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REMOTE SENSING APPLIED TO LAND-USE STUDIES IN WYOMING

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ABSTRACT

Impending development of Wyoming's vast fuel resources requires a quick and efficient method of land-use inventory and evaluation. Presently, little or no land-use information or cartographic control is available for many areas of concern. Proper control of development depends upon land-use and physiographic information representing all aspects of the affected area, including agricultural and urban development, natural vegetation, hydrology geology, topography, and mineral resources development. Preliminary evaluations of ERTS-1 imagery have shown that physiographic and land-use inventory maps can be compiled by using a combination of visual and automated interpretation techniques.

Test studies in the Powder River Basin showed that ERTS image interpretations can provide much of the needed physiographic and land-use information. Water impoundments as small as one acre were detected and water bodies larger than five acres could be mapped and their acreage estimated. Flood plains and irrigated lands were successfully mapped, and some individual crops were identified and mapped. Coniferous and deciduous trees were mapped separately using color-additive analysis on the ERTS multispectral imagery. Gross soil distinctions were made with the ERTS imagery, and were found to be closely related to the bedrock geology. Several broad unstable areas were identified. These were related to specific geologic and slope conditions and generally extended through large regions. Some new oil fields and all large open-cut coal mines were mapped.

The most difficult task accomplished was that of mapping urban areas. Most Wyoming towns are surrounded by agricultural land, natural flood plains, and/or rangeland. With these widely varying settings the populated areas are often difficult or impossible to delineate by visual photointerpretation techniques. Densitometry proved to be of considerable aid in making the subtle distinctions necessary in urban mapping. Four-color isodensitracings were made for each of the four ERTS-MSS bands. Interpretation of these isodensitracings permitted accurate mapping of the populated area, and usually allowed segregation of new

and old residential, industrial, commercial and business, and open segments within the towns. Larger features such as airstrips, factories, schools, golf courses, parks, and cemeteries were mappable as individual installations but most could not be identified.

Areas of new development can usually be defined, allowing a capability for change detection and updating of obsolete maps. Snow-cover provides a considerable degree of enhancement of the urban areas by increasing the contrast between the populated areas and the surrounding country. Work in the urban areas provides a striking example of this snow-enhancement and the detail available from a snow-enhanced image.

TEXT

Land-use considerations have become critically important in Wyoming where greatly increased development of natural resources is anticipated. Of prime concern at the present is the development of coal resources in the Green River and Powder River Basins as fuel for huge generators. The direct impact of mining, the diversion of water, and the effluent from coal-fired electrical generators will be considerable, but the associated increase in population and the necessary urbanization will have far-reaching effects on the environment in Wyoming. The construction and operation of the power plants and supporting mines will result in a substantial increase in the state's population (perhaps as much as 50%). These population increases will, in turn, affect almost every aspect of land-use.

Governmental agencies have recognized the need for thorough land-use planning in order to properly control development and prevent costly or unnecessary damage to the land and its inhabitants but there is very little land-use data available for use as a basis for such planning. As is commonly the case, the problem requires an immediate solution. It is totally impractical to begin a program for gathering detailed land-use data by conventional means because 1) such a program would be too expensive, 2) insufficient time is available, 3) much of the data would be obsolete by the time the program is complete. Consequently, planners must find a rapid and efficient means of obtaining the necessary land-use information and a way to continually up-date that information.

As soon as it became apparent that the ERTS satellite program offered considerable potential for obtaining much of the needed land-use data, the state planning office of the Department of Economic Planning and Development contracted the University of Wyoming Remote Sensing Laboratory for a pilot study to determine what land-use data might be gained from the ERTS-1 imagery. The pilot program was to be a quick-look study designed to assess the ERTS-1 imagery as a tool for acquisition of land-use data. The Powder River Basin was chosen as a general

test area (Fig. 1) and suitable sub-areas within the basin were selected for testing individual applications.

