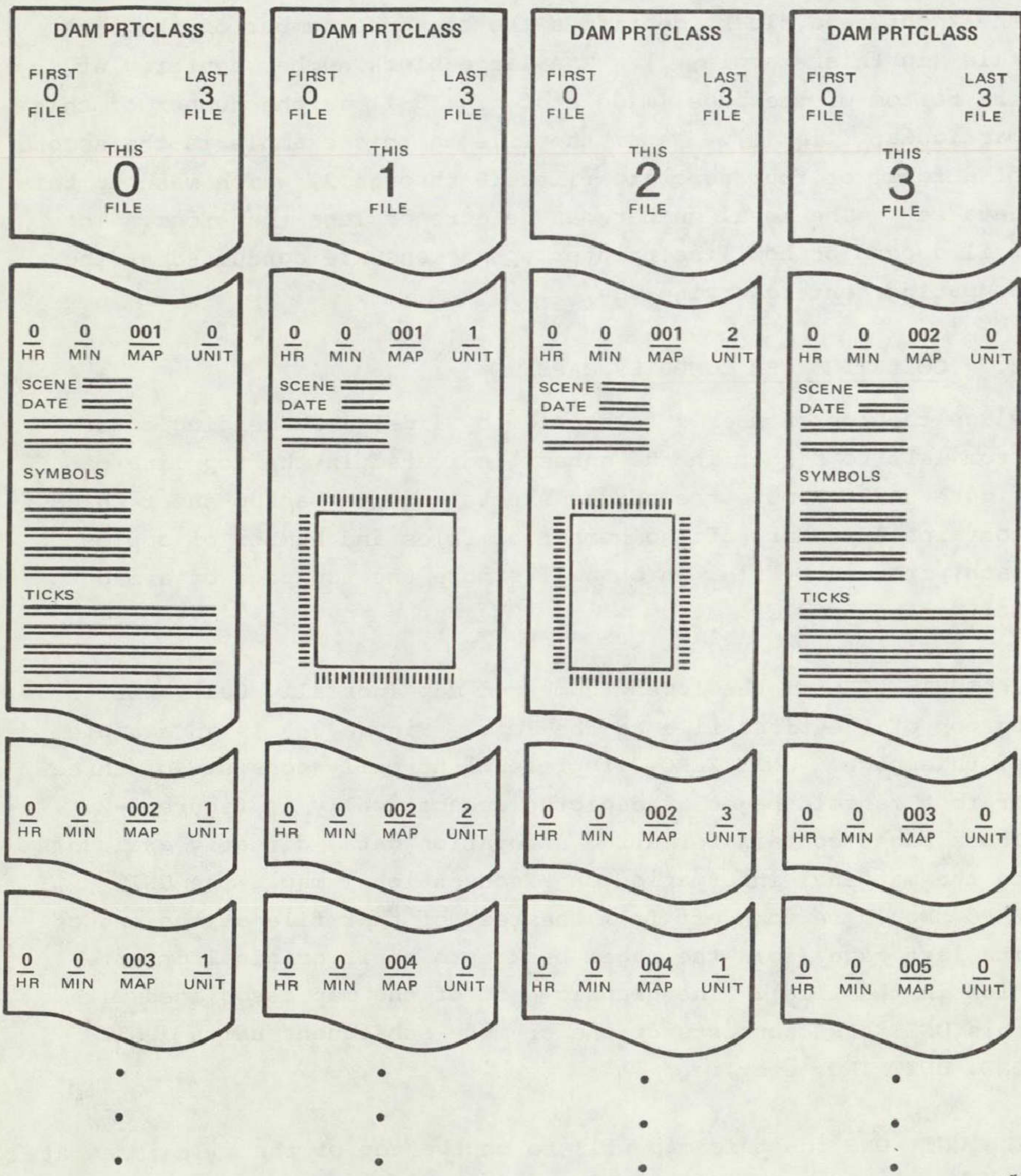
the right hand block identifies the sequence number of the last file (in this example, 3). The large block number centered at the bottom of the page (middle of fig. 3-1) is the number of this particular file (1). Thus, the file in this example is the second of a total of four separate files (0 through 3) which make up this data set. The total number can be more or less than four. This will depend on how line printer operations are conducted at the computing center serving you.

3.2 COLLATING THE COMPUTER MAPS

Place the four numbered files side by side, in ascending order from left to right, in the manner indicated in the top line of figure 3-2. Remove the header sheet (and its backup sheet which contains a summary of the number of files and number of copies each) from each file, which will expose the top page of a map unit in each file.

The UNIT ZERO of the lowest numbered map (normally 001), will be on top of the first file at the left. Figure 3-3 is an example of this page. UNIT ZERO (if present) normally consists of three or four fanfold pages as depicted schematically in figure 3-2. These pages contain formatted annotation data, directly analogous to the marginal information on a conventional map. The UNIT ZERO should be torn off from the rest of that file at the end of its last page (fold the pages back into their original orientation in the file). The graphic part of the map associated with this UNIT ZERO consists of one or more subsequent units (UNIT ONE, UNIT TWO, etc.).

The UNIT ONE for this map will be on the top of the file immediately to the right of the file which contained UNIT ZERO. The UNIT ONE may now be detached from its file (split the perforations between the last sheet of this unit and the header sheet of the next unit). Refold this unit and place it under the UNIT ZERO for this map which was previously detached.



ORIGINAL PAGE IS OF POOR QUALITY

Figure 3-2.– Typical sequence of maps and units within DISPLAY/MAP PRINT FILES.

Repeat the above process to find, separate, refold, and collate the UNIT TWO (and THREE, if it exists – for standard USGS quadrangle map sheets, there is no possibility of a UNIT FOUR).

Once all units of a given computer map have been collated, continue the process by finding the UNIT ZERO (if present) of the next higher numbered computer map (normally 002). According to the pattern, this new UNIT ZERO should appear on the top of the file immediately to the right of the file which contained the last unit of map 001. Figure 3-2 illustrates how the number of units varies from map to map. Each computer map will always have a UNIT ONE and may or may not have a UNIT ZERO. The printer page length of the various units varies from map to map. This separating, refolding, and refiling process may now continue until all of the original four files have been redistributed into however many integral computer maps they contained.

3.2.1 COMPUTER MAP BOUNDARIES

The completeness of a DAM computer map can be verified by examining the boundary frames of UNIT ONE (and TWO and THREE if present). Each unit map area is bounded on all four sides by a single line (column) of colons. (The colon is used throughout as the symbol for no data.) These colons correspond to the neat lines on a conventional map. Immediately above and below the colons at the top and bottom of the computer map there are four-digit printer column numbers. These increase from left to right. Immediately outside and adjacent to the colons bounding the sides of the map area there is another series of four-digit numbers. These are printer line numbers. These increase from top to bottom.

If a map UNIT ONE has line numbers printed down both sides, then there will be no corresponding UNIT TWO. If UNIT ONE has colons only, without numbers down the right side boundary, then there is a continuation of the map data on a UNIT TWO. If there should also be an associated UNIT THREE, the UNIT TWO will have only colons along the right margin, and so on. These characteristics provide the analyst with an independent check on the completeness of any particular DAM map unit set. Figure 3-2 illustrates schematically the side boundaries of a two-unit map.

3.3 CONTENTS OF THE UNIT ZERO

This unit contains the computer map legend, including information on source, reliability, and scale. Because UNIT ZERO information is not needed for all computer maps, UNIT ZERO sheets may be selectively suppressed by the regional processing center.

3.3.1 PAGE ONE

Refer to figure 3-3. In the top line, the numbers following DAM PRTCLASS give the software version, processing date, and time. The last triplet of numbers identify: the computer map number within this program execution - the unit number within this computer map - and the page number within this map unit. The second line gives accounting, routing, and quality control information. The third line normally gives the map name, series, and state.

The large block ID numbers repeat the time, map number, and unit number, in a form easily read from a distance.

Scene date is the date on which the scanner data was recorded by the satellite. Map origin for a standard map (conventional or computer-generated) is normally the latitude and longitude of its southeast corner.

3.3.2 PAGE TWO

This page presents a legend of the symbols used on this map (see fig. 3-4). The NO DATA (:), PRIMARY TICK (*), and SECONDARY TICK (+) symbols are always used for these purposes, and for no

ORIGINAL PAGE IS
OF POOR QUALITY

```
ESL8X /ESL8X     DAM PRTCLASS(7802)       04/10/78   03:23   026-0-0001
10420-18303 / X00976 / USAED SEATTLE / EHS
CLEAR LAKE 15 WASH

   333333          333333            0000           222222          666666           0000
 3333333333      3333333333        00000000       2222222222      6666666666       00000000
333      333    333      333      000    000     222      222    666      66      000    000
33        33    33        33     000      000    22       222    66              000      000
          33              33     00        00            222     66              00        00
       333             333       00        00          222       66 6666666      00        00
       333             333       00        00        222         66666666666     00        00
          33              33     00        00       222          66        66    00        00
33        33    33        33     000      000      222           66        66    000      000
333      333    333      333      000    000       222           66        66     000    000
 3333333333      3333333333        00000000        22222222222    6666666666       00000000
   333333          333333            0000          EHS22222222      666666           0000

  ========        ========      ====================================================  ========
    HOUR           MINUTE                           MAP NUMBER                          UNIT
```

```
ERTS SCENE: 10420-18303
DATE:  16 SEP 73
SUN ELEV:  39 DEGREES
SUN AZIMUTH:  149 DEGREES

CCT STRIPS:             1      2      3      4
DATE CLASSIFIED:          012478
MINIMUM LINE:           0      1      0      0
MAXIMUM LINE:           0   2340      0      0
MINIMUM SAMPLE:         0    811      0      0
MAXIMUM SAMPLE:         0   1620      0      0
MATERIAL CLASSIFIED:  WATER (CH4/CH1)

ORIGIN:   48:15:00.0 LAT,  122:00:00.0 LON

MAP SCALE:  1: 62500
PROJECTION:  TRANSVERSE MERCATOR
SPHEROID:  CLARKE 1866
CENTRAL MERIDIAN:   121.9400 DEGREES

CONTROL:  26 POINTS COVERING  55. PERCENT OF ERTS SCENE
ROOT MEAN SQUARE ERROR:   59. METERS
```

Figure 3-3.— Typical UNIT ZERO page 1.

```
ESL8X /ESL8X      DAM PRTCLASS(7802)        04/10/78   03:23   026-0-0002
10420-18303 / X00976 / USAED SEATTLE / EHS
CLEAR LAKE 15 WASH


SYMBOLS FOR COUNT OF PIXELS CLASSIFIED WITHIN
SPECTRAL LIMITS AND DENSITY RANGE (10-19)

 SYMBOL   NUMBER   MEANING

   :               NO DATA
   *               PRIMARY TICK
   +               SECONDARY TICK
(BLANK)     000
   1        001
   2        002
   3        003
   4        004
   5        005
   6        006
   7        007
   8        008
   9        009
   A      010-014
   B      015-019
   C      020-024
   D      025-029
   E      030-034
   F      035-039
   G      040-044
   H      045-049
   I      050-054
   J      055-059
   K      060-064
   L      065-069
   M      070-074
   N      075-079
   O      080-084
   P      085-089
   Q      090-094
   R      095-099
   S      100-109
   T      110-119
   U      120-129
   V      130-139
   W      140-149
   X      150-159
   Y      160-169
   Z      170-255
```

Figure 3-4.— Typical UNIT ZERO page 2.

other. The remaining symbols describe the number of water-classified Landsat MSS pixels whose centers lie within the line printer character displaying the symbol.

