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DEVELOPMENT AND APPLICATION OF AN ECOLOGICALLY BASED REMOTE SENSING LEGEND SYSTEM FOR THE KANANASKIS, ALBERTA, REMOTE SENSING TEST CORRIDOR (SUBALPINE) FOREST REGION)

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ABSTRACT

The development and application of an ecologically based remote sensing legend system designed for multistage inventory of earth resources and land use is presented for the Kananaskis Alberta Remote Sensing Test Corridor. The symbolic legend follows a computer-compatible decimal system and devisive hierarchical logic. The system provides for treatment of natural vegetation, vegetation height and crown closure classes and land uses that have changed the natural landscape. Also in a fundamental ecological context, the legend system provides for assessment of those features of the physical environment that are important in land and resource management and that may generally be identified or indexed from image features by qualified interpreters. These environmental features include: macro-relief, land-forms, surficial geology and soils. In the present study, these physical features of the landscape were not given detailed consideration. A four stage resource inventory example from the ERTS-I satellite (1:1,000,000) to 1:29,000 aircraft imagery illustrates how the natural ecological units of the landscape become the common denominator and facilitate information transfer through application of a unified legend.

BACKGROUND AND LEGEND DEVELOPMENT

A legend for resource analysis is a shorthand by which one describes, explains and annotates a landscape, its resources and uses. When one begins to use synoptic imagery -- aircraft and space acquired -- it is quickly realized that a synoptic or uniform manner of classifying landscapes is needed. The luxury of changing classification systems with changing jurisdictional agencies across the synoptic image scene is no longer desirable. A classification oriented to single-use interests is equally objectionable and unnecessarily costly. The need is for a legend or resource and land classification that is fundamentally ecological, yet which provides for an integration of data about the landscape, its resources and its modifying uses. In the modern context it must also have a consistent logic and be a computer-compatible information system. An integrated information system implies that it is adaptable to team efforts in acquisition, compilation, summary and interpretation. Because we now have increased capability to exploit space and aircraft imagery in combination with ground based data acquisition, legends must be hierarchical in their design so that they match the resolution and information content possible at any specified scale and intensity of examination or at each level of a multistage sampling design.

Legend flexibility must also permit the level of generalization most appropriate to each problem. Highly generalized information is required for policy and broad planning decisions and to provide a prospective for rational action. Highly specific information, on the other hand, is required for management decisions.

In general two factors determine the degree of interpreted detail on the imagery:

(1) the scale and resolution of available imagery.

(2) ultimate use or objective of the end products.

Figure 1 diagrams the numerical legend concept as it has evolved through practical applications since the mid-1960's (Poulton, 1972).

The accompanying symbolic, technical and descriptive legend (Table I and Table II) is designed primarily to explain legend classes as an aid to photo interpreters and resource managers. Ideally the descriptive legend is refined and expanded as the basic inventory progresses.

All legend classes are hierarchical from general to specific. They are based on devisive criteria that are unique to each primary class. The criteria for vegetation classes 300 and 400 are, for example, physiognomic and structural (i.e. similarity of appearance and layered vertical structure of the plant communities) through the third level. The quaternary level is floristically determined. More refined levels are based on plant sociological criteria that define specific plant communities, ecosystems, or habitat-types. A similar logic appropriate to each of the other primary classes, 100 through 900, is used in their respective hierarchical sets.

The following is a well-tested ecological legend concept with the entire legend included to illustrate its broad applicability. It follows the concept that vegetation mirrors the unique environments occupied by each vegetation system (numerator Figure 1) and allows for an assessment of macrorelief, landforms, surficial geology and soils (denominator Figure I).

For convenience, with a base ten numeral system, we have held each level in the symbolic legend to a maximum of nine components.

A Comprehensive Ecological Legend Format

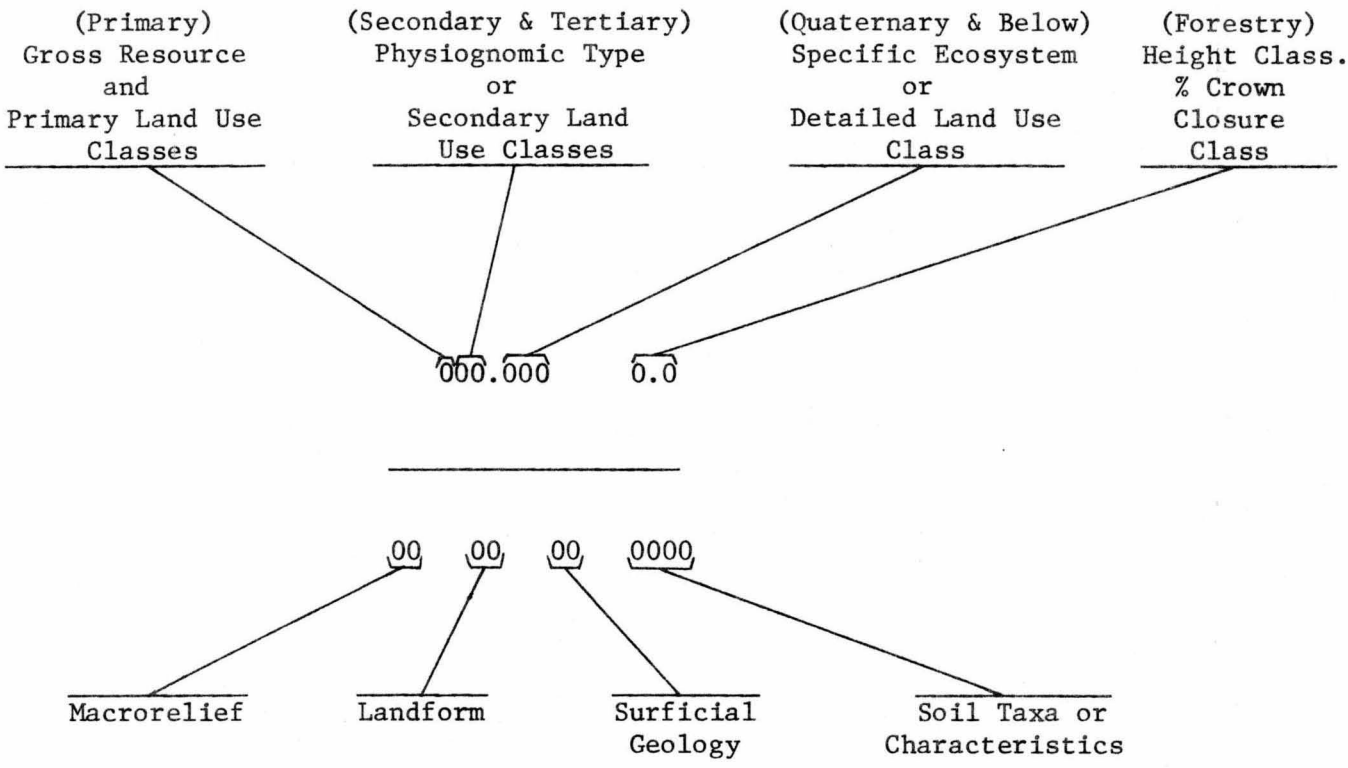

FIGURE 1. The Detailed Format for a Comprehensive Ecological Legend. The legend is designed to treat multiple natural features of the landscape as well as land use and to be computer compatible (in Poulton, 1972 modified).