Because the pilot program was time-limited, a suite of tasks was selected as a representative group of ERTS applications which might yield information necessary for land-use planning. Included in this group were:

1. Identification and mapping of water impoundments
2. Detection of potentially unstable areas
3. Mapping of flood plains, irrigated land, and crops
4. Discrimination of coniferous and deciduous trees
5. Range mapping (type and/or quality)
6. Mapping of soil types
7. Slope estimation
8. Mapping of mined areas
9. Mineral resources mapping (actual and potential)
10. Areas having potential for construction materials
11. Mapping of areas of urban and rural development

Application of standard photointerpretation, color-additive viewing, and/or isodensitometry to these tasks provides results which suggest that many of these tasks can be done routinely. Figure 2 is a land-use classification map for the Powder River Basin test area, constructed from interpretations of ERTS imagery. In addition to the broad land-use categories represented on this map, there is a great deal of other significant land-use information available from the ERTS data.

Water impoundments can be readily mapped from the infrared (band 7) ERTS imagery. Impoundments covering 5 acres or more can be mapped reliably and most impoundments larger than 1 acre can be located. However, the actual size of these smaller impoundments cannot be accurately estimated because they are represented by too few scanner resolution elements.

Although in some parts of Wyoming, local unstable areas (landslides, slumps, etc.) have been identified from the ERTS imagery none could be identified in the Powder River Basin test area. Potentially unstable areas were identified on the basis of their regional associations. The potentially unstable areas in the Powder River basin mappable from ERTS include 1) dune fields, 2) flood plains, 3) areas of potential mineral development (coal, oil, uranium), and 4) areas likely to be underlain by clay-bearing soils. Identification of these areas from the ERTS imagery required integrated interpretation of all ERTS bands. Color-additive viewing provided some enhancement of the flood plains and aided in soil and lithologic distinctions.

Color-additive viewing was of considerable utility in mapping of natural flood plain vegetation and irrigated farm land. The red and infrared bands (5 and 7) have the greatest utility in distinguishing

