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Two standardized land classification systems designed for use with remote sensor data were studied comparatively. One of the classification systems is proposed for review and testing in U. S. G. S. Circular 671 (Legend I) (Anderson *et al.*, 1972); the other is a hierarchial legend system in use since 1968 (Legend II) (Poulton, 1972). Both of these classification systems could be adopted for use by federal, state, and local agencies. Both are proposed for general use throughout the United States.

The basic objective of this study was to determine through multistage sampling and photo interpretation testing, the advantages and disadvantages in each of these two land-use and resource classification systems. Each legend system was tested in terms of photo identification accuracy, ease of use, and completeness of land-use and resource categories.

First level legend units from the two systems were mapped on a State of Oregon ERTS-1 space photo mosaic. The mapping effort was verified by a ground truth check. The results showed that 90 percent of the primary categories under Legend I, and 94 percent of the primary categories under Legend II were correctly interpreted.

Second level legend units were mapped on high flight color infrared photography (scale 1:120, 000) taken over Marion County, Oregon. Results showed 88 percent of the secondary categories under Legend I, and 83 percent of the categories under Legend II to be correctly interpreted.

A photo interpretation test was performed with a total of 15 different interpreters. The test involved identification of previously mapped categories on ERTS-1 and high flight imagery; and photographs taken of land-use subjects at ground level. Results of the test showed interpreters generally chose similar or analogous categories from the two systems when classifying test sites.

Test sites classified by the interpreters and compared against a key were statistically analyzed by analysis of variance. The analysis showed no significant differences in the ability of interpreters to classify land-use subjects from either legend system. Extreme variation in the ability of interpreters to identify test sites existed between experience groups. Individuals with the most prior photo and land-use interpretation experience consistently identified test sites more accurately on ERTS-1 and high flight photos than the less experienced interpreters.

A consolidated legend system for use with remote sensing data has been suggested. This legend draws together categories under Legends I and II that have the highest probability of being identified on space and high flight imagery, and which provide the most information at first and second levels of classification.

A Comparative Study of Two Land Classification Systems for Use With Remote Sensor Data

by

Kirk Cole Mc Daniel

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COMPARATIVE STUDY OF TWO LAND CLASSIFICATION SYSTEMS FOR USE WITH REMOTE SENSING DATA

INTRODUCTION

Historically, the collection, compilation, and interpretation of data on use of land in the United States has proved invaluable in the study of land-resource problems. With the recent awareness, by a part of the population, that wildland resources are limited there has been an increasing demand for land-use planning and management. Today, the distinction between urban planning and resource planning is no longer valid--the two are inextricably related. This awareness has stimulated the integrated approach to land-use planning that "... reflects concern for the resources, the people, and their interactions ..." (Gates, 1972).

With recent developments in data-processing and remote-sensing technology, land-resource professionals now have a new tool to aid them in land-use planning and decision-making processes. Small scale space and high flight imagery now provide the manager a synoptic view of large areas of the land mosaic that cannot be fully appreciated when directly on the ground. As urban planners and resource managers continue to make use of aerial imagery in classifying large areas of land it has "... become imperative that a common system be developed for the characterization of both the natural and the altered features of landscapes . . ." (Poulton, 1972).

The classification of land-use and resource information obtained from remote-sensing techniques have generally been performed by special interest groups. This is not unexpected as each land classification system is developed to suit specific needs of the user, and few users will be satisfied with a system that does not meet their objectives. Nevertheless, there is the need, at least for the purposes of classifying land use at the national and state level, for a conforming legend system compatible with the use of remote-sensing techniques.

Two separate land classification systems for use with remote sensing aids have been developed to meet this need. One classification system is proposed for review and testing in U. S. G. S. Circular 671 (Anderson _et al._, 1972); the other is a hierarchial legend system in use since 1968 (Poulton, 1972). Both of these classification systems could be adopted for use by federal, state, and local agencies. Both are proposed for general use throughout the United States.

The basic objective of this study was to determine through multistage sampling and photo interpretation testing, the advantages and disadvantages in each of these two existing land-use and resource classification systems. Each legend system was tested in terms of photo identification accuracy, ease of use, and completeness of land-use and resource categories. Specifically, each of the two classification systems were evaluated by the following criteria:

1. A minimal level of accuracy from photo interpretation with which each system can be used.
2. Repeatable and repetive results in photo interpretation from one interpreter to another with the two systems.
3. The adaptability and usability of each classification system for use in the State of Oregon.

LITERATURE REVIEW

Land Classification and Remote Sensing

Several land classification systems designed for use with remote sensing techniques have been developed in recent years. In New York state, a classification system designed for use with aerial photography at the 1:24, 000 scale is being utilized in an inventory of statewide land and natural resource uses (New York State Office of Planning Coordination, 1969). With the use of aerial photographs, the New York State Office of Planning Coordination is able to monitor changes and upgrade their inventory by obtaining new imagery over time. This is necessary, as one detailed inventory will be adequate for only a relatively short period of time. Land-use patterns change along with demands for natural resources, which in turn affect the development of land-use patterns (Anderson et al., 1972).

In Canada a land inventory and comprehensive survey of "... land capabilities and use for various purposes ..." is being conducted (Dept. of Forestry, Can., 1965). The survey includes classifying rural land according to 1) its physical capability for use in agriculture, forestry, recreation and wildlife management; 2) the present land use in these areas; and 3) the socio-economic factors relative to their present use. In this survey, the use of airphotos and airphoto interpretation techniques play a strong role in the collection and processing of land-use data into map and computer compatible form.

For the most part, earlier systematic attempts to design schemes for classifying land in this country stemmed from the desire to better understand the distribution and production of agriculture commodities (Anderson, 1972). During this period the scale of aerial photos used by the government agencies was generally less than the 1:20, 000 ratio used by the U. S. Department of Agriculture. While much of the interest in land use in the 1930's and 1940's was focused on rural areas, attention to the dynamic meeting place of rural-urban oriented land uses became a focal point for important issues in the 1950's and 1960's (Anderson, 1972). In the late 1960's and early 1970's new high altitude and space photography became available. This photography, taken from high altitude platforms provides the opportunity to examine larger land areas at scales of 1:40, 000 to 1:100, 000 or smaller (Hardy, 1972).

Early attempts at identifying earth surface features from space photos were somewhat restricted by the scale and indifferent resolution of the imagery. Aldrich _et al_. (1969), found that though there were resolution difficulties, the forest-tundra ecotone in Canada could be differentiated by mapping on weather satellite imagery.

Rudd and Highsmith (1970), in an early attempt to simulate the potential future of orbital imagery for land-use mapping created a 1:400, 000 scale photomosaic of part of northwest Oregon. They developed a generalized land classification system suitable for use with this scale imagery and were able to map most of their categories on the photomosaic.

Anderson and Place (1972), found that land-use maps in the Phoenix, Arizona, area could be compiled at a scale of 1:250, 000 from Apollo 9 and aircraft imagery. They felt orbital imagery, used in conjunction with other sources of map information, could enhance the collection and analysis of land-use information. In their development of a classification scheme for use in the Phoenix Pilot Project they felt there was a further need for agreement on a framework of a land-use classification system for use with orbital imagery.

Poulton et al. (1970) reflecting on the need for a universal land-resource classification system for use with space imagery wrote:

> "In the interest of a fully effective earth resource observational satellite system, some one group should develop and publish the framework for the broader (resource classification) hierarchial levels on a continent-wide basis. The possibility exists that a successful system developed for one continent would be global in applicability or at least serve as a model for adaptation to other continents."

The philosophy exemplified in the preceding two paragraphs by Anderson and Poulton initiated the need to develop the two land-use resource classification systems examined in this study.

The Need for Standardization

Several land classification systems have been developed which because they have been designed to meet specific needs, or because they can not be adapted for use with aerial photography, are unsuited for the purposes of a standardized classification system for use with remote sensing data (Nunnally and Witmer, 1970). Probably the best example in trying to establish a standardized classification system comes from the Standard Land Use Coding Manual prepared by the Urban Renewal Administration and Bureau of Public Roads (1965). This system was developed primarily for use in urban areas and for planning purposes. The classification consists of 76 first and second digit categories and nearly 1, 142 categories throughout a four digit system. While many of the categories could be incorporated into a classification system for use with remote sensors, it is generally "...unsuited for a remote sensing operation..." (Shelton, 1968).

The need to develop a standardized land classification system was illustrated by Gerlach (1972), when he found it to be a "painful experience" gathering nonconforming pieces of land-use information from local, regional, and state agencies; at different dates, scales, and incompatible categories for a National Atlas of the United States. He suggested that federal agencies adopt a land-use classification system receptive to data inputs from remote sensors on high altitude aircraft and satellite platforms to obtain frequent synoptic overviews of the entire country. Such a system he felt would need to contain a framework whereby "... broad categories of more detailed land use studies by regional, state, and local agencies can be aggregated upward for more generalized smaller scale use at the national level...."

Clawson (1972), in reference to the relatively poor quality of land-use data in this country and the role that a common classification system for use with remote sensing might play in the future stated:

> "Remote sensing is a very valuable source of information about land use, but it is only one of several sources that may be used. There is an enormous range of interest in land use, thus an effectual land use classification system must provide easy accessibility to data and also considerable flexibility for use. If an overall system can be set up which is flexible and usable at different levels, a significant contribution will have been made to the collection and handling of land use information."

According to Anderson (1972), once a classification system has been decided upon, three basic rules or standards serve to guide its creation and use. The classification should be 1) comprehensive, 2) allow discreet assignment of any item, and 3) provide a unique description of each item. In addition, Hardy (1972), felt that in devising a system for use with remote sensing, the details about what information can be gotten from airphotos, rather than designing first a comprehensive and complete land-use classification, is necessary.

The future need for a standardized land classification system for use at the state and national level is demonstrated by a bill presently before the United States Senate. This bill, commonly known as the Jackson Land Use Bill or S268, authorizes the Secretary of the Interior to:

1. Make grants to assist the States to develop and implement state land-use programs,
2. coordinate Federal programs and policies which have a land-use impact,
3. coordinate planning and management of Federal lands and adjacent nonfederal land, and,
4. establish an Office of Land Use Policy Administration in the Department of Interior.

Such a bill would have a far ranging impact on the way state and national land-use information is currently being processed. For the new Office of Land Use Policy Administration would be delegated the responsibility to "... develop standard methods and classification for the collection of land use data." It seems logical that remote sensing could play a strong role in compiling, and in the future monitoring such data.

REVIEW OF THE TWO LAND CLASSIFICATION SYSTEMS

Two separate land classification systems designed to be used with remote sensing techniques and proposed for use at the national and state levels are evaluated in this study. The classification of "land uses" with remote-sensing aids is the basis of the legend system proposed in U.S. Geological Survey Circular 671 (Anderson et al., 1972). In a classification system in use by Poulton (1972) and his associates, there is a distinction made between "land use" and what is termed as "earth surface features." In each of these two classification systems it is of importance to note that land cover is the primary basis for categorization at first and second levels, and the activity dimension of land use appears in the lower levels. The concept of land cover has been described by Burley (1961) as "... the vegetational and artificial constructions covering the land surface...."

Review of the Land-Use Classification System Proposed in U.S. Geological Survey Circular 671

This classification system reviewed by Anderson et al. (1972), and heretofore referred to as Legend I, is a proposed framework for a national land-use classification. The classification system is a multi-level scheme with generalized first and second levels that are intended to be receptive to data from instrumented satellite and high-altitude aircraft platforms. It is intended that the upper two levels in the proposed legend system remain "concrete" for use by federal and state agencies. Subsequent levels have not been specified and are meant to remain "open-ended" so that local interest may develop a more detailed land-use classification to meet their own needs.

In the development of this classification system, it was intended that the more generalized first level categories be delineated or interpreted by satellite imagery with very little supplemental information; and second level categories be interpreted from high-altitude and satellite imagery combined with topographic maps.

A detailed description and definition of each category is given in Anderson et al. (1972). The proposed Legend I land-use classification system for use with remote-sensor data includes:

LEGEND SYSTEM I

Level 1	Level 2
10 Urban and Built-up Land	11 Residential 12 Commercial and services 13 Industrial 14 Extractive 15 Transportation, communication, utilities 16 Institutional 17 Strip and clustered settlement 18 Mixed 19 Open and other
20 Agricultural Land	21 Cropland and pasture 22 Orchards, groves, bush fruits, vine-yards and horticultural areas 23 Feeding operations 24 Other
30 Rangeland	31 Grass 32 Savannas (palmetto prairies) 33 Chaparral 34 Desert shrub
40 Forestland	41 Deciduous 42 Evergreen (coniferous and other) 43 Mixed
50 Water	51 Streams and waterways 52 Lakes 53 Reservoirs 54 Bays and estuaries 55 Other
60 Nonforested Wetlands	61 Vegetated 62 Bare
70 Barrenland	71 Salt flats 72 Beaches 73 Sand other than beaches 74 Bare exposed rock 75 Other
80 Tundra	81 Tundra
90 Permanent Snow and Icefields	91 Permanent snow and icefields

Review of Poulton's Integrated Legend System

According to Poulton (1972), this legend system utilizes a hierarchical classification scheme that treats land-use and resource analysis in an ecological context. This system, heretofore referred to as Legend II, provides treatment of natural vegetation, and land uses that have altered the natural landscape. The hierarchical classification scheme is a computer compatible decimal system and is designed to allow broader classes to interpretation by space and high flight imagery. Subordinate classes are subsets of the higher hierarchical levels.

Development of the classification system was begun in 1968 by a group of investigators in the Rangeland Resources Program at Oregon State University. Since this time, the legend classes have been revised and refined. The urban-industrial-transportation legend classes were adapted from the U.S. Department of Transportation Standard Land Use Coding Manual (1969).

First and secondary levels in this integrated natural resource and land-use legend system are as follows:

LEGEND SYSTEM II

Level 1	Level 2
10 Barren Land	11 Playas, dry or intermittent lake basins
	12 Aeolian barrens
	13 Rocklands
	14 Shorelines, beaches, tide flats
	15 Badlands (barren silts and clays)
	16 Slicks (saline, alkali, non-playa)
	17 Mass movement
	18 Man-made barrens
	19 Undifferentiated complexes
20 Water Resources	21 Ponds, lakes and reservoirs
	22 Water courses
	23 Springs, seeps, and wells
	24 Lagoons and bayous
	25 Estuaries
	26 Bays and coves
	27 Oceans, seas and gulfs
	28 Snow and ice
	29 Undifferentiated complexes
30 Natural Vegetation	31 Herbaceous types
	32 Shrub-scrub types
	33 Savanna-like types
	34 Forest and woodland types
40 Agricultural Land	41 Cover crops, field and seed
	42 Row crops, vegetable
	43 Orchard and vine crops, fruit, nut
	44 Animal agricultural facilities (large animal)
	45 Animal agricultural facilities (small animal)
	46 Pasture (improved on farm)
	47 Horticultural specialties
	48 Nonproducing fallow, transition, or entrapped land
	49 Other agricultural uses (buildings, etc.)

LEGEND SYSTEM II--Continued.

Level 1	Level 2
50 Urban and Industrial	51 Residential
	52 Business and industry
	53 Transportation
	54 Power and fuel transmission
	55 Resource extraction (mines, quarries)
	59 Undifferentiated urban (510-520 complexes)

METHODS

Operationally there were five basic steps to this study: (1) preparatory work, (2) photo interpretation, (3) ground truth, (4) photo interpretation testing, and (5) interpretation and analysis of the results (Figure 1).

Preparatory Work and Preliminary Consideration

Preparation of and familiarity with the necessary photo aids is the primary step to any photo interpreted land-use resource mapping. Materials used in mapping should be readily available and designed specifically for the task at hand. A work area should be designed so as to be conducive to the required concentration needed in photo interpretation. Fortunately, such an environment and most of the photo interpretation tools required for the study were available and were provided by the Oregon State University Environmental Remote Sensing Application Laboratory (ERSAL).

Prior to the actual interpretation job, there is a need to standardize the guidelines that will be used in mapping. Guidelines which should be considered according to Poulton and Faulkner (1973) are: (1) where complexing is necessary, each mapping unit should be limited to no more than two components; (2) delineate pure types wherever possible; and (3) treat units that are too small to be mapped separately and which comprise less than ten percent of the mapped area as inclusions. During the initial interpretation job in this study an attempt was made at mapping only pure types.

In this study criteria used in setting a standard for the scale and size of delineated units were principally those as outlined in U. S. Geological Survey Circular 671 (Anderson *et al.*, 1972), with some adjustment as deemed necessary.