TABLE I

Symbolic and Technical Legend Classes

EARTH SURFACE AND LAND-USE FEATURES

PRIMARY CLASSES

100 - BARREN LAND
200 - WATER RESOURCES
300 - NATURAL VEGETATION
400 - CULTURAL VEGETATION
500 - AGRICULTURAL PRODUCTION
600 - URBAN, INDUSTRIAL, TRANSPORTATION
700 - EXTRACTIVE INDUSTRY, NATURAL DISASTERS
800 - RECREATION AND OPEN SPACE-RELATED
900 - OBSCURED LAND

PRIMARY CLASSES

SECONDARY CLASSES

TERTIARY CLASSES

QUATERNARY CLASSES

100 - BARREN LAND
- 110 - Playas, dry, or intermittent lake basins
- 120 - Aeolian barrens (other than beaches and beach sand)
  - 121 - Dunes
  - 122 - Sandplains
  - 123 - Blowouts
- 130 - Rocklands
  - 131 - Bedrock outcrops (intrusive & erosion-bared strata)
  - 132 - Extrusive igneous (lava flows, pumice, cinder and ash)
  - 133 - Gravels, stones, cobbles & boulders (usually transported)
  - 134 - Scarps, talus and/or colluvium (system of outcropping strata)
  - 135 - Patterned rockland (nets or stripes)
- 140 - Shorelines, beaches, tide flats, and river banks
- 150 - Badlands (barren silts and clays, related metamorphic rocks and erosional wastes)
- 160 - Slicks (saline, alkali, soil structural, non-playa barrens)
- 170 - Mass movement
- 190 - Undifferentiated complexes of barren lands

200 - WATER RESOURCES
- 210 - Ponds, lakes, and reservoirs
  - 211 - Natural lakes and ponds
  - 212 - Man-made reservoirs and ponds
- 220 - Water courses
  - 221 - Natural water courses
  - 222 - Man-made water courses

PRIMARY CLASSES

SECONDARY CLASSES

TERTIARY CLASSES

QUATERNARY CLASSES

230 - Seeps, springs and wells
  231 - Seeps and springs
  232 - Wells
240 - Lagoons and bayous
250 - Estuaries
260 - Bays and coves
270 - Oceans, seas, and gulfs
280 - Snow and Ice
  281 - Seasonal snow cover
  282 - Permanent snow fields and glaciers
290 - Undifferentiated water resources

300 NATURAL VEGETATION
  310 - Herbaceous types
    311 - Lichen, cryptogam, and related communities
    312 - Prominently annuals
    313 - Forb types
    314 - Grassland, steppe, and prairie
    315 - Meadows
    316 - Marshes
    317 - Bogs and muskegs
    319 - Undifferentiated complexes of herbaceous types
  320 - Shrub/Scrub Types
    321 - Microphyllous, non-thorny scrub
    322 - Microphyllous thorn scrub
    323 - Succulent and cactus scrub
    324 - Halophytic shrub
    325 - Shrub steppe
    326 - Sclerophyllous shrub
    327 - Macrophyllous shrub
      327.1 - Willow *(Salix)* Predominent Vegetation
      327.2 - Birch *(Betula)* Predominent Vegetation
      327.3 - Alder *(Alnus)* Predominent Vegetation
      327.4 - Mixed Shrub *(Prunus/Symphoricarpos/Crataegus)*
      327.9 - Undifferentiated Shrub-Types
    328 - Microphyllous dwarf shrub
      328.1 - Spruce-Fir *(Picea-Abies)* Krummholz Types
      328.2 - Mountain Heath Types *(Vaccinium/Cassiope/Phyllodoce)*
      328.3 - Mountain Avens Types *(Dryas)*
      328.4 - Juniper *(Juniperus)*-Bearberry *(Arctostaphylos)* Types
      328.9 - Undifferentiated
    329 - Undifferentiated complexes of shrub/scrub types
  330 - Savanna-like Types
    331 - Tall shrub/scrub over herb layer
    332 - Broad-leaved tree over herb layer
    333 - Coniferous tree over herb layer
    334 - Mixed tree over herb layer
    335 - Broad-leaved tree over low shrub layer

PRIMARY CLASSES

SECONDARY CLASSES

TERTIARY CLASSES

QUATERNARY CLASSES

336 - Coniferous tree over low shrub layer
337 - Mixed tree over low shrub layer
339 - Undifferentiated complexes of savanna-like types
340 - Forest and Woodland Types
341 - Conifer forests
341.1 - Pine *(Pinus)* Prominent Vegetation
341.2 - Douglas Fir *(Pseudotsuga)* Prominent
341.3 - Pine/Spruce *(Pinus/Picea)*
341.4 - Spruce *(Picea)* Prominent
341.5 - Spruce/Fir *(Picea/Abies)*
341.6 - Fir/Larch *(Abies/Larix)*
341.9 - Undifferentiated
342 - Broadleaf Forests
342.1 - Poplar *(Populus)*Prominent Vegetation
342.2 - Birch *(Betula)* Prominent Vegetation
343 - Conifer-broadleaf mixed forests and woodlands
343.1 - Pine/Poplar *(Pinus/Populus)*
343.2 - Spruce/Poplar *(Picea/Populus)*
343.3 - Douglas Fir/Poplar *(Pseudotsuga/Populus)*
344 - Broadleaf-conifer mixed forests and woodlands
344.1 - Poplar/Pine *(Populus/Pinus)*
344.2 - Poplar/Spruce *(Populus/Picea)*
344.2 - Poplar/Douglas Fir *(Populus/Pseudotsuga)*
349 - Undifferentiated complexes of forest and woodland types
390 - Undifferentiated Natural Vegetation

400 - CULTURAL VEGETATION
410 - Cultural herbaceous types
411-419 - Tertiary levels duplicate those of Natural Vegetation (300)
420 - Cultural shrub/scrub types
421-429 - Tertiary levels duplicate those of Natural Vegetation (300)
430 - Cultural savanna-like types
431-437, 439 - Tertiary levels duplicate those of Natural Vegetation
440 - Cultural forest and woodland types
441-443, 449 - Tertiary levels duplicate those of Natural Vegetation
490 - Undifferentiated cultural vegetation types

500 - AGRICULTURAL PRODUCTION
510 - Field crops
520 - Vegetable and truck crops
530 - Tree, shrub, and vine crops

PRIMARY CLASSES

SECONDARY CLASSES

TERTIARY CLASSES

QUATERNARY CLASSES

540 - Pasture
550 - Horticultural specialties
560 - Non-producing fallow, transitional, or idle land
570 - Agricultural production facilities
580 - Aquaculture
590 - Undifferentiated agricultural production

600 - URBAN, INDUSTRIAL, AND TRANSPORTATION
610 - Residential
620 - Commercial and services
630 - Institutional
640 - Industrial
650 - Transportation, communications, and utilities
651 - Man and Material Transport
651.1 - Rail
651.2 - Motor Vehicle
651.3 - Water
651.4 - Air
651.5 - Trails, foot and animal
651.9 - Undifferentiated
652 - Utilities distribution
653 - Power production
654 - Communication
655 - Sewer and solid waste
659 - Undifferentiated
670 - Vacant plots and lots
690 - Undifferentiated urban

700 - EXTRACTIVE INDUSTRY AND NATURAL DISASTERS
710 - Non-Renewable Resource Extraction
711 - Sand and Gravel
712 - Rock quarrie
713 - Petroleum Extraction - Gas and oil fields
714 - Oil shale and sand extraction
715 - Coal/peat
716 - Non-metalic, chemical, fertilizer, etc.
717 - Metalic
719 - Undifferentiated
720 - Renewable resource extraction
721 - Forest harvest
721.1 - Clearcut Forest
721.2 - Selective Forest Cut
722 - Fisheries
729 - Undifferentiated

PRIMARY CLASSES

SECONDARY CLASSES

TERTIARY CLASSES

QUATERNARY CLASSES

730 - Natural disasters
- 731 - Earth
- 732 - Air
- 733 - Fire
- 734 - Water
- 735 - Disease
- 739 - Undifferentiated

800 - RECREATION AND OPEN SPACE RELATED
- 810 - Natural greenways, open space and buffer zones
- 820 - Preservation areas and natural museums
- 830 - Improved and developed open space
- 840 - Historical and archeological sites
- 850 - Scenic views
- 860 - Rock hounding, paleontological sites
- 870 - Recreation facilities
- 880 - Designated destructive use areas
- 890 - Undifferentiated

900 - OBSCURED LAND
- 910 - Clouds and fog
- 920 - Smoke and haze
- 930 - Dust and sand storms
- 940 - Smog
- 990 - Undifferentiated obscured land

TABLE II

Descriptive Legend for Selected Classes

100 - BARREN LAND: Barren land is somewhat relative but it is intended to cover all situations where the earths surface is essentially barren, rock, gravel, or mineral soil. It is impossible to specify a vegetational cover percentage threshold for barren land. For example, a talus slope with a few shrubs around the periphery or rarely within the talus would still be a barren land class. This class is primarily intended for natural barren lands and not man modified landscape.

1XO - Experience has shown that barren land subclasses should never go beyond tertiary level and frequently it is unnecessary to go beyond the secondary class. To do so makes the barren land class redundant with geological information where the latter is assessed as a component of the physical environment or land surface.

Practically all of the secondary classes under 100 are self-explanatory.

200 - WATER RESOURCES: Include all ground surface areas covered by natural or man-made water surfaces -- streams, lakes, reservoirs, snow and ice, canals, enclosed acueducts, and other water bodies lacking a surface vegetational cover. This class includes lakes and ponds with heavy "algal bloom" but not ponds with a floating or moderately dense, emergent vegetational covering.

2XO - These secondary subclasses are all self-explanatory or defined in standard dictionaries. The main divergence of this legend system from others in use is the inclusion of snow and ice, 280, as a sub-category. This seems far more logical to us than separating snow and ice at primary levels as is sometimes done. By inclusion as a subset it permits easy agglomeration of

all water resource features in a study area or watershed.

300 - NATURAL VEGETATION: This class includes natural or native vegetation consisting of essentially indigenous species or introduced species that have been essentially naturalized to the region and that have found an ecological niche as though they were a part of the original vegetation. This class includes all successional stages in the natural vegetation. In mapping and identification, one should avoid trying to map the presumed "climax" or eventual equilibrium vegetation. One can instead map and identify vegetation as it exists at the time imagery was obtained. The postulation of the climax areas comes later as an interpretation of the basic inventory.

310 - Herbaceous Types: That vegetation (annual, biennial, or perennial) which in aspect is dominantly herbaceous -- including any or all grasses, grass-like plants, forbs, and non-vascular or vascular cryptogams. Other growth forms of vegetation may be present but they are decidedly subordinate in terms of aspect.

311 - Lichens, Cryptogam, and Related Communities: Areas with lichens, mosses, liverworts, algae, fungi, vascular cryptogams and any other non-woody non-angiospermous plants occurring as the dominant vegetation. This class is primarily used in arctic and alpine tundra conditions. Lichens covered rocklands should be classed 130, not 310.

312 - Prominently Annuals: Areas often devoid of vegetation during much of the year with more or less dense annual plants growing during certain seasons of favorable precipitation. This class usually possesses a gramineous aspect. (Not applicable in Kananaskis Remote Sensing Test Corridor)

313 - Forb Types: Biennial or perennial broadleaved herbs forming the dominant vegetation. This class does not include

prominence of grasses, grass-like plants, and vascular cryptogams.

314 - Grassland, Steppe, and Prairie: Any land area dominated by grass vegetation. Tall grass prairies, short grass prairies, desert grasslands, "midgrass plains", bunchgrass, and grass dominant steppes are all included in this category.

315 - Meadows: Areas dominated generally by species of Gramineae (grasses) or Cyperaceae (and related families, sedges and rushes, grass-like) where soil moisture conditions fluctuate greatly from one season to the next but tend toward mesism. Alpine and sub-alpine meadows are located here.

316 - Marshes: This is a broad class primarily intended to include hygric (very wet) vegetation which may be dominated by Gramineae (grasses), Juncaceae (ruches), Typhaceae (cattails) and other aquatic and sub-aquatic flowering plants.

317 - Bogs and Muskegs: Hygric (very wet-standing water) to moist conditions dominated by *Sphagnum* and other mosses, Cyperaceae (sedges), occasionally Juncaceae (ruchses), Cryptogams (lichens, liverworts, etc.) and such as *Salix* (willows), and *Ledum* (Labrador Tea). These areas are largely under the direct influence of the water table especially in permafrost zones.

320 - Shrub/Scrub Types: All types of shrubs are the prominent vegetation. These usually form a closed or nearly closed layer so that the herbaceous layer is subordinate. The herbaceous ground layer of this vegetation is highly variable but can be important. The aspect is one of a prominently low woody vegetation.

327 - Macrophyllous Shrub: Large-leaved, deciduous shrubs occurring as the dominant vegetation; including Salicales (willows), Rosales (rose), *Shepherdia, Symphoricarpos* (snow-bush), some Ericales (heaths), *Alnus* (alder), *Elaeagnus* (wolfberry) and *Menziesia* (false azalea), and *Lonicera* (honeysuckle).

328 - Microphyllous Dwarf Shrub: Small-leaved shrubs forming the dominant vegetation type; including ericaceous arctic and alpine heath vegetation such as *Arctostaphylos* (bearberry), *Vaccinium* (blueberry), *Cassiope* (heather), *Ledum* (Laborador Tea), *Juniperus* (juniper) and *Dryas* (avens). Although this is primarily an arctic-alpine class (i.e. above timberline) members of this designation are found at lower elevations in the mountains and foothills.

329 - Undifferentiated Complex of Shrub/Scrub Types: Utilised in the Kananaskis study area where it is impossible to determine the prominence of either 327 or 328.

330 - Savanna-like Types: The world literature in no way agrees on the definition of a savanna. We have thus been somewhat arbitrary in phrasing the following descriptive definition that seems to fit most temperature and many tropical situations where the expression savanna has been used to describe the unique community. In contrast to some tropical writers, we are not including the tall grass, sparse overstory with a dense shorter grass understory as savanna. This latter belongs in the 310, herbaceous class. Vegetation consisting of sparse, taller woody plants interspersed somewhat regularly throughout by a more dense low shrub or herbaceous layer to give a distinct two-storied community.

We have tested many percentage cover thresholds in the tall woody layer to differentiate or characterize the savanna. Most of these have been difficult to apply consistently because of variation in the size of the individuals in the tall layer. The larger the size, the more widely they can be dispersed and still present an accurate savanna-like aspect. We therefore prefer not to specify such thresholds but to say that the vegetations should be savanna-like in their appearance or aspect to match as closely as possible the intent of the above description.

340 - Forest and Woodland Types: The tree layer forms the dominant vegetational feature. This layer often forms a closed canopy over a variety of subordinate vegetation types.

341 - Conifer Forests: Forested areas of cone-bearing trees dominated by any Coniferales or Taxales. The major genera represented are as follows: *Pinus* (pine), *Picea* (spruce), *Abies* (fir), *Larix* (larch) and *Pseudotsuga* (Douglas-fir).

342 - Broadlead Forests: Deciduous, semi-deciduous, or ever-green angiospermous (flowering) forest species: *Populus* (Poplar).

343 - Conifer-Broadleaf Mixed Forest and Woodland: Any conifers and Taxales and broadleaf angiosperms mixed in a dense forest growth or more open woodlands. Cover of the conifer-broadlead mixture may vary from 50-80%.

344 - Broadleaf-Conifer Mixed Forest and Woodland: Any broadleaf and Conifers and Taxales mixed in a dense forest growth or more open woodlands. Cover of the broadleaf conifer mixture may vary from 50-80%.

400 - CULTURAL VEGETATION: This class provides for the culturally introduced and intensively managed vegetations where the management objective is essentially maintenance of a permanent stand subsequently managed and manipulated through ecological rather than agronomic principles.

The class is designed primarily to provide for seeded rangeland and planted coniferous forests where the intention is permanency of cover.

Some would argue that this class should be in primary category 500, agricultural production. We prefer the class 400 because, generally, foresters and range managers prefer to identify these intensively treated areas as forests and rangeland respectively. In the context of land use and image interpretation such landscape modification could fall in primary category 700, extractive industry and natural disasters. For example, a clearcut forest or selectively logged forest is clearly evidence of renewable resource extraction and photo identifiable. If these cutover areas were allowed to revert to natural successional patterns then the areas are classed in the appropriate 300 category. These types are treated as seral vegetation. If, however, such areas were additionally planted to exotic species not initially natural to the site, they would then be classed under the appropriate 400, cultural vegetation, category. By complexing primary categories 700 and 300 or 400 the information content is maximized.

500 - AGRICULTURAL PRODUCTION: These are land areas cleared of the natural vegetation and managed by agronomic principles for production of food, fiber or fodder crops. The class includes any land areas or structures and facilities directly related to intensive agricultural practices. These agricultural lands are characterized by the relatively constant manipulation by man through control of the vegetation and micro-environment (fertilization, irrigation, etc.).

This class includes the permanent pasture managed for maximum yield by fertilization, irrigation and periodic renovation. These are pastures generally included within or in juxtaposition with the crop field boundary also meeting the above criteria.

Forests or woodlocks, windbreaks and woodlocks included within the cropland area would be treated by the appropriate 300 or 400 subclass if the units are of mappable size.

510 - Field Crops: Cereals, grains, forage, drugs, spices, oil, fiber crops and other field crops which are the dominant land use.

520 - Vegetable and Truck Crops: Legumes, leafy vegetables, roots, tubers, bulbs, cucurbit, solanaceous, and perennial vegetable crops (including other herbaceous crops such as fruit crops) are in this category.

530 - Tree, Shrub, and Vine Crops: Fruit, nut, and beverage crops with three, shrub, or vine growth forms.

540 - Pasture: Any intensively managed land (fertilized, irrigated and/or renovated or appropriate) utilized for grazing or browsing, with or without periodic mechanical harvest. A pasture may be harvested as a "permanent" crop or managed as a temporary lay in a crop rotation plan.

550 - Horticultural Specialties: Artifically planted and maintained flower, shrub, or tree stock. This includes nursery stock, flowers (whether grown for seed, rootstocks, corns, bulbs, tubers, or blooms), and other herbaceous horticultural plants occurring in various sized production lots.

560 - Non-Producing Fallow, Transition, or Entrapped Land: Fallow plowed (or variously worked), and leached cropland including

harvested fields; included here are abandoned or idle croplands, fields, and pastures as well as entrapped lands that are isolated from effective agricultural production by being surrounded or blocked from access by class 600 lands.

570 - Agricultural Production Facilities: At all but the largest of inventory scales, these features usually represent point data, i.e., of non-mappable size but they may be particularly important to annotate, especially in complete land-use inventories. Structures and facilities utilized for animal or plant production (except fisheries, see class 580) make up this category. Barns, sheds, holding pens, and greenhouses are examples.

580 - Aquaculture: Fish and shellfish hatcheries or other structures, rearing areas, and production ponds are included in this category.

600 - URBAN, INDUSTRIAL AND TRANSPORTATION: This class includes all urban, industrial and transportation activities that have modified the natural landscape. Transportation is taken in the broad sense and includes communications and utilities. Primary category 800, recreation and open space related can also be utilized. In a manner similar to the discussion of complexing primary categories 700 and 300 or 400 (extractive industry and natural or cultural vegetation respectively) category 800, may be complexed with natural or cultural vegetation and again maximize our information content.

650 - Transportation, Communications and Utilities: Highways and railways make up the two basic transportation means that require stationery routings visible on remote sensing images. Facilities related to all transportation types are included in this category (seaports, airports, runways, railroad terminals, bus terminals,

highways, roads, etc.). Resource transportation facilities that are non-mobile themselves are included in this category (oil pipelines, gas, electricity and airwave facilities). Power production facilities such as dams, nuclear plants, solar cells, geothermal and coal-fired plants are included. Sewer and solid waste disposal such as sewage lagoons, settling ponds, and dumps are readily identifiable and found in this class.

700 - EXTRACTIVE INDUSTRY AND NATURAL DISASTERS: This category was developed to account for the modification of the natural landscape by man as resources are extracted in contrast to the natural barrens of category 100. In addition the consideration of the natural disorders of nature such as caused by fire, water, wind and plant diseases and insect outbreaks are included as photoidentifiable events present at the time of image acquisition.

710 - Non-Renewable Resources Extraction: The classes listed in this category are intended to cover man's modifications of the landscape such as by surface and subsurface mining (sand, gravel, coal, petroleum, etc.). The concept of a non-renewable resource is taken in the broad sense and is delimited by finite time.

720 - Renewable Resource Extraction: Primarily directed at the forest industry to cover such practices as clearcut and selective cut logging. These categories have a great deal of room for expansion however. The area of commercial fisheries could readily be included under this category, for example.

730 - Natural Disasters: This category arose to account for catastrophic natural disruptions of the landscape which are due to short term events such as forest and grassland fires, floods, earthquakes, hurricanes, tornados, cyclones, plant and insect induced diseases, etc. The subcategories are under development

at present.

800 - RECREATION AND OPEN SPACE: A category which is intended to allow description of man's recreational habits in both urban and rural settings. Some of the classes under development are interpretive such as 850, scenic views. The nature of the science of recreation is such that it requires a framework to allow for meaningful discussions and sound management decisions and design. Much of the current information vaccuum in this area exists because of single-use orientation and failure in the information transfer processes. Real time analysis in decision making is critical for sufficient feedback and wise management.

900 - OBSCURED LAND: This class is intended to provide for those portions of remotely sensed imagery in which the earth's surface is essentially obscured by clouds and other atmospheric obstruction. It is used primarily where it becomes necessary to account for 100% of the image frame area.

910 - Clouds and Fog: Naturally occurring water vapor obscuring the land surface.

920 - Smoke and Haze: Natural or man-caused smoke or haze dense enough to obscure the land surface.

930 - Dust and Sand Storms: Sand, silt and/or clay particles born aloft and dense ehough to obscure the land surface.

940 - Smog: Man-caused particulate matter, vapors, chemicals and other smog substances suspended in the atmosphere densely enough to obscure the land surface.

Also, in each case beyond the primary classes, we have retained the digit 9 to signify an undifferentiated complex of classes at the indicated level, e.g., 09 or 009.

If, for example, one wishes to indicate any or all classes within a set without being specific, only the appropriate digit between 1 and 8 is used. If, on the other hand, one wishes to denote an unspecified set of classes at a given level, e.g., a completely unspecified kind of shrub/scrub vegetation, the designator 320 would be used. If, on the other hand, one is specifying a shrub/scrub area in which two or more specific kinds of shrubby vegetation are prominent but their amounts are not proportioned, the designator 329 should be used (Table I). This designation connotes a more restricted but still undifferentiated complex of shrub/scrub vegetation. The undifferentiated complex designator is then explained completely in the descriptive legend for the project area.

An addition to the legend system which was specifically designed for foresters concerns vegetation height and percentage crown closure classes. To maintain continuity with the decimal system, height and percentage crown closure classes are broken into a maximum of nine components. The delineation for each class is a function of the users needs. A possible approach is listed as follows:

Height Class	
1	0 - 10 feet
2	11 - 20 feet
3	21 - 30 feet
4	31 - 40 feet
5	41 - 50 feet
6	51 - 60 feet
7	61 - 70 feet
8	71 - 80 feet
9	81 - 90 feet

% Crown Closure	Class
.1	0 - 10 %
.2	11 - 20 %
.3	21 - 30 %
.4	31 - 40 %
.5	41 - 50 %
.6	51 - 70 %
.7	71 - 80 %
.8	81 - 90 %
.9	91 - 100%

For example, an overstocked lodgepole pine forest 20 feet high would be symbolized as 2.9. The system can be expanded as needs are defined.

Physical feature classes are omitted from detailed discussion here and are under development for the east slopes of the Alberta Rocky Mountains with emphasis on the Kananaskis, Alberta Remote Sensing Test Corridor. For details of tertiary level legend units see Poulton (1972).

LEGEND APPLICATION

A portion of the legend system is illustrated as it has been adapted and applied in the southern Canadian Rockies -- Kananaskis, Alberta Remote Sensing Test Corridor. In the examples only the numerator is utilized to illustrate the multistage and hierarchical dimensions of the legend system.

Plate I (stage I) is a satellite perspective using a portion of an ERTS-I false color composite image (MSS: bands 4,5,6) taken October 5, 1972. The image shows part of the eastern slopes of the Rocky Mountains of Alberta including the town of Cochrane (extreme right), The Trans Canada Highway, The Bow and Elbow Rivers and a portion of the Kananaskis remote sensing test corridor outlined in a solid black line (extreme right). The Environmental Sciences Centre (Kananaskis) of the University of Calgary and the Kananaskis Forest Experimental Station are both located on the shores of Barrier Lake as seen in Plates, I, II and III.

The subsample of Stage I shown in Plate II illustrates the increase in information content with increasing scale from Stage I (1:100,000 original) to Stage II (1:94,000 original).

LEGEND PLATE I

130 Rocklands
210 Ponds, lakes, and reservoirs
212 Man-made reservoirs and ponds
220 Water courses
314 Grasslands, steppe and prairie
320 Shrub/scrub vegetation
341 Conifer forests
342 Broadleaf forests
343 Conifer-broadleaf mixed forests and woodlands
344 Broadleaf-conifer mixed forests and woodlands
500 Agricultural production
651 Man and material transport
653 Power production
910 Clouds

LEGEND PLATE II

130 Rocklands
133 Gravels, stones, cobbles, and boulders (usually transported)
211 Natural lakes and ponds
212 Man-made reservoirs and ponds
221 Natural water course
314 Grassland, steppe and prairie
315 Meadows
317 Bogs and muskegs
327 Macrophyllous shrub
327.1 Willow *(Salix)*
328 Microphyllous shrub
329 Undifferentiated complexes of shrub/scrub types
341 Conifer forests
341.1 Lodgepole Pine *(Pinus)* predominant vegetation
341.3 Mixed conifer *(Pinus/Picea)*
341.5 White Spruce/Alpine fir *(Picea/Abies)*
342 Broadleaf forests
342.1 Poplar *(Populus)* predominant vegetation
343 Conifer-broadleaf mixed forests and woodlands
343.1 Lodgepole Pine/Poplar *(Pinus/Populus)*
343.2 White Spruce/Poplar *(Picea/Populus)*
344 Broadleaf-conifer mixed forests and woodlands
344.1 Poplar/Lodgepole Pine *(Populus/Pinus)*
344.2 Poplar/White Spruce *(Populus/Picea)*
344.4 Poplar/mixed conifer *(Populus/Pinus/Picea)*
610 Residential
630 Institutional
640 Industrial
650 Transportation, communications and utilities
651.1 Railroad
651.2 Motor vehicle (highway)
652 Utilities distribution
653 Power production
655 Sewer and solid waste
711 Sand and gravel
712 Rock quarry
721 Forest harvest
830 Improved and developed open space (campground)
910 Clouds

