THE USE OF HIGH ALTITUDE AERIAL PHOTOGRAPHY TO INVENTORY WILDLIFE HABITAT IN KANSAS: AN INITIAL EVALUATION

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INTRODUCTION

The Kansas Forestry, Fish and Game Commission is charged with the responsibility of managing the wildlife resource of the state. This resource constitutes an important aesthetic and economic asset in Kansas and, as in most states, is experiencing increased pressures, a consequence of public demand for more and better quality recreation. Maintenance and enