DEVELOPMENT OF USER APPLICATIONS FOR EARTH RESOURCES SURVEY DATA IN URBAN AND REGIONAL PLANNING IN THE PUGET SOUND AREA

L-17

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ABSTRACT

User applications of remote sensing in Washington State are being developed by programs of the State Department of Natural Resources, the University of Washington, and the Pacific Northwest Regional Commission. The Remote Sensing Applications Laboratory of the University of Washington has been involved for three years in developing applications in urban and regional planning in the Puget Sound area through cooperative programs with governmental agencies.

Two such activities are described. The first project created a multi-temporal land use/land cover data base for the environs of the Seattle-Tacoma International Airport, to serve planning and management operations of the Port of Seattle. The second is an on-going effort to develop a capability within the Puget Sound Governmental Conference, a council of governments (COG), to inventory and monitor land use within its four-county jurisdiction. Developmental work has focused on refinement of land use/cover classification systems applicable at this regional scale and various levels of detail in relation to program requirements of the agency. Related research, refinement of manual methods, user training and approaches to technology transfer are discussed.

INTRODUCTION

Major centers of remote sensing applications activity in Washington State are the State Department of Natural Resources and the University of Washington. The Department of Natural Resources, through its Resource Inventory Section and State Remote Sensing Coordinator, utilizes both contract aerial photography, and LANDSAT and NASA aircraft imagery in inventory operations and research related to the Department's responsibilities for management of state lands. The Department also has an active mapping and orthophoto program. It provides information services and sale of aerial photography to the public and assists statewide users in the disciplines of forestry and agriculture.

At the University of Washington in Seattle, the Remote Sensing Applications Laboratory (UW-RSAL) of the Departments of Urban Planning and Geography has been involved during the last three years in developing applications among other user groups, particularly urban and regional planning agencies and other governmental units involved in land use or environmental planning. The vehicle for this development has been a series of cooperative programs with agencies at various jurisdictional levels from local (municipal) to state, with major emphasis on regional-level governments in the Puget Sound area such as large urban counties, councils of governments (COG's), and port authorities. Principal support has come from the Earth Resources Observation Systems (EROS) Program of the U.S. Department of the Interior, with aircraft data support from the Earth Resources Aircraft Program of NASA. Applications development at UW-RSAL has received and is continuing to receive direct support from the user agencies involved, including commitment of personnel time for training and participation in research, for purposes of technology transfer.

A third important activity which has recently come into being is a program of the Pacific Northwest Regional Commission, an organization composed of the governors of Washington, Oregon, and Idaho, funded by the U.S. Department of Commerce, and empowered to establish programs contributing to the economic development of the Pacific Northwest region. The Commission has established a Land Resource Inventory Task Force which has undertaken, jointly with NASA Ames Research Laboratory and the U.S. Department of Interior EROS and Geography Programs, a two-year Land Resource Inventory Demonstration Project. The project will involve a group of disciplinary user teams from the three states in several phases of development, including definition of information needs, design of information products, experiments in digital and interactive image analysis, development of multi-purpose geographic information systems, user training, and planning for future development including programs and facilities for regionally based user assistance. A University Advisory Committee has been established to assist the Commission Task Force in this effort, and includes representation from the University of Washington.

In the context of these activities and programs, this paper describes two applications research efforts of UW-RSAL. Both involved user agencies in the Puget Sound area with operational responsibilities in urban and regional planning. Both projects were concerned with the establishment of land use/land cover data bases, and monitoring of change.

DESCRIPTION OF COOPERATIVE APPLICATIONS RESEARCH PROJECTS

Port of Seattle - Sea-Tac Airport Project

This study surveyed land surface cover and utilization in the vicinity of the Seattle-Tacoma International Airport, a major air transportation hub located in an unincorporated area of King County 13 miles south of the Seattle central business district. The airport is operated and managed by the Port of Seattle, a regional, special-purpose authority having rather broad powers for planning and capital programs related to ports, airports, and associated industrial development in the region; its powers include eminent domain.

Since initial airport construction during the period 1943-1948, the 130 sq. km. (50 square miles) surrounding the airport site have been transformed from a predominently rural area to an intensively built-up urban and suburban area with a population of 150,000. Residential and commercial development have encroached on all sides of the airport perimeter. Amid these circumstances, the airport environment has become a subject of pronounced concern and it appeared that a history of recent and long-term change in the character of the area as could be disclosed from aerial imagery might be basic to formulating policies to guide or regulate development. It was on this basis that the Port of Seattle supported the study.

Analyses aided by remote sensing data included several factors, such as:

1. How the airport site itself has developed, grown, and been modified since initial construction, 30 years ago.
2. How a major node of airport-related commercial activity has arisen adjacent to the airport, and continues to grow.
3. How the larger, surrounding area has developed, in part influenced by the airport, but also as a result of more general trends of metropolitan growth which have in certain respects conflicted with the airport.
4. How the surrounding transportation network has been altered by the airport.
5. Water quality problems produced by runoff from the large areas of impermeable surface on the airport site and adjacent commercial area; also sedimentation from exposed runway fills on the margins of the airport site, and its effect on creeks which drain the site westward into Puget Sound.
6. Specific instances of land use conflict, such as the location of schools and other institutional uses in relation to the airport approach pattern.
7. The relationship of superimposed noise contour data to observed land use in the vicinity of the airport.