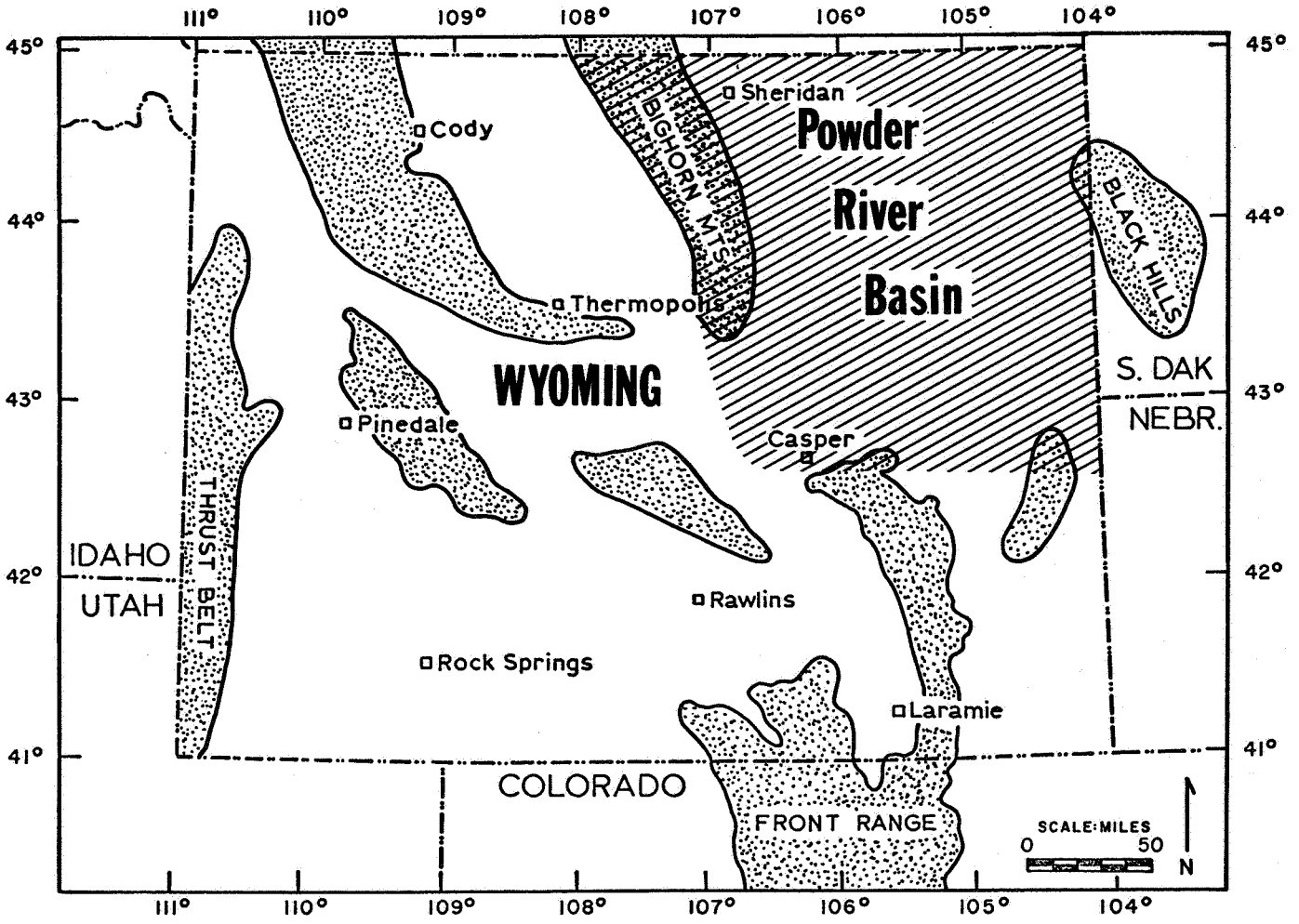

Figure 1. Index map showing the location of the Powder River Basin test area (cross-hatched).