The basic minimum land surface area mapped on the space imagery was 640 acres; while the minimum persistently water covered areas were at least 1/8 mile wide or 160 acres in extended cover. The minimum land and water surface areas mapped on the high flight photos were at least 40 acres in areal extent, or if linear, at least 1/8 mile wide.

Photo Interpretation Phase

It was the intent that information obtained during this photo interpretation phase would aid in evaluating the interpretability of each classification level with its respective intended source of imagery. Separate procedures were followed in mapping upon space imagery, and high flight photos respectively (Figure 2).

Mapping level 1 on ERTS-1 space imagery

In order to map level 1 from each of the two proposed classification system, space imagery received by the Earth Resources Technology Satellite-1 (ERTS-1) was utilized. Twenty-four 9"x9" image frames (scale 1:1, 000, 000) cover the entire State of Oregon (Figure 3). For purposes of mapping, black and white transparencies, both positives and negatives, including spectral bands 1, 2, 3, and 4 were used. These spectral bands, received by a multispectral scanner system aboard ERTS-1, refer to optical energy detected in four visible spectral bands from 0.5 to 1.1 micrometers (ERTS-1 Data User Handbook, 1972). Each of these spectral bands provide unique and different information about various land-use types. For example, natural vegetation appears most distinctive on band 2 imagery; while barrenland and water resources are generally easiest to detect from band 4 imagery. In addition, when available, color reconstituted ERTS-1 photo images, both positive and negative, aided in making the interpretation. All imagery interpreted was taken between the months of July and October, 1972. This was more a matter of imagery availability rather than choice. For the most part imagery received during winter months was more than 50 percent cloud covered, or it had poor resolution due to development processing.

Land-use resource categories from each of the legend systems were mapped on separate acetate overlays laid over the original 9"x9" image frames. The only supplemental information used

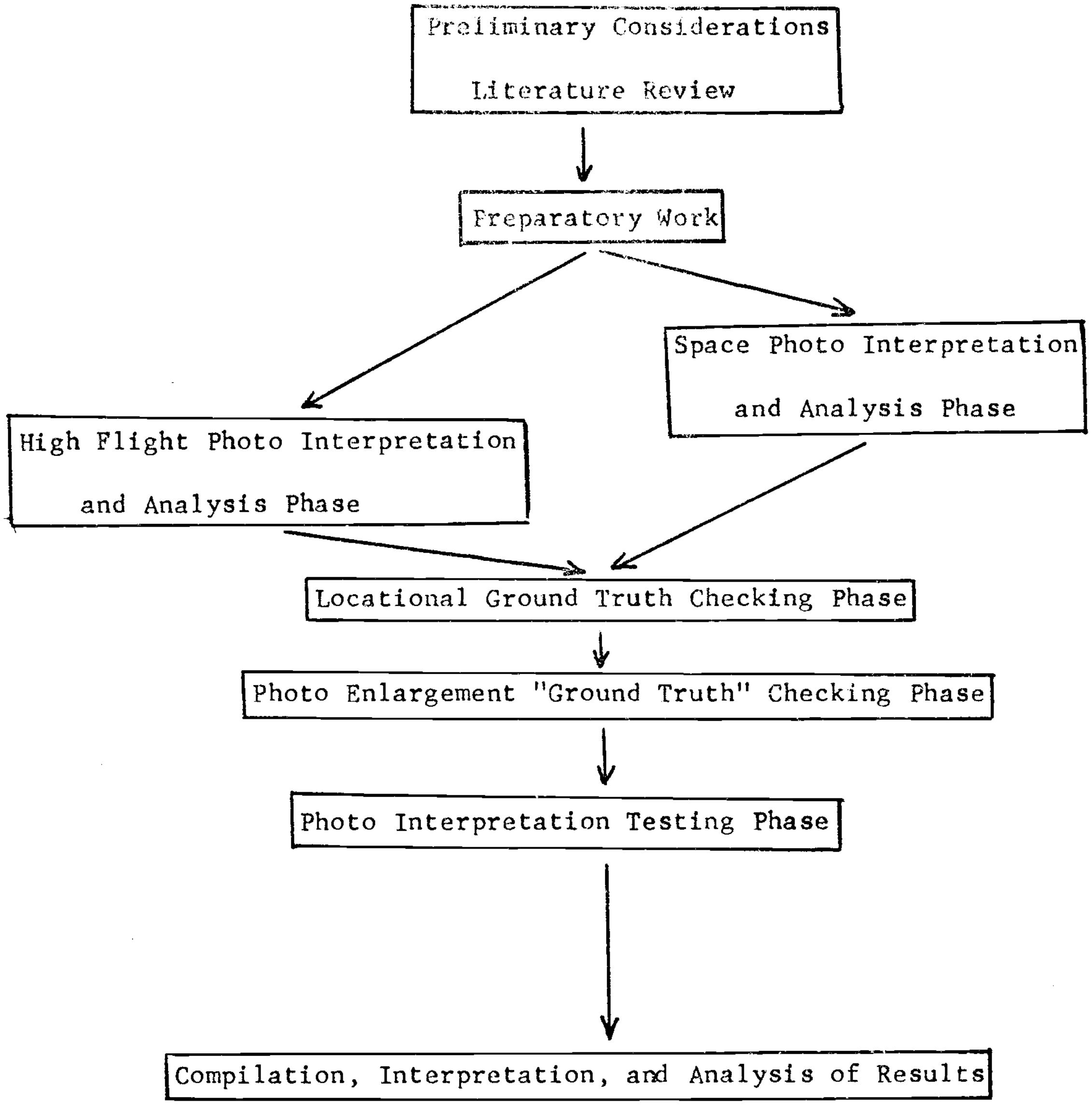

Figure 1. Flow diagram showing major activities in this study.

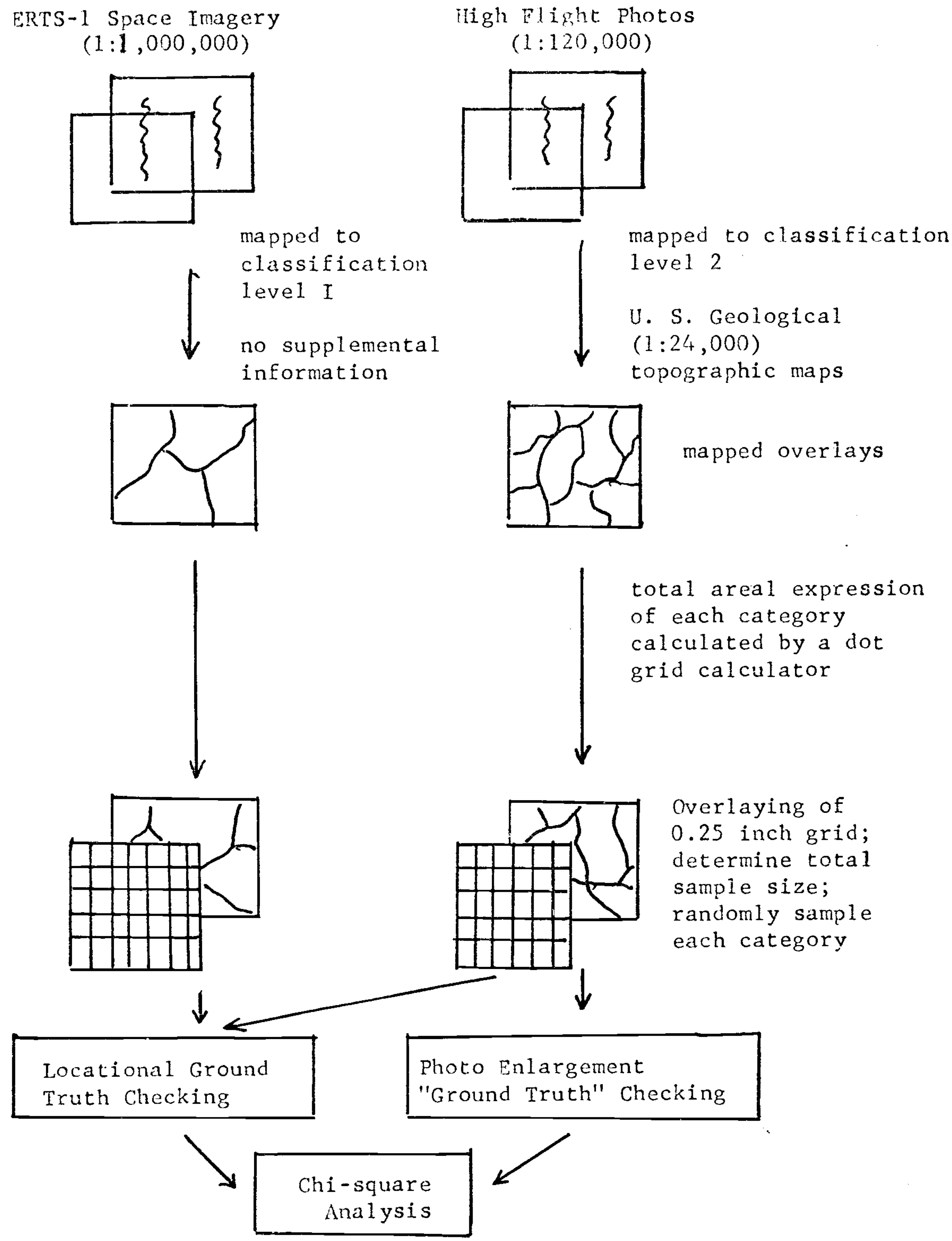

Figure 2. Flow diagram showing the procedure of the photo interpretation mapping phase.

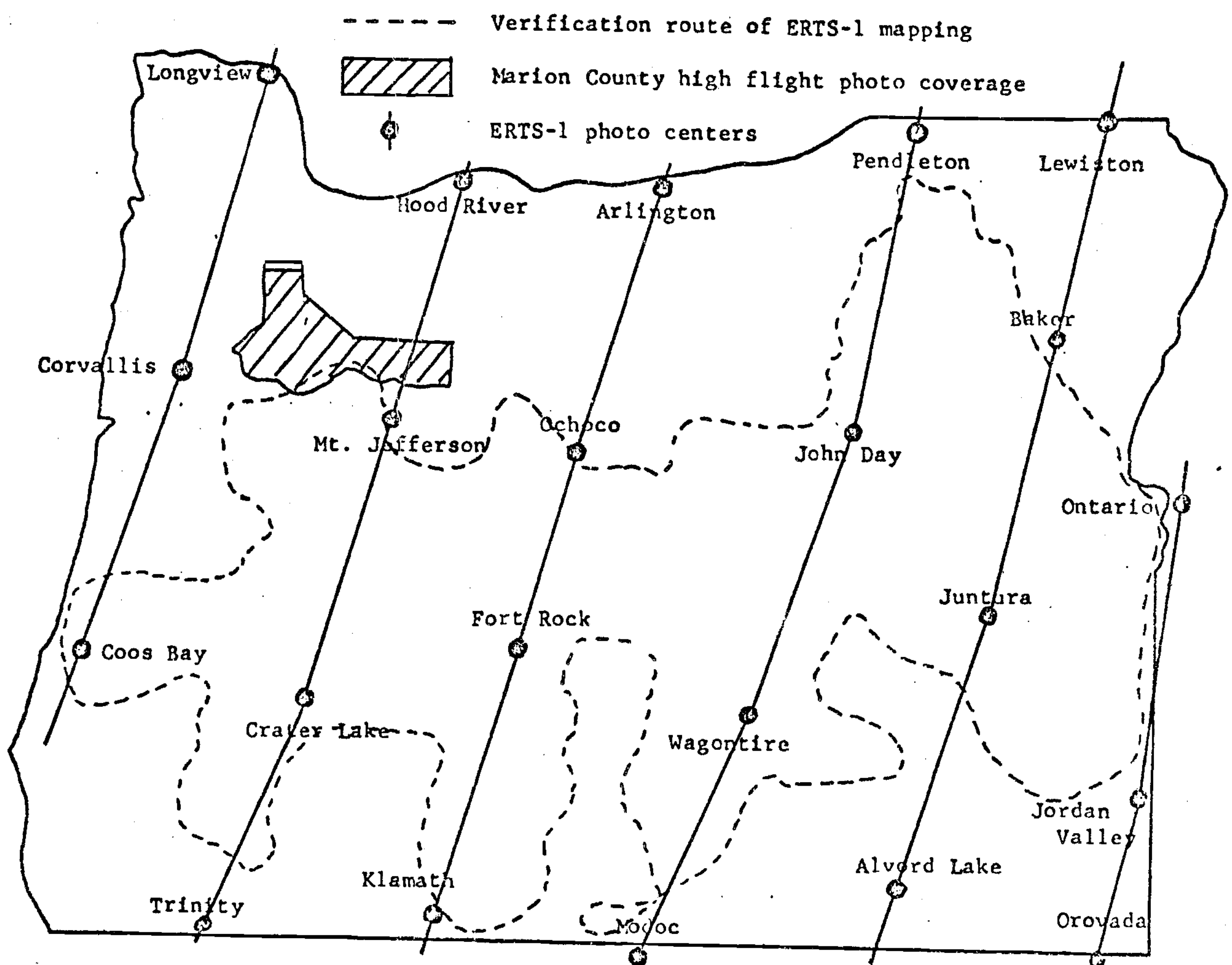

Figure 3. Map of Marion County and the State of Oregon showing ERTS-1 and high flight photo coverage.

besides the necessary photo aids was the narrative description for each legend class given in Anderson _et al._, 1972, and Poulton, 1972.

During the initial mapping effort only first level categories from each of the respective legend systems were interpreted. Upon completion of this first effort it was felt that a number of second level categories could also be mapped. An additional pass through the photos was made to map as many of these categories as feasible.

Following completion of the first mapping effort a State of Oregon black and white uncontrolled ERTS mosaic (scale 1:1, 000, 000) prepared by David Faulkner (1973), was made available. A second mapping effort was then made on the mosaic by piecing together the first run overlays onto one composite overlay. When it became apparent that some significant areas had been omitted in the original mapping, additional delineations were made as necessary. The composite overlay was then used as the final product before validating the mapping effort.

Mapping level 2 on high flight photos

Second level categories were delineated on 9"x9" high altitude (scale 1:120, 000) color infrared photographs provided by NASA as a part of the Earth Resource Aircraft Project. The photographs were taken by a Vinten System B/RC-10 sensor package with a six inch focal length lens. Twenty-five high quality photographs taken from a U-2 aircraft at 65,000 feet in July, 1972, provided nearly complete stereo coverage of Marion County, Oregon (Figure 3). Marion County, with the city of Salem along its western boundary, is one of the nine counties found within the Willamette Valley. The choice of Marion County as the study area for this more intensive mapping effort was based on four primary advantages:

1. High quality space and high flight imagery was available that provided nearly complete coverage of the county.
2. The county is highly heterogenous in land types and contains a representative number of the defined categories in each of the classification systems.
3. As the study involved a political unit, county land planners may find the results of this study useful.
4. In terms of access, time, and funds available, Marion County was a highly desirable study area.

In this mapping phase no supplemental information, other than the given two legend systems was used. All mapping was done in stereo under an Old Delft scanning stereoscope and a Dietzen stereoscope. The Old Delft stereoscope allows for more detail and precise mapping such as within urban areas, while the Dietzen stereoscope is advantageous for more broad generalized mapping such as forest boundaries.

In an initial round of mapping, boundary lines were drawn around first level land-use resource units. A second pass through the photos was then made to map second level units, and to annotate the appropriate legend symbol within the delineated units. In mapping, those land units which met the requirements for two or more categories were delineated and annotated to the highest use category. For example, when mapping from Legend I (system proposed in U.S.G.S. Circular 671), an urban area (10) which could be delineated among a forested area (40) would be annotated as urban (10).

Ground Truth Phase

In order to verify the mapping effort described, a test procedure was devised to assess the utility of each of the classification systems. The procedure involved drawing a sample of sites proportional to the land-use resource categories represented, then comparing the mapped units at each site with ground truth. A separate procedure was used to sample upon ERTS-1 and high flight imagery. The sampling design utilized in this verification procedure is similar to the one used by Rudd and Highsmith (1970).

Verifying Interpretations on ERTS-1 imagery

A stratified sampling design was developed to verify the two land-use resource map overlays drawn on the State of Oregon

ERTS-1 mosaic.

Sampling design:

1. The total areal expression of each category was estimated from the mapped overlays.

2. A total of 2, 270 potential sample sites were created by constructing a 3/8 inch grid overlay and placing it upon the mosaic. A grid scale this size approximates the area of a township on a scale 1:1, 000, 000 map. A ten percent sample was chosen for a total sample size of 227. These samples were then stratified into appropriate categories; a minimum of three sites was selected from the category with the smallest areal expression.