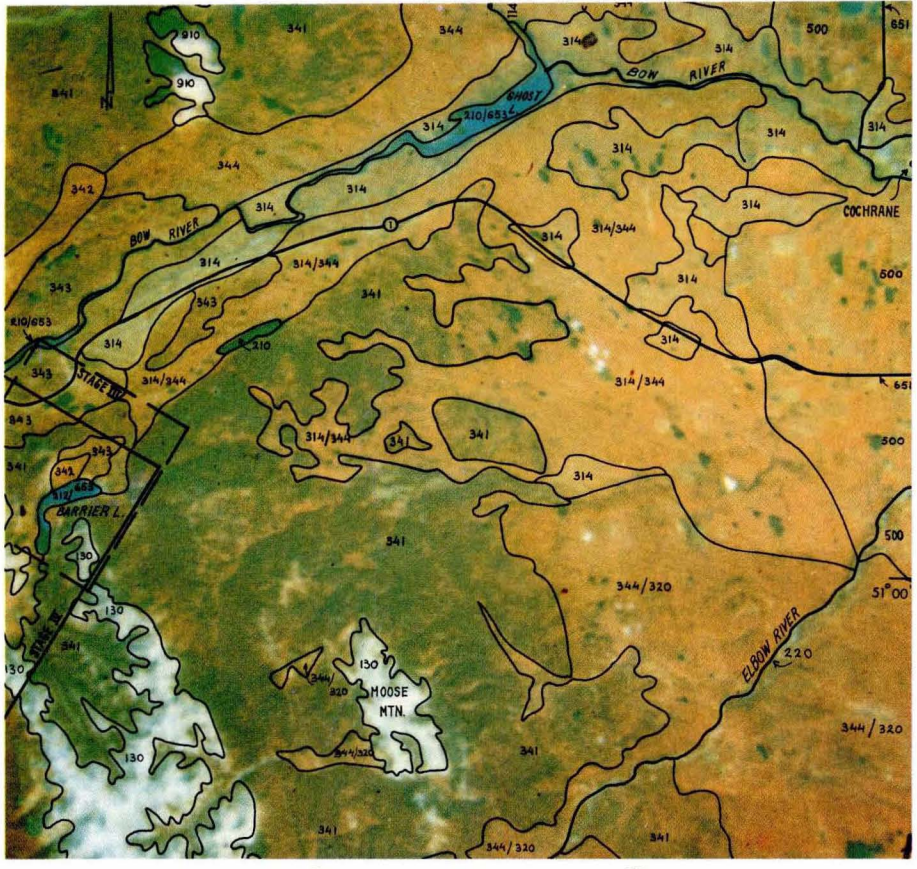

PLATE I

ERTS Image E1344-18075, July 2, 1973

Showing a portion of the eastern slopes of the Rocky Mountains and part of the Kananaskis, Alberta remote sensing test corridor. Stage I of the ecological legend application for a four-stage sampling design is illustrated.

Produced from bands 4, 5 and 6 with blue, green and red filters respectively, using a color additive viewer.

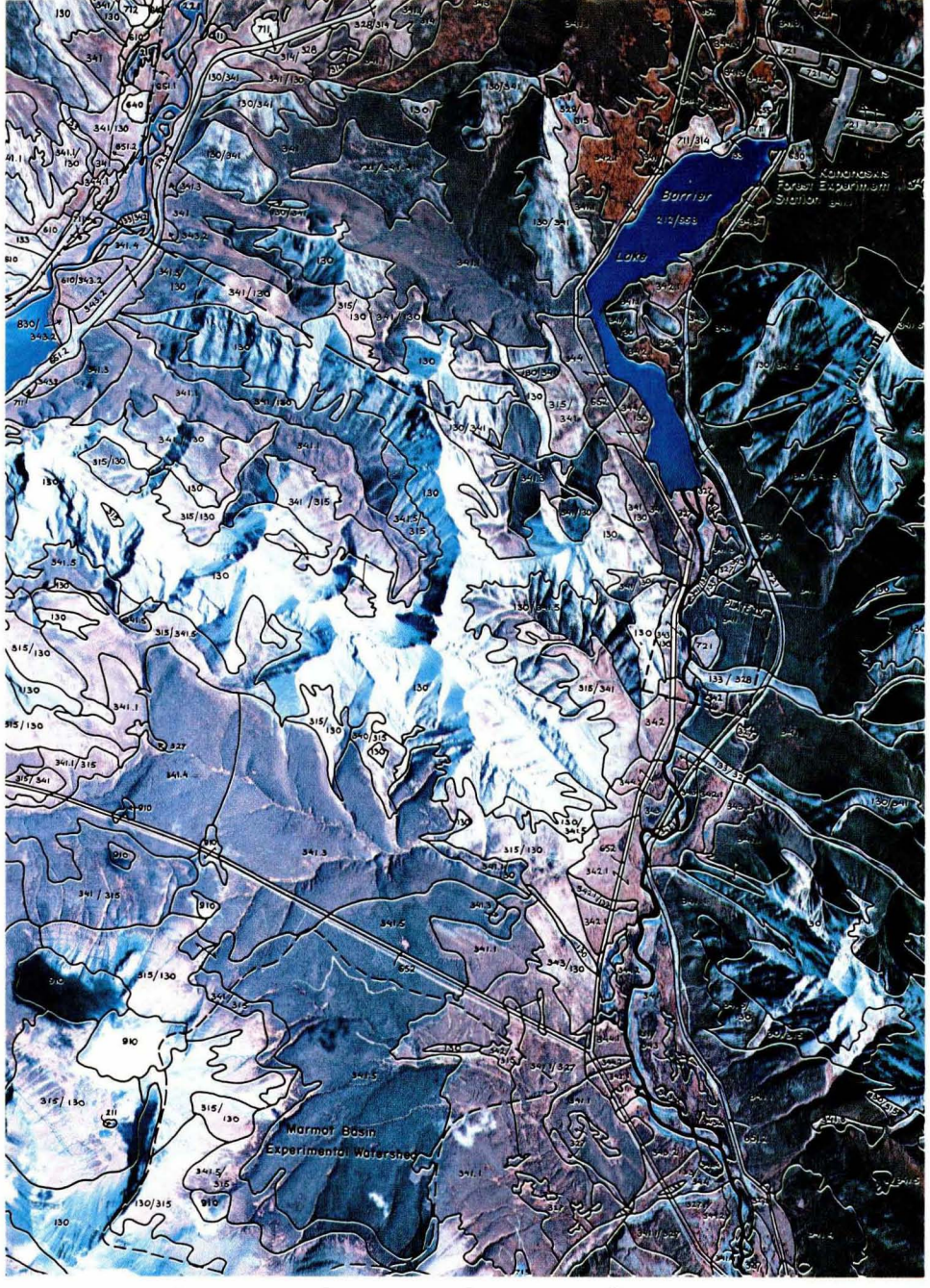

PLATE II

Portion of the Kananaskis, Alberta remote sensing test corridor. Stage II of a four stage sampling design is illustrated. Original scale 1:94,000, Aerochrome Infrared (2443)