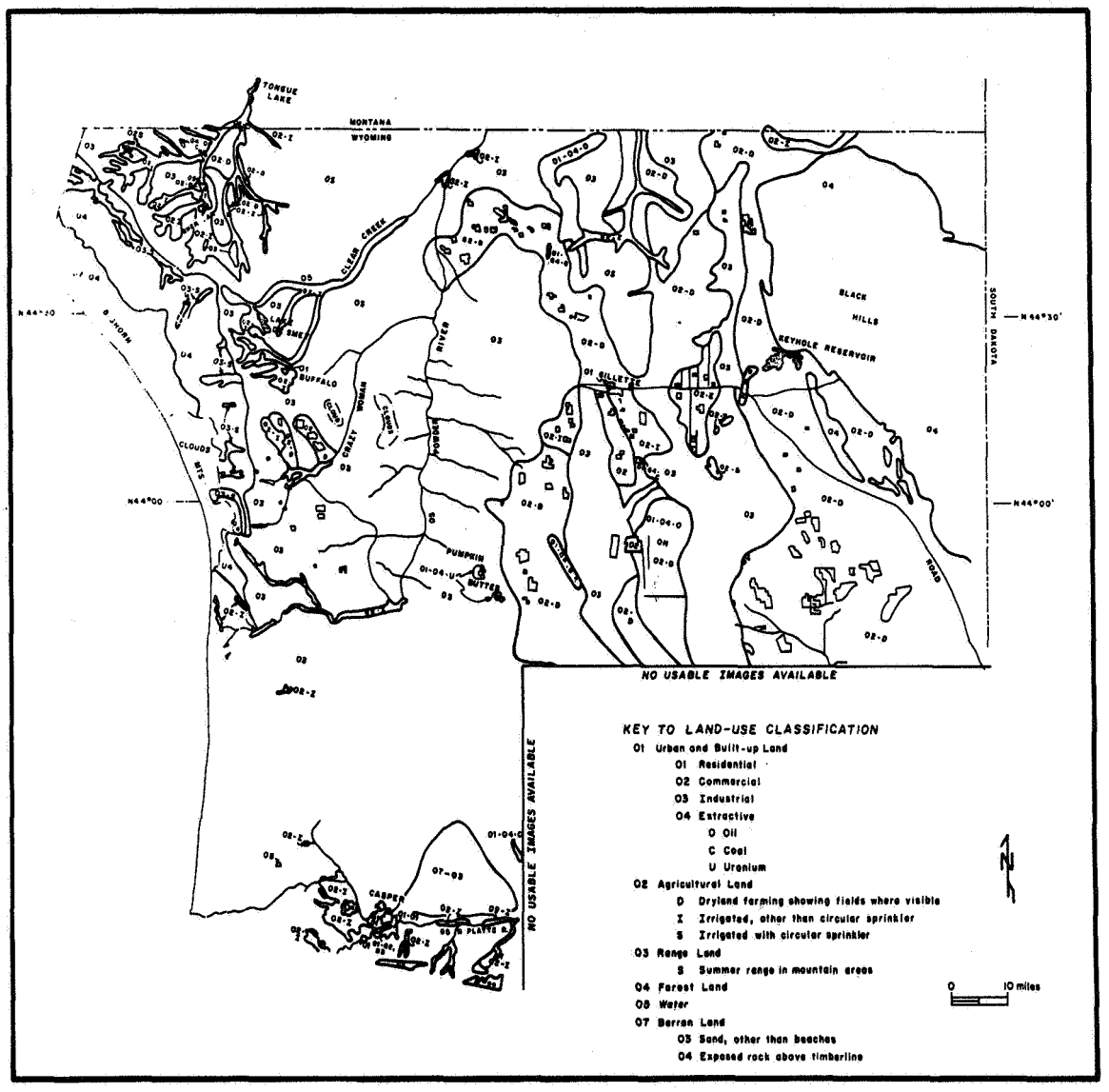

Figure 2. Land-use classification map for the Powder River Basin, Wyoming constructed from ERTS-1 image interpretations.

contrasts within the vegetation. Interpretation of the ERTS-1 imagery provided adequate detail for mapping broad-scale agricultural patterns. Some detail features were recognized in the agricultural pattern. These might allow crop identification if supplemented with other image interpretations showing seasonal variations.

Maps of distribution of conifers and deciduous vegetation were compiled from ERTS-1 interpretations for the Bighorn Mountains. These maps are necessarily generalized due to the very small scale of the ERTS images, but they yield a fairly reliable estimate of the distribution of these major forest subdivisions.

Rangeland is readily distinguishable from other agricultural lands and can be subdivided on the basis of tone and texture. The resulting map can be correlated to standing biomass at the time of the satellite overpass, but range type and quality (a time-dependent factor) cannot be established without control data and complementary interpretations from repetitive coverage.

Broad soil classifications can be interpreted from the ERTS imagery on the basis of tone, texture, and regional association. The resulting maps show excellent correspondence with the state soil map which classifies soils on the basis of composition (which relates to parent material). Very little correlation is evident between the soil interpretations derived from ERTS and the more detailed soil maps based on the newer Seventh Approximation classification, but similarities may exist between the larger soil groups and the ERTS interpretation.

Slope estimations were based on stream pattern analysis. The frequency and patterns of drainages were used as criteria for subdividing the Powder River Basin into zones of equivalent slope. The actual slope values for the various areas were then determined from the topographic maps. This application was particularly successful in the Powder River Basin which has a very intricate system of small drainages that reflect even subtle changes in regional slope.

Abandoned, producing, and developing open-cut coal mines are visible on the ERTS imagery, but small open-cut uranium, bentonite, and gypsum mines and surface evidence of underground mines in the Powder River Basin could not be seen on the ERTS imagery. However the large uranium mines in the Gas Hills district of central Wyoming can be seen on the imagery.

A map of known and potential coal resources was constructed from the combined mine locations and geologic interpretations of the Powder River Basin. This generalized map is useful for defining areas of probable or possible coal mine development for the proposed electrical power installations or other energy needs. Maps of potential areas for the development of other mineral resources were compiled with the favorable

locations defined on the basis of geologic interpretation. For example, dunes and terraces were designated as potential sources of sand and gravel, areas of limestone outcrop were mapped as possible sources of lime, and areas of structurally favorable geologic patterns were designated as areas of potential petroleum resources (although virtually all structures visible on the surface have already been tested).

Perhaps the most difficult task attempted was the mapping of urban areas. Cities and towns of Wyoming are relatively small (population 60,000 or less). Early attempts to outline the areas of urban development by standard photointerpretation techniques were unsuccessful. Although the urban areas could generally be located on the imagery, there was often insufficient contrast with the surrounding rural development to allow definition of the urban area. Color-additive viewing was useful in some instances where subtle contrasts on two or more bands could be enhanced by composite display, but it was soon discovered that the ability to discern urban areas was largely dependent on the overall contrast with the surrounding area, and that the urban areas were generally too small to exhibit a characteristic texture or pattern. Even under magnification the urban areas generally appear as fuzzy-grey areas with subtle variations in internal tone and texture. The patterns are too intricate and tonal variations too subtle for visual interpretation.

This problem was circumvented by employing the isodensitracer as a tool for enlarging the images for the urban areas (up to 50X) and enhancing subtle density contrasts. Interpretation of the resulting isodensity contour maps usually allows separation of the urban areas from the surrounding rangeland and natural vegetation but still provides little distinction between urban and agricultural land. A more powerful technique was devised to segregate urban areas from agricultural land. In this technique, four color isodensitracings are prepared for each of the multispectral images and the isodensitracings are then composited to form a color composite map.

Both isodensitracing techniques reveal patterns within the urban areas that can often be related to type or intensity of development. In some instances the industrial and/or business districts can be segregated from residential areas. New residential areas are commonly distinct from older residential areas which have mature trees. Parks or recreational areas are sometimes identifiable.

The advantages of repetitive coverage are well demonstrated in our attempts at urban mapping. We were forced to go to great lengths to accurately define urban areas and significant zones within the urban areas using the early ERTS images (taken in the summer and autum of 1972). However, when we received the first winter maps over Wyoming, it became apparent that snow-cover provides great enhancement of urban areas. Not only does the snow mask all contrasts in rural areas and increase the contrast between the urban areas and their surroundings, but it provides

means of obtaining a pseudo-thermal map that records intensity of cultural activity in remarkable detail. The urban areas and transportation routes are readily apparent on the images showing snow-cover and, with isodensity contouring, zones of increased activity (business districts, industrial facilities, etc.) are shown in patterns of increasing density which reflect the degree to which the snow-cover has been disturbed. Interpretations of the isodensity contour maps from these winter ERTS images compare very favorably with interpretations of comparable aircraft photography and provide considerable data for updating most city maps (Fig. 3).

This study demonstrates, that even though photointerpretative techniques using ERTS data cannot provide detail that many land-use applications require, it is capable of providing a great deal of broad-scale, basic land-use data on a continuing basis. This information can be derived from the ERTS data far more quickly and efficiently than by conventional techniques. Consequently, the ERTS program can supply information for land-use planning as long as there is a need for constructing or revising the broad-scale land-use data base.

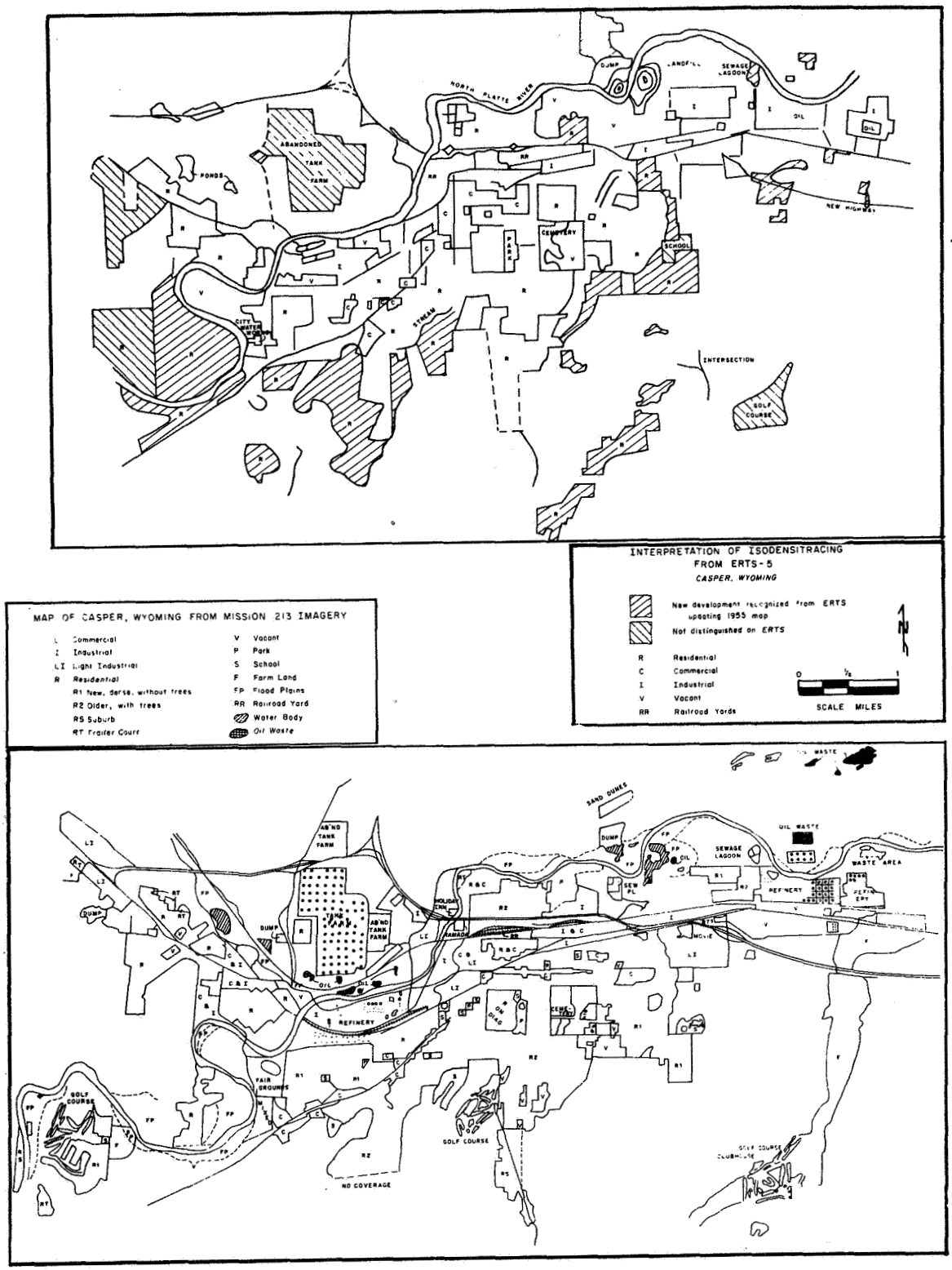

Figure 3. Comparison of interpretation of an ERTS image isodensitracing with an interpretation of a 1:30,000 scale aerial photograph. The ERTS image (1101-17185) was taken with snow on the ground.