3. The sample sites were plotted at grid intercepts along a preselected route on a separate overlay laid on the mosaic; and on a BLM (scale 1:1, 000, 000) recreation map which showed township boundaries, land in public ownership, and major roads. The route selected was on largely improved roads through as many mapped categories as feasible and yet still allow coverage in the major physiographic provinces in the State (Franklin and Dyrness, 1973).

4. When visiting each ground truth site by automobile, land-use types encountered were noted according to the two legend systems. In addition, a record was kept of major

vegetation types, location, elevation, landform, image characteristics, alternative land-use types and any other relevant or unique characteristic of a particular sample site area. Supporting ground photos were also taken at each site with a 35 mm camera using Kodachrome II film. Information obtained in this way allowed for a more thorough understanding of ground subject-photo characteristics that had been mapped on the mosaic. It is of importance to note that during the field trip the precise location of any given sample site, even when plotted as a point on the space imagery, was not realistically possible. Therefore some subjectivity was necessary in locating and recording the observed category.

From the experience gained during the field check, a final effort was made to map land-use patterns in Oregon. Using the State of Oregon ERTS-1 mosaic, and additional supplemental maps including a State of Oregon highway map (scale 1:1, 000, 000) and a map of rangeland types of Oregon prepared by W. E. Anderson, two interpretive land-use maps were prepared. These maps each using one of the two legend systems as a basis for classification, are displayed in Figures 4 and 5.

Figure 4. Interpretive land-use map of Oregon drawn on a State of Oregon ERTS-1 photo mosaic. Land-use and resource categories from Legend II were adopted as a basis for classification.

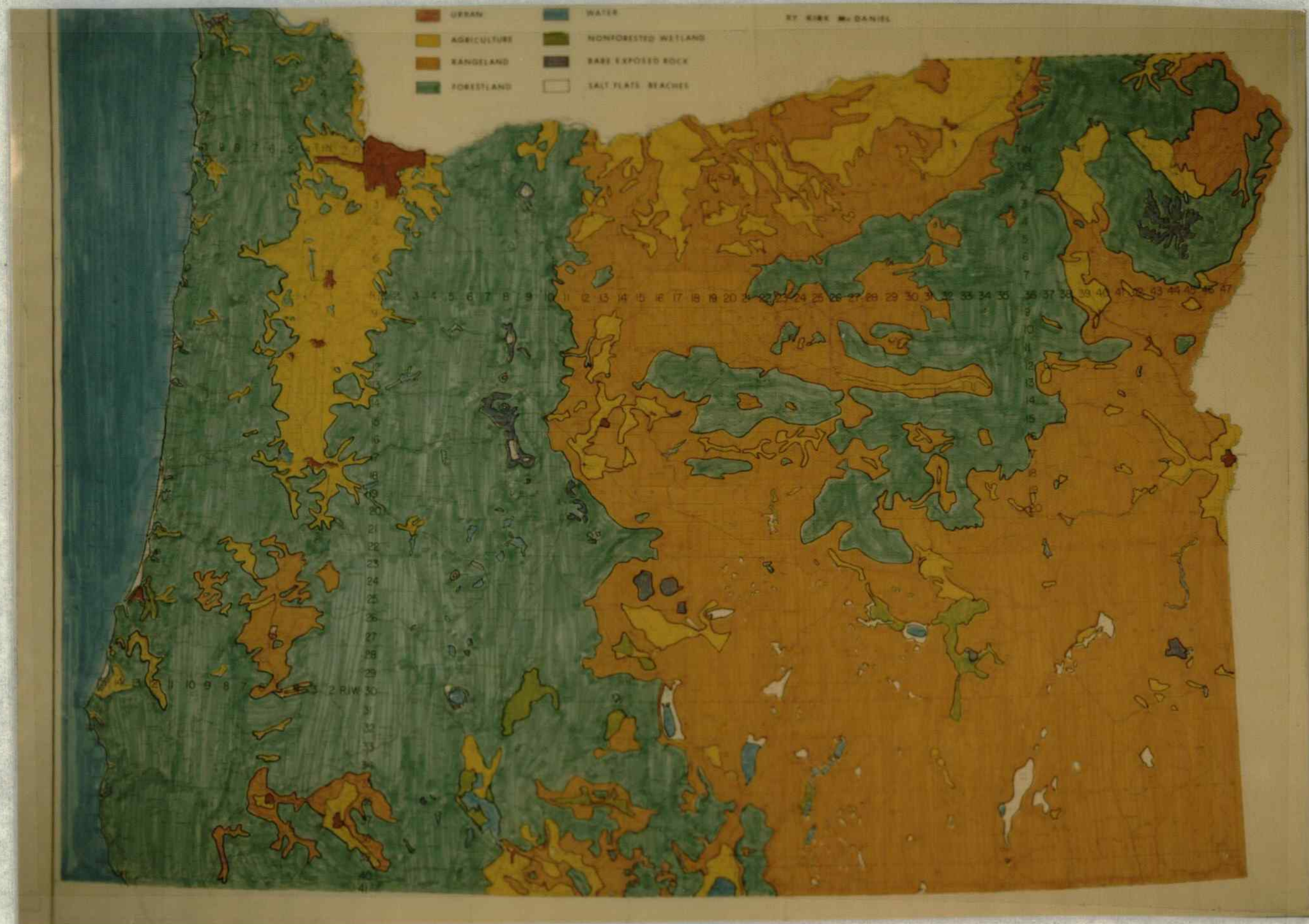

Figure 5. Interpretive land-use map of Oregon drawn on a State of Oregon highway map. Land-use categories from Legend I were adopted as a basis for classification.

<u>Verifying interpretations on high flight photos</u>

To verify the accuracy of each mapped category on high flight photos, a stratified random sampling design was developed.

Sampling design:

1. To determine the proportional number of sites to be sampled within each mapped unit, an area dot-grid calculator was utilized to calculate the total areal expression of each category.
2. A grid overlay with 0.25 inch spacing was then constructed to create 9,384 total potential sample sites in Marion County. Using a five percent sample, a total sample size of 479 was then selected for ground truth verification.
3. For each mapped category a list of grid intersections were randomly compiled excluding those falling on boundary lines; then random selection of appropriate size for each category was drawn.
4. In order to check the accuracy of the high flight photo maps, two methods of ground truth checking were used.
    a. <u>Locational ground truth (LGT)</u> - A representative subsample from within each mapped category was selected and a visit was made to the ground location so that subject-image relationships could be

established. A total of 133 sites were visited. Each site was located directly on the photos; and for ease and use in the field, on U. S. G. S. topographic maps (scale 1:24, 000). Those sites randomly located near accessible roads and trails were chosen to be visited. At each locational ground truth site checked, a record was kept of expected and observed mapped types. Supporting ground photos were also taken at each site with a 35 mm camera.

b. Photo enlargement ground truth (PEGT) - In view of time, funds, and accessibility required in field checking all randomly distributed sampling sites, it was considered, at least for this study, that this means of validation was unfeasible. Therefore, to verify the remaining 346 sites which could not be visited, a second method employing photo enlargements (scale 1:32, 000) from the original high flight imagery was used. Sample sites selected and located on the original 1:120, 000 scale photos were relocated and identified by a number on the photo enlargements. In validating each sample an unobstructed view of each point site was made and classified with the surrounding area in mind; thus, creating what is here called a photo enlargement ground truth.

5. To compare the mapped overlays with each version of ground truth, data were subjected to the Chi-square test using the formula

$$X^2 = \sum_{i=1}^{k} \frac{(o_i - e_i)^2}{e_i}$$

where o_i is observed ground truth frequency and e_i is map frequency.

The Chi-square value is used to determine whether or not a population satisfies a normal distribution (Alder and Roessler, 1968). It may be interpreted as indicating the probability that differences as large as those found between predicted and observed data could have arisen due to chance or sampling variation.

6. The results were arranged into tables showing comparisons between correct and incorrect interpretations, and errors of omission and commission. Ross (1973) explains omission errors as correct responses which are left out of a particular group; and commission errors as incorrect responses which are erroneously included in a group.

These tables are most useful for observing accuracy within and among the land categories as well as the total interpretive accuracy.

Photo Interpretation Test Phase

A photo interpretation test was designed to assess the ease of use and photo identification accuracy of the two proposed classification systems. The test involved identification of previously mapped categories on the space and high flight imagery. Interpretations were made on 21 test sites located on color reconstituted and black and white ERTS-1 space photos; 15 sites placed on high flight stereomodels; and 25 photographs taken of land-use subject at ground level. A complete set of test photos and a summary of how interpreters classified each test site is found in Appendix A.

Test sites were selected from previously determined ground truth sample sites. Selection of sample sites to be used as test examples were based on three primary considerations. First, only those sample sites previously determined from the stratified random sampling design were used. Secondly, test examples used had to be a reasonably homogeneous example of one of the land-use categories found in the two legend systems; and thirdly, representative test sites covering as many different legend categories as possible was desired to adequately test the completeness of the two systems.

Fifteen volunteers with varying degrees of photo and land-use interpretation experience were asked to participate in the test. Each participant was provided a notebook containing an information form seeking photo and land-use interpretation experience, instructional sheet, two photo interpretation record sheets, a pocket stereoscope, and a set of test photos (Appendix A).

Both Legends I and II along with their definition and criteria for use were provided for separate testing. An advantage in having interpreters classifying from both systems is that results could be studied comparatively among the individual as well as between different interpreters. A disadvantage is that probably a certain degree of learning occurs between the first and second test. Therefore, two approaches at trying to reduce possible bias was taken. First, to reduce carryover recall, interpreters were asked to take a one day period between consecutive test. Secondly, the sequence for taking either Legend I or II first was alternated each time a new interpreter was given the test.

RESULTS AND DISCUSSION

Mapping Upon ERTS-1 Space Imagery

Legend I

Results obtained from mapping upon the ERTS-1 imagery taken over the State of Oregon using Legend I are summarized in Table 1. The results displayed in Table 1 show comparisons between correct interpretations, Chi-square analysis, and errors of omission and commission made while mapping first level categories from Legend I. From a total of 226 sites checked, 23 were misinterpreted for a 10.2 percent omission-commission error; or 89.8 percent of the samples agreed with the interpreted areas they represented. Certain second level categories which can be identified from the ERTS-1 imagery are considered in Table 2. Most secondary units under rangeland (30), forestland (40), water (50), nonforested wetlands (60), and barrenlands (70) have, with exceptions, a good to excellent chance of being identified if they encompass areas large enough to be seen on the imagery. Secondary categories under urban (10) and agriculture (20) generally are more difficult to interpret due principally to the size of the units involved and the resolution limitations of the imagery. Since second level categories under tundra (80) and permanent snow and icefields (90) are the same as their primary levels they require little

Table 1. Comparison between correct interpretations, chi square analysis, and errors of omission and commission made while interpreting first level land use categories under Legend I upon the State of Oregon ERTS-1 photomosaic.

		ACTUAL OBSERVED TYPE									TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS	CHI SQUARE
		10	20	30	40	50	60	70	80	90				
PHOTO INTERPRETED TYPE	10	7			1						8	1	12.5	0.13
	20	1	22	3	1		2				29	7	24.1	1.69
	30		2	71	1		1	2			77	6	7.8	0.51
	40			5	81						86	5	5.9	0.29
	50		1			5		1			7	2	28.6	0.57
	60						5				5	0	0.0	0.00
	70			1				5			6	1	16.7	0.17
	80								5		5	0	0.0	0.00
	90							1		2	3	1	33.3	0.32
TOTAL OBSERVED		8	25	80	84	5	8	9	5	2	226	23		3.68
# OMISSION ERRORS		1	3	9	3	0	3	4	0	0	23	203	89.8	df. 8
% OMISSION ERRORS		13	12	11	4	0	38	44	0	0		89.8	10.2	.870

Table 2. Interpretability of second level categories from Legend I using ERTS-1 imagery.

Excellent 90-100%	Good 80-89%	Fair 60-79%	Poor < 60%
Evergreen forest	Cropland and pasture	Savanna*	Residential
Vegetative wetlands	Chaparral	Deciduous forest	Commercial and service
Beaches	Desert shrub	Mixed forest	Industrial
Rivers	Grassland	Lakes	Extractive
	Bays and estuaries	Reservoirs	Strip and clustered settlement
	Bare rock	Salt flats	Open and other urban
	Tundra	Mixed Urban	Institutional
	Permanent snow and icefields	Bare wetlands	Orchards, vineyards, etc.
		Transportation	Feeding operations

*Special criteria for this category in Oregon was established. It principally included savanna-like juniper and oak woodlands.

additional effort when mapping. A complete set of results obtained from mapping second level categories under Legend I are presented in Appendix B.

When considering the combined number of omission and commission type errors by each land-use type shown in Table 1, the descending order of interpretability of these primary level categories was as follows:

		Land-Use Type	% Omission-Commission Type Error
1.	Category 80	Tundra	0
2.	Category 40	Forestland	5
3.	Category 30	Rangeland	10
4.	Category 10	Urban	13
5.	Category 50	Water	17
6.	Category 20	Agriculture	19
7.	Category 90	Permanent Snow	20
8.	Category 60	Nonforested Wetland	23
9.	Category 70	Barrenland	33

Category 10, urban land, had better than 87 percent of its sample sites in agreement with the interpreted areas they represented (Table 1). From eight sites mapped as urban, seven were correctly identified; one site misinterpreted should have been designated as forestland (40), giving a commission type error. One other site erroneously classified as agriculture (20), should have been mapped as urban land, giving an omission type error. Mapping of urban lands was generally restricted to core population centers occupying a minimum of 340 acres, or about 10, 000 people. It was found that towns and communities smaller than this become obscure and could not with reliability be identified or delineated upon the imagery. When the location of these smaller communities was desired, a supplementary map at a scale of 1:1, 000, 000 was found to be a useful reference. With the aid of the supplementary map these smaller towns could then be plotted as point data directly upon the imagery. Within some of the larger urbanized areas in Oregon, such as Portland, it was possible to differentiate the city center from the peripheral suburban areas. Major airports throughout much of the State could also be identified, but for the most part the remaining secondary urban categories could not be interpreted with satisfaction.

Category 20, agricultural land, was correctly identified 76 percent of the time (Table 1). This category contained 30 percent of the total error, which was the largest. Five out of the seven errors made were due to category 20 being misinterpreted as 31 (grassland) and 61 (vegetated nonforested wetlands). The confusion between these categories occurred because these areas were all actively growing during the July to October, 1972 period, when the ERTS-1 imagery interpreted was taken over parts of central and eastern Oregon. These types often had a similar dark gray signature on the spectral band 2 black and white ERTS-1 photos. On color reconstituted infrared imagery they showed up as a distinctive bright red color in contrast to lighter gray-blue nonirrigated surrounding rangeland types. The problem was identifying which areas were natural grasslands undergoing late summer growth; which were improved pastures being irrigated; or which were natural wetland herbaceous types. In some cases field patterns aided in recognition as did associated land-use types found in the area. Nevertheless, it seems that some amount of confusion and misinterpretation can be expected when mapping these units.

Category 30, rangelands, was correctly interpreted nearly 92 percent of the time (Table 1). Considering errors made while interpreting second level rangeland categories the accuracy dropped to 81 percent. This is still considered a good level of interpretability (Table 2). One secondary category found difficult to work with in Oregon under its present definition was savanna-palmetto prairies (33). According to the definition provided in U.S.G.S. Circular 671, this category is to include grasses with scattered palms and shrubs found in parts of Florida. A broader meaning savanna-like category similar to the one provided in Legend II is necessary for mapping certain juniper and oak woodland types found in Oregon.

Category 40, forestlands, was consistently identified better than any other primary level category for the size of sample sites involved (94%). An estimated 40 percent of the state is forested with nearly 90 percent of this being of the evergreen-coniferous type. The distinction between deciduous and evergreen forest was not satisfactorily determined from the imagery. The photo signature of forestlands in general was probably the easiest to identify with its darkness, even tone, and texture occupying large land surface areas. Some confusion was found in determining the ecotone between forestland and rangeland. The errors that commonly occurred were in oak and juniper woodland gradients or transition zones between dense forest and other range types.

Category 50, water, generally was not difficult to identify from the imagery. An exception was distinguishing between large bodies of water such as lakes, and certain basalt lava flows which occur in the Cascade Ranges and parts of central and eastern Oregon. One error of this type was recorded (Table 1). A secondary water resource category found noticeably absent from the classification was one encompassing oceans, seas, and gulfs. Such a category, similar to the one provided in Legend II, is necessary to cover these broadest of water surface types.

Category 60, nonforested wetlands, contained no commission errors, but three omission type errors did occur (Table 1). Areas which should have been mapped as 60 were misinterpreted as categories 20 and 30. Again the problem of differentiating actively growing grasslands and, irrigated agricultural land, from marshland types caused the errors.

While interpreting category 70, barrenland, two types of errors were found (Table 1). First, as previously mentioned, certain basalt flows were confused with lakes having a similar photo signature. This similarity in signatures is due primarily to the range of reflected energy received and recorded by the electronic scanners aboard ERTS-1. A second source of error was noted when the ecotone between salt flats (71) or playas were not adequately delineated from desert shrub types. Shrub and grass species including principally greasewood (Sarcobatus vermiculatus) and salt grass (Distichlis stricta) are predominant along the border of these areas but do not exert enough influence to appear in contrast to the white colored barren areas.

Although all test sites checked within category 80, tundra, were in agreement, there was some difficulty in mapping this type. Classification of tundra was restricted to high elevational areas above timberline in the Cascade Range. An effort was made to map habitats supporting alpine plant communities in the narrow elevation belt between the timberline and the line of permanent snow and ice. This region described by Franklin and Dyrness (1973), as the Alpine Zone, is not well developed in the mountains of Oregon. While field checking the tundra sample sites it became increasingly apparent that vegetative communities mapped as tundra were not as extensive as originally interpreted. Areas mapped as tundra were overestimated in contrast to what should have been designated rocklands or other barren types.

From a total of three sites checked within category 90, permanent snow and icefields, two were correctly interpreted. The one commission type error made was due to extensive light colored granitic rocklands in the high elevational areas of the Wallowa mountains being misinterpreted as snow.

Legend II

Results while interpreting land-use resource categories from Legend II upon the State of Oregon ERTS-1 mosaic are summarized in Table 3. Nearly 94 percent of the samples agreed with the interpreted mapped areas they represented. For the most part all first level categories under Legend II were satisfactorily identified. By combining the number of omission and commission type errors within each land-use category, the descending order of interpretability was found as follows:

	Land-Use Type	% Omission-Commission Type Error
1. Category 30	Natural vegetation	3
2. Category 50	Urban	13
3. Category 40	Agriculture	13
4. Category 20	Water	18
5. Category 10	Barrenland	20

Category 30, natural vegetation, was correctly identified 97 percent of the time (Table 3). About 75 percent of the state was mapped within this category which included forestland (40%) and nonforested

Table 3. Comparison between correct interpretations, chi square analysis, and errors of omission and commission made while interpreting first level land use categories under Legend II upon the State of Oregon ERTS-1 photomosaic.

PHOTO INTERPRETED TYPE	ACTUAL OBSERVED TYPE					TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS	CHI SQUARE
	10	20	30	40	50				
10	10	1	1			12	2	17	0.33
20	1	7		1		9	2	22	0.44
30	2		165	1	1	169	4	2	0.10
40			4	24	1	29	4	17	1.04
50					7	7	0	0	0.00
TOTAL OBSERVED	13	8	170	26	9	226	13		1.84
# OMISSION ERRORS	3	1	5	2	2	13	213	94	df. 4
% OMISSION ERRORS	23	13	3	8	22		94	6	.995

natural vegetation types (35%). Category 30 was confused most often with category 40, agriculture. Five errors between these types were made accounting for 38 percent of the total error, which was the highest. Errors made were due mainly to misclassifying herbaceous types (31) as pasture (46) and cover crops (41) rather than the reverse. Category 50, urban, was the second best identified primary category. It has eight percent of the total error which was the lowest. No commission type errors were noted, but two omission type errors were made when sites erroneously classified as agriculture (40) and natural vegetation (30), should have been mapped as urban. Category 40, agriculture, was the third best interpreted primary category with 83 percent of its mapped areas in agreement (Table 3). It has 27 percent of the total error, which was the second largest. Category 20, water, was next with 78 percent of its sites correctly identified. Twelve percent of the total error was included in this class. Category 10, barrenland, was fifth with 83 percent of its mapped areas interpreted correctly (Table 3). It had 19 percent of the total error. Five errors occurred when barrenlands were confused with certain water resources and natural vegetation areas.

The interpretability of certain second level categories from Legend II are displayed in Table 4. This table includes only those secondary categories which were actually attempted to be identified on the imagery. A complete set of results from mapping second level categories are presented in Appendix B. Secondary categories under barrenland (10) and water resources (20), generally had a good to excellent chance at being identified (Table 4). Secondary units under natural vegetation (30) also had a good probability of being identified. From a total of 165 samples, sites correctly identified as natural vegetation types, 16 were misinterpreted at the second level of classification (10%). Twelve of these errors were made between herbaceous (31), shrub-scrub (32), and savanna-like types (33); particularly, when they were in close association with each other or when the transitional boundary between them was unclear.

Only three out of the nine provided secondary units under category 40, agriculture, were identified upon the imagery (Table 4). These subcategories included field and cover crops (41), pasture (46), and an agricultural complex (41/42/43). The development of an agricultural complex category was found necessary to adequately describe areas consisting of several different crop types in close proximity to each other. These areas, nearly always under intensive management and in most cases irrigated, were delineated in contrast to areas where dryland farming of wheat and grass seed predominated. These latter agricultural types would be designated as 41, cover and field crops.

Table 4. Interpretability of second level categories from Legend II using ERTS-1 imagery.

Excellent 90-100%	Good 80-89%	Fair 60-79%	Poor < 60%
Shorelines, beaches, tide flats	Playas, dry or intermittent lake basins	Aeolian barrens	Seeps, springs, and well
Water courses	Rocklands	Badlands	Orchards
Bays and coves	Ponds, lakes, and reservoirs	Estuaries	Animal facilities (large and small)
Oceans, seas and gulfs	Lagoons and bayous	Savanna-like types	Residential
Snow and ice	Herbaceous types	Row crops	Business and industry
Forest and woodland types	Shrub-scrub types	Pasture	Resource extractive
	Cover crops	Transportation	
	Undifferentiated urban	Power and fuel transmission	

Mapping Upon High Flight Photos

Two methods were employed to verify the mapping effort upon the high flight aerial photos taken over Marion County. Data compiled from a locational ground truth (LGT) and a photo enlargement ground truth (PEGT) check were combined into a total ground truth (TGT) and are displayed in Tables 5 and 6. Two points are worth mentioning about the information displayed within these tables. First, it is not surprising to find a higher degree of accuracy in the PEGT in comparison to the LGT version. During the LGT field trip a disproportional number of sites were checked in categories other than forested types. For the most part, sample sites located in remote forested areas were correctly interpreted, thus increasing the amount of accuracy. Secondly, the PEGT was made after the LGT check, thus a number of the subject-photo characteristics were better understood. This aided greatly in reducing the number of errors that might have been repeated if only photo enlargements were used in the validation effort.

Legend I

Legend I categories involved in the total ground truth check (TGT) are summarized in Table 5. From a total of 479 sample sites checked, 424 (88%) were correctly interpreted. Results shown in Table 5 compare the mapping of second level categories under Legend I with each

Table 5. Summary of results from mapping second level categories under Legend I on high flight photos.

			LEGEND I																				
	Mapped Categories		11	12	13	14	15	16	17	18	19	21	22	33	41	42	43	52	53	74	81	91	TOTAL
Total Ground Truth	Locational Ground Truth	No. in sample	4	3	1	2			5	2		79	3	3	11	15	4		1	1			134
		Agree	2	3	0	2			4	2		71	0	3	0	12	3		1	1			104
		Disagree	2	0	1	0			1	0		8	3	0	11	3	1		0	0			30
		% Agree	50	100	0	100			80	100		90	0	100	0	80	75		100	100			77.6
	Photo Enlargement Ground Truth	No. in sample	8	4	3	3	4	4	6	3	4	187	6	3	11	206	6	3	4	7	4	3	479
		Agree	6	3	1	3	3	1	4	3	2	173	2	3	0	202	4	3	4	4	0	3	424
		Disagree	2	1	2	0	1	3	2	o	2	14	4	0	11	5	2	0	0	3	4	0	55
		% Agree	75	75	33	100	75	25	67	100	50	92	33	100	0	98	66	100	100	57	0	100	88.5

Table 6. Summary of results from mapping second level categories under Legend II on high flight photos.

		LEGEND II															
	Mapped Categories	13	21	28	31	32	33	34	41	42	43	51	52	53	55	59	TOTAL
Total Ground Truth — Locational Ground Truth	No. in sample	1	1				3	36	28	43	3	9	5		2	3	134
	Agree	1	1				3	34	25	22	1	6	4		2	3	102
	Disagree	0	0				0	2	3	21	2	3	1		0	0	32
	% Agree	100	100				100	94	89	51	33	67	80		10	100	76.1
Total Ground Truth — Photo Enlargement Ground Truth	No. in sample	7	9	3	3	1	3	229	64	118	5	14	14	4	2	3	479
	Agree	4	7	3	0	0	3	223	58	70	2	8	11	3	2	2	396
	Disagree	3	2	0	3	1	0	6	6	48	3	6	3	1	0	1	83
	%Agree	57	78	100	0	0	100	97	90	59	40	57	79	75	100	67	83.0

version of ground truth. When these results are aggregated upwards to the broader primary levels the descending order of interpretability was found as follows:

		Land-Use Type
1.	Category 50	Water
2.	Category 90	Permanent snow and ice
3.	Category 30	Rangeland
4.	Category 40	Forestland
5.	Category 20	Agriculture
6.	Category 10	Urban
7.	Category 70	Barrenland
8.	Category 80	Tundra

Category 60, nonforested wetlands, was not interpreted on the imagery. Under category 50, water, the only two secondary categories interpreted were lakes (52) and reservoirs (53) (Table 5). No errors occurred while mapping these bodies of water as they are quite distinct on the imagery.

Three sample sites verified as category 90, permanent snow and icefields, were located in the high elevational areas of 12,000 foot Mt. Jefferson (Table 5). The sites were checked by photo enlargements so the validity of knowing if the snow cover was permanent or seasonal is considered suspect. There are definitely permanent snow and glacial areas upon Mt. Jefferson, but the amount of snow observed during the late July, 1972, flight date most likely contributed to overestimating the extent of this type.

Category 30, rangeland, contained three sites all of which were identified as chaparral (33) (Table 5). The areas designated as such were located on gently sloping south facing foothills in Marion County. The principal vegetation types consisted of snowberry (Symphoricarpos albus), wild rose (Rosa eglanteria), bracken fern (Pteridium aquilium), native and introduced grasses, and scattered white oak (Quercus garrayanna). This vegetation community does not fit as a chaparral type in the true sense of the meaning and illustrates the need for dealing with vegetation types that do not fit within any of the provided legend units. An additional category dealing with undifferentiated or special vegetation types would probably help reduce such confusion.

While mapping category 40, forestland, a difficulty arose when distinguishing deciduous forest (41) from evergreen forest (42). During the original photo interpretation phase the extent of land thought to be deciduous forest was considerably over estimated. For the most part forested areas along creek bottoms and woodlands on the Willamette Valley floor and foothills were mapped as 41 (Figure 4). After the LGT check it became apparent that this category had been inaccurately yet consistently misinterpreted. Upon returning from the field this category was extensively remapped. The areas remapped were validated by the photo enlargements and these results were combined with LGT records into the TGT (Table 5).

Errors made while mapping category 20, agriculture, were principally of two sorts. First, eight errors were noted when sample sites fell within small woodlands occurring within extensive agricultural areas. These woodlands, often growing along valley creek bottoms and generally less than 1/8 mile wide, were not properly identified or delineated in the original mapping effort (Fig. 6). After the verification checks it became apparent that a number of these areas could have been mapped. A second source of error occurred while trying to distinguish croplands (21), from orchards and vineyards (22). The main problem here was the inability to properly identify unique photo signatures for vinecrops such as loganberries and hops from other agricultural types.

Secondary classes under category 10, urban, were as a group the most difficult to interpret on the photos. Eleven out of a total of 13 errors (82%) were made while attempting to interpret one urban type from another. The general order of interpretability of these units from greatest to least accuracy was:

		Land-Use Type
1.	Category 14	Extractive
2.	Category 15	Transportation and communication
3.	Category 12	Commercial and services
4.	Category 11	Residential
5.	Category 19	Open and other
6.	Category 13	Industrial
7.	Category 16	Institutional

Figure 6. An example of two selected problems found while mapping upon high flight photos using Legend I.

A. Forested areas along creek bottoms and on the Willamette Valley floor and foothills were erroneously mapped as deciduous forest. These woodlands should have been classified as coniferous forest or mixed forest.

B. A number of small or narrow woodlands growing along valley creek bottoms and generally less than 1/8 mile wide were not properly identified during the original mapping effort. They were considered an inclusive part of agriculture.

For the most part, units 12, 13, and 16 were often confused and not properly identified. The reason being is they do not necessarily have unique photo signatures, thus preventing consistent identification. From the experience in mapping these types in Marion County it is felt, at least for photo interpretation purposes, best to combine them into a single inclusive second level urban category. Further breakdown of these types would probably be more advantageous at lower prescribed levels in use with larger scale imagery.

Legend II

Results from mapping second level land-use resource categories under Legend II are summarized in Table 6. Nearly 83 percent of the photo interpreted units were accurately identified as indicated by the total ground truth check. By aggregating these results upwards into the five primary levels the descending order of interpretability was found as follows:

	Land-Use Type
1. Category 30	Natural Vegetation
2. Category 20	Water Resources
3. Category 40	Agriculture
4. Category 50	Urban
5. Category 10	Barrenland

The high degree of interpretability of category 30, natural vegetation, can largely be attributed to the success in mapping forest and woodland types (34). Nearly one-half of Marion County is forested. From a total 239 sample sites located within areas interpreted as forestland, 223 (97%) were in agreement (Table 6). Unfortunately, the remaining three natural vegetation types were not as well represented in Marion County. These units including herbaceous (31), shrub-scrub (32), and savanna-like types (33), added little to the final evaluation of this category.

Errors made while mapping second level units under 10, barrenland, and 20, water resources, in Legend II were basically the same as those in the same categories in Legend I. In classifying rocklands (13), three out of seven sample sites checked (57%) were in actuality recently clearcut or burned over forestlands (Table 6).

While there was a high degree of interpretability in mapping 40, agricultural land (96%), second level agricultural units were less successfully identified (70%) (Table 6). A total of 51 of 56 errors (86%), were made while misclassifying among three secondary agricultural types. Generally, in areas where single crops such as grass seed (41) are extensively grown, the delineated units were correctly identified. In addition, fields usually greater than 160 acres supporting row crops (42) such as bushbeans, or orchards (43) such as filberts, were also successfully mapped (Fig. 7). It was in agricultural areas of highly diversified and complexed cropping patterns that the greatest number of errors occurred. In these areas units

Figure 7. Example of problems found while interpreting second level agricultural types under Legend II from high flight photos.

A. Fields usually greater than 160 acres supporting row crops (42), such as the field of bush beans growing here, were successfully mapped.

B. In some areas units 41, 42, and 43 appear as an interwoven matrix on the photos making meaningful delineations difficult. Within the area circled here, bush beans (42), mint (41), and an orchard of filberts (43) are grown.

41, 42, and 43 appear as an interwoven matrix on the imagery making meaningful delineations difficult. In such areas where there is no single dominating agriculture type it is advantageous to delineate and annotate the croplands as a complex or undifferentiated agriculture. This lessens confusion and reduces the required intensiveness of mapping these areas.

Secondary categories under 50, urban, were correctly identified 70 percent of the time. From a total of 11 errors, 6 (55%) were made when one urban type was confused with another (Table 6). The descending order of interpretability found while mapping second level urban units was:

		Land-Use Type
1.	Category 55	Resource extraction
2.	Category 52	Business and industry
3.	Category 53	Transportation
4.	Category 59	Undifferentiated urban
5.	Category 51	Residential

Categories 55, 52, and 53, were delineated correctly better than 75 percent of the time. The secondary urban categories most often confused were residential (51) and business and industry (52). Errors between them were made largely in intermixed residential and commercial type neighborhoods. Many of these areas should have been mapped as undifferentiated urban lands (59) for purposes of increasing photo interpretation accuracy.