The basic data collection supportive of these analyses took the form of a manually interpreted coextensive surface cover account on a 4.05 hectare (10-acre) cell basis for the approximately 48 square-mile sections of the Sea-Tac Community Planning Area, for the periods 1943, 1948, 1953, 1965, and 1972. The 10-acre unit of analysis, aligned to the Township and Range coordinate system, was chosen for consistency with data files of the Port and County based on 1/16 sections (16.2 hectares or 40 acres), which included noise monitoring data. Thus the surface cover information compiled from aircraft imagery was considerably more detailed than other data subsequently interfaced. It would have been preferable to use a metric cell unit aligned to the Universal Transverse Mercator (UTM) coordinate system, as this would have produced more accurate overall classification because of randomized cell placement in areas where parcel boundaries conform to the Township and Range system, however, in this case, the user's requirements were considered paramount.

A "two-digit" surface cover classification was used. This was developed in consultation with the Port, through modification of existing systems such as the Urban Renewal Administration - Bureau of Public Roads Standard Land Use Code[1] to produce a classification that: (1) emphasized surface cover categories rather than activities in depicting both urban and non-urban land use, (2) could be consistently applied at the two-digit level using high-altitude aircraft imagery, and (3) contained categories indicative of land utilization common or unique to the Puget Sound area. Development of land classification systems in relation to user needs and remote sensing capabilities is further discussed in the next section describing the Puget Sound Governmental Conference project.

An important technical aspect of the Sea-Tac work was the development of simple methods for constructing and registering grid overlays accurately scaled to each set of aerial photography. The 1972 data consisted of high-quality NASA color-infrared aircraft imagery at a scale of 1:50,000.[2] The historical coverage, all panchromatic black-and-white, varied considerably in quality; it consisted of contact prints and photomosaics at scales from 1:24,000 to 1:60,000. It was necessary to apply map control to all this photography by transferring section coordinates from 7-1/2' quad maps, transferring these points to scribe-coat material, mechanically interpolating cell boundary lines, and then making film positives from the scribe-coat sheets. The result was a set of grid overlays distorted to compensate for the distortions in each image (Fig. 1). Use of an optical transfer scope avoids the need for overlay construction since the grid can be constructed on the base map, and superimposition is automatic with image-to-map registery, however the above-described method may serve the needs of users lacking this or other photogrammetric equipment.

A standard display was developed to show the progression of surface cover change for each section over each time interval (Fig. 2). The five surface accounts are shown in the lefthand column; shaded cells have changed in surface cover since the previous time period. The histograms in the right column show the cellwise distribution of surface cover among the categories represented, which are ordered generally according to increasing intensity of land utilization, to reflect the progression of change in that direction. Note, in the section shown, that agricultural cover was supplanted by residential, which peaked about 1965, and has since been sacrificed to commercial, highway, and airport cover categories. These accounts have been computerized to interface with noise contour and other data.

A subsequent experiment indicated that LANDSAT-1 imagery could provide less detailed surface cover information at the 4-hectare (10-acre) level. With manual interpretation directly from separate-band imagery and diazo color composites this was limited to a relatively few cover types associated with features of high reflectance in all bands (e.g., bare soil, construction sites, quarries, extensive concrete especially where fresh, tracted residential with aggregate roofs, mobile home parks) and features of relatively low IR reflectance (e.g., asphaltic surfaces and water). It is apparent that these include many of the cover classes representative of recent and on-going change in the study area, and development at the urban fringe in general. High contrast of these features in color-IR with the prevailing forest vegetation of the Puget Sound area makes manual interpretation of LANDSAT imagery for purposes of change detection more practicable here than in some other environments.

Single-band level slicing of LANDSAT-1 MSS bands 5 and 7 using interactive display hardware at the University of California, Berkeley, improved the accuracy of these interpretations and made possible the detection of a sediment plume in Puget Sound adjacent to the airport, a water quality indication which was correlated with airport surface runoff.[3]

The Puget Sound Governmental Conference Project

The Puget Sound Governmental Conference (PSGC) is a regional council of governments (COG) in the central Puget Sound area, consisting of the counties of King, Snohomish, Pierce, and Kitsap, 29 constituent cities, and two Indian tribes. This four-county region contains the Seattle-Everett and Tacoma SMSA's, with a total population of two million people. Like COG's in other metropolitan areas, the role of PSGC is one of intergovernmental coordination for purposes of regional planning. Its influence lies chiefly in federal recognition of the Conference and its plans as a basis for "A-95" review of federal aid to local government in some 100 funding categories which include local planning, housing, transportation, airports, utilities, parks and recreation, health, law enforcement, and many others.[4] The Conference also reviews Environmental Impact Statements under the 1969 National Environmental Policy Act and the 1971 State Environmental Policy Act.

The basic policy tool supportive of this review process is a Regional Development Plan (RDP) which incorporates local and areawide goals, policies, and plans for the future development of the region. Preparation of the RDP is a lengthy process still in progress, while an interim plan guides present decision-making. The RDP will include many elements. Fundamental among these is a land use element incorporating plans of local government, but additionally defining relationships between land use and other functional elements of the RDP such as highways, transit, sewer, water, and specific land use allocations, so that the land use consequences of development policies can be ascertained. An Activity Allocation Model (AAM) will be used to allocate areawide forecasts of population and employment to subareas and translate these allocations into land use changes, thereby to assess the probable impact of regional policies on land use and urban growth.

An understanding of this background was necessary to begin to relate to this agency as a potential user of remote sensing data. Through discussion it became apparent that development of the RDP through implementation of AAM was impeded by the lack of adequate methods for inventorying present land use and for monitoring change. Although land use data exists in the building records and assessor's files of some 80 local governments, it is too disaggregated and varied in form to be practicably used or even accessed. An examination of the land use data requirements of the AAM in relation to prior work done at UW-RSAL such as the Sea-Tac project indicated that these needs could be met initially through manual interpretation of high-altitude aircraft imagery. Presentations to PSGC established the potential of this approach, and a cooperative agreement was reached for development of methodology, shared use of facilities and data, and training of PSGC personnel.

A pilot project was undertaken in Kitsap County, on the west side of Puget Sound. The smallest and least populated of the four counties, Kitsap was of special interest because of the anticipated impact of construction of the West Coast Trident Nuclear Submarine Base at Bangor, estimated to bring about 40,000 new residents into the area in the next few years. The objective of the pilot project was to compile a land use data base for Kitsap County which would be computerized and fully operational within the Activity Allocation Model, with the data derived from remote sensing interpretation carried out by the PSGC staff.

Probably the most important developmental aspect of this work was the design of a land use classification system fitting these purposes, based on user input, and suitable for manual — and later, machine-aided remote sensing interpretation. A number of weeks were devoted to the classification design process. The result is shown in Table I. Cursory examination of this classification system may not be revealing of the amount of thought that went into it, however, some of its attributes are as follows:

1. The system is fully compatible with and translatable to land use categories already defined in the Activity Allocation Model, which had been designed without

consideration of potential remote sensing input.

2. The system is largely compatible with, and reflects much of the thinking of the USGS Circular 671 classification system.[5] Like Circular 671, it incorporates both land use and land cover categories, i.e., land use is represented in terms of manifest cover types, along with natural cover. At the "one-digit" level, the PSGC-Kitsap system divides simply into "Undeveloped", meaning predominantly natural, plus agriculture, "Developed", meaning man-impacted, including all urban, "Construction", or transitional between the above categories, and "Military Lands", a necessary exclusion in this particular case. This breakdown reflected a program need to be able to call out the total urban service area for the county. The second-level breakdown is comparable in many respects to level one of Circular 671, except that it reflects a more urban bias in terms of a breakdown under "Developed" comparable in detail to the natural systems breakdown under "Undeveloped".

3. At all levels the system is particularly suited to remote sensing interpretation from various scales and types of input. Even at levels three and four, urban categories such as commercial area types are based on distinct spatial, and morphological characteristics (e.g., business districts, commercial strips, large and small nucleations, etc.) rather than traditional definitions of use related to activities, types of goods or services sold, etc. Although some planners are reluctant to adopt such new definitions, a strong arguement can be made that they relate better to actual considerations of environmental impact which are paramount in physical planning today.

In the pilot project interpretation was done from 1973 U-2 1:135,000 color-infrared imagery on an optical transfer scope, recording on frosted mylar overlays on a USGS 7-1/2' base.[6] Initial products included a level-two classification of the entire county, and a level-three classification of one quadrangle. The interpretation was recorded in polygons of two-hectare (5-acre) minimum size . An exercise was also conducted in intertemporal analysis, whereby an area was interpreted at level-three first from 1973 data and then from 1965 1:60,000 black-and-white photography. It was found that this could be done most effectively if the more recent interpretation was done first, utilizing the available CIR aircraft imagery, and then doing the interpretation for the earlier time period as another overlay on top of the first interpretation, and using pencil of a different color to do the delineation. For a developing area, this becomes a simple task of determining whether structures or other land uses in the "Developed" category already interpreted for the later date were present at the earlier date (and if so they are readily recognized); if not, it is a matter of removing and enlarging polygons as areas revert to adjacent "Undeveloped" categories.

Over a period of three months, five agency personnel, four of whom had no prior experience in photo interpretation, were brought to an operational level of capability in these techniques. Training also included ground truth verification procedures based on windshield transects of the study area.

The data from the initial work has been digitized and tested in the AAM. A preliminary decision has been made to change from a polygonal to a grid system utilizing a 2.23-hectare (5.5-acre) cell, partly determined by hardware and programming requirements of the AAM. Training exercises have been defined to extend manual interpretation abilities to include cellwise classification on the transfer scope, with emphasis on the decision processes involved in this type of data aggregation.

The next phase of the project is a translation of these techniques to digitally-processed LANDSAT data. PSGC is a designated user under the Pacific Northwest Regional Commission Land Inventory Demonstration Project mentioned in the Introduction, and the central Puget Sound area has been designated as the Washington State test site for users of the urban discipline team. PSGC personnel involved in the manual interpretation project are attending sessions at NASA-Ames and the EROS Data Center at Sioux Falls intended to familiarize them with the use of interactive hardware and automated spectral classification procedures to determine how and to what extent these methods can now be applied to replicate or supplement an already established information collection process. The first such digital product, a supervised clustering of LANDSAT-1 data for the Bremerton area of Kitsap County has been compared with the manually derived information, and further refinement including aggregation to the 2.23-hectare (5.5-acre) cell unit is currently under development.

RELATED RESEARCH

As the foregoing has shown, a major emphasis of the research at UW-RSAL has been the improvement of manual techniques for the use of modern remote sensing image data products, particularly for purposes of land use/land cover classification. A related area of research is directed at achieving adequate levels of accuracy, consistency, and reproducibility of results in manual interpretation involving multiple interpreters over time.

