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# LOW-COST COMPUTER CLASSIFICATION OF LAND COVER IN THE PORTLAND AREA, OREGON BY SIGNATURE EXTENSION TECHNIQUES

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# LOW-COST COMPUTER CLASSIFICATION OF LAND COVER IN THE PORTLAND AREA, OREGON BY SIGNATURE EXTENSION TECHNIQUES

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## ABSTRACT

Computer-aided techniques for interpreting multispectral data acquired by Landsat offer economies in the mapping of land cover. Even so, the actual establishment of the statistical classes, or "signatures," is one of the relatively more costly operations involved. Analysts have therefore been seeking cost-saving signature extension techniques that would accept training data acquired for one time or place and apply them to another. Opportunities to extend signatures occur in preprocessing steps and in the classification steps that follow. In the present example, land cover classes were derived by the simplest and most direct form of signature extension: Classes statistically derived from a Landsat scene for the Puget Sound area, Wash., were applied to the Portland area, Oreg., using data for the next Landsat scene acquired less than 25 seconds down orbit. Many features can be recognized on the reduced-scale version of the Portland land cover map shown in this report, although no statistical assessment of its accuracy is available.

The cost of classifying 5,607 square kilometers (2,165 sq. mi.) in the Portland area was less than 8 cents per square kilometer ($0.0788, or $0.2041 per square mile). Besides saving in costs, this and other signature extension techniques may be useful in completing land use and land cover mapping in other large areas where multispectral and multi-temporal Landsat data are available in digital form but other source materials are generally lacking.

## A NEED AND AN OPPORTUNITY

One advantage of using sensor data from Landsat for surveys of land cover is that a large area is covered by a single scene (34,000 $km^2$). Another advantage is that the data are in digital format. These advantages, combined with improved analytical techniques and declining processing costs (Ray, 1975), make Landsat digital data more and more attractive as a primary source for timely surveys of land cover over a large area. When the need for such a survey extends beyond a single Landsat scene, even greater analysis efficiency can be obtained through signature extension. A "signature" is a statistical characterization of the multispectral data at a given time and in a place that represents land cover categories in the area being surveyed. The hypothesis tested in the experiment reported here is that spectral signatures developed for classification of land use and land cover from one Landsat scene can be successfully applied, unaltered, to data for an adjacent scene less than 25 seconds down orbit and having a similar land cover and geographic environment.

As part of the Pacific Northwest Land Resources Inventory Demonstration Project supported by the National Aeronautics and Space Administration (NASA), U.S. Geological Survey (USGS), and the Pacific Northwest Regional Commission, land use and land cover in the Puget Sound region were mapped with the cooperation and assistance of State, regional, county, and city planning agencies by using multispectral scanner digital data acquired from Landsat-1 scene 1690-18245 on June 13, 1974 (Gaydos and Newland, 1976). USGS personnel determined the multivariate spectral signatures through interactive training, clustering, and statistics editing. They used the EDITOR analysis software developed by the Center for Advanced Computation at the University of Illinois for use on the nationwide Advanced Research Projects Agency (ARPA) network of computers (Ray and others, 1975).

## SIGNATURE EXTENSION

An experiment was devised in which land cover signatures for the Puget Sound region were applied to Landsat data for the Portland area, which was in an adjacent scene in the same orbit. The relation of three Landsat scenes to the Puget Sound region and Portland area is shown in figure 1. June 13, 1974 was a clear day in the Pacific Northwest. Landsat scene 1690-18245 over Puget Sound was cloud-free. The scene to the north (1690-18243), reaching well into British Columbia, was also clear of clouds. The scene to the south (1690-18252), over Portland, was clear except for fog covering the mouth of the Columbia River. The southeast corner of the Portland scene was chosen for this experiment in signature extension. This area provided an extreme test of signature extension because it lay furthest from the Puget Sound region. The Portland area scene also included a range of land use and land cover types similar to that in the Puget Sound region.