Photo Interpretation Test

The photo interpretation test given was designed to assess the ability of volunteers, with varying degrees of land-use and photo interpretation experience, to identify legend units from each of the two land classification systems. The test involved interpretation of previously mapped land-use categories on the space and high flight imagery, and from a set of photographs taken at ground level. The classification of test sites by each interpreter was aligned against a key developed by the author during the ground truth checks. Those sites classified in disagreement with the key were considered errors (Table 7). Using the data from this test a one-way four factor analysis of variance test was performed to examine possible interactions or differences between the legend systems, experience groups, and imagery types. The analysis of variance showed no significant differences in the ability of interpreters to classify land use with either legend system at the 0.01 level of significance (Table 8). Interpreters averaged 7.3 errors with Legend I, and 7.1 errors with Legend II when classifying test sites from the three imagery types. A complete set of test photos and a summary of how interpreters classified each test site is presented in Appendix A.

There was a significant difference between experience groups and their ability to identify test sites on the different imagery

Table 7. Summary of photo interpretation test errors by fifteen interpreters placed within experience groups using Legends I and II.

Legend	Experience Rating	Imagery Type	Errors by each Interpreter (Reps) 1	2	3	4	5	Total	Mean X
I	1 (High)	1 (ERTS)	5	0	6	1	2	14	2.8
		2 (H.F.)	5	5	2	4	4	20	4.0
		3 (G.P.)	4	5	7	3	3	22	4.4
	2 (Moderate)	1	3	10	4	9	8	34	6.8
		2	6	6	5	8	6	31	6.2
		3	7	9	3	12	6	37	7.4
	3 (Low)	1	10	10	10	15	12	57	11.4
		2	6	6	6	9	8	35	7.0
		3	6	7	5	8	6	32	6.4
II	1	1	4	0	8	1	2	15	3.0
		2	4	6	1	6	2	19	3.8
		3	4	2	8	3	4	21	4.2
	2	1	6	6	4	8	6	30	6.0
		2	5	6	5	5	7	28	5.6
		3	6	6	5	10	6	33	6.6
	3	1	11	9	7	15	10	52	10.4
		2	5	10	6	9	9	34	6.8
		3	8	9	4	9	8	38	7.6

Table 8. Analysis of variance of data from the photo interpretation test.

Source of variation	Sum of squares	D. F.	Mean square	F
Legend (L)	0.544	1	0.544	1.00
Rating (R)	338.756	2	169.378	35.41**
Imagery (I)	15.356	2	7.678	1.61
L X R	4.356	2	2.178	1.00
L X I	1.622	2	0.811	1.00
R X I	93.178	4	23.294	4.87
L X R X I	5.578	4	1.394	1.00
ERROR	344.400	72	4.783	
Total	803.789	89		

types (Table 8). Experience group 1 (most prior photo and land-use interpretation experience), identified sites more accurately on the ERTS-1 and high flight photos than did the moderate group (Fig. 8). Experienced interpreters also classified the ground photos more consistently correct than the moderate or low rated groups. Interpreters in the moderate group identified sites on the ERTS-1 and high flight imagery more accurately than the low group, but there was little difference between the two groups when classifying ground photos. In general, all three experience groups made fewer errors when classifying with Legend II on the ERTS-1 and high flight imagery but these differences were not significantly apart from those errors made while using Legend I.

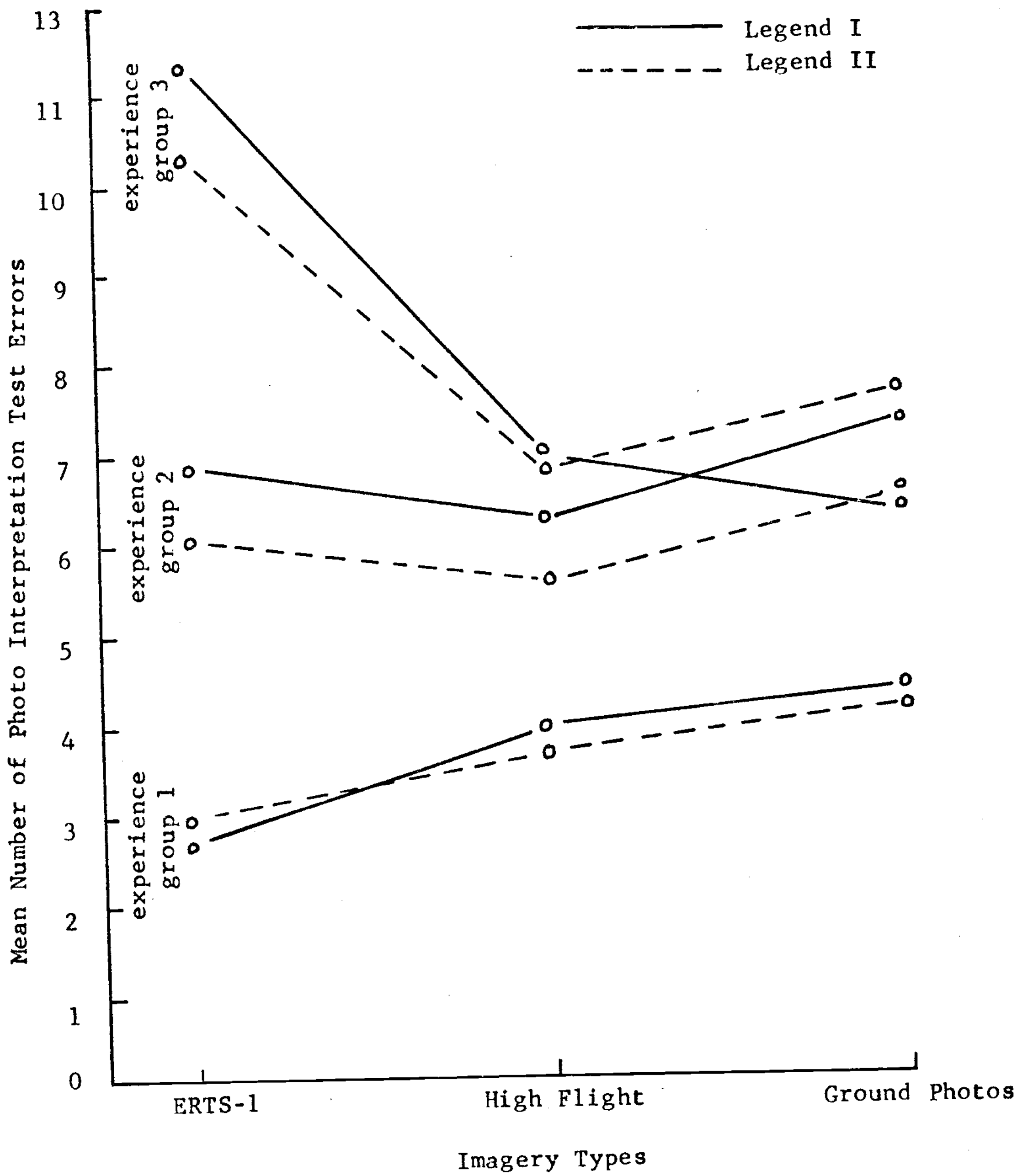

Figure 8. Average number of errors made by experience groups on three imagery types using Legends I and II.

Classifying test sites on ERTS-1 imagery

The nature of errors made while interpreting test sites on ERTS-1 imagery to first level categories using Legends I and II are summarized in Table 9. From a total of 315 test sites classified, the interpreters correctly identified 69 percent of them using Legend II, and 66 percent with Legend I. Test sites classified to second level land-use categories were correctly interpreted 58 percent of the time. In general, interpreters chose similar or analogous categories from the two systems when classifying test sites. The extent of this similarity in classifying test sites can be illustrated by consolidating certain first level categories and listing them in order of their interpretability from greatest to least accuracy:

Legend I Land-Use Type	Legend II Land-Use Type
20 Agriculture	40 Agriculture
40 Forestland	34 Forest
50 Water 90 Permanent Snow	20 Water Resources
30 Rangeland 60 Nonforest Wetland 80 Tundra	30 Natural Vegetation other than forest
10 Urban	50 Urban
70 Barrenland	10 Barrenland

Two points concerning the interpretability of these categories and the photo interpretation test in general deserve attention. First, it should

Table 9. Comparison between correct interpretations, and errors of omission and commission made by 15 people classifying 21 different land use test sites on ERTS-1 photos using a) Legend I, and b) Legend II.

a)

LEGEND I PHOTO INTERPRETED UNITS	ACTUAL OBSERVED UNITS 10	20	30	40	50	60	70	80	90	TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
10	13	8	4	1	2	2				30	17	57
20	5	40								45	5	11
30			23				7			30	7	30
40		1	11	62	1					75	13	17
50				1	32	3	7		2	45	13	29
60					11	3	1			15	12	80
70			1		30		25		4	60	35	58
80												
90						1	2	1	11	15	4	27
TOTAL OBSERVED	18	49	30	64	76	9	42	1	17	315	106	
# OMISSION ERRORS	5	9	16	2	44	6	17	1	6	106	209	66
% OMISSION ERRORS	27	18	53	3	58	66	40	100	35		66	34

b)

LEGEND II PHOTO INTERPRE-TED UNITS	ACTUAL OBSERVED UNITS 10	20	30	40	50	TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
10	24	34	1	1		60	36	60
20	9	47	4			60	13	22
30	9	15	95	1		120	25	21
40		1	2	37	5	45	8	18
50			9	6	15	30	15	50
TOTAL OBSERVED	42	97	111	45	20	315	97	
# OMISSION ERRORS	18	50	16	8	5	97	218	69
% OMISSION ERRORS	43	52	14	18	25		69	31

be recognized that the results given above and presented in Table 9 are averages. They do not show which individual test sites were more often misclassified than others. This information is presented in the summary of results for each test photo (Appendix A). Secondly, test sites selected for examination were meant to represent a cross section of the various land-use categories. Since there were a limited number of different categories actually presented on the photos the levels of accuracy shown here are not truly indicative of what can be achieved during a comprehensive mapping effort. Therefore, it is suggested that results presented here be viewed as relative rather than definitive in nature. Despite these additional considerations, useful conclusions can be made based on the quantitative results from the photo interpretation test. The following comments are generally applicable to both legend systems:

(1) Agricultural land was the best identified first level category on the ERTS-1 imagery. Three test examples of this type were given. It was confused mainly with urban lands. This was probably because of the close proximity these two land uses share with each other.

(2) Forestland was represented in the most number of test sites: five. Forested sites misinterpreted were generally classified as rangeland or other natural vegetation types (Table 9). One test site included a juniper woodland area and was misinterpreted by nearly one-half of the interpreters. It was misclassified mainly as savanna-

like and shrub type vegetation.

(3) Water resources were correctly identified better than 70 percent of the time (Table 9). Four sites were given showing different second level water categories. One test site was placed around Harney Lake, located in central Oregon. A majority of the interpreters chose to classify this permanent body of water as a barrenland type--mainly as a salt flat or playa. Confusion between these categories was probably due to a large amount of bare alkali soil being exposed around the perimeter of this seasonally fluctuating lake. The actual test site though, included only water found within the lake during the late summer period when the ERTS-1 imagery was taken. On another site encompassing Coos Bay, Oregon, interpreters using Legend I were in total agreement in classifying the test site as 53, bays and estuaries. When interpreters classified the same site with Legend II they were divided in their choice between 25, estuaries, and 26, bays and coves; suggesting that for photo interpretation purposes it might be best to combine these units into one category. A snow covered mountain range was placed within another test site and was correctly identified as 28, snow, by interpreters using Legend II. Fewer interpreters using Legend I chose to classify the area as 91, permanent snow and icefields. In all probability not all of the circled test site included permanent snow and some interpreters apparently felt this was the case. Those who did not classify this area as

category 91 preferred to designate it as 74, rocklands, or 81, tundra.

(4) Rangeland and natural vegetation types other than forest, were shown in an area known as the shrub-steppe or high desert region of central and eastern Oregon. Nearly 70 percent of the interpreters agreed the area was rangeland or a natural vegetation type other than forest (Table 9). The test sites were most often confused with barrenland types.

(5) Urban lands were poorly recognized from the two test examples given. Nearly one-half the interpreters classified these sites as some other primary category; usually agriculture or rangeland (Table 9).

(6) Barrenland was included in four test examples, three of which were rocklands, and one a salt flat or playa. Three sites encompassing lava rock flows were in every case misclassified by a majority of the interpreters as lakes and reservoirs. Less than 40 percent of the interpreters correctly identified these areas (Table 9). The water level in Summer Lake, located in central Oregon, fluctuates seasonally and a test site was located around a portion of the remaining white colored alkali ground surface. This site was correctly identified as a barren type about 60 percent of the time. Due principally to the color it was thought to be snow by some interpreters.

Classifying test sites on high flight photos

As was found when test sites were classified on the ERTS-1 imagery, the interpreters generally selected similar categories under the two legend systems to describe land-use subjects on the high flight photos. The second level categories which should have been identified on the photos, and the percent accuracy achieved by interpreters classifying them are displayed in Table 10. From this table it can be observed that 12 of the total 15 test sites given were secondary units under agricultural and urban classes. Secondary categories under these major land uses were emphasized for two primary reasons, 1) with the exception of forest land, they occupy the major land portion of Marion County; and 2) second level categories under agriculture and urban classes are the most diverse and complex units to interpret on the high flight photos.

The nature of errors made while interpreting test sites on the high flight photos are summarized in Tables 11 and 12. Overall, interpreters accurately classified 65 percent of the sites using Legend I, and 63 percent while using Legend II. The following comments from the results obtained during this portion of the photo interpretation test are worth noting:

Table 10. Second level land-use categories given as photo interpretation test examples on high flight photos.

Legend I Land-Use Type	% Agree	Legend II Land-Use Type	% Agree
(11) Residential	100	(51) Residential	93
(12) Commercial and service	93	(52) Business and industry	57
(16) Institutional	13		
(15) Transportation	85	(53) Transportation	100
(17) Strip and clustered development	30	(59) Undifferentiated urban	60
(21) Cropland and pasture	74	(41/48) Field crops and fallow	80
		(42) Row crops	30
(22) Orchards and vine crops	13	(43) Orchards	13
(42) Evergreen forest	73	(34) Forest	73
(74) Bare exposed rock	53	(13) Rockland	47
(91) Permanent snow and icefields	60	(28) Snow	87

Table 11. Comparison between correct interpretations, and errors of omission and commission made by 15 people classifying 15 different land use test sites on high flight photos using Legend I.

LEGEND I PHOTO INTERPRETED UNITS	ACTUAL OBSERVED UNITS 11	12	13	14	15	16	17	18	19	21	22	23	33	42	43	51	74	81	91	TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
11	15																			15	0	0
12		14						1												15	1	7
15			1		13					1										15	2	15
16	2			3		2	3						1	2			2			15	13	87
17	5	3					9	13												30	21	70
21										63	11	1								75	12	16
22									1	12	2									15	13	87
42													3	11	1					15	4	27
74													1	2	1		8	1	2	15	7	47
91																1	3	2	9	15	6	40
TOTAL OBSERVED	22	17	1	3	13	2	12	14	1	76	13	1	5	15	2	1	13	3	11	225	79	
# OMISSION ERRORS	7	3	1	3	0	0	3	1	1	13	11	1	5	4	2	1	5	3	2	79	146	65
% OMISSION ERRORS	32	18			0	0	25			17	85			27			38		22		65	35

Table 12. Comparison between correct interpretations, and errors of omission and commission made by 15 people classifying 15 different land use test sites on high flight photos using Legend II.

		ACTUAL OBSERVED UNITS																			TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
		13	17	18	22	28	31	32	34	41	42	43	46	48	49	51	52	53	55	59			
LEGEND II PHOTO INTERPRETED UNITS	13	7	3		1	2	1		1												15	8	53
	28	2				13															15	2	13
	34		1					3	11												15	4	27
	41/48			1						25	5	2	2	10							45	9	20
	42									12	9	2		1	5	1					30	21	70
	43									8	3	2			1	1					15	13	87
	51															14	1				15	1	7
	52									3					2	3	17		3	2	30	13	43
	53																	15			15	0	0
	59															8	4			18	30	12	40
TOTAL OBSERVED		9	4	1	1	15	1	3	12	48	17	6	2	11	8	27	22	15	3	20	225	84	
# OMISSION ERRORS		2	4	1	1	2	1	3	1	23	8	4	2	1	8	13	5	0	3	2	84	141	63
% OMISSION ERRORS		22				13			8	48	47	66		9		48	23	0		10		63	37

(1) Residential, transportation (airport), and commercial and service categories were satisfactorily identified from one test photo showing these urban land-use types. On another photo a test site encompassing Mount Angel Seminary was misinterpreted by more than 85 percent of the interpreters (Table 10). It should have been designated institution (16) under Legend I, or as business and industry (52) under Legend II (Tables 11 and 12). It was confused mainly with other urban categories.