3.3.3 PAGE THREE

Figure 3-5 illustrates this page. It contains part of a table giving coordinate locations for the tick symbols printed on subsequent units of the map. The example shown is for a 15-minute, 1:62 500-scale map.

Tick tables are continued on additional paper, if required.

3.4 CONTENTS OF UNIT ONE (AND HIGHER)

The marginal information presented at the top of UNIT ONE is identical to the presentation on page one of the UNIT ZERO with the single exception of the unit number at the end of the very top line, and in the last of the large block ID numbers. The rest of the printout is all map data, surrounded by the four line printer neat lines as described in section 3.2.1. Figures 3-6 and 3-7 show the units associated with map 026. There are three special rules concerning the appearance of tick symbols.

a. Primary tick symbols are always printed on the computer map, <u>even at the expense of suppressing (eliminating) water data which would have been present in the character occupied by the asterisk</u>.

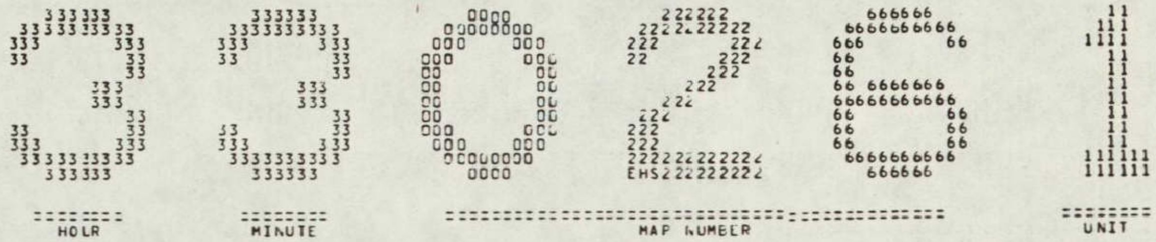
b. Secondary tick symbols are printed at all proper locations on the computer map (these can be confirmed by noting the line printer coordinates in the tick table, UNIT ZERO) provided they do not displace either a water symbol or a primary tick symbol. <u>Water symbols take precedence over secondary tick symbols</u>. Any secondary tick symbol which has been suppressed on the computer map due to conflict with a

ESL8X /ESL8X DAM PRTCLASS(7802) 04/10/76 03:23 026-0-0003
10420-16303 / X00976 / USAED SEATTLE / EHS
CLEAR LAKE 15 WASH

TICK SYMBOL	SCANNER LINE	SCANNER SAMPLE	(DEG:MIN:SEC) LATITUDE	(DEG:MIN:SEC) LONGITUDE	(DEGREES) LATITUDE	(DEGREES) LONGITUDE	UTM (KM) EASTING NORTHING	PRINTER LINE	PRINTER COLUMN
*	1628	1401	48:30:00	122:15:00	48.5000	122.2500	********************	953	766
*	1601	1555	48:30:00	122:07:30	48.5000	122.1250	********************	942	822
*	1574	1709	48:30:00	122:00:00	48.5000	122.0000	********************	932	879
*	1797	1468	48:22:30	122:15:00	48.3750	122.2500	********************	1021	786
*	1770	1622	48:22:30	122:07:30	48.3750	122.1250	********************	1011	843
*	1743	1777	48:22:30	122:00:00	48.3750	122.0000	********************	1000	899
*	1967	1535	48:15:00	122:15:00	48.2500	122.2500	********************	1089	806
*	1940	1690	48:15:00	122:07:30	48.2500	122.1250	********************	1079	863
+	1628	1401	48:30:00	122:15:00	48.5000	122.2500	********************	953	766
+	1619	1452	48:30:00	122:12:30	48.5000	122.2083	********************	950	784
+	1610	1504	48:30:00	122:10:00	48.5000	122.1667	********************	946	803
+	1601	1555	48:30:00	122:07:30	48.5000	122.1250	********************	942	822
+	1592	1606	48:30:00	122:05:00	48.5000	122.0833	********************	939	841
+	1583	1657	48:30:00	122:02:30	48.5000	122.0417	********************	935	860
+	1574	1709	48:30:00	122:00:00	48.5000	122.0000	********************	932	879
+	1684	1423	48:27:30	122:15:00	48.4583	122.2500	********************	976	772
+	1675	1475	48:27:30	122:12:30	48.4583	122.2083	********************	972	791
+	1666	1526	48:27:30	122:10:00	48.4583	122.1667	********************	969	810
+	1657	1577	48:27:30	122:07:30	48.4583	122.1250	********************	965	829
+	1648	1629	48:27:30	122:05:00	48.4583	122.0833	********************	962	848
+	1639	1680	48:27:30	122:02:30	48.4583	122.0417	********************	958	867
+	1630	1731	48:27:30	122:00:00	48.4583	122.0000	********************	954	886
+	1741	1446	48:25:00	122:15:00	48.4167	122.2500	********************	999	779
+	1732	1497	48:25:00	122:12:30	48.4167	122.2083	********************	995	798
+	1723	1549	48:25:00	122:10:00	48.4167	122.1667	********************	991	817
+	1714	1600	48:25:00	122:07:30	48.4167	122.1250	********************	988	836
+	1705	1651	48:25:00	122:05:00	48.4167	122.0833	********************	984	855
+	1696	1703	48:25:00	122:02:30	48.4167	122.0417	********************	981	874
+	1687	1754	48:25:00	122:00:00	48.4167	122.0000	********************	977	892
+	1797	1468	48:22:30	122:15:00	48.3750	122.2500	********************	1021	786
+	1788	1520	48:22:30	122:12:30	48.3750	122.2083	********************	1018	805
+	1779	1571	48:22:30	122:10:00	48.3750	122.1667	********************	1014	824
+	1770	1622	48:22:30	122:07:30	48.3750	122.1250	********************	1011	843
+	1761	1674	48:22:30	122:05:00	48.3750	122.0833	********************	1007	861
+	1752	1725	48:22:30	122:02:30	48.3750	122.0417	********************	1003	880
+	1743	1777	48:22:30	122:00:00	48.3750	122.0000	********************	1000	899
+	1854	1491	48:20:00	122:15:00	48.3333	122.2500	********************	1044	793
+	1845	1542	48:20:00	122:12:30	48.3333	122.2083	********************	1040	811
+	1836	1593	48:20:00	122:10:00	48.3333	122.1667	********************	1037	830
+	1827	1645	48:20:00	122:07:30	48.3333	122.1250	********************	1033	849
+	1818	1696	48:20:00	122:05:00	48.3333	122.0833	********************	1030	868
+	1809	1748	48:20:00	122:02:30	48.3333	122.0417	********************	1026	887
+	1800	1799	48:20:00	122:00:00	48.3333	122.0000	********************	1022	906
+	1910	1513	48:17:30	122:15:00	48.2917	122.2500	********************	1067	799
+	1901	1564	48:17:30	122:12:30	48.2917	122.2083	********************	1063	818
+	1892	1616	48:17:30	122:10:00	48.2917	122.1667	********************	1060	837
+	1883	1667	48:17:30	122:07:30	48.2917	122.1250	********************	1056	856
+	1874	1719	48:17:30	122:05:00	48.2917	122.0833	********************	1052	875
+	1865	1770	48:17:30	122:02:30	48.2917	122.0417	********************	1049	894
+	1967	1535	48:15:00	122:15:00	48.2500	122.2500	********************	1089	806
+	1958	1587	48:15:00	122:12:30	48.2500	122.2083	********************	1086	825

Figure 3-5.– Typical UNIT ZERO page 3.