Date: August, 1972

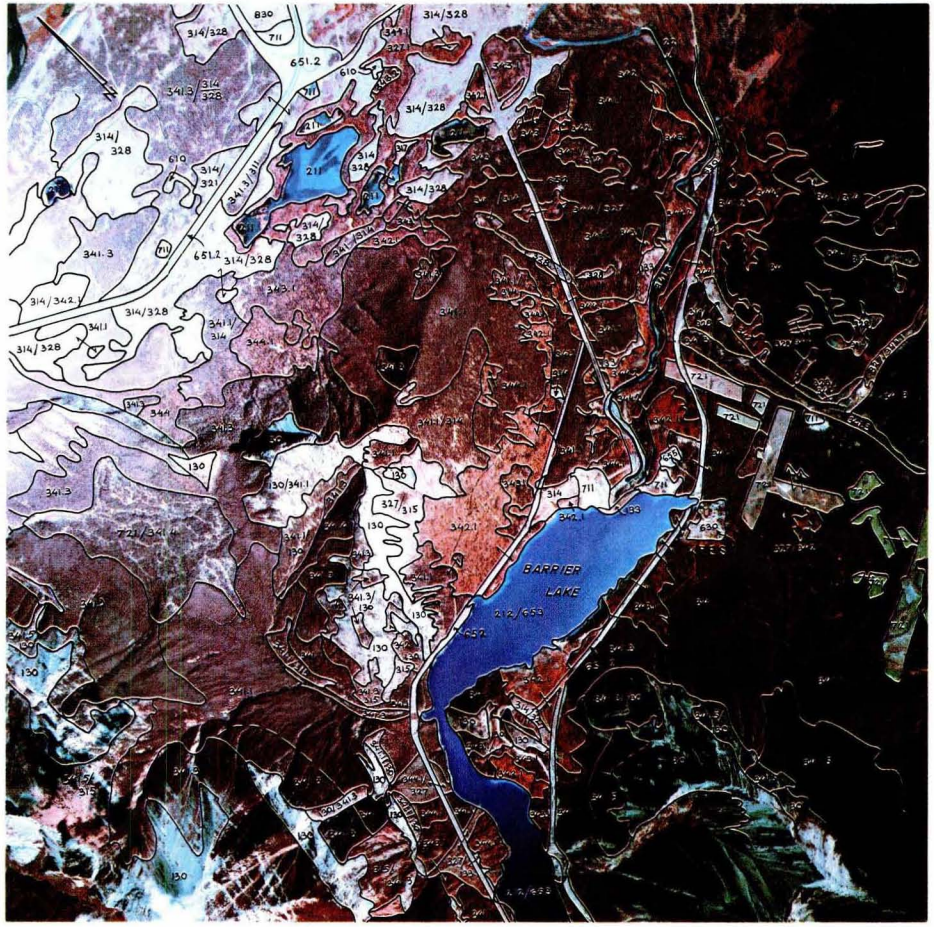

PLATE III

Portion of the Kananaskis, Alberta remote sensing test corridor. Stage III of four stage-sampling design is illustrated. Original scale: 1:47,000, Aerochrome Infrared (2443).
Date: August, 1972

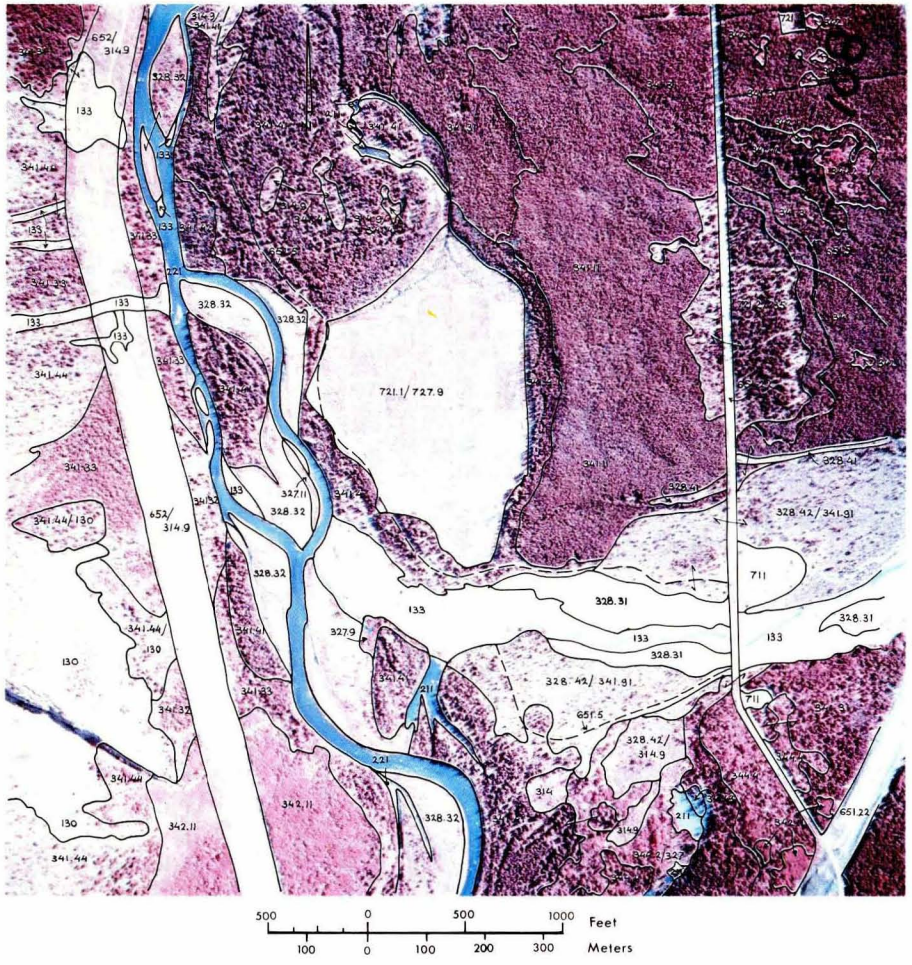

PLATE IV

Small portion of the K.F.E.S. Experimental Forest.
Stage IV of the legend application of a four-stage sampling design is illustrated.
At this level of resolution many site types can be determined. This is shown by the fifth level designation. Greater refinements are possible.
Original scale: 1:29,000, Camera: Vinten 70MM. Aerochrome Infrared (2443).
Date: August, 1972