Fig. 3 represents one type of consistency analysis, a graphic and numerical comparison of results obtained in two grid cell surface cover accounts of a sample area in central Seattle, a densely built-up residential, commercial and mixed-use area. In this example, two interpreters, A and B, made separate accounts from the same 1:120,000 color-infrared aircraft imagery using a 100-meter grid cell as the unit of analysis (400 data records for the 4 sq. km. sample area), with the grid aligned to UTM coordinates. These accounts appear at the bottom. The matrix shows the total number of cells classified according to a given two-digit code for each interpreter. The diagonal records the number of times a given classification used by Interpreter A was also used by Interpreter B. The off-diagonal row figures (for row i) represent the instances where Interpreter B made a different classification than i for cells classified i by Interpreter A, and the distribution of these different classifications.

In most comparisons of this kind it was found that the major part of the variability in classification away from the diagonal remains within the same general (one-digit) surface cover grouping, as shown at the top of the matrix. This type of analysis has been used to evaluate relationships between each of the several variables involved, e.g., experienced and inexperienced interpreters, sample areas of varying character, imagery of different types and scales, and variation in classification content and detail. The general finding has been that the level of consistency suggested by Fig. 3 is not unusual for surface cover accounting at the two-digit level from high-altitude aircraft imagery, given an appropriate cell size, and interpreters having had a few weeks of experience at this specific task, including ground verification experience.

A closely related problem is that of achieving as much objectivity as possible in interpretation — defining the way in which each category in the classification is applied and interpreted, and the way the data is aggregated in creating the primary information product, whether it be a delineation of polygons or an annotation of cells. For this purpose, much attention has been given to documentation of the interpretation process, including definition of the decision processes involved. The following is an excerpt of documentation developed for applying two level-three residential cover categories where a 4.05-hectare (10-acre) cell is used:

1. Single-family housing, tracted. Includes all areas of small-lot development, one-acre or less, in which lots are consecutively layed out and continuously or predominantly built-up over at least one-quarter of the cell area, i.e., 2.5 acres. If less than one-quarter of the cell is occupied by a housing tract, but more than one house, it would generally be classified as untracted (see 2, below)

   This category includes older, built-up residential sections of existing settlements as well as newer suburban tract developments. In most cases these are areas layed out and built under one plat, or a succession of plats, during a relatively short interval of time, however gradual in-filling to this defined density also results in this classification. In some areas the latter process is apparent, i.e., no evidence of unified or systematic development.

2. Single-family housing, untracted. Pertains to less dense settlement — areas of rural-residential homesteads, farm or non-farm, larger than one acre. No maximum size is applied to such properties, nor should any attempt be made to interpret parcel boundaries. If two or more housing units appear in a cell under these density conditions, it should be given this classification. Under the one-acre lot criterion, ten or more houses in a 10-acre cell then require a tracted classification. (avg. lot $\leq$ 1 acre), unless four or more of these are contained in a tracted area occupying less than one-quarter of the cell area. In this case the number of houses in the cell can reach as high as 12 or 14 before the housing-tracted classification is applied, but such limiting cases are rare.

   The tracted versus untracted distinction is significant in terms of residential growth potential — "in-filling" can be expected to occur in untracted areas but not in tracted areas. Cell area, if used directly, is, of course, a very gross measure of residential area, particularly in the case of cells classified as housing-untracted. Streets, associated land not built upon, and small areas devoted to other land uses may be and usually are included. Cell measurement of total residential acreage will tend to be very large compared to any other method, this discrepancy varying with cell size, however cell measurement may represent fairly well the total land area committed to residential use.

   The exclusion of cells containing only one housing unit from any housing classification is a compensating factor for this exaggeration of residential area. Were such cells classified as housing, a great many additional cells would be involved, with effective loss of density discrimination and information pertaining to open space. The one disadvantage in not doing this is that the record is not complete as to occurrence of housing.

In the case of the PSGC project, this documentation is taking the form of a manual with illustrative examples of interpretation intended to help the agency in continuing application of these techniques.

A third area of related research is the development of simple but effective methods for interfacing information derived from remote sensing with data from other sources. An example of this was the combination of noise contour data with land use for the Sea-Tac Airport area. Both files of data were in a form permitting this to be done by computer, with tabular or alphanumeric output. In many cases a graphic superimposition is equally or more effective, since planners are accustomed to displaying information in map form. Therefore it was effective to show noise contours directly superimposed on the cellular data record, and, separately, on the imagery itself.

Two other studies which cannot be detailed here relied heavily on superimposition techniques, which we refer to as "visual modeling". One concerned a study done for Skagit County of secondary land use effects of a proposed nuclear power plant on the Skagit River; the other related to a study coordinated by the Oceanographic Commission of Washington of the feasibility of developing petroleum transfer facilities for Alaskan oil at alternative Puget Sound and coastal sites. In both studies the impact of urbanization attendant to these proposed developments was assessed in relation to available land resources at alternative locations through visual superimposition of projected development and growth patterns directly upon imagery and upon various thematic data extractions from imagery.

CONCLUSIONS

Some general conclusions drawn from this varied experience in developing user applications are as follows:

1. Mechanisms are needed for user assistance, training, and technology transfer, parti-

cularly in the field of urban and regional planning, where users typically have little or no experience with remote sensing and high initial resistance to its use. Organizations that can serve this function are universities and state agencies able to address a wide range of user disciplines at local and regional as well as state levels. Pooling of resources and specialties among a group of governmental and academic organizations in a state or multi-state region is one approach demonstrated by the Pacific Northwest Regional Commission program.