ESL8X /ESL8X DAM PRTCLASS(7802) 04/10/78 03:23 026-1-0001
10420-18303 / X00976 / USAED SEATTLE / EHS
CLEAR LAKE 15 WASH



ERTS SCENE: 10420-18303
DATE: 16 SEP 73
SUN ELEV: 39 DEGREES
SUN AZIMUTH: 149 DEGREES

CCT STRIPS:	1	2	3	4
DATE CLASSIFIED:		012478		
MINIMUM LINE:	0	1	0	0
MAXIMUM LINE:	0	2340	0	0
MINIMUM SAMPLE:	0	811	0	0
MAXIMUM SAMPLE:	0	1620	0	0

MATERIAL CLASSIFIED: WATER (CH4/CH1)

ORIGINAL PAGE IS OF POOR QUALITY

ORIGIN: 48:15:00.0 LAT, 122:00:00.0 LON

MAP SCALE: 1: 62500
PROJECTION: TRANSVERSE MERCATOR
SPHEROID: CLARKE 1866
CENTRAL MERIDIAN: 121.9400 DEGREES

CONTROL: 26 POINTS COVERING 55. PERCENT OF ERTS SCENE
ROOT MEAN SQUARE ERROR: 59. METERS

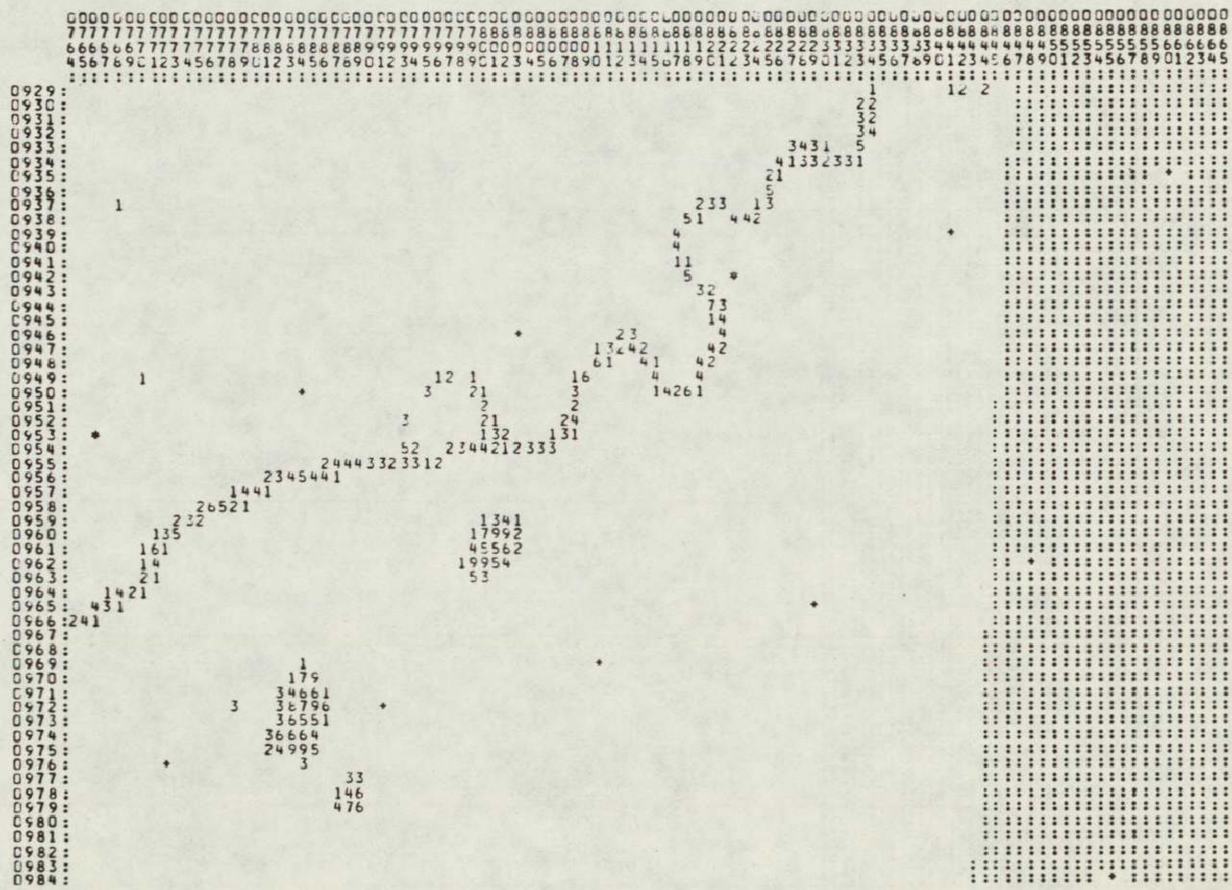
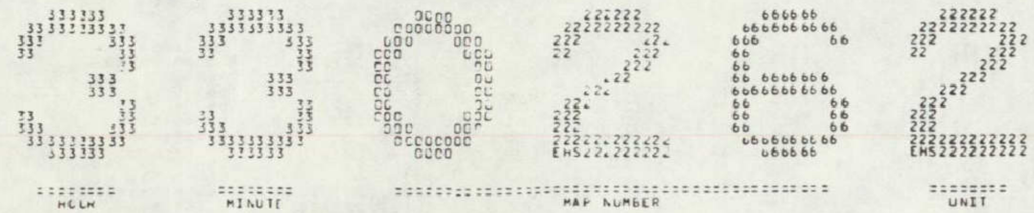


Figure 3-6.– Top of typical UNIT ONE.

```
ESL6X /ESL8X      DAM PRTCLASS(7802)       04/10/76   03:23   026-2-0001
10420-18303 / XU0976 / USAED SEATTLE / EHS
CLEAR LAKE 15 WASH
```



```
ERTS SCENE: 10420-18303
DATE:  16 SEP 73
SUN ELEV:  39 DEGREES
SUN AZIMUTH:  149 DEGREES

CCT STRIPS:              1       2        3       4
DATE CLASSIFIED:              012478
MINIMUM LINE:            0       1        0       0
MAXIMUM LINE:            0    2340        0       0
MINIMUM SAMPLE:          0     811        0       0
MAXIMUM SAMPLE:          0    1620        0       0
MATERIAL CLASSIFIED:  WATER (CH4/CH1)

ORIGIN:   46:15:00.0 LAT,  122:00:00.0 LON

MAP SCALE:  1: 62500
PROJECTION:  TRANSVERSE MERCATOR
SPHEROID:  CLARKE 1866
CENTRAL MERIDIAN:    121.9400 DEGREES

CONTROL:  26 POINTS COVERING  55. PERCENT OF ERTS SCENE
ROOT MEAN SQUARE ERROR:   59. METERS
```

Figure 3-7.— Top of typical UNIT TWO.

water symbol may be manually plotted, if necessary, from its coordinates as given in the tick table.

c. Both primary and secondary ticks appear in place of no data symbols. Further, the no data symbols immediately adjacent to the tick symbol on that printer line are also suppressed, providing a "halo" which assists in locating the tick mark. These special situations appear in the NO DATA area at the top of the computer map shown in figure 3-6.

A final comment on the computer-generated maps — because they are constructed at an oblique angle with the neat lines of the related base map, they will always subtend a larger dimension, both vertically and horizontally, than the related base map.

3.5 INDEXING AND SCREENING

Once the collating process is completed, the data is organized into sets of computer-map sheets ("units"), ready for assembly into the individual complete computer maps (see section 3.6). At higher latitudes and smaller scales, the complete map will probably consist of just one unit. At lower latitudes and larger scales, the complete computer map will be composed of several units. A full Landsat scene will generate between 200 and 300 maps at various scales. Fewer maps will be produced for scences which, in part, are cloud-covered or lie outside the area to be mapped. The largest number of computer maps will be those which cover the scene area at the largest scale, that of the USGS quadrangle map (1:24 000).

The lowest numbered computer map(s) for a Landsat scene normally will cover the entire usable portion of the scene at a scale of 1:250 000, with tick symbols every 7.5 minutes of latitude and longitude. These 1:250 000-scale maps provide an overview of the classification results for the scene. They are useful as an indexing tool for the larger scale computer maps of the same area, and for identifying areas of potential difficulties because of haze or clouds, by reference to an original Landsat data scene. For partial Landsat scenes, "overview" maps may be omitted.

The 1:250 000-scale computer-generated map(s) should be assembled first, before any other maps for this scene, using the techniques given in section 3.6. Once this has been done, use colored pencils and straightedge to outline the boundaries of 15-minute (blue) and 7.5-minute (red) quadrangle maps by drawing the meridians and parallels connecting all the tick symbols. The latitudes (longitudes) of these lines should be determined from the tick table in UNIT ZERO, and then annotated on the map. Once this is completed, the names of the published quadrangle maps can be determined from the standard USGS 1:1 000 000 index map, and then annotated on the 1:250 000 computer-generated map. This annotated map will now be used along with other considerations, to determine which individual large-scale computer maps need to be assembled and the order in which they should be interpreted.

The first consideration is the areas(s) assigned for interpretation and analysis and perhaps priorities. This is an operational matter which will vary between districts. The technical considerations are the availability of maps and the location of areas which will require special attention because of spotty cloud cover, or which are unusable because of extensive haze or cloud cover. Normally the latter will have been eliminated by the regional processing center. The regional processing center will process only the most cloud-free scene available. An overlay showing the published map coverage in the area will be furnished by the Regional Processing Center. Cloudy or hazy areas will usually be indicated on this overlay. The analyst should examine the overlay as a check, and then annotate the 1:250 000-scale computer map.

The areas of affected maps to be interpreted with caution are now well pre-identified. In cases where proper evaluation cannot be made, the regional processing center will provide alternate coverage on request.

The larger scale computer maps to be assembled can now be selected. Computer maps are selected at scales which match the large scale topographic maps available. This applies to all computer maps, including those which indicate no detected water at all. After assembly, each computer map will be overlaid on its related topographic map to check for mis-located or apparently missing dams, as well as new impoundments. Use of the largest map scales available assures the best accuracy possible of interpretation and coordinate measurements.

The indexing and screening has now been completed.

3.6 TRIMMING AND FITTING THE MOSAIC

The joining of two contiguous aerial photographs into one is called mosaicking. The same process is followed in assembling UNIT ONE and UNIT TWO into a complete computer map. It is made easier by the fact that the line printer character geometry automatically provides a grid which is used as a guide for trimming the excess paper away from the left edge of UNIT TWO and for positioning it exactly tangent to the right edge of UNIT ONE. Figure 3-8 shows where to cut off the left margin of UNIT TWO. The cut is made vertically from the very top of the unit to the bottom, immediately to the right of the column of colon symbols (:) which signify the left edge of the mapped data. The column to the right of the colons contains map data. When it is blank, the column can still be located by noting the print column scales at the top and bottom of the map area.

```
CCT STRIPS:                   1      2       3       4
DATE CLASSIFIED:            012478
MINIMUM LINE:                 0      1       0       0
MAXIMUM LINE:                 0   2340       0       0
MINIMUM SAMPLE:               0    811       0       0
MAXIMUM SAMPLE:               0   1620       0       0
MATERIAL CLASSIFIED:  WATER (CH4/CH1)

ORIGIN:    48:45:00.0 LAT,   122:00:00.0 LON

MAP SCALE:  1: 62500
PROJECTION:  TRANSVERSE MERCATOR
SPHEROID:  CLARKE 1866
CENTRAL MERIDIAN:     121.9400 DEGREES

CONTROL:  26 POINTS COVERING   55. PERCENT OF ERTS SCENE
ROOT MEAN SQUARE ERROR:    59. METERS

      0000000000000000000000000000000000
      5888888888888888888888888888888888
      0001111111111222222222233333333334
      7890123456789012345678901234567890
      ::::::::::::::::::::::::::::::::::
0656 :     1                            :0656
0657 :                               36 :0657
0658 :                                  :0658
0659 :                                1 :0659
0660 :                       114        :0660
0661 :                       1          :0661
0662 :                     2 1     1551 :0662
0663 :                                  :0663
0664 :                                  :0664
0665 :
0666 :
0667 :
0668 :
0669 :
0670 :        11
0671 :        1
0672 :          1
0673 :
0674 :       1
0675 :
0676 :
0677 :
0678 :                                  :0678
0679 :                                1 :0679
0680 :                                  :0680
0681 :                                  :0681
0682 :                                  :0682
0683 :                                  :0683
0684 :                                  :0684
0685 :                               11 :0685
0686 :                              322 :0686
0687 :                                  :0687
0688 :                                  :0688
0689 :                                  :0689
0690 :                                  :0690
0691 :                                  :0691
0692 :                                  :0692
0693 :                                  :0693
0694 :                                  :0694
```

TRIM AS INDICATED BY DASHED LINE

NOTE THAT THE COLON SYMBOL (:) DOES NOT FILL A PRINT CHARACTER, BUT IS POSITIONED AT THE RIGHT EDGE OF THE CHARACTER. TO REMOVE THE LEFT EDGE OF UNIT TWO (THE COLUMN OF 5 CHARACTERS WHICH CONTAIN SYMBOLS FOR 4 NUMERIC DIGITS AND 1 COLON), CUT THE PAPER IMMEDIATELY TO THE RIGHT OF THE COLON SYMBOLS. IF ANY OF THESE COLON SYMBOLS REMAIN ON UNIT TWO, NOT ENOUGH PAPER HAS BEEN TRIMMED. IF THE COLONS ON THE TRIMMED STRIP TO BE DISCARDED JUST TOUCH ITS RIGHT EDGE, THEN THE PROPER AMOUNT OF PAPER HAS BEEN CUT OFF.

Figure 3-8.– Illustration of location of trim line for UNIT TWO.

The UNIT TWO sheet may then be fitted over the right margin of the UNIT ONE sheet. Long heavy straightedges or map weights should be placed along the entire length of the join line, on both sides, to ensure that the map units lie perfectly flat. Once both units are aligned so that the print column scales at the top and bottom line up exactly, both vertically and horizontally, they should be taped together securely.

It will be noted that trimming the UNIT TWO sheet rather than the UNIT ONE produces an overlap joint with no printing on the underlaying map edge (other than a single column of colons). If the UNIT ONE were trimmed and fitted over the UNIT TWO, the UNIT TWO left margin line numbers would show through on a light table, making registration and interpretation more difficult in the region of the mosaic seam.

The marginal data provided at the top, bottom, and sides of the UNIT ONE/UNIT TWO mosaic are important and <u>must not</u> be trimmed off. Similarly, the legend and tick table in UNIT ZERO are important and should be kept with the associated mosaic.

4. INTERPRETATION AND ANALYSIS

Before examining the details of interpretation and analysis of DAM computer maps, it is useful to recall the criteria for reporting in the national inventory. These are: all dams 25 feet or higher, which impound at least 15 acre-feet of water, and all dams which impound 50 acre-feet or more, which are at least 6 feet high. Obviously, satellite data alone will never provide measurements of this precision. The whole purpose of the DAM package is to provide a method of rapidly screening very large areas for surface water in general, and impounded water in particular. Discrimination between impounded and non-impounded surface water, location of the impounding structures, and the reduction of misclassifications caused by gross shadows are the key interpretation services provided by the analyst.

4.1 PIXEL SIZE AND CONTIGUITY

It will be recalled that at a scale of 1:24 000, one Landsat pixel is approximately equal in area to one line printer character. The area on the ground uniquely recorded by one Landsat pixel covers approximately 1.1 acres. The DAM package classification processing selects "pure" water pixels, which means that the pixels classified as water are entirely water, and contain no significant soil, rock, or vegetation on the surface. Pixels which contain mixtures of water and vegetation (typical of marshes and of lakes choked with hydrilla), or water, shoreline and land combined, are classified as non-water. For these reasons, pixels classified as water will generally be surrounded on all sides by edge pixels not classified as water.

The number of edge pixels and the proportions of water to non-water in each edge pixel will vary with the size and shape of the water body as well as the degree of alignment between its shoreline and the grid of scanner pixels. As a consequence, the surface area of a water body cannot be determined by simply counting the number of contiguous pixels classified as water and multiplying by 1.1 (or by any other number). For example, three contiguous pixels classified as water generally correspond to a surface area of approximately ten acres, but the actual area of any individual 3-pixel water body may vary from four acres to twenty acres. Likewise a single pixel classified as water corresponds to a surface area between two and ten acres.

Nevertheless, the number of contiguous water pixels detected is a useful, if crude, indication of the areal extent of the actual water body. Contiguous pixels are defined as those which are adjacent at a side or corner.

Pixel contiguity can always be determined from the 1:24 000 scale computer maps. The line printer symbols will be adjacent at a side or corner if and only if the corresponding pixels are adjacent. In this determination, two water symbols represent contiguous pixels even if separated by a mutually contiguous NO DATA (:) symbol.

Pixel contiguity cannot always be determined from computer maps at 1:62 500 and smaller scales. Figure 4-1 illustrates some problems in attempting to determine pixel contiguity from different scale computer maps. At "A", two symbolizations of three contiguous pixels at 1:24 000-scale are shown, and several different ways these can appear in the related 1:62 500 computer map.

At "B", two symbols (and their corresponding pixels) are contiguous, but the third (and its corresponding pixel) is not. In the 1:62 500 computer map, two different presentations are shown of the same data (their difference lies in where the 1:62 500 map character falls with the actual Landsat pixel centers). Without the information contained in the 1:24 000 map, the analyst would, looking at either of the 1:62 500 presentations, erroneously conclude that all three pixels were contiguous.

Part "C" of figure 4-1 illustrates one other special situation. The 1:24 000 computer maps show water areas which include NO DATA colons inserted by the computer program to preserve the map scale (see section 2.4.1). Water symbols which are above and below a colon, or diagonally opposite across a colon, <u>do</u> represent contiguous water pixels.

Of course, the final determination of whether neighboring noncontiguous pixels belong to two separate water bodies or to a single very narrow water body <u>cannot</u> be made by any computer but depends on human judgement in interpreting both the computer maps derived from satellite data and the elevation contour lines on topographic maps.

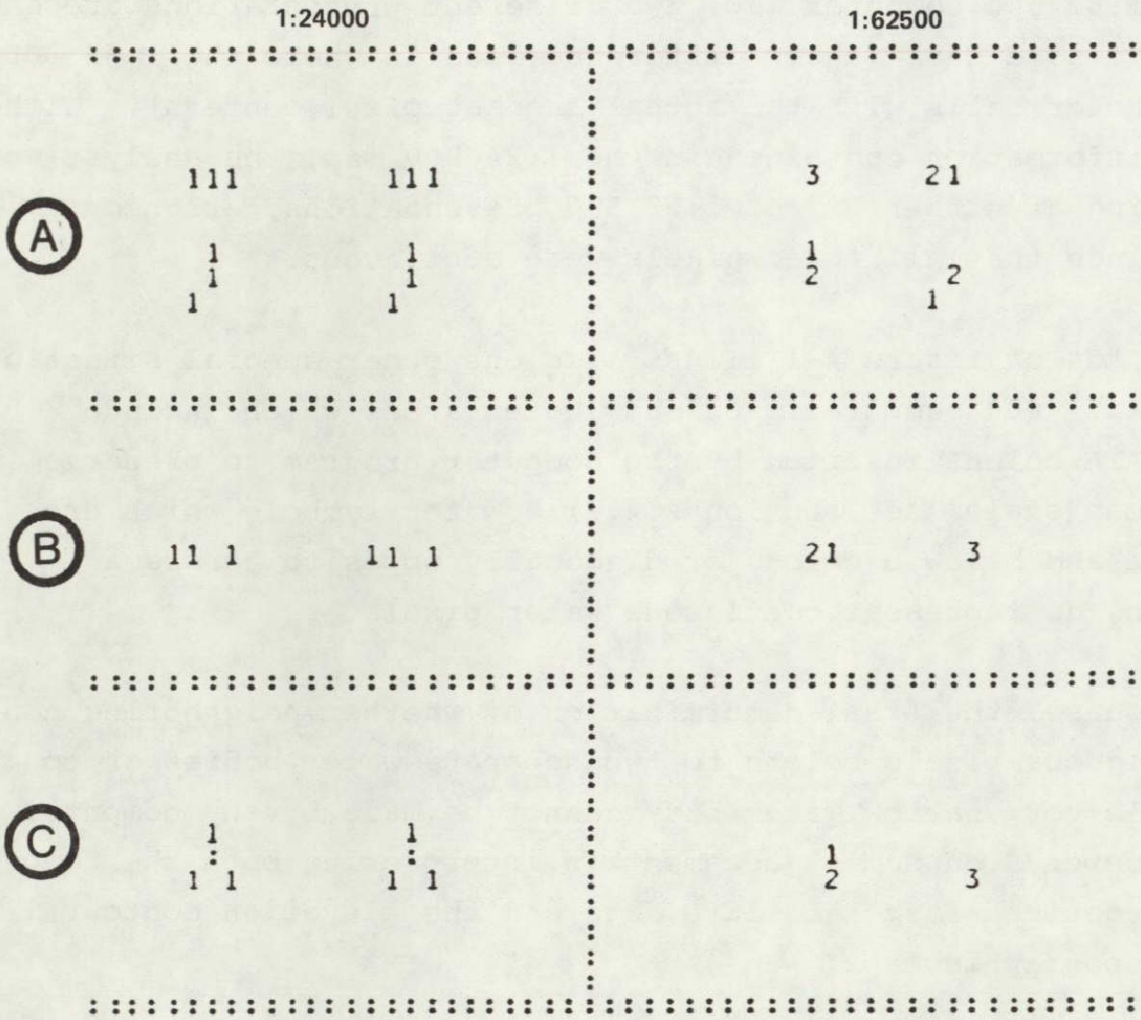


Figure 4.1.– Determination of pixel contiguity from maps at two different scales

4.2 PRELIMINARY EXAMINATION OF THE DATA

In the two following examples, USGS 15-minute quadrangle maps were available, but not 7.5-minute quadrangles. The DAM software printed out a single 1:62 500 map and the four subordinate 1:24 000 maps. Prior to beginning interpretation of the data, the analyst should study the topographic map to familiarize himself with the general nature of the terrain. He should also note the year in which the map was compiled and field-checked, and compare this with the date of the Landsat data. To commence interpretation, the analyst places the topographic map and the corresponding computer-generated map on a light table.

4.3 REGISTRATION TO THE BASE MAP

The computer generated map and the conventional map, overlayed on the light table, are shifted and rotated so that the computer-produced tick symbols match the tick marks on the conventional map.

It is important to note that standard 7.5- and 15-minute USGS quadrangle maps occasionally are extended (usually in the vicinity of international boundaries) to cover areas outside of their normal corner tick marks. In these special cases some corners of the published maps will not correspond to tick marks; the analyst must locate the actual ticks using the annotations in the quadrangle map margins.

Which map should be on top? If there is much apparent surface water, the analyst will probably prefer to have the topographic map on top of the computer-generated map. The elevation contour lines describe the terrain relief, a major consideration in ruling on both terrain shadows and whether or not a water body is natural or impounded. Since the contour lines are printed in a moderate brown color in the standard four color map, these must be viewed directly if detailed study is required. However, if the interpretation can be made with the computer map on top, this arrangement is more convenient for noting conclusions directly on the computer map.

4.4 ANCILLARY MAPS

If published 1:24 000 topographic maps are not available, the 1:24 000 computer-generated maps need not be assembled. However, their units must be available to the analyst since they may be needed to examine apparent water impoundments with better resolution. The 1:24 000-scale computer maps which cover the four 7.5-minute quadrants of a 15-minute map immediately follow the 15-minute computer map. Thus, if the 1:62 500 map is number 015, then map numbers 016-019, inclusive, are the 1:24 000 maps for its four 7.5-minute quadrants. These four 7.5-minute computer maps will all bear the same name (that of the 15-minute quadrangle), but can be distinguished by the latitude and longitude of their origins (southeast corners).

4.5 REJECTION OF SPURIOUS WATER PIXELS

As discussed in section 3.5, inspection of 1:1 000 000 Landsat image or overlay furnished by the regional processing center will quickly show whether the areas to be analyzed are cloud free. If they are clouded, the regional processing center should be asked for alternate data. However, if the clouds are scattered and relatively small the data is marginal and may be useable with caution of two kinds - interpretation of the potential for a water impoundment in the terrain obscured by the cloud itself, and identification of apparently detected surface water which is actually the cloud's shadow. An apparent water body located on the sunny slopes of a mountain without a source watershed may well be a cloud shadow. The cloud itself will be located along the back-azimuth of the sun azimuth, and will be about the same size as the shadow. The distance may be anywhere from about one to three miles (assuming typical cumulous cloud altitudes of 10,000 feet, sun angles from 30° to 60°). If terrain factors suggest possible impoundments in the vicinity of clouds, the data should be rejected.

In the downtown areas of major cities, other spurious indications of water from the satellite data can arise: large groupings of tall buildings will cast shadows on the streets and parking areas to their northwest. If these are extensive enough and dark enough, some of the pixels falling within them will likely be indistinguishable to the Landsat MSS from clear, deep water. Most such misclassifications (as locating a lake in the midst of the New York financial district) can be readily screened out by the analyst. However, some caution is necessary: lakes within urban parks will be properly classified as water (if large enough), and are likely to be man-made (and thus, reportable). Likewise, cooling ponds, settling basins, sludge ponds, acid pits, flooded quarries, abandoned contour strip mines, large flat building roofs with standing water, etc. will be correctly identified as surface water by the computer processing (if large enough), and some of these may be reportable.

Transmission problems with data from the satellite may occasionally result in straight horizontal or vertical lines of apparent water running across an entire scene, particularly along its rightmost edge. These spurious "water bodies" should be ignored.

We now move to an analysis of spurious water detection caused by terrain shadows. Figure 4-2 is the northeast corner of the Van Zandt 15-minute quadrangle map in Whatcom County, Washington, on the western side of the Cascade Mountains. The terrain is extremely rugged and the annual rainfall is substantial. The

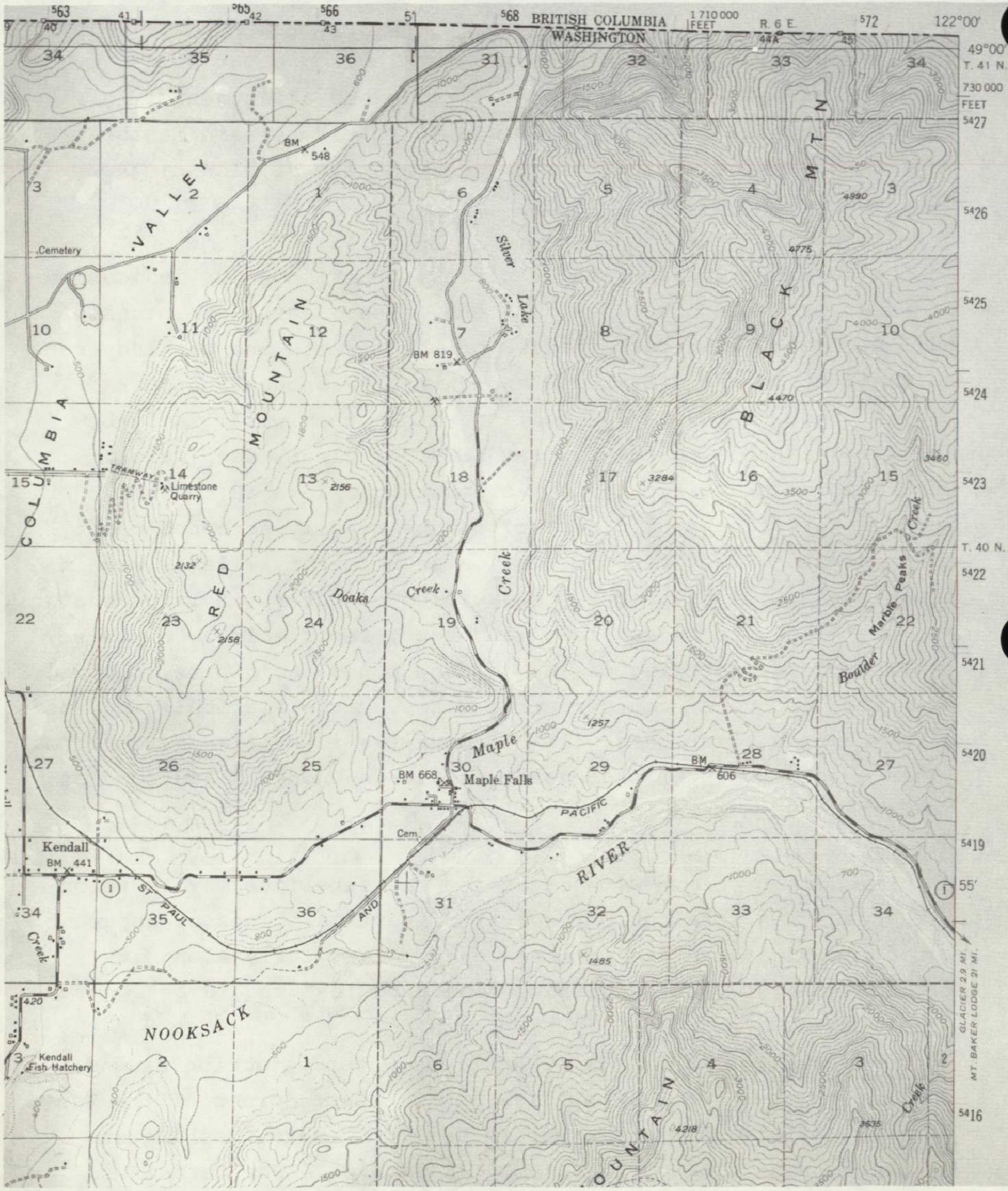


Figure 4-2.— Northeast corner of Van Zandt (Washington) 15-minute USGS quadrangle map.

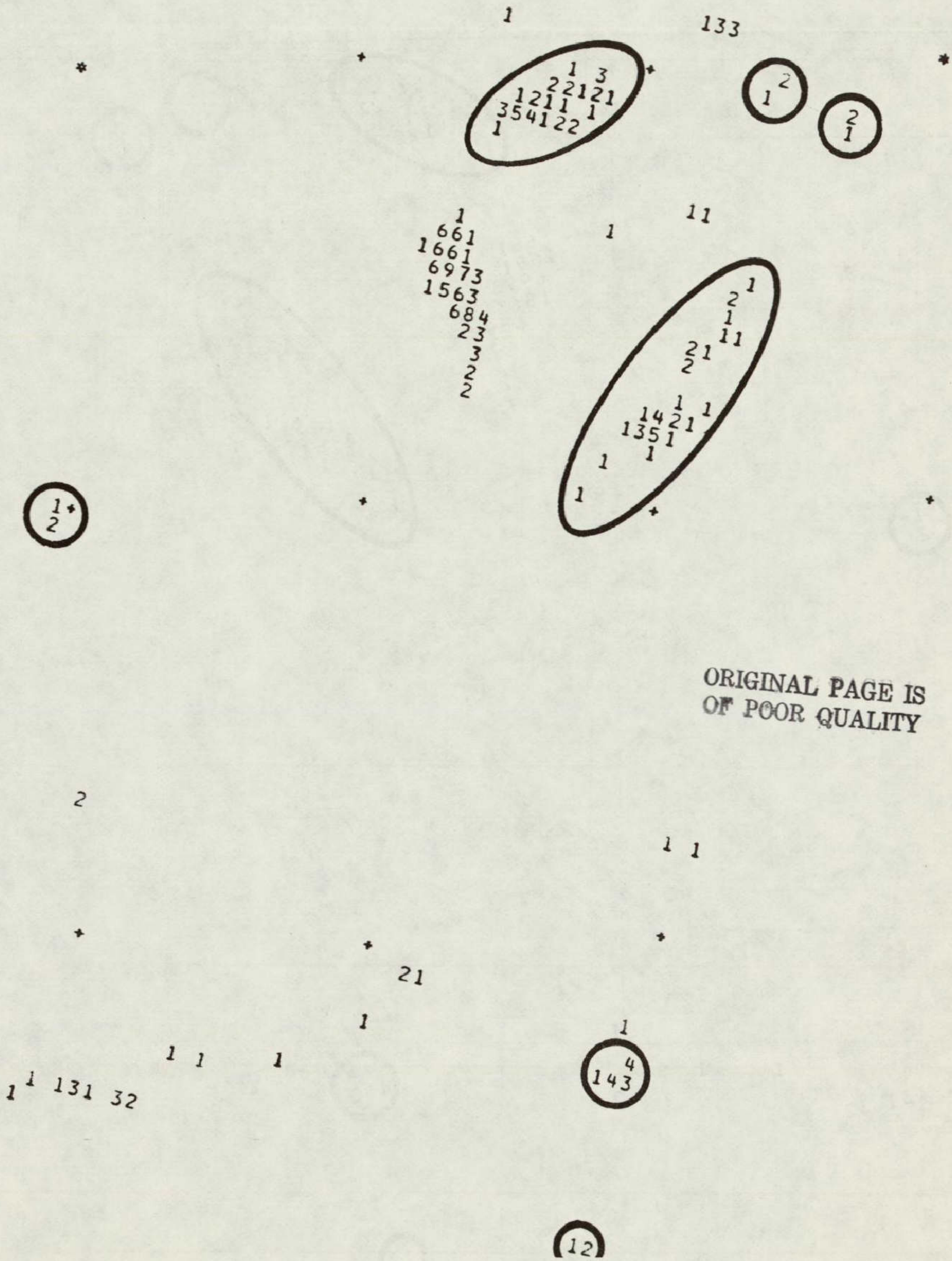


Figure 4-3.– DAM package computer-generated map corresponding to portion of USGS 15-minute quadrangle map shown in figure 4-2.

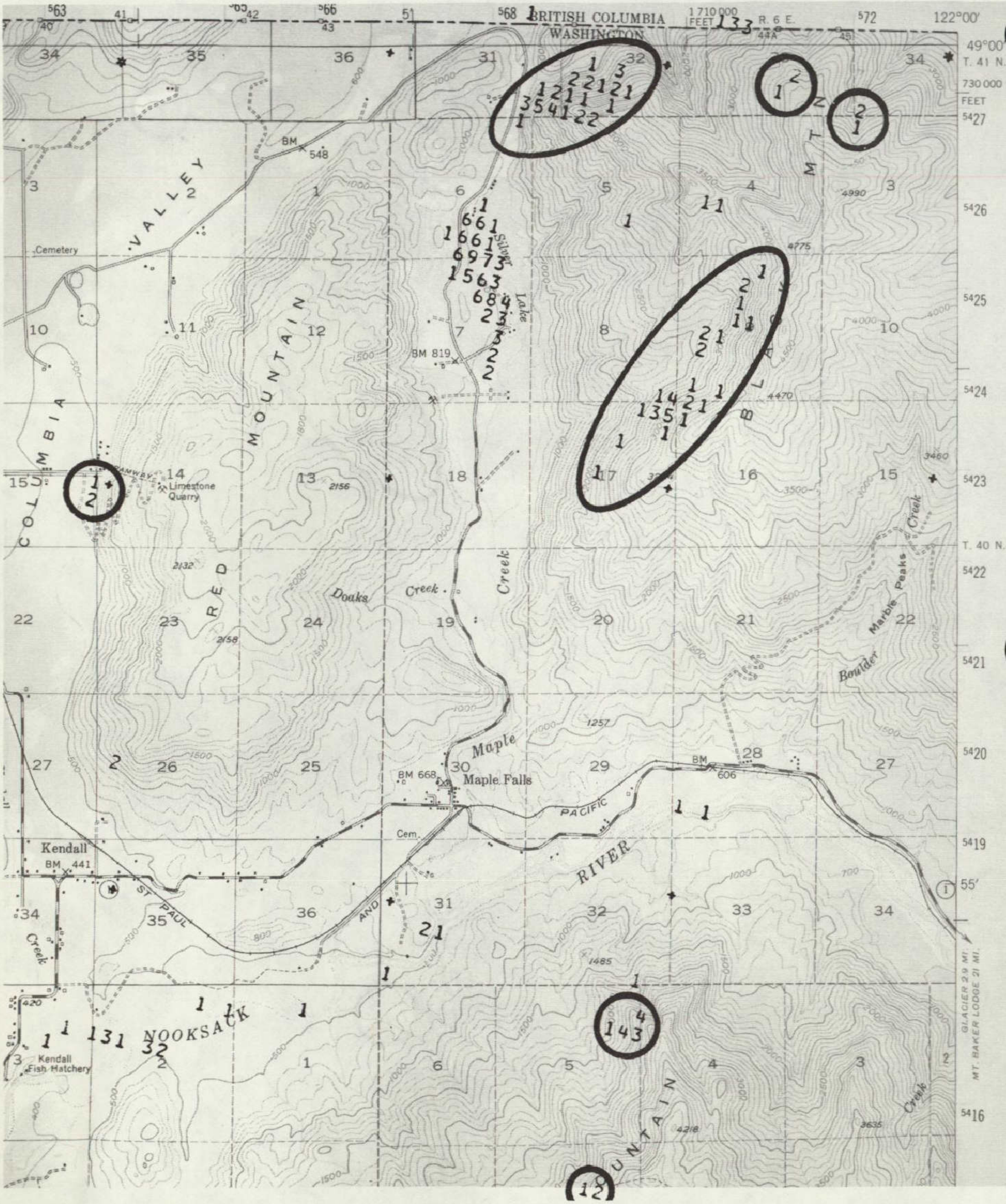


Figure 4-4.– DAM package computer-generated map of figure 4-3 superimposed on portion of Van Zandt 15-minute USGS quadrangle map shown in figure 4-2.

developed areas are confined to the narrow valleys of the Nooksack River and its tributaries. The Canadian border is the top neat line of this map.* Figure 4-3 is the corresponding part of the related computer-generated map. the marginal information on this map indicates that the data was obtained by Landsat-1 on September 18, 1973, and that at the time the data was acquired, the Sun elevation was 39 degrees and the Sun azimuth was 149 degrees. Therefore, some northwest slopes in the steep terrain of Van Zandt area may be shadowed. Examination of figure 4-4 proves this to be so. The water pixels confirmed on the map are (1) a natural lake, Silver Lake; and (2) the meandering portions of the Nooksack River, big enough to contain "pure" water pixels. All of the other "water" pixels which have been circled are clearly not water. They are all located in the steep areas of northwest slopes, or in deep draws or ravines. In 1973, then, there were no impoundments in this area where people would be extremely vulnerable to an unsafe dam. This data set illustrates the analyst's critical role: to add intelligence to the DAM package which the computer cannot.

4.6 SELECTION OF QUALIFYING WATER BODIES

To further illustrate this process of interpreting water bodies, more data is presented from the same Landsat scene. The area selected is 15 nautical miles south of the Van Zandt quadrangle. Figure 4-5 shows the northwest area of the Clear Lake 15-minute quadrangle. The principal features of this region are, again, the Cascade Mountains, but also more lowlands. The developed community of Sedro-Woolley is partially included in the quadrangle

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*In section 4.3 it was suggested that not all USGS quadrangle sheet corners would be at exact multiples of 7.5 minutes or 15 minutes. This sheet is one of the odd ones. It extends to the north about 200 meters beyond the 49th Parallel to the actual United States-Canada border in this area.

Figure 4-5.— Northwest portion of Clear Lake (Washington) 15-minute USGS quadrangle map.

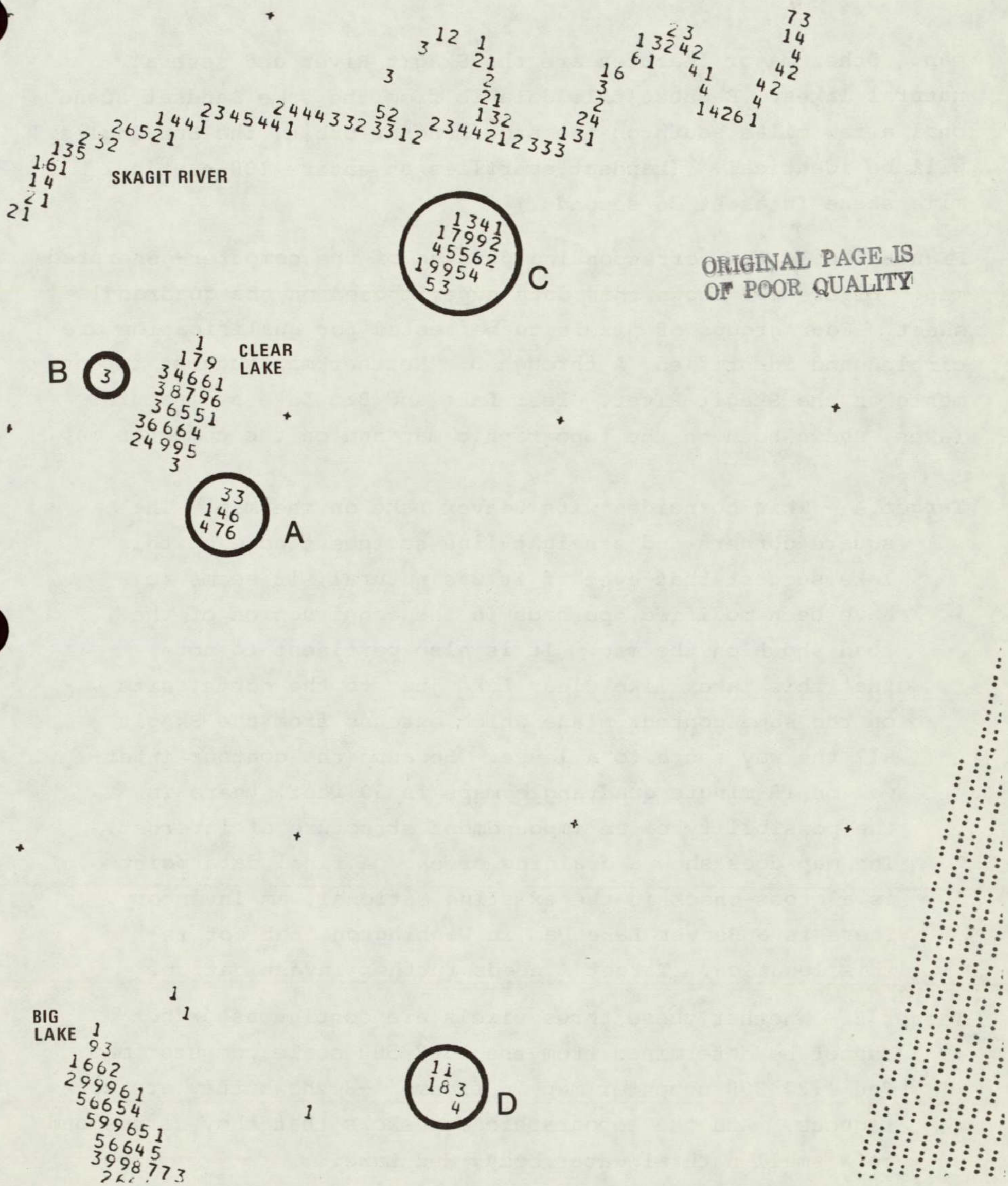

Figure 4-6.— DAM package computer-generated map corresponding to portion of USGS 15-minute quadrangle map shown in figure 4-5.

map. Other major features are the Skagit River and several natural lakes. Because this data is from the same Landsat scene onal a few miles south on the same Landsat orbit, the Sun angles will be identical. (Landsat overflies an entire 100-nautical mile scene in about 26 seconds.)

Figure 4-6 is the corresponding portion of the computer-generated map. Figure 4-7 shows this data superimposed on the quadrangle sheet. Four groups of pixels to be tested for qualification are circled and identified, A through D. Neither map suggest impoundments on the Skagit River. Clear Lake and Big Lake are natural lakes, shown both on the topographic map and on the computer map.

Target A — This coincides with Beaver Lake on the map. The square corners and straight-line southwest edge of this lake suggest that even if it was natural, it seems to have been modified, perhaps in the construction of the road shown on the map. It is also pertinent to note that this lake, like Clear Lake just to the north, sits on the same contour plane which extends from the Skagit all the way south to a levee. Because the contour interval on 15-minute quadrangle maps is 50 feet, there is the possibility of an impoundment structure of interest. The map does show a draining creek. A final data point is a cross-check in the existing National Dam Inventory. There is a Beaver Lake Dam in Washington, but not in this location. Target A needs further investigation.

Target B — Whether these three pixels are contiguous or not cannot be determined from the 1:62 500 scale computer map. The 1:24 000 computer map in figure 4-8 shows they are contiguous. And the topographic map shows that they correspond to a small natural water body, Mud Lake.

Target C — The water pixel count in this large flat area located south of a bluff 300 feet above the Skagit is

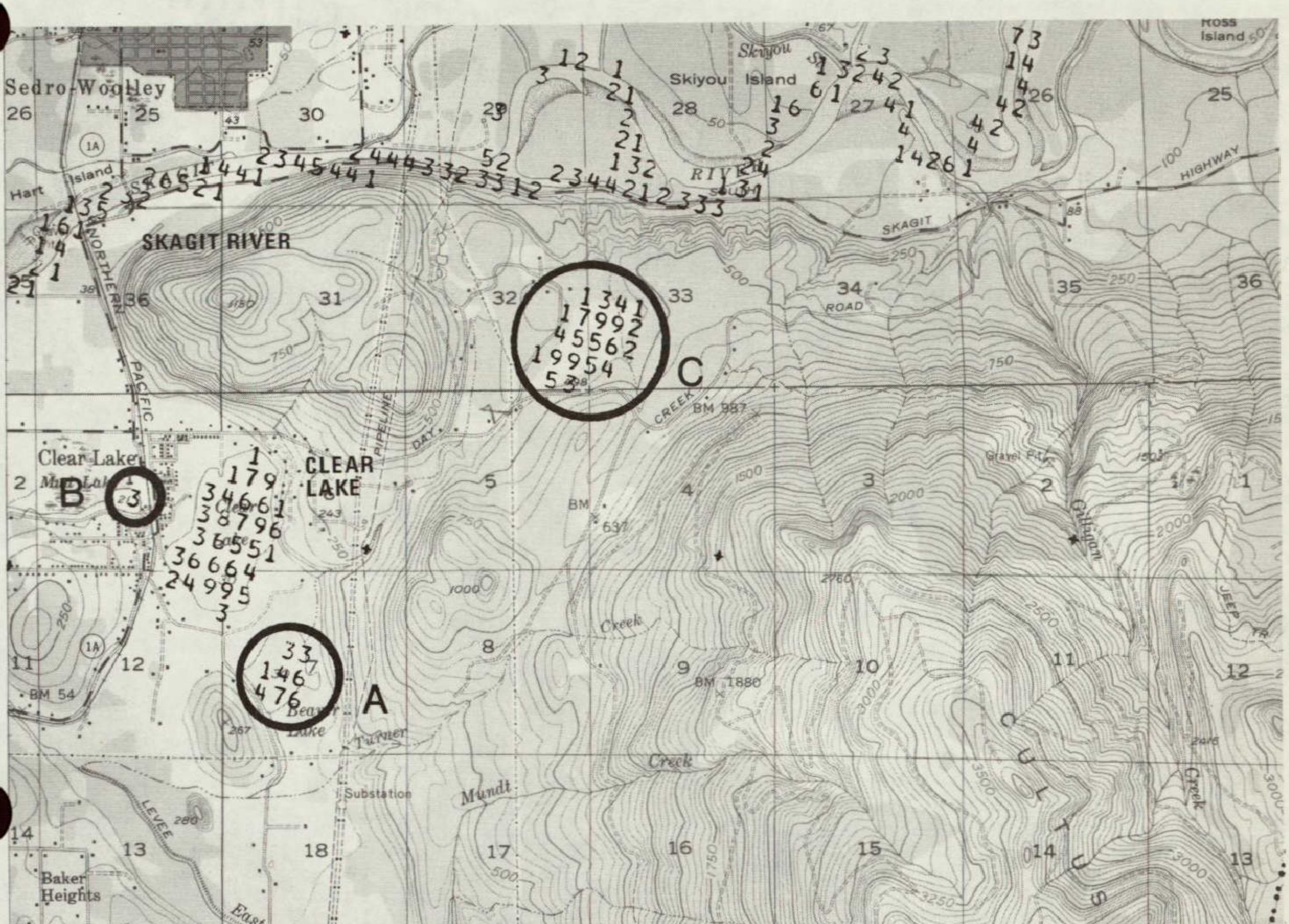

Figure 4-7.— DAM package computer-generated map of figure 4-6 superimposed on portion of Clear Lake 15-minute USGS quadrangle map shown in figure 4-5.

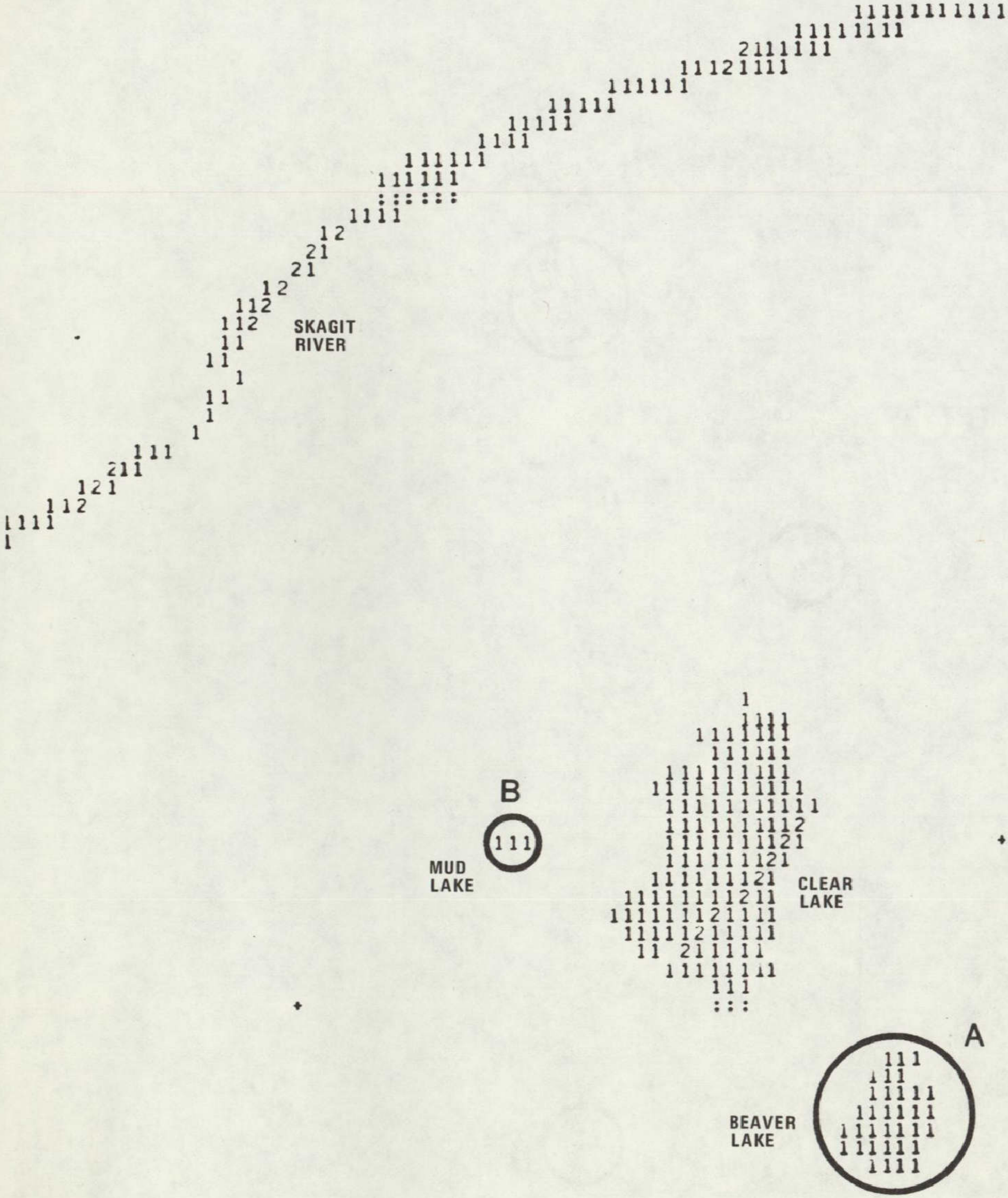

Figure 4-8.— Portion of DAM package computer-generated 1:24 000-scale map corresponding to pertinent area of 1:62 500-scale map depicted in figure 4-7.

95. This represents a water surface of the order of 150 acres, and is not indicated at all on the quadrangle sheet. The marginal data for the quadrangle sheet states that it was based on planetable surveys in 1941, updated by aerial photographs in 1947-48, and field checked in 1956. The satellite data is, of course, 13 years newer. The elevation contours show a watershed quite capable of feeding an impoundment. The area is flat, and the Sun angle is higher than the potential shadowing of the Cultus Mountain system to the southeast. (If this conclusion is challenged, it is easy to construct a terrain profile along the Sun azimuth line from the top of Cultus Mountain, elevation 3950 feet, to the center of the suspected impoundment, about 430 feet, over a distance in excess of 3 miles. The suspect area is not shaded.) The analyst will report this finding as a new impoundment.

Target D — These 18 water pixels are centered on a map feature which indicates an intermittent creek (light blue dashed line along the V-points of the contour lines). The contours in the area of the suspect impoundment are not too helpful and again, they are at 50-foot intervals. It can be seen by examining any well defined stream line that the contour V's point upstream. There is sufficient watershed to feed an impoundment here, which drains to the northwest into Walker Creek. Without any information to the contrary, this target will be reported as a new impoundment. The most probable location of the new dam center can be estimated from the location of the edge pixels on the northern (downstream) region of the detected surface water and reported in the desired coordinate system(s).

Pixels between Big Lake and Target D — Three water pixels were detected to the northeast of Big Lake. The southernmost one appears to be on a plateau with no obvious drainage pattern, in or out. If it is not a false alarm, it is probably a small pond. The same conclusion cannot be drawn about the two northern pixels since they are located on a natural drainage line. The symbols for these two pixels are located in diagonally adjacent print characters. Whether the pixels themselves are contiguous or not can only be determined by referring to the 1:24 000 computer map for this area. This information on water pixels, together with an analysis of the elevation contour lines and drainage from the topographic map, must then be used in determining the number of impoundments present and whether any of them warrant further checking. A final determination can only be made by field work or (perhaps) the use of aerial photography.

4.7 REPORTING CRITERIA

The analyst serves as a filter whenever he eliminates surface water which is obviously not impounded. All of the Skagit River contained in the Clear Lake quadrangle (fig. 4-5) is a case in point. Similarly, natural lakes are of no interest for the NPID program. With the possible exception of Beaver Lake, all of the lakes in the Clear Lake quadrangle are natural. None have either of the conditions which suggest an impounding dam: (1) a pronounced change in terrain elevation along one edge of the water body, determined by analysis of the map contours all around the water, and (2) a man-made shaped edge. The latter is readily discernable in large scale maps. Figure 4-9, a section of the Huntsville (Texas) 7.5-minute quadrangle, offers several excellent examples. Figure 4-10 shows the same map with computer-generated map data superimposed. The map was printed in 1963, based on aerial photographs taken in 1960, with field checks in 1963. The Landsat data was collected on August 29, 1972. Club Lake (1940), Elkins Lake (1920), and Sunset Lake (1951) dams are all on

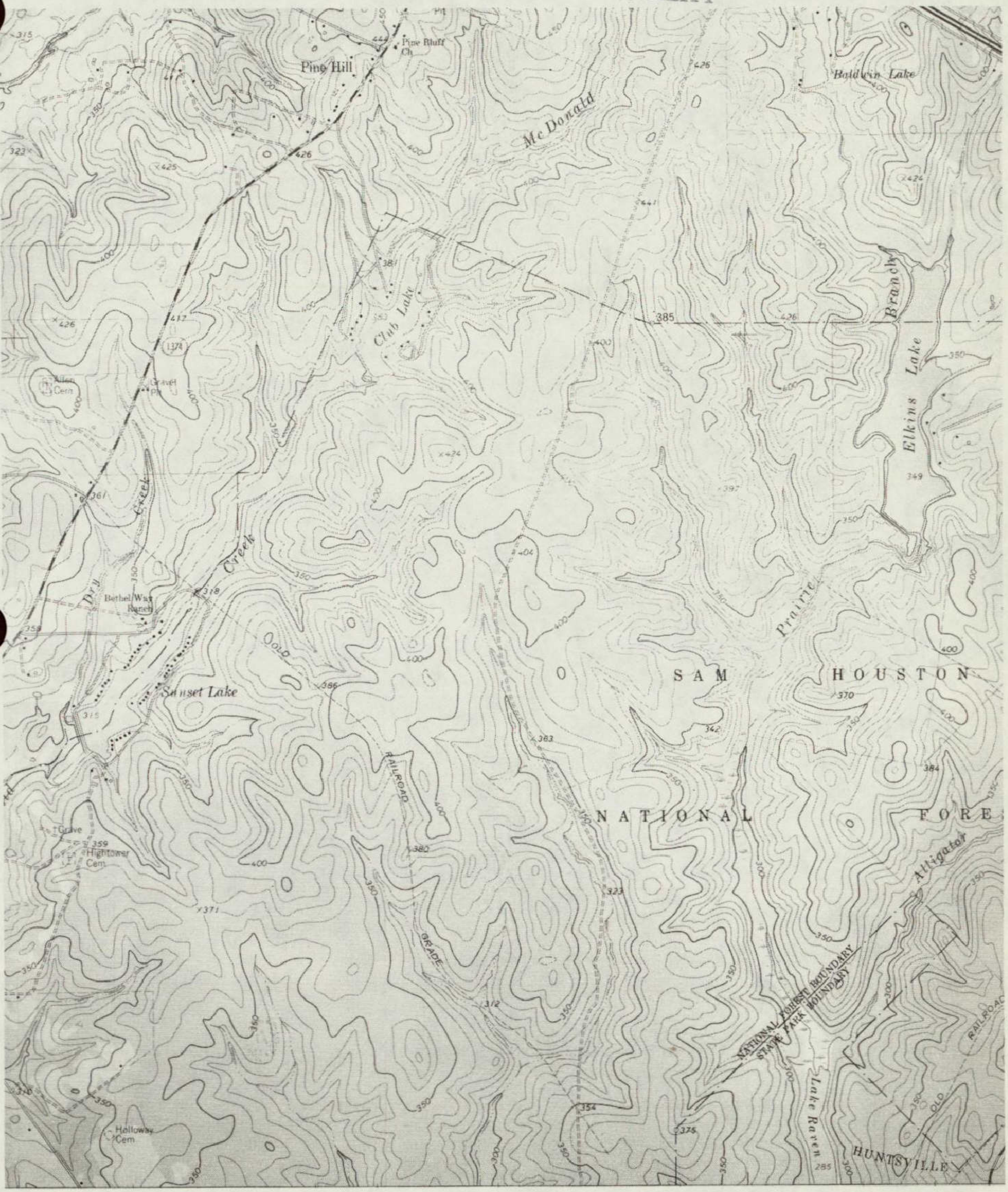

Figure 4-9.— Portion of Huntsville (Texas) 7.5-minute USGS quadrangle map.

Figure 4-10.— Portion of Huntsville (Texas) 7.5-minute USGS quadrangle map with corresponding DAM package computer-generated map superimposed.

the map and confirmed by the satellite data. Baldwin Lake, north of Elkins Lake, seems to have disappeared. On the other hand, it measures only about 150 meters wide in the Landsat scan direction. It is possible that no pure water pixels were seen by the Landsat scanner. Contours on the downstream side of the dam suggest that it is 20 feet or more high. This dam was not included in the 1974 National Dam Inventory for Walker County, Texas. Because the Baldwin Lake impoundment is marginal from both detection and qualification considerations, it should be reported to supervision for a subsequent decision on whether or not to have it field checked. The computer-generated map also shows a new water impoundment, well over ten acres in surface area, on McDonald Creek, 300 meters north of Club Lake. This should be reported.

All of the preceding text calls for the following criteria for reporting information deduced from analysis of both conventional maps and computer-generated maps.

a. Rejected pixels, ruled as not being water, should never be reported.

b. All non-impounded water is excluded from reports

c. Water impoundments which appear in the National Dam Inventory, or the existing map, or both, are reported.

d. Qualifying water impoundments which appear on the published map, but not on the computer-generated map are reported.

e. Qualifying water bodies which appear on the computer-generated map, but not on the published map are reported.

f. Any substantial changes in the areal extent of water bodies should be reported.

4.8 REPORT ELEMENTS

The formats and techniques for consolidating data on dams exist in all Corps of Engineers district and regional offices. It is not the purpose of this manual to codify these existing procedures. The report elements suggested below summarize the information which should develop during the correlation and interpretation of the computer-generated maps and published maps.

a. Name and scale of published map

b. Map origin coordinates (latitude-longitude of the southeast corner of the map)

c. Date of last map revision

d. Date and scene number of Landsat scene

e. Name of dam (if known)

f. Name of river or stream

g. Center of interpreted impounding structure (latitude-longitude)

h. Number of water pixels and/or surface area of impoundment.

i. Is the dam shown on the published map?

j. Is water seen on the published map missing in the computer-generated map?

k. Is the dam listed in the district (regional, national) inventory?

l. Area change: the impoundment shows on both the published maps and the computer-generated maps, but appears to be significantly different in areal extent and/or shape.

4.9 INTERPRETING WITH INADEQUATE PUBLISHED MAPS

There are regions of the United States where only 1:250 000 topographic maps are available. Since these are unsuitable for local terrain analysis, other map sources must be sought. The best substitute will be up-to-date orthophoto maps. If the regional processing center has been provided advance information on the scales and formats of these published maps, then corresponding classification maps (as well as their constituent unpublished 1:24 000 7.5-minute maps) will be generated by the DAM software.

4.10 INTERPRETATION WITH NO PUBLISHED MAPS

Under these circumstances, the interpreter can only report all water bodies detected that do not appear to be large natural water bodies. Because the computer map does not convey small shapes well, there is no way to distinguish between impoundments and small natural lakes. The analyst can only report locations of suspect impoundments for checking by other means.

5. REFERENCES

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