(2) Two test sites contained small towns located within Marion County. Interpreters classifying these sites with Legend I were divided in their choice of categories mainly between strip and clustered development (17) and mixed urban (18). More interpreters classified the sites as undifferentiated urban under Legend II. This seems to suggest that for photo interpretation purposes it might be advantageous to combine categories 17 and 18.

(3) Croplands and pasture (21) were satisfactorily classified by interpreters when using Legend I. While using Legend II the distinction between field crops (41) and row crops (42) was not successfully achieved. Two test sites encompassed grass seed fields (41) and were correctly identified greater than 80 percent of the time; but three sites located within areas where units 41 and 42 were intermixed were poorly recognized (Table 12). Less than 30 percent of these sites were properly classified.

(4) A test site surrounding a field where hops (22 or 43) are grown was misinterpreted by 87 percent of the interpreters (Tables 11 and 12). It was confused mainly with other agricultural types.

(5) One test site surrounded a large boulder field (74 or 13) in the Cascade Range. Nearly half of the interpreters confused the site with forest, snow, or other barren land types.

(6) One test site included a portion of snow covered Mt. Jefferson and was accurately classified as snow (28) by 87 percent of the interpreters using Legend II (Table 11). While using Legend I only 60 percent of the interpreters felt the area was under permanent snow (91) (Table 12). Again, as was found to be the case when this same category was classified on the ERTS-1 test photos, those disliking the choice of permanent snow preferred to classify the site as bare exposed rock (74) or tundra (81).

Classifying Ground Photographs

Twenty-five photographs taken of various land-use subjects at ground level were classified by the interpreters in this final portion of the photo interpretation test. Each photograph classified was compared with a key developed by the author during the verification checks. Overall, 77 percent of the interpreters using Legend I and 78 percent using Legend II agreed with the recorded observed land-use type. These results are not in themselves particularly meaningful unless one considers how each individual photograph was classified, as is shown in Table 13. In this table a comparative examination of how interpreters classified each photograph from the two legend systems is offered. For example, photo number 13, which showed a portion of the Umpqua River, was correctly classified by 12 (80%) interpreters using Legends I and II, respectively. In addition, two interpreters using Legend I misclassified this river as a reservoir (53); and one interpreter misclassified it as a bay or estuary (54). While using Legend II, two interpreters categorized the photograph as showing a lake or reservoir (21), and one interpreter felt it was an estuary (25).

The reason for giving photographs taken at ground level in this test was to try to emulate the situation actually encountered by the author during the verification checks. In reviewing the results of how interpreters classified these photos (Table 13), it is of imporetance to note that categories selected which disagreed with the recorded observed land-use unit might not have been chosen if an actual visit to the ground truth site was made. The information contained within a photograph is obviously restricted and does not offer the same perspective obtained on the ground. In addition, information shown in a photograph may be unclear or may not provide sufficient detail to properly classify the land-use type. One photograph that may have been categorized differently, and probably with more

Table 13. Summary of test interpretations by 15 people on 25 photographs taken at ground level using Legend's I and II.

Photo No. *	Photo Subject Matter	Observed Legend I Unit (key)	No. Agree	% Agree	Other Units Interpreted Legend I	Observed Legend II Unit (key)	No. Agree	% Agree	Other Units Interpreted Legend II
13	Umpqua River	51	12	80	2(53), 1(54)	22	12	80	2(21),1(25)
14	Campbell marsh	31/61	14	93	1(21)	31	13	87	2(46)
15	Alvord desert	71	11	73	1(52),1(53),1(74), 1(75)	11	13	87	2(21)
16	Badlands	75	7	47	1(31),5(34),2(74)	15	11	73	1(17),3(32)
17	Shrub	34	15	100		32	14	93	1(31)
18	Eugene	12	14	93	1(16)	52	15	100	
19	Juniper woodland	42	9	60	2(32),1(33),3(34)	34	7	47	4(32),4(33)
20	Grassland	31	15	100		31	14	93	1(32)
21	Mixed forest	43	9	60	1(32),4(41),1(42)	34	10	67	5(33)
22	Volcanic rock	74	9	60	1(32),3(42),2(41)	13	8	53	1(17),2(18),1(31) 2(34),1(41)
23	Hart Lake	51	11	73	2(53),1(54),1(61)	21	12	80	1(11),1(26),1(31)
24	Mint field	21	13	87	1(22),1(24)	41	13	87	1(42,1(46)
25	Extractive	14	14	93	1(13)	55	14	93	1(18)
26	Power	15	15	100		54	12	80	3(53)
27	Bush beans	21	8	53	7(22)	42	15	100	
28	Coos Bay	54	10	67	5(51)	26	8	53	4(22),3(25)
29	Wheat field	21	15	100		41	12	80	1(31),1(42),1(48)
30	Pasture	21	15	100		46	12	80	2(31),1(41)
31	Gates	17	11	73	3(12),1(15)	52	10	67	3(54),2(59)
32	Coniferous forest	42	13	87	2(43)	34	11	73	2(31),1(32),1(48)
33	Cemetery	19	6	40	5(12),4(16)	52	10	67	1(47),1(51),1(55) 2(59)
34	Vegetative wetland	61	12	80	1(22),1(43),1(54)	31/24	12	80	3(25)
35	Lumber mill	12	14	93	1(15)	52	14	93	1(55)
36	Deciduous forest	41	4	27	2(33),1(42),8(43)	34	8	53	3(32),3(33),1(43)
37	Commercial	12	13	87	1(13),1(17)	52	14	93	1(53)

*Refer to Appendix A for test photograph examples.

agreement had interpreters viewed the site on the ground, was photo number 22. This photo showed an area of dark rock rubble created from past volcanic activity in the Cascade Range. Nine (60%) of the interpreters using Legend I correctly identified the area as category 74 (rockland). The six interpreters who misclassified the site felt the area was forest or rangeland that had been burned. In this case, the photograph did not clearly show that the area was in fact a rock-land.

Ideally, it would be desirable for all interpreters to classify a land-use subject at ground level by a single legend category. If one category is repeatedly and consistently selected to classify a particular land-use subject, then this would seem to suggest its usefulness in adequately describing the land-use type. Conversely, if the choice of legend categories to describe a land-use subject is widely varied, then this would seem to indicate a possible weakness in the classification system; i.e., an insufficient legend unit which properly defines or describes the given land-use subject matter. An example of a land type which was repeatedly and consistently classified by the interpreters was one shown in photo number 17 (Table 13). This photo's subject matter contained low sagebrush (<u>Artemesia arbuscula</u>) growing on a portion of Oregon's rangeland. Fifteen (100%) of the interpreters using Legend I, and 14 (93%) using Legend II agreed that the site was desert shrub (34) or a shrub-scrub type (32).

An example of a land type that was repeatedly (i.e., had a high degree of agreement between interpreters), yet was inconsistently classified was photo number 15. This photo, showing much of the Alvord Desert, was correctly classified by 11 (73%) of the interpreters as category 21 (salt flats) using Legend I; but it was also erroneously classified into four other categories. Whereas, interpreters using Legend II repeatedly classified this photograph better (87%) as category 11 (playas and intermittent lake basins), and confused it less often with only one other category. Therefore, it can be said that category 11 under Legend II, might be more descriptive than category 71 under Legend I, to describe this barrenland type.

An example of a land-use type that was consistently yet erroneously classified was shown in photo number 27. The photo contained a bush bean field growing in Marion county. Interpreters classifying from Legend II all agreed in categorizing the site as category 42 (row crops). Only eight (53%) of the interpreters using Legend I classified the site correctly as category 21 (cropland and pasture). The remaining seven interpreters felt category 22 (orchards, vineyards, bush fruits, and horticultural specialties) more adequately described this agricultural type.

A Consolidated Legend System for Use with Remote Sensing Data

Conducting a comparative testing of two land classification systems seems to imply differences exist making portions of one system more advantageous than the other for certain purposes. These differences may be small or major and may influence one's thinking about the usefulness of an entire legend system. While basic differences may occur, the probability for similarities is even greater. If enough similarities occur, and the differences capable of improving either system, then consolidation is possible. This can make both legends more effective for their intended purpose of being a standardized land classification system.

The consolidated legend system suggested here is from the author's experience in mapping upon ERTS-1 and high flight imagery taken over the State of Oregon, and from the results obtained from the photo interpretation test. By drawing together certain categories from Legends I and II and by forming what is felt to be a workable system in Oregon, it is likely that this system could be useful at a national level.

The following consolidated legend is not meant to represent a new land classification system, but simply a more usable variation of Legends I and II:

CONSOLIDATED LAND-USE - RESOURCE CLASSIFICATION SYSTEM

Level 1	Level 2
10 Urban	
	11 Residential
	12 Commercial and service (business, institutional)
	13 Industrial
	14 Transportation
	15 Communication and utilities (power and fuel transm.)
	16 Open and other
	17 Resource extraction (mines, quarries, etc.)
	19 Undifferentiated urban (mixed, strip and clustered)
20 Agricultural Land	21 Cover crops, field and seed
	22 Row crops, vegetables
	23 Pasture
	24 Orchards, groves, bush fruits, vineyards, horticultural
	25 Other (including animal facilities, buildings, etc.)
	29 Undifferentiated agriculture (21, 22, 23, 24, or 25 complex)
30 Rangeland	
	31 Grassland and herbaceous types (meadows, vegetative wetlands, etc.)
	32 Shrub-scrub types (desert shrub, chaparral, mountain brush, etc.)
	33 Savanna-like types
	39 Undifferentiated rangelands (including complexes and nonconforming natural vegetation communities)
40 Forest Land	
	40 Deciduous (broadleaf and other)
	42 Evergreen (coniferous and other)
	43 Mixed
50 Water	
	51 Streams and waterways (water courses)
	52 Lakes and ponds
	53 Reservoirs
	54 Lagoons and bayous
	55 Bays, coves, and estuaries
	56 Oceans, seas and gulfs
	57 Snow and ice
	58 Other water resources (springs, seeps, wells, etc.)
	59 Undifferentiated complexes

CONSOLIDATED LAND-USE - RESOURCE CLASSIFICATION SYSTEM --Continued.

Level 1	Level 2
60 Barren Lands	61 Playas, dry or intermittent lake basins, salt flats
	62 Rocklands (bare exposed rock, mass movement)
	63 Shorelines, beaches, tide flats, and river banks
	64 Sand other than beaches, aeolian barrens
	65 Other barren lands (badlands, man-made barrens, etc.
	69 Undifferentiated complexes.

SUMMARY AND CONCLUSION

Two land classification systems designed for use with remote sensing data were studied comparatively. Each legend system was tested in terms of photo identification accuracy, ease of use, and completeness of land-use and resource categories.

First level legend units from the two systems were mapped on a State of Oregon ERTS-1 photo mosaic. The mapping effort was verified by a ground truth check. The results showed that 90 percent of the primary categories in Legend I, and 94 percent of the primary categories in Legend II were accurately interpreted. Data from Legend I when subjected to the Chi-square test computed to 3.68, which, with eight degrees of freedom gave a probability level of approximately .870. The computed Chi-square value of data from Legend II was $X^2=3.68$, which, with four degrees of freedom gave a maximum probability level of greater than .995. Whereas the Chi-square value for Legend II exhibited a better goodness of fit than the value for Legend I, they are both considered acceptable probability levels here.

Second level legend units were mapped on color infrared high flight aerial photography taken over Marion County, Oregon. Two methods were employed to verify the mapping effort. The first method used was probably the best as an actual visit was made to ground truth sample sites. Photo enlargements were used to validate sample sites inaccessible by automobile. This second validation method is considered especially useful if subject-photo characteristics are well understood. Data from both validation methods were combined into a total ground truth. The results showed 88 percent of the secondary categories under Legend I and 83 percent of the categories under Legend II to be correctly interpreted.

A photo interpretation test was performed with a total of 15 different interpreters. The test involved identification of previously mapped categories on ERTS-1 and high flight imagery; and photographs taken of land-use subjects at ground level. The results of the test showed interpreters generally chose similar or analogous categories from the two systems when classifying test sites.

Test sites classified by the interpreters and compared against a key were statistically analyzed by an analysis of variance test. The analysis showed no significant differences in the ability of interpreters to classify land-use subjects from either legend system. Extreme variation in the ability of interpreters to identify test sites existed between experience groups. Individuals with the most prior photo and land-use experience consistently identify test sites more accurately on ERTS-1 and high flight photos than the less experienced interpreters.

Considering the author's mapping efforts upon the ERTS-1 and high flight imagery, and the results from the photo interpretation test, the most consistently identified primary level land-use - resource categories were:

Legend I

Agriculture
Rangeland
Forestland
Water

Legend II

Agriculture
Natural Vegetation
Water

Primary level categories less consistently identified were:

Urban
Nonforested wetland
Barrenland
Tundra
Permanent snow and icefields

Urban
Barrenland

Second level land-use - resource categories that demonstrated the highest probability for being identified and classified upon either ERTS-1 or high flight photos were:

Legend I

Residential
Commercial and service
Transportation, communication
Strip and clustered settlement
Open and other
Cropland and pasture

Grassland
Desert shrub
Evergreen forest
Mixed forest

Legend II

Residential
Business and industry
Transportation
Undifferentiated urban

Cover crops
Row crops
Pasture
Herbaceous types
Shrub-scrub types
Forest and woodland

Legend I	Legend II
Streams and waterways	Water courses
Lakes	Ponds, lakes, and reservoirs
Reservoirs	Lagoons and bayous
Bays and estuaries	Bays and coves
Vegetated wetlands	
Salt flats	Playa, dry or intermittent lake basin
Beaches	Shorelines, beaches, tide flats
Sand other than beaches	Aeolian barrens
Bare exposed rock	Rocklands

Second level categories not as consistently identified were:

Legend I	Legend II
Industrial	Power and fuel transmission
Institutional	Resource extraction
Extractive	
Mixed urban	Row crops
Orchards, groves, vineyards	Orchards and vinecrops
Feeding operations	Animal facilities (lg. and sm.)
	Horticultural specialties
	Nonproducing fallow
Chaparral	Savanna-like types
Savannas	
Deciduous forest	Estuaries
Bare nonforested wetland	Springs, seeps, wells
Bare exposed rock	Badlands
	Slicks
Tundra	Mass movements
	Man-made barrens
Permanent snow and icefields	

The two legend systems comparatively examined in this study are in many cases quite similar in their approach to land-use - resource classification. Basic differences do exist though which tend to strengthen and in some cases weaken portions of either legend system. By eliminating the areas of weakness and by combining differences which are capable of improving either system, consolidation is possible. This can make both legends more effective for their intended purpose of being a standardized land classification system. From the author's experience in mapping upon the ERTS-1 and high flight imagery; and from the results obtained from the photo interpretation test, a consolidated legend system for use with remote sensing data has been suggested. This land classification scheme draws together categories under Legends I and II that have the highest probability of being identified on space and high flight imagery, and which provide the most information at first and second levels of classification.

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APPENDICES

APPENDIX A

Example of the Photo Interpretation Test

Given to 15 Volunteer Interpreters

Instructional Sheet

1. The following information and equipment is enclosed and should be returned upon completion of the test.

   Information form
   Two copies of land use legends
   Two photo interpretation record sheets
   One pocket stereoscope
   Set of test photos

2. Fill in the general information form.

3. Remove land-use Legend I and a photo interpretation record sheet from the pouch on the inside cover. Land-use Legend II and the other photo interpretation record sheet will be used in Part 2 of this test.

4. Examine the land use categories provided under Legend I. The definition and criteria for use of each category is attached. The legend provided is a two level hierarchal classification system; meaning the second level land use units are subclasses of the more generalized level I land use units; i.e. residential land is a subclass of urban land.

5. Look at the stereo photo example . These are two color infrared aerial photographs placed side by side for stereo viewing. Using the pocket stereoscope you will note there are three circled areas labeled A, B, C. Each circle contains an area of ground or water surface that can be classified to one of the level II legend units. For example, circle A on the photo example includes an area of residential land; thus it would be classified as 51 or 11 (depending upon which legend you are using).

Part I Testing Procedure

6. Using Legend I

a. You are being asked to classify land use on 3 color and 4 black and white ERTS space photos; 5 high altitude aerial stereo photo pairs; and 25 color photographs.

b. Examine the area within and around the circled area on the photos.

c. Classify the area within the circle to one of the level II land use categories (note: use the pocket stereoscope for only those photos which are in stereo).

d. Using the number preceding the level II land use categories, record the unit identified on the photo interpretation record form. Record only one number in the space provided.

e. Upon completion of the test, place the legend and photo interpretation record form back in pouch.