2. Such an organization or group of organizations must be able to work cooperatively with potential users to develop application relating to on-going problems and needs. They can provide initial contact with the remote sensing data itself, and access to necessary equipment and facilities. Also they can help users relate to NASA and other federal programs and sources of data. (For example, some 50 orders of data from the EROS Data Center originating from users in the Pacific Northwest have been assisted, and in many instances suggested or initiated by UW-RSAL. This kind of user assistance is probably common, but not evident in orders as received at EDC.)

   Of related importance are training programs. University short courses and workshops are one example. Special purpose training of an agency's personnel, as in the PSGC project, is another.

3. Many attempted applications still, and perhaps always will, require a certain amount of new, applied research. Hence the need for an on-going research function which can probably best be served by a university. Such research would be directed at specific, identified user needs, and undertaken in the context of an established relationship with a user. It is critically important that the users served be directly involved in the design and conduct of applied research related to attempted applications.

4. A principal area of such user design input is in the development or modification of land classification systems suitable for remote sensing data input, but which also serve the operational program needs of an agency. This is perhaps the most crucial of steps in utilization of remote sensing; whatever our concept of information is in relation to a problem, it is embodied in classification. Too often an existing or arbitrary classification system, or one dictated by requirements or limitations of hardware, software, or other tools to which an a priori commitment has been made, is adopted, without full realization that this is one of the most fertile areas for relating on specific terms to user needs and involving users.

5. There are many avenues of improvement and refinement in manual techniques which are worth developing, both for their own value and as a necessary background for intelligent design and application of machine methods. Photo interpretation from high-altitude aircraft and satellite imagery is different from that based on conventional aerial photography, incorporating new knowledge of pattern and spectral variation — visual knowledge which can be learned. Again, the design of classifications systems based on attainable capabilities of signature recognition as well as information needs is an essential link in demonstrating application. If this is accomplished first at a manual level, so that the essential nature of these relationships is understood, then the way is open for introducing users to the possibilities of machine assistance.

6. It is possible and practicable to train users in the planning field to do interpretation and use remote sensing data on their own. The idea that planners without prior experience will not learn to do photo interpretation is perhaps an initially gained impression, but our experience suggests that this can be overcome with persistence, and if an unmet information need exists. Whether long-term, continuing commitments of personnel and resources by agencies can be achieved remains to be seen, and will certainly depend upon convincing demonstrations of both broad applicability and cost effectiveness.

7. Because synthesis of information and analysis is a fundamental activity in the field of urban and regional planning, it is important that attention always be given to the way in which remote sensing derived information is subsequently used and combined or related to other information. Planning users are sometimes reluctant to accept remote sensing input because they cannot immediately visualize how it could be related to other material they employ. Deliberate design of interface media is required, of which visual or graphic superimposition can be one of the most effective. Successful combinations of data are, in a real sense, "more than the sum of parts," and can be persuasive demonstrations of the power of remote sensing as a tool of analysis; this is especially true where other data of a clearly vital nature are involved, and the combination permits an interpretation of that data which would not be possible without the contribution of remote sensing.

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3. LANDSAT-1, July 29, 1972, #E-1006-18313 (Seattle-Tacoma scene), MSS bands 5 and 7.

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TABLE I.

LAND USE CODING KEY - REMOTE SENSING PROJECT FOR KITSAP COUNTY

1.	UNDEVELOPED
1.1.	Water
1.1.1.	Saltwater (marine)
1.1.1.1.	Estuarine waters
1.1.2.	Lakes, ponds
1.1.3.	Reservoirs, impoundments (non-utility oriented)
1.1.4.	Rivers, streams (primary channel or streamway)
1.1.4.1.	Sloughs, side channels
1.1.4.2.	Bars
1.1.4.3.	Islands
1.2.	Shorelands
1.2.1.	Beaches
1.2.1.1.	Spits
1.2.1.2.	Barrier bars
1.2.2.	Bluff
1.2.2.1.	Head land
1.2.3.	Inter-tidal mudflats
1.2.3.1.	Estuarine mudflats
1.3.	Wetlands
1.3.1.	Emergent vegetation
1.3.2.	Marsh
1.3.2.1.	Freshwater
1.3.2.2.	Saltwater
1.3.3.	Estuarine Wetland
1.3.4.	Bogs
1.3.5.	Brush swamps
1.3.6.	Swamps
1.3.7.	Areas subject to periodic ponding or inundation
1.4.	Forested open space
1.4.1	Cut lands (0-20 years)
1.4.1.1.	Clear-cut
1.4.1.2.	Selected
1.4.2.	Second growth forest
1.4.2.1	Deciduous (broad leaf, hardwood)
1.4.2.2.	Mixed
1.4.2.3.	Coniferous
1.4.3.	Old growth
1.4.4.	Unique forest vegetation
1.4.5.	Riparian vegetation
1.5.	Non-forested open space
1.5.1.	disturbed vegetation
1.5.1.1.	Grassy (herbacious)
1.5.1.2.	Brush
1.5.2.	Meadows
1.5.3.	Rock lands
1.5.4.	Talus slopes
1.5.5.	Glaciers

TABLE I. (Cont'd)