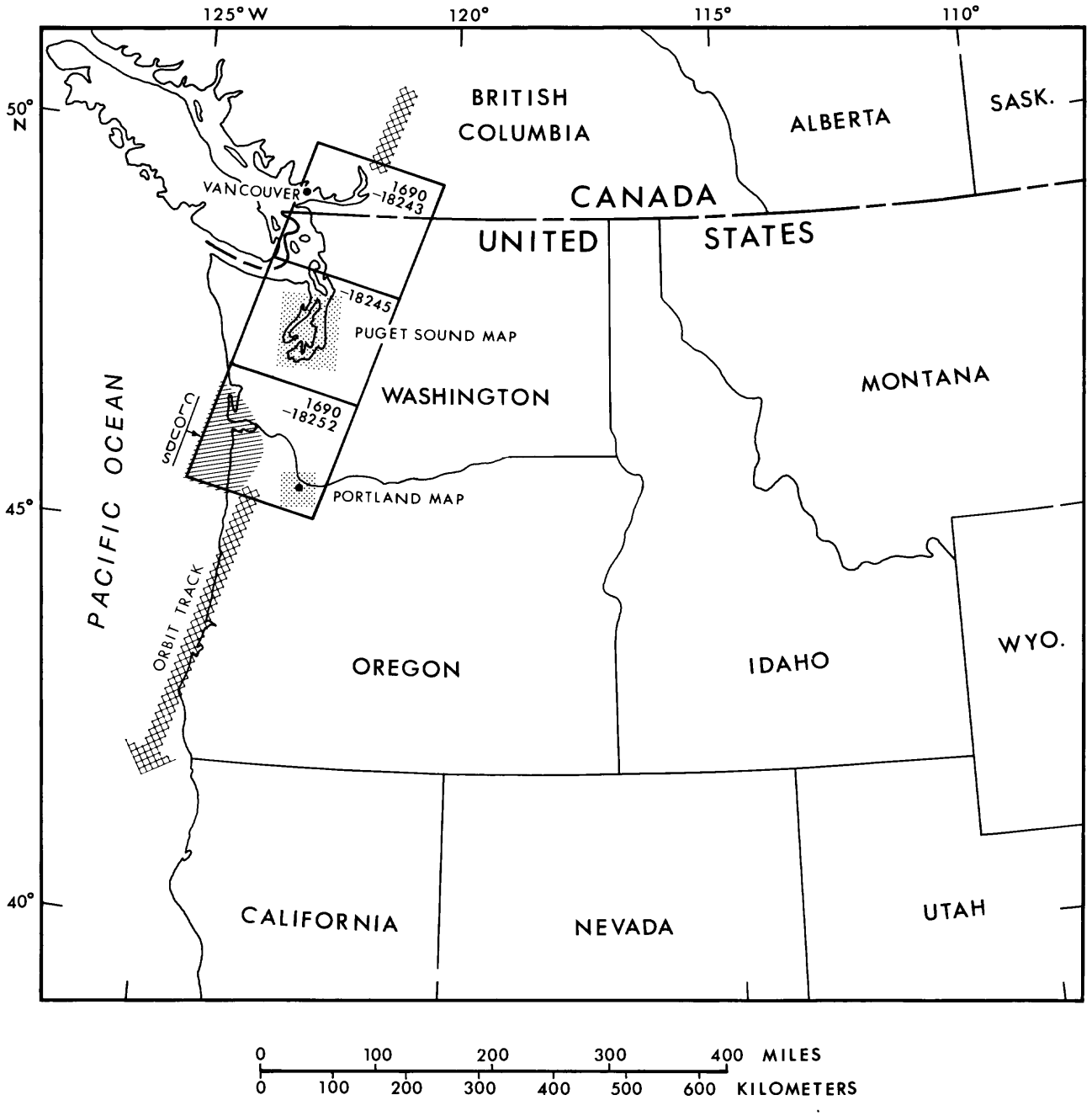


Figure 1.--Landsat scenes and land use and land cover maps of the Puget Sound region and Portland area. The large rectangles represent three successive Landsat scenes acquired approximately 25 seconds apart on June 13, 1974 in a southwesterly orbital pass. The small rectangles denote areas shown on land cover maps of the Puget Sound region and Portland area, Oreg.

A digital map of land cover in the Portland area produced in color by a film recorder is shown in figure 2. The land cover classification data can be reproduced in statistical form on tape and in map form as color or black-and-white prints at different scales.

Computer compatible tapes (CCT's) of the three scenes, and photo prints of bands 5 and 7 at a scale of 1:500,000, were obtained from the EROS Data Center. Fifteen control points identifiable on both the Landsat images and the Portland 1:250,000 scale topographic map were digitized using a TI-733 remote computer terminal and a SAC GP-3 sonic digitzer that accessed EDITOR software installed on a PDP-TENEX computer on the ARPA Network at Bolt, Baranek and Newman, Inc., Boston (fig. 3).[1/] This operation established a first-stage geometric correction by matching line and column coordinates of data cells (picture elements, or "pixels") on the Landsat tape to their corresponding latitude and longitude on the topographic map. The operation also established the parameters necessary for removing skew from the digital data and rotating the data cells into west-east lines and north-south columns (Donovan and others, 1975). The skew and diagonal scan lines result from the rotation of the Earth in relation to the southerly movement of the satellite in an oblique orbit during the time the scanner is acquiring data.