LEGEND PLATE III

130 Rocklands
133 Gravels, stones, cobbles and boulders (usually transported)
211 Natural lakes and ponds
212 Man-made reservoirs and ponds
221 Natural water course
314 Grassland, steppe and prairie
315 Meadows
327 Macrophyllous shrub
327.1 Willow *(Salix)*
328 Microphyllous shrub
341.1 Lodgepole Pine *(Pinus)* predominant vegetation
341.2 Douglas Fir *(Pseudotsuga)* predominant vegetation
341.3 Mixed conifer *(Pinus/Picea)*
341.5 White Spruce/Alpine Fir *(Picea/Abies)*
342 Broadleaf forests
342.1 Poplar *(Populus)* predominant vegetation
343 Conifer-broadleaf mixed forests and woodlands
343.1 Lodgepole Pine/Poplar *(Pinus/Populus)*
343.2 White Spruce/Poplar *(Picea/Populus)*
344 Broadleaf-conifer mixed forests and woodlands
344.1 Poplar/Lodgepole Pine *(Populus/Pinus)*
344.2 Poplar/White Spruce *(Populus/Picea)*
610 Residential
630 Institutional
640 Industrial
651.2 Motor vehicle (highway)
652 Utilities distribution
653 Power Production
655 Sewer and solid waste
711 Sand and gravel
712 Rock quarry
721 Forest harvest
830 Improved and developed open space (campground)

LEGEND PLATE IV

130 - Rocklands
133 - Gravels, stones, cobbles and boulders (usually transported)
211 - Natural lakes and ponds
221 - Natural water course
314.9 - Grassland (Undifferentiated)
327.11 - White Willow *(Salix glauca)*
327.9 - Undifferentiated shrub/scrub but Willow, Wolfberry and Alder present
328.31 - Yellow Mountain Avens/Spike Trisetum *(Dryas drummondii/Trisetum spicatum)*
328.32 - Yellow Mountain Avens/White Willow *(Dryas drummondii/Salix glauca)*
328.41 - Creeping Juniper/Bearberry *(Juniperus horizontalis/Arctostaphylos uva-ursi)*
328.42 - Creeping Juniper/Bearberry/Cinquefoil *(Juniperus horizontalis/Arctostaphylos uva-ursi/Potentilla fruticosa)*
341.11 - Lodgepole Pine/Buffalo berry/Ground Juniper *(Pinus contorta/Shepherdia canadensis/Juniperus communis)*
341.31 - White Spruce/Lodgepole Pine/Green Alder *(Picea glauca/Pinus contorta/Alnus crispa)*
341.32 - White Spruce/Douglas Fir/Bearberry *(Picea glauca/Pseudotsuga menziesii/Arctostaphylos uva-ursi)*
341.33 - White spruce/Lodgepole Pine/Bearberry *(Picea glauca/Pinus contorta/Arctostaphylos uva-ursi)*
341.41 - White Spruce/Green Alder *(Picea glauca/Alnus crispa)*
341.42 - White Spruce/Willow/Labrador Tea *(Picea glauca/Salix glauca/Ledum groenlandicum)*
341.43 - White Spruce - Standing Dead *(Picea glauca)*
341.44 - White Spruce/Bearberry *(Picea glauca/Arctostaphylos uva-ursi)*
341.91 - Undifferentiated mixed conifer, Limber Pine/Lodgepole Pine/White Spruce *(Pinus flexilis/Pinus contorta/Picea glauca)*
342.11 - Aspen or Balsam/Prickly Rose *(Populus tremuloides* or *P. balsamifera/Rosa acicularis)*
344.2 - Poplar/White Spruce *(Populus balsamifera* or *P. tremuloides/Picea glauca)*
344.4 - Poplar/mixed conifer *(Populus/Pinus-Picea-Pseudotsuga)*
651.21 - Main Highway
651.22 - Old Forestry Trunk Road
651.5 - Trails, foot
652 - Utilities distribution
711 - Sand and gravel pit
721.1 - Clearcut Forest Harvest
721.2 - Selective Cut Forest Harvest
735 - Disease (In this case Dwarf Mistletoe *(Arceuthobium)*)

A comparison of Plate III (1:47,000 original) legend units with Plate II (1:94,000 original) legend units shows that little increased detail has been mapped. The same comparison of Plates II and III to Plate IV quickly indicates an increase in mapping detail as evidenced by fifth level legend units. Thus a highly detailed vegetation-land use map has been made of a part of the Kananaskis Valley which in Plate I was treated as coniferous forest (341). Plate IV shows that coniferous forests do dominate the area as mapped on Plate II but in a complex setting which include many other plant communities that are mappable at this scale (1:29,000 original).

CONCLUSION

The central objective of this study was to test and adopt the ecological legend system developed by Poulton (1972) for use in the Kananaskis Alberta Test Corridor. This investigation revealed that the system was readily adaptable to conditions found on the east slopes of the Rocky Mountains.

Multistage samples of four image types obtained on the east slopes of the Rocky Mountains were mapped using this legend system. Due to sensor, scale, film, and date differences in the imagery different levels of detail were identifiable and mappable on each image. It was demonstrated that the primary, secondary, and tertiary legend levels developed by Poulton (1972) were sufficient to provide the integrated basis for developing a more detailed regional legend classification for the Kananaskis Alberta Test Corridor within the 100, 200, 300, 600 and 700 classes (other classes were not dealt with).

The multistage sampling scheme demonstrated that a given area of the Earth's surface can easily be 1) viewed in a regional perspective (stage I, E.R.T.S. imagery); 2) viewed in perspective within a more

localized framework (stage II, 1:94,000 color infrared photography); 3) analyzed in detail sufficient for many inventory and management needs (stage III, 1:47,000 color infrared photography); and 4) mapped in intensive detail for highly site specific information needs (stage IV, 1:29,000 color infrared photography).

In addition, once the basic vegetational-soils-landforms classification system has been established data gathered at any one level of detail can be applied to ecologically analogous areas using the legend system as the common denominator. Limits of direct applicability of data are clearly understood by reference back to the legend technical descriptors. Attempts to expand a limited data source beyond ecologically known levels can be avoided.

The results of this preliminary investigation suggest that further and more widespread studies to develop regional classifications based on this remote sensing legend for ecological provinces within the east slopes of the Alberta Rocky Mountains is justified. The holistic approach of this legend system provides a picture of land use and human activity in an ecological perspective in a current time frame which we feel is superior to any other system presently in use.

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