1.6.	Agriculture
1.6.1.	Crop land
1.6.2.	Orchard
1.6.3.	Pasture
1.6.4.	Tree farms
2.	DEVELOPED
2.1.	Residential
2.1.1.	Untracted single family
2.1.2.	Tracted single family
2.1.3.	Multi-family
2.1.4.	Mobile home courts
2.2.	Commercial
2.2.1.	Business districts
2.2.1.1.	Central business districts
2.2.1.2.	Neighborhood/community business districts
2.2.2.	Commercial strips
2.2.3.	Shopping centers
2.2.3.1.	Regional shopping centers
2.2.3.2.	Community shopping centers
2.2.4.	Large isolated retail
2.2.5.	Small nucleations (2 to 6 retail establishments)
2.3.	Wholesale commercial/light industry
2.3.1.	Wholesale commercial, warehousing, light industry
2.3.2	Light industry or office parks
2.3.3.	Wrecking yards
2.4.	Industrial, manufacturing
2.4.1.	Food and kindred products
2.4.2.	Lumber and wood products
2.4.3.	Pulp and paper products
2.4.4.	Oil and chemical products
2.4.5.	Metal processing
2.4.6.	Stone and concrete products
2.4.7.	Transportation equipment
2.4.9.	Other
2.5.	Transportation
2.5.1.	Major highway R.O.W.
2.5.2.	Major rail R.O.W.,railyards
2.5.3.	Rail terminal facilities, shops (intensive use)
2.5.4.	Motor transport terminals
2.5.5.	Bus terminals
2.5.6.	Ports
2.5.7.	Ferry terminals
2.5.8.	Airports
2.5.8.1.	Commercial air transport
2.5.8.2.	General aviation

TABLE I. (Cont'd)

2.6.	Utilities and communications
2.6.1.	Communications
2.6.1.1	Intensive
2.6.1.2.	Extensive
2.6.2.	Utilities
2.6.2.1.	Intensive
2.6.2.1.1.	Water Supply/treatment
2.6.2.1.2.	Reservoir structure
2.6.2.1.3.	Sewage treatment plants (including lagoons and settling ponds)
2.6.2.1.4.	Power plants, stations
2.6.2.2.	Extensive
2.6.2.2.1.	Water supply system (aqueducts, pipelines, canals)
2.6.2.2.2.	Power transmission ROWs
2.6.2.2.3.	Pipelines (oil, gas)
2.7.	Institutional
2.7.1.	Government
2.7.2.	Schools
2.7.3.	Hospitals
2.7.9	Other
2.8.	Parks and recreation
2.8.1.	Intensive recreation, amusement (stadiums, zoos, race tracks)
2.8.2.	Golf courses
2.8.3.	Parks
2.8.3.1.	Municipal
2.8.3.2.	County
2.8.3.3.	State
2.8.4.	Cemetaries
2.8.5.	Marinas
2.9	Mining and landfill
2.9.1.	Sand and gravel
2.9.2.	Coal
2.9.9.	Landfill, improvement
3.0.	CONSTRUCTION (transitional)
4.0.	MILITARY LANDS