The center of the area to be transformed, as well as its desired size in lines and columns, was determined by use of the Calculate Coordinates command within EDITOR. This command is a computer program that uses a calibration file determined from the control points to translate latitude and longitude coordinates to line and column coordinates. These were used along with the horizontal and vertical skew parameters as input to the skew-transformation software developed by the Center for Advanced Computation and installed on the IBM 360/67 computer at NASA Ames Research Center. The original scene tapes were then read, and the "window" of lines and columns of data for just the Portland area were reformatted onto another tape. The tape contains 1,340 lines and 940 columns and is centered on line 918 and column 2,604 of the original scene (approximately latitude 45° 30' North, longitude 122° 37.5' West).

Spectral signatures from four channels of the Landsat scene for the Puget Sound region were punched on cards and used along with the skew-transformed data for the Portland area. The Portland data were classified on the CDC 7600 computer at the Ames Research Center into 37 spectral classes using a maximum likelihood decision rule. The classification output went to two tapes, one at 800 and the other at 1600 bits per inch (bpi) density.

[1/] Any use of trade names and trademarks in this paper is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

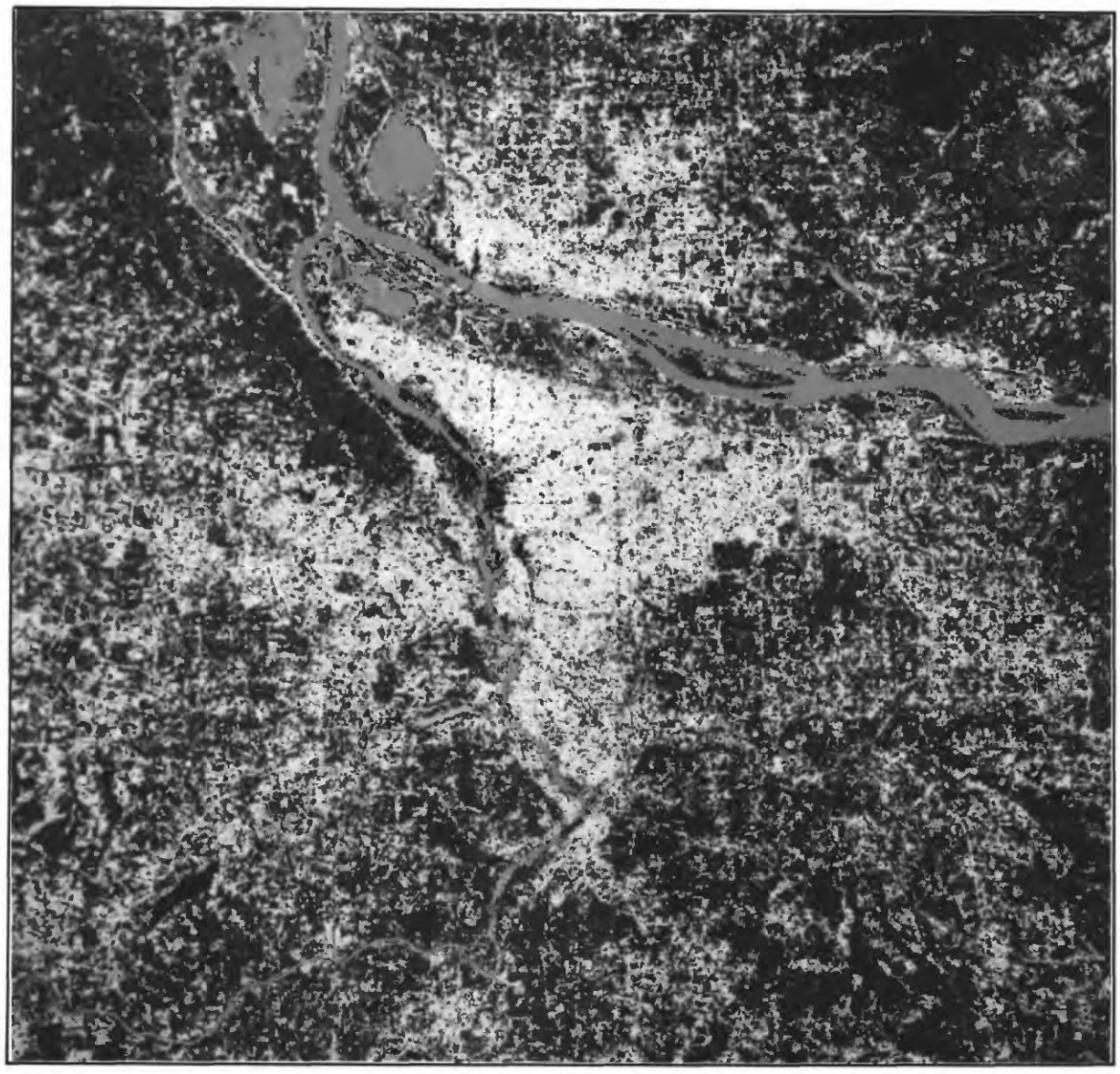


Figure 2.--Land cover map of the Portland area, Oreg., 1974. The map is a reproduction from an original produced in color on a film recorder. Classification was prepared by machine processing of Landsat digital data and by extending signatures for land cover classes from the Puget Sound region, 250 km north.

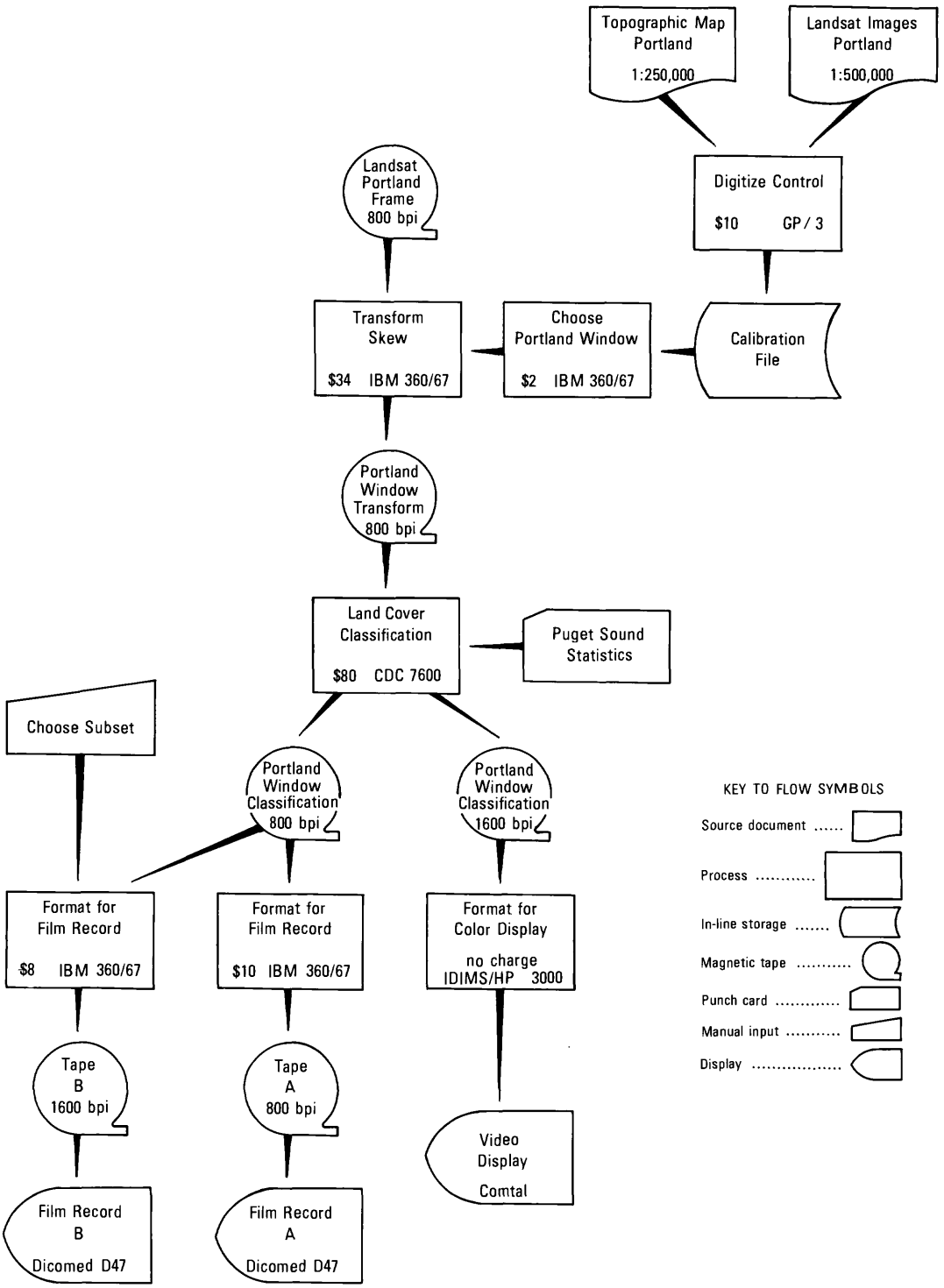


Figure 3.--Procedure for land cover classification of the Portland area, Oreg. by signature extension, including computation costs.