Part II Testing Procedure

7. Using Legend II

a. Repeat the above procedure using Legend II. It is preferable that a break is taken before resuming Part II. A one day period between consecutive testing is most desirable.

GENERAL INFORMATION

Name ____

Position or
Present Occupation ______________________________________

Date ____

Photo interpretation experience, check one:

_____ Have limited experience, have never more than casually viewed aerial and/or space photography, if at all.

_____ Have moderate interpretation experience with one or several types of photography.

_____ Am an experienced photointerpreter, have had a considerable amount of job or research experience in photo interpretation.

Land use interpretation experience, check one:

_____ Have limited experience, have never performed actual land use mapping, legend development or use, or been involved in land use planning.

_____ Have moderate experience in land use planning, mapping, and/or legend development and use.

_____ Have considerable experience in land use planning. Have been involved in research or a job which required land use mapping, planning, and/or legend development.

NAME ____________________ STARTING TIME __________

LEGEND ____________________ FINISH TIME __________

PHOTO INTERPRETATION RECORD SHEET

Photo 1 a) __________
b) __________
c) __________

Photo 2 a) __________
b) __________
c) __________

Photo 3 a) __________
b) __________
c) __________

Photo 4 a) __________
b) __________
c) __________

Photo 5 a) __________
b) __________
c) __________

Photo 6 a) __________
b) __________
c) __________

Photo 7 a) __________
b) __________
c) __________

Photo 8 a) __________
b) __________
c) __________

Photo 9 a) __________
b) __________
c) __________

Photo 10 a) __________
b) __________
c) __________

Photo 11 a) __________
b) __________
c) __________

Photo 12 a) __________
b) __________
c) __________

13 __________
14 __________
15 __________
16 __________
17 __________
18 __________
19 __________
20 __________
21 __________
22 __________
23 __________
24 __________
25 __________

26 __________
27 __________
28 __________
29 __________
30 __________
31 __________
32 __________
33 __________
34 __________
35 __________
36 __________
37 __________

Photo 1 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	31	33	34	41	42	52	53	74	75	81	91	61
A	volcanic rock						6	2	6*	1			
B	Juniper woodland	2	2	4	1	5	1						
C	snow								2	1	2	9*	1

Legend II

Test Site	13	15	21	28	29	32	33	34	48
A	6*								1
B		1		1		6	3	4*	
C				13*	1		1		

Photo 2 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	32	33	34	52	53	71	74	75	91
A	Diamond Crater				10	1		4*		
B	Summer Lake						8*	1	1	4
C	Shrub-steppe	1		9*			5			

Legend II

Test Site	11	13	21	28	31	32
A	1	3*	11			
B	9*		1	5		
C		4			1	10*


B
C
A
NOV • 73


C
B
A
NOV • 73

Photo 3 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	11	12	13	18	19	21	22	31	41	42	61	34
A	grass seed fields	1	1				11*	1					
B	forest						1			1	13*		
C	Eugene	1	1	1	3*	2	3		1		1	1	1

Legend II

Test Site	17	31	32	34	41	42	46	48	51	52	59
A					11*	1		2*		1	
B	1		1	13*							
C		2	1	1	2		1		2		6*

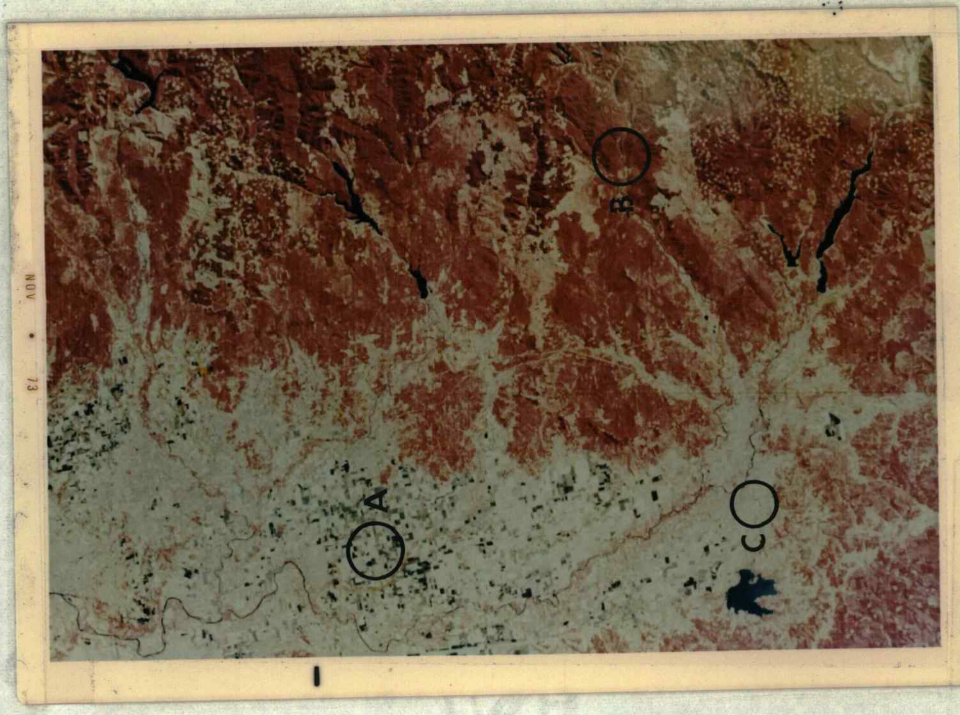
Photo 4 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	18	19	21	22	33	34	42	51	52	61	43
A	wheat			15*								
B	forest					1		12*		1		1
C	La Grande	2*	3	4	1		2		2		1	

Legend II

Test Site	21	31	32	33	34	41	42	46	48	51	59
A						9*	4		1*	1	
B	1	1			9*	4					
C		1	2	1	1	1		2		2	5*


A
B
C


A
B
C

Photo 5 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	11	21	31	34	42	52	53	71	74	75	43
A	Mixed agriculture	3	12*									
B	basalt lava rock					1	8	2		3*		1
C	shrub-steppe		1	4	8*				1		1	

Legend II

Test Site	11	13	21	31	32	33	34	41	42	51
A			1		1	1		5*	4*	3
B		5*	9		1					
C	1			4	7*		2	1		

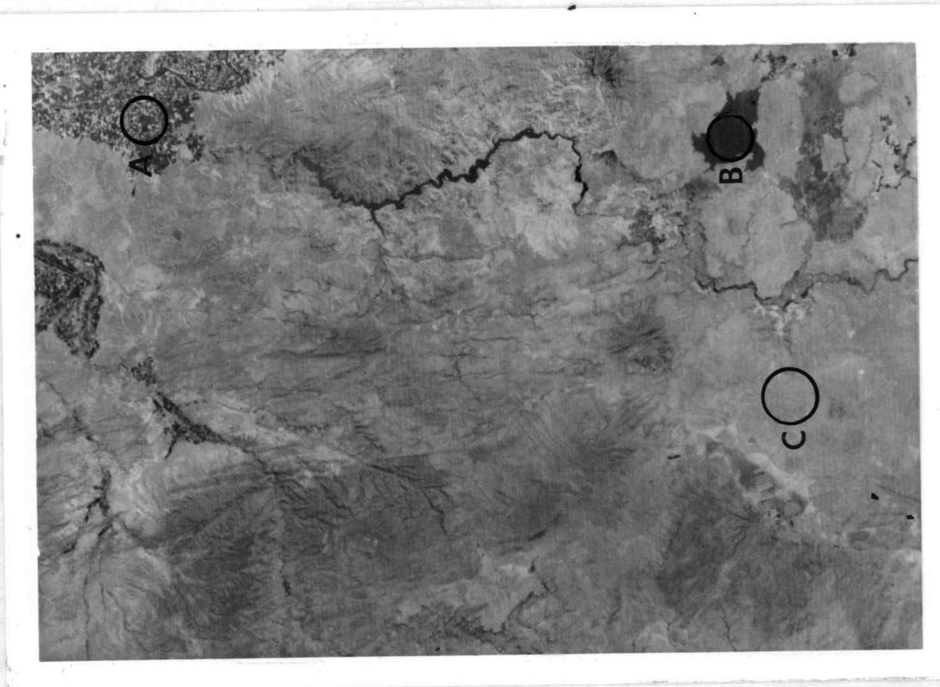
Photo 6 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	33	41	42	43	51	53	54	55	72	73
A	forest	1	1	10*	2				1		
B	bay					1		14*			
C	Pacific ocean			1					12*	1	1

Legend II

Test Site	25	26	27	32	33	34	14
A			2		1	11*	1
B	11*	4*					
C			12*	1		2	


A
B
C

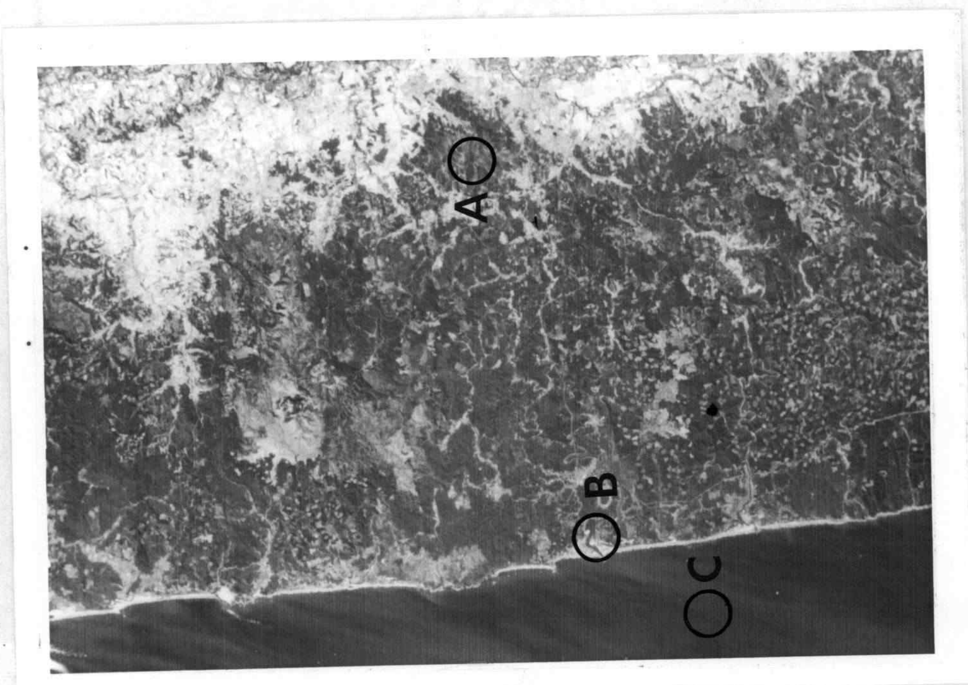

A
B
C

Photo 7 Interpretation Summary

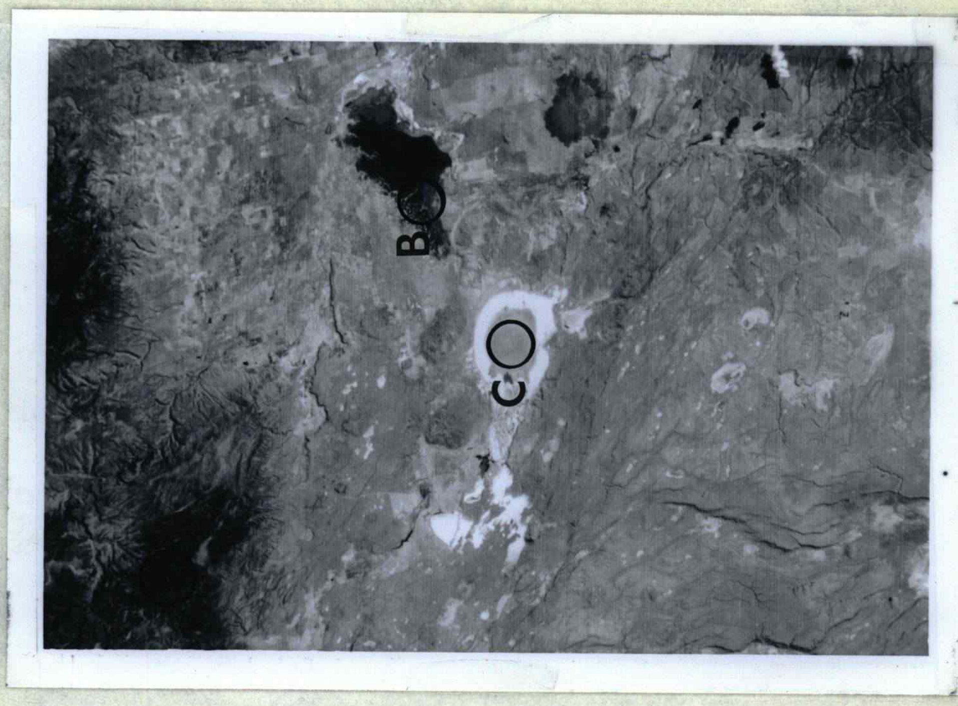
Test Site	Subject Matter	Units interpreted from Legend I: 31	42	52	53	61	62	71	74	75	91
A	forest	1	14*								
B	Malheur marsh			10	1	3*				1	
C	Harney lake			5*			3	2	1	2	2

Test Site	Legend II: 11	21	25	27	28	31	32	34
A		1					1	13*
B		9	2			3*		1
C	9	3*		1	2			

Photo 8 Interpretation Summary

Test Site	Subject Matter	Units interpreted from Legend I: 11	12	17	18	21	22	23
A	Grass seed field					13*	1	1
B	Grass seed field					14*	1	
C	Clustered develop.	4	2	4*	5			

Test Site	Legend II: 18	41	42	46	48	51	52	59
A	1	8*		1	5*			
B		9*	1		5*			
C						7	1	7*


B
C


A
B
C

Photo 9 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	33	42	43	51	74	75	81	91
A	forest	3	11*	1					
B	rock outcrop	1	2	1		8*	1	2	
C	snow				1	2	1	2	9*

Legend II

Test Site	13	17	19	22	28	31	32	34
A		1					3	11*
B	7*	3		1	2	1		1
C	1		1		13*			

Photo 10 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	11	12	13	15	18	21
A	residential	15*					
B	central Salem		10*	4*		1	
C	airport			1	13*		1

Legend II

Test Site	51	52	53
A	14*	1	
B	1	14*	
C			15*


A
B
C


A
B
C

Photo 11 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	21	22
A	bushbean field	15*	
B	bushbean field	12*	3
C	mint field	9*	6

Legend II

Test Site	41	42	43	44	46	48	49
A	8	2*			1	4	
B	4	7*	1	1		1	1
C	8*	4	2		1		

Photo 12 Interpretation Summary

Units interpreted from Legend I

Test Site	Subject Matter	11	12	14	16	17	18	19	21	22	23	43	74
A	clustered develop.	1	1			5*	8						
B	Mtn. Angel Abbey	2		3	2*	3					1	-2	2
C	hop field							1	12	2*			

Legend II

Test Site	34	41	42	43	44	48	49	51	52	55	59
A								1	3		11*
B	3				1		1	2	3*	3	2
C		8	3	2*		1		1			


A
B
C


A
B
C

Photo 13 Interpretation Summary

Subject Matter	Units interpreted from Legend I		
	51	53	54
Umpqua River	12*	2	1

Legend II		
21	22	25
2	12*	1

Photo 14 Interpretation Summary

Subject Matter	Units interpreted from Legend I		
	31	61	21
Campbell marsh	14*	*	1

Legend II	
31	46
13*	2

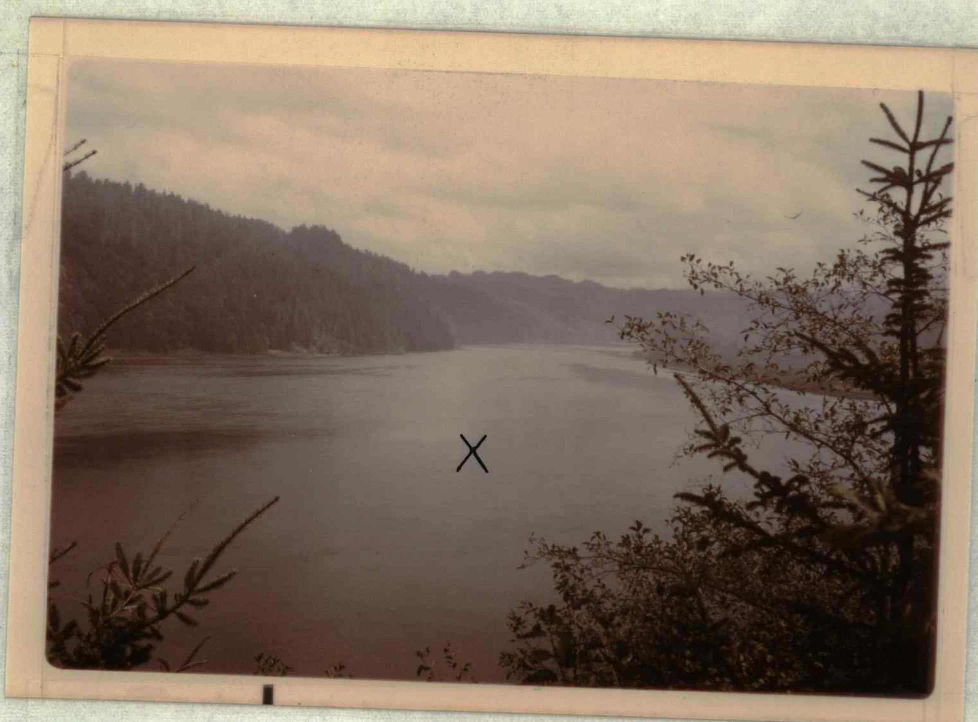


Photo 15 Interpretation Summary

	Units interpreted from Legend I				
Subject Matter	52	53	71	73	74
Alvord desert	1	1	11*	1	1

Legend II

11	21
13*	2

Photo 16 Interpretation Summary

	Units interpreted from Legend I			
Subject Matter	31	34	74	75
badlands	1	5	2	7*

Legend II

15	17	32
11*	1	3

Photo 17 Interpretation Summary

Units interpreted from
Legend I

Subject Matter	34
Low sagebrush	15*

Legend II

31	32
1	14*

Photo 18 Interpretation Summary

Units interpreted from
Legend I

Subject Matter	12	16
central Eugene	14*	1

Legend II

52
15*

Photo 19 Interpretation Summary

	Units interpreted from Legend I			
Subject Matter	32	33	34	42
Juniper woodland	2	1	3	9*

	Legend II		
	32	33	34
	4	4	7*

Photo 20 Interpretation Summary

	Units interpreted from Legend 1
Subject Matter	31
Grassland	15 *

	Legend 11	
	31	32
	14 *	1

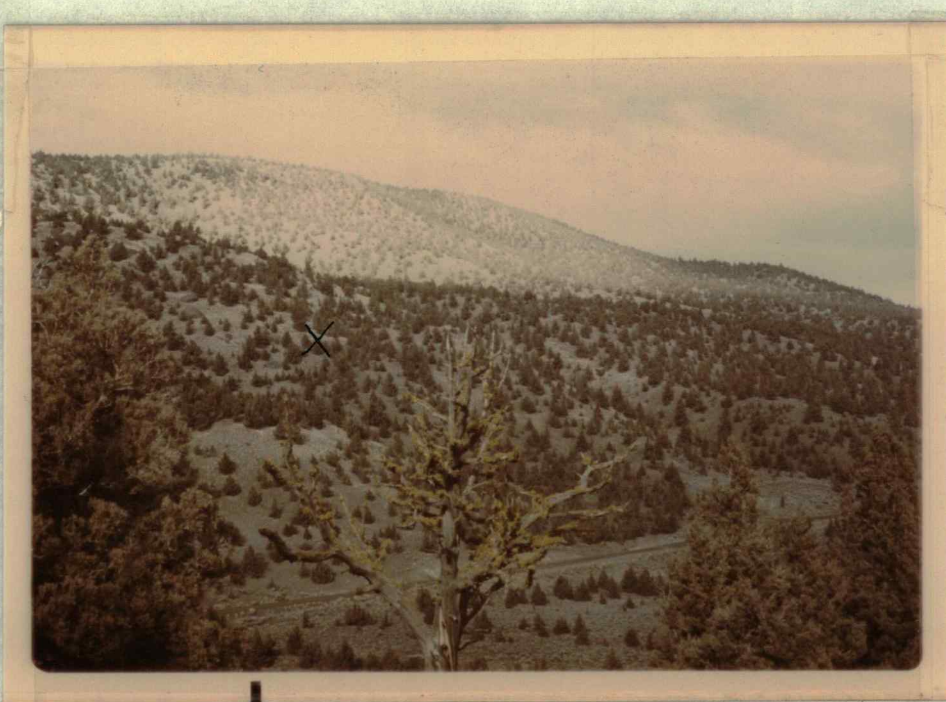


Photo 21 Interpretation Summary

Units interpreted from
Legend 1

Subject Matter	32	41	42	43
Mixed Forest	1	4	1	9*

Legend 11

33	34
5	10*

Photo 22 Interpretation Summary

Units interpreted from
Legend 1

Subject Matter	32	42	74	41
Volcanic rock	1	3	9*	2

Legend 11

13	17	18	31	34	48
8*	1	2	1	2	1

Photo 23 Interpretation Summary

Subject Matter	Units interpreted from Legend I			
	52	53	54	61
Hart Lake	11*	2	1	1
	Legend II			
	11	21	26	31
	1	12*	1	1

Photo 24 Interpretation Summary

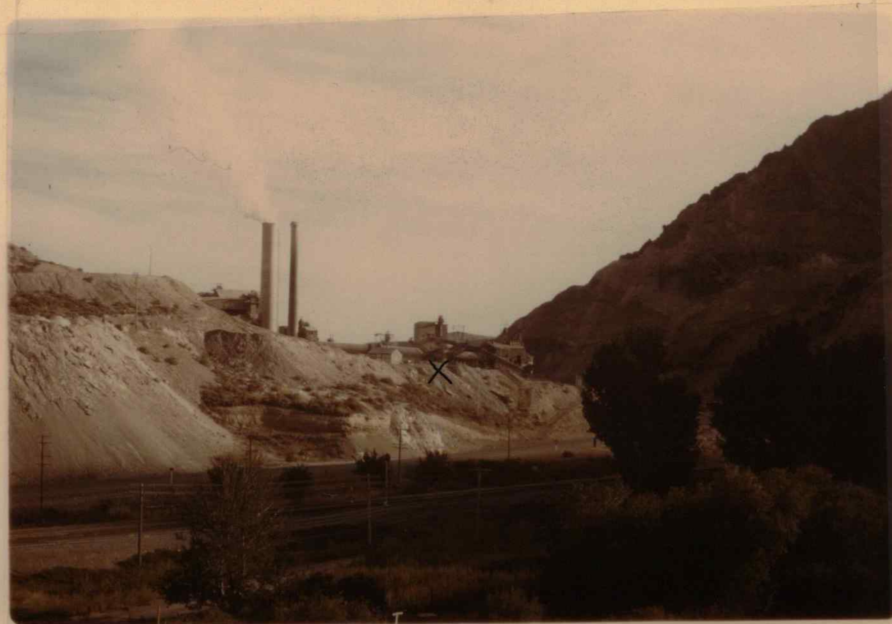
Subject Matter	Units interpreted from Legend I		
	21	22	24
Mint field	13*	1	1
	Legend II		
	41	42	46
	13*	1	1

Photo 25 Interpretation Summary

	Units interpreted from Legend 1
Subject Matter	13 14
Extractive	1 14*
	Legend 11
	18 55
	1 14*

Photo 26 Interpretation Summary

	Units interpreted from Legend 1
Subject Matter	15
Power	15*
	Legend 11
	53 54
	3 12*



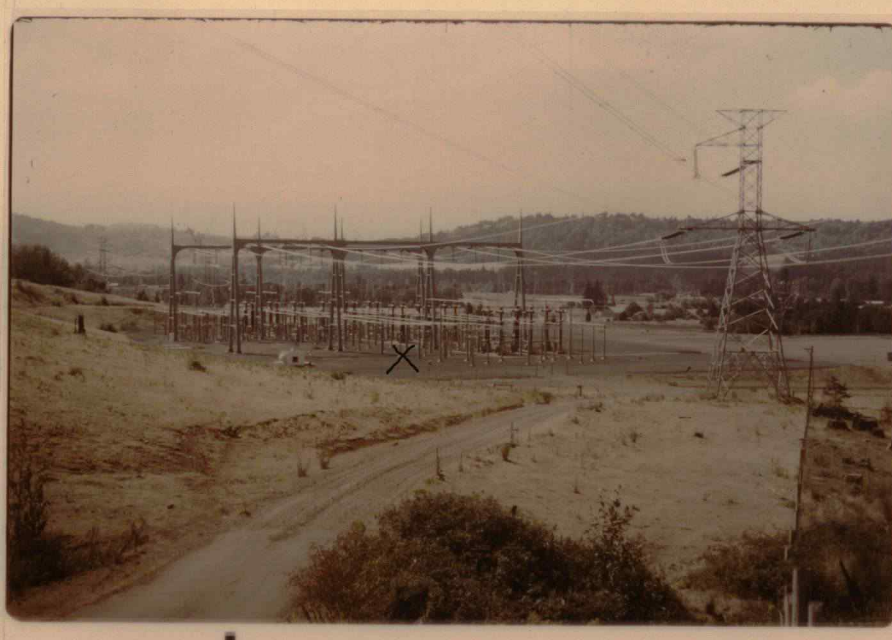


Photo 27 Interpretation Summary

Subject Matter	Units interpreted from Legend 1	
	21	22
Bush beans	8*	7

	Legend 11
	42
Bush beans	15*

Photo 28 Interpretation Summary

Subject Matter	Units interpreted from Legend 1	
	51	54
Coos Bay	5	10*

	Legend 11		
	22	25	26
Coos Bay	4	3	8*

Photo 29 Interpretation Summary

	Units interpreted from Legend 1
<u>Subject Matter</u>	<u>21</u>
Wheat field	15*

Legend 11

31	41	42	48
1	12*	1	1

Photo 30 Interpretation Summary

	Units interpreted from Legend 1
<u>Subject Matter</u>	<u>21</u>
Pasture	15*

Legend 11

31	41	46
2	1	12*

Photo 31 Interpretation Summary

Subject Matter	Units interpreted from Legend 1		
	12	15	17
Strip Development	3	1	11*

	Legend 11		
	52	54	59
Strip Development	10*	3	2

Photo 32 Interpretation Summary

Subject Matter	Units interpreted from Legend 1	
	42	43
Forest	13*	2

	Legend 11			
	31	32	34	48
Forest	2	1	11*	1


COOK
SHACK
GATES
TRAILER
RANCH

Photo 33 Interpretation Summary

	Units interpreted from Legend 1		
Subject Matter	12	16	19
Cemetery	5	4	6*

	Legend 11				
Subject Matter	47	51	52	55	59
Cemetery	1	1	10*	1	2

Photo 34 Interpretation Summary

	Units interpreted from Legend 1			
Subject Matter	22	43	54	61
Vegetated wetland	1	1	1	12*

	Legend 11		
Subject Matter	24	25	31
Vegetated wetland	3*	3	9*

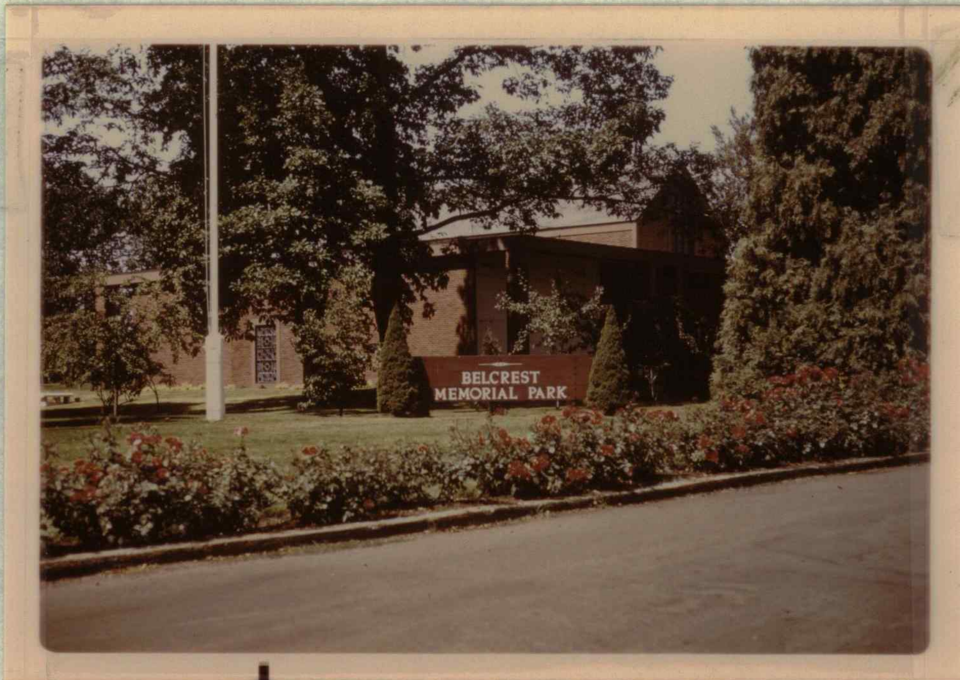

BELCREST
MEMORIAL PARK

Photo 35 Interpretation Summary

Units interpreted from
Legend 1

Subject Matter	13	15
Lumber mill	14*	1

Legend 11

	52	55
	14*	1

Photo 36 Interpretation Summary

Units interpreted from
Legend 1

Subject Matter	33	41	42	43
Deciduous forest	2	4*	1	8

Legend 11

	32	33	34	43
	3	3	8*	1


U.S. PLYWOOD -
CHAMPION PAPERS

Photo 37 Interpretation Summary

	Units interpreted from Legend 1
Subject Matter	12 13 17
Commercial	13* 1 1
	Legend 11
	52 53
	14 1


FAIRWAY INN
MOTEL
AFEWAY

APPENDIX B-1

Comparison between correct interpretations, chi square analysis, and omission and commission made while interpreting second level land use categories under Legend I upon the State of Oregon ERTS-1 photo mosaic.

LEGEND I PHOTO INTERPRETED UNITS	ACTUAL OBSERVED UNITS																		TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
	10	21	31	32	33	34	42	43	52	53	54	55	61	71	72	74	81	91			
10	7						1												8	1	13
21	1	22	2			1	1						2						29	7	24
31		1	9																10	1	10
32			1	9	2		1												13	4	31
33					1														1	0	0
34			2	2		45							1			2			53	8	15
42			2	3			77												82	5	6
43								4											4	0	0
52									2							1			3	1	33
53		1								1									2	1	50
54											1								1	0	0
55												1							1	0	0
61													5						5	0	0
71			1											3					4	1	25
72															1				1	0	0
74																1			1	0	0
81																	5		5	0	0
91																1		2	3	1	33
TOTAL OBSERVED	8	25	17	14	3	46	80	4	2	1	1	1	8	3	1	5	5	2	226	30	
# OMISSION ERRORS	1	3	8	5	2	1	3	0	0	0	0	0	3	0	0	4	0	0	30	196	87
% OMISSION ERRORS	13	12	47	36	67	2	4	0	0	0	0	0	38	0	0	80	0	0		87	13

APPENDIX B-2

Comparison between correct interpretations, chi square analysis, and omission and commission made while interpreting second level land use categories under Legend II upon the State of Oregon ERTS-1 photo mosaic.

LEGEND II PHOTO INTERPRETED UNITS	ACTUAL OBSERVED UNITS																TOTAL # INTER-PRETED	# COM-MISSION ERRORS	% COM-MISSION ERRORS
	11	13	14	15	21	26	27	28	31	32	33	34	41	41/42	46	59			
11	3				1				1								5	2	40
13		6															6	0	0
14			1														1	0	0
15																			
21					4								1				5	1	20
26						1											1	0	0
27							1										1	0	0
28		1						1									2	1	50
31									15						1		16	1	6
32	1			1					5	43	3						53	10	29
33										1	11	1				1	14	3	31
34									3	1	2	80					86	6	7
41												1	11			1	13	2	15
41/42														4			4	0	0
46									2	1					9		12	3	25
59																7	7	0	0
TOTAL OBSERVED	4	7	1	1	5	1	1	1	25	46	16	82	12	4	10	9	226	29	
# OMISSION ERRORS	1	1	0	1	1	0	0	0	10	3	5	2	1	0	1	2	29	197	87
% OMISSION ERRORS	25	14	0	100	20	0	0	0	40	7	31	2	8	0	10	22		87	13