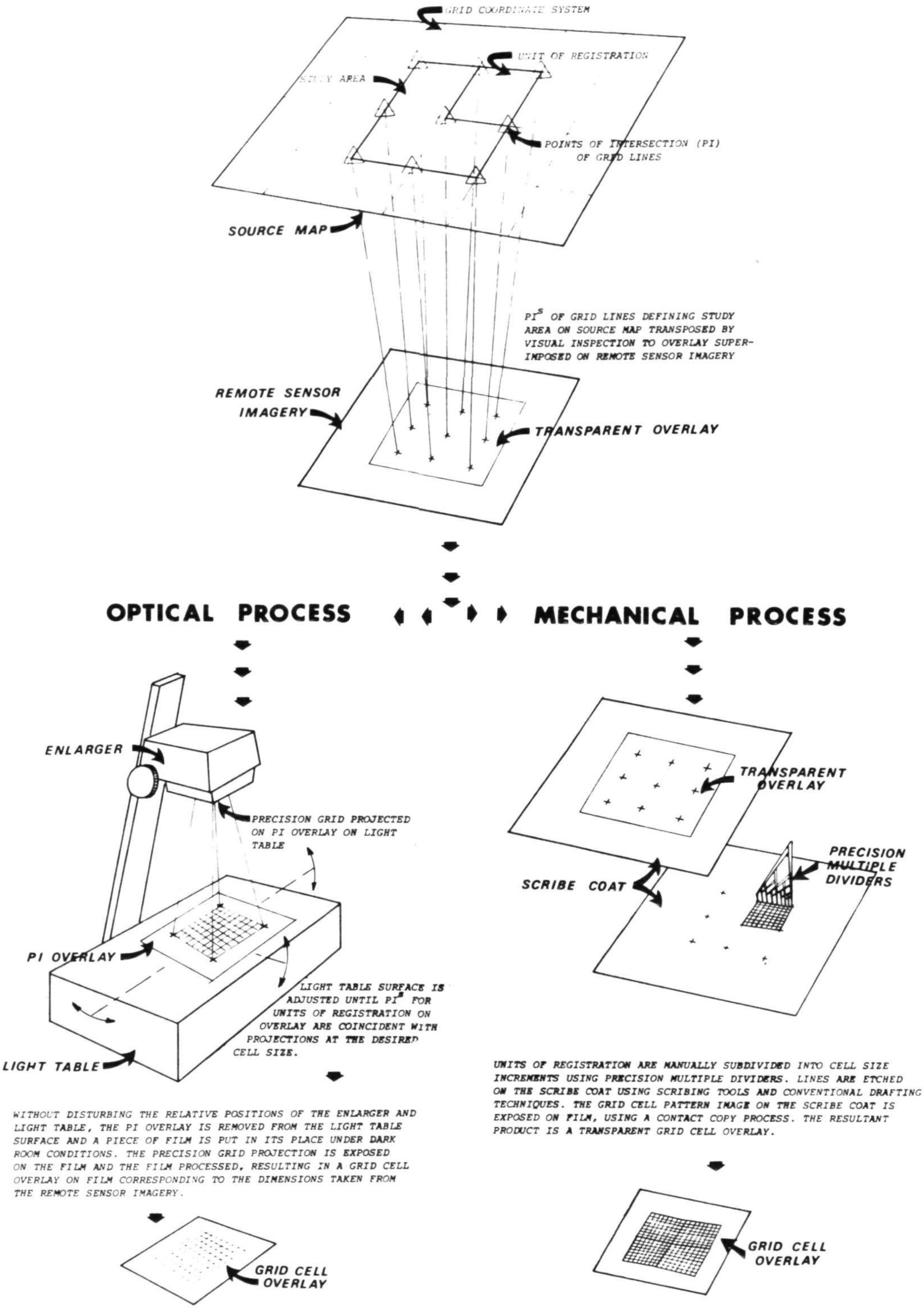
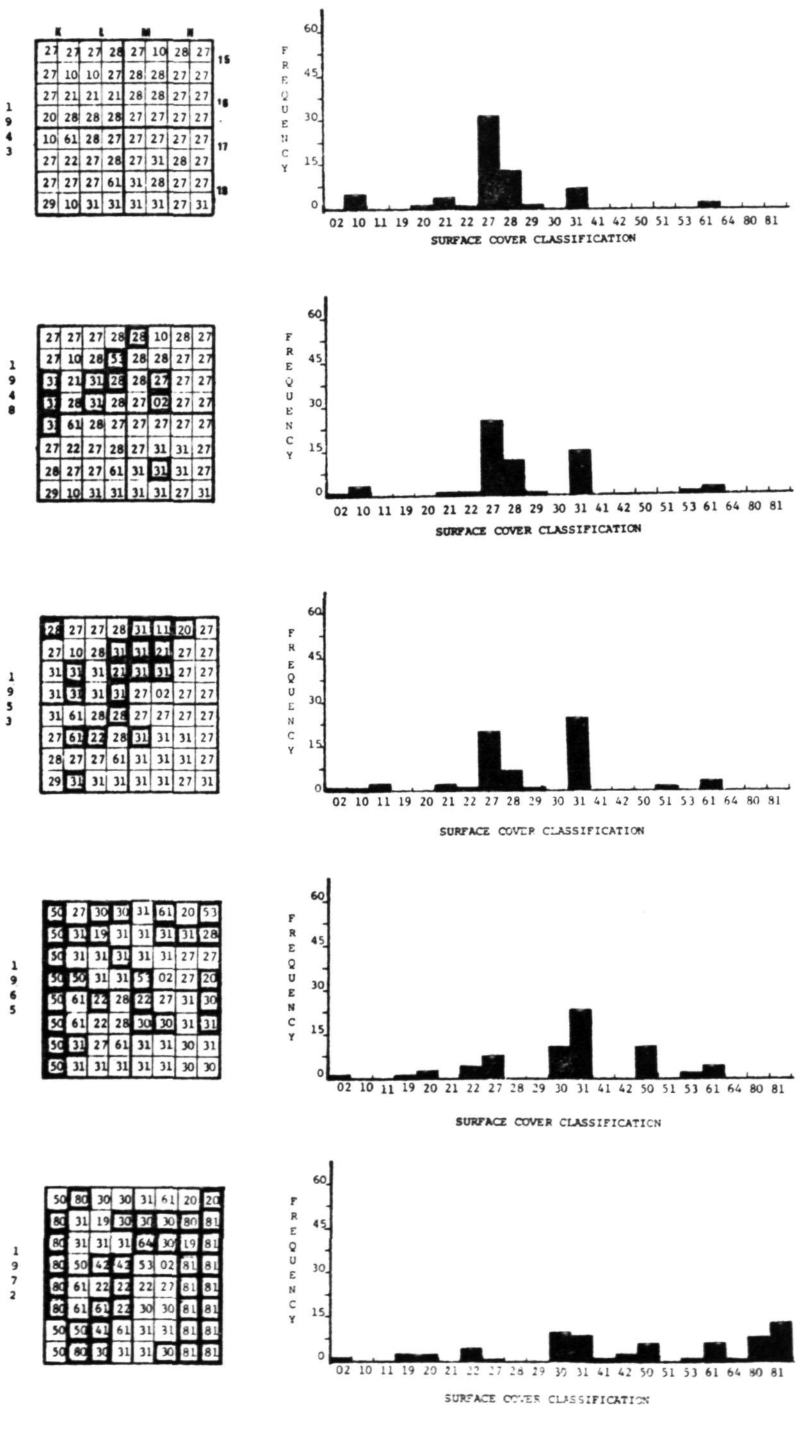


Figure 1.- Grid cell alignment on imagery, and development of grid overlay.

SEA-TAC COMMUNITY PLANNING AREA

SURFACE COVER ACCOUNTS, 1943 – 1972

SECTION **20** TOWNSHIP **23N** RANGE **R 4E**



LEGEND

02 **Lakes, ponds**

10 **Unimproved open space**

11 **Forested** (with or without forestry activity)

19 **Green belt** - undeveloped vegetated zone within an urbanized area

20 **Improved open space**

21 **Agricultural** (e.g., pasture, grazing, feedlot, etc.)