The 800 bpi tape was taken to the IBM 360/67 computer at Ames where it was formatted onto yet another tape in order to display the classified data in 20 colors on the Dicomed D47 film recorder. After a color Polaroid print of the classified data had been viewed, a subset containing only 762 lines and 1,024 columns was selected for expanded display. The program was rerun, and this subset of pixels was displayed again, this time using a matrix of four raster units on the film recorder per pixel of data. Every second line was displayed as six raster units per pixel to adjust for the pixel aspect ratio and thereby maintain a north-south scale equal to the west-east scale.

The 1600 bpi tape was used for interactive viewing of the mapped classes on the ESL IDIMS system at Ames Research Center (ESL, 1976). The tape was copied to a disk on the HP 3000 computer in order to view the map in color on the display screen. Trial combinations of spectral classes, land cover classes, and map symbol colors were displayed and compared with a high-altitude color-infrared air photograph. This procedure made it possible to check that the classification data for the Puget Sound region produced a reasonable mapping of land use and land cover patterns in the Portland area. One combination of classes was selected and the results were recorded in color on the film from which figure 2 was made.

## COST OF LAND COVER CLASSIFICATION

A flow diagram that describes the operations and gives the compilation costs of the land cover classification of the Portland area is shown in figure 3. Table 1 summarizes all costs by category and selected units of area. All the computer programs were run and tapes created in 8 work hours over 3 days' elapsed time. Although a rigorous evaluation of the results has not yet been completed, an examination of the film recorder map products indicates that the Portland land cover classification is realistic and that the concept of land cover classification through signature extension down orbit (or even up orbit) does appear promising. An attempt is now being made to extend signatures to an adjacent scene in an adjacent orbit on the following day. This extension requires an additional operation, the calibration of radiometric data for the two different times.

The costs of these operations do not include the cost of reference materials, such as aerial photography, the cost of developing the original land cover classes for Puget Sound, nor the cost of making a reproduction from the colored land cover map produced on the film recorder. Moreover, the costs do not include the expense of a second-stage geometric correction that would be needed if one were to fit the present film recorder map of Portland land cover to a base map of the area.

Table 1.--Cost of land cover classification in the Portland area by extension of signatures from the Puget Sound region.

| Cost category | Total | Cost ($) per unit area | |
|---|---|---|---|
| | | $km^2$ | $mi^2$ |
| COMPUTATION COSTS ..... | $ 144 | 0.0257 | 0.0665 |
| Digitize control ... $ 10 | | | |
| Choose area ..... 2 | | | |
| Transform skew ..... 34 | | | |
| Classify land cover 80 | | | |
| Create film record A 10 | | | |
| Create film record B 8 | | | |
| MATERIALS COSTS ..... | $ 242 | 0.0431 | 0.1117 |
| Landsat tapes ..... $200 | | | |
| Landsat prints ..... 16 | | | |
| Topographic map .... 1 | | | |
| Blank Tapes ..... 25 | | | |
| LABOR COSTS ..... | $ 56 | 0.0010 | 0.0259 |
| 8 hours at $7 per hour .....$ 56 | | | |
| TOTAL COSTS ..... | $ 442 | 0.0788 | 0.2041 |
| Total area classified: | 1,385,560 acres<br>1,259,600 pixels | | 5,607 $km^2$<br>2,165 $mi^2$ |

## AVAILABILITY OF DATA

A color photo print of the Portland land cover classification, with only the first-stage geometric correction, can be ordered through the National Cartographic Information Center (NCIC). USGS is preparing experimental interim map and statistical land cover products for the Puget Sound region using machine-processed Landsat data for 1975, a year later than the data used in the Portland signature extension experiment.

## ACKNOWLEDGMENTS

Willard Newland of USGS developed the spectral signatures for the Puget Sound region. Margaret Elliott and James Wray of USGS planned the illustrations. The NASA Ames Research Center, Moffett Field, Calif. provided computation facilities.

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