22 **Developed parks, recreation areas, playgrounds, playing fields**

27 **Croplands, orchards, vineyards**

28 **Improved open space with farm type buildings**

29 **Other open air livelihood** (e.g., commercial parking lots, open-air storage, nurseries)

30 **Single-family residential** (tracted)

31 **Single-family residential** (untracted)

41 **Multifamily residential**, off street parking and or open space

42 **Mixed residential** (single-family and multi-family)

50 **Business district** (mixed retail, office, professional and consumer services)

51 **Commercial strip** (mixed retail, services, etc.)

53 **Isolated retail** (e.g., supermarkets, discount department stores, gas stations not associated in terms of areal distance with any other retail land use)

61 Schools

64 Churches

80 **Area devoted to transportation net** (e.g., freeway or highway R.O.W.)

81 **Major airport Facility**

Figure 2.- Display of surface cover distribution for one section, for five time periods.

INTERPRETER B

ONE DIGIT SURFACE COVER (LAND USE) CLASSES

WATER & WATER ORIENTED ACTIVITIES / ACTIVITIES & FUNCTIONS RELATING TO OPEN SPACE / RESIDENTIAL (Multi Family) / BUSINESS & COMMERCIAL / INSTITUTIONAL / LIGHT INDUSTRIAL & WAREHOUSING / TRANSPORTATION & UTILITIES / TOTAL OBSERVATIONS

INTERPRETER A	00	07	22	42	50	51	60	62	63	70	80	83	85	TOTAL
00	51													51
07		30												30
22			1											1
42				51										51
50				1	167						1			169
51						26								26
60							6							6
62					1			12						13
63									4					4
70					1					8				9
80								1			32			33
83												7		7
85													1	1
														400

IMAGERY PARAMETERS

SCALE: 1:120,000
RESOLUTION: HIGH
FILM: COLOR INFRARED
IMAGE FORMAT: 9"x 9" TRANSPARENCY
UNIT OF ANALYSIS: 100 METER CELL
DATE: SEPTEMBER 1971

INTERPRETER A

50	50	50	50	50	50	50	50	50	50	50	50	50	80	80	51	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	42	42	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	51	51	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	51	42	42	42	42	51
80	50	50	50	50	50	50	50	50	50	50	50	80	80	42	42	42	42	42	51
50	50	50	50	50	50	50	50	85	50	50	50	80	42	42	42	50	50	50	50
83	80	50	50	50	50	50	50	50	50	50	50	80	42	42	42	50	50	50	50
07	83	80	70	50	50	50	50	50	50	50	50	80	42	42	42	42	60	51	51
07	07	83	80	70	50	50	50	50	50	50	50	80	42	42	42	51	51	51	51
00	07	07	83	70	80	70	50	50	50	50	50	80	63	63	63	51	51	51	51
00	00	00	07	07	70	70	50	50	50	60	50	80	80	63	50	60	50	50	50
00	00	00	00	07	83	70	50	50	50	50	62	62	80	50	50	60	60	60	51
00	00	00	00	07	07	07	70	50	50	50	50	62	80	42	42	51	51	51	51
00	00	00	00	00	07	07	70	50	50	50	50	62	80	80	42	42	42	51	51
00	00	00	00	00	07	07	83	50	50	50	50	50	62	80	80	42	42	42	42
00	00	00	00	00	07	07	07	83	50	50	50	50	50	62	80	80	42	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	22	62	80	80	42	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	50	50	80	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	62	50	80	80	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	62	62	50	50	80

INTERPRETER B

50	50	50	50	50	50	50	50	50	50	50	50	50	80	80	51	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	42	42	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	51	51	42	42	42	51
50	50	50	50	50	50	50	50	50	50	50	50	50	80	51	42	42	42	42	51
80	50	50	50	50	50	50	50	50	50	50	50	80	80	42	42	42	42	42	51
50	50	50	50	50	50	50	50	85	50	50	50	80	42	42	42	50	50	50	50
83	80	50	50	50	50	50	50	50	50	50	50	80	42	42	42	42	50	50	50
07	83	80	70	50	50	50	50	50	50	50	50	80	42	42	42	42	60	51	51
07	07	83	80	70	50	50	50	50	50	50	50	80	42	42	42	51	51	51	51
00	07	07	83	70	80	70	50	50	50	50	50	80	63	63	63	51	51	51	51
00	00	00	07	07	70	70	50	50	50	60	50	80	80	63	50	60	50	50	50
00	00	00	00	07	83	70	50	50	50	50	62	62	80	50	50	60	60	60	51
00	00	00	00	07	07	70	50	50	50	50	50	62	80	42	42	51	51	51	51
00	00	00	00	00	07	07	70	50	50	50	50	50	62	80	42	42	42	51	51
00	00	00	00	00	07	07	83	50	50	50	50	50	62	80	80	42	42	42	42
00	00	00	00	00	07	07	07	83	50	50	50	50	50	62	80	80	42	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	22	62	80	80	42	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	50	50	80	42	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	62	50	80	80	42
00	00	00	00	00	00	07	07	07	50	50	50	50	50	62	62	62	80	50	80

Figure 3.- A comparison of surface cover accounts for a sample area by two different interpreters: a measure of consistency in manual interpretation of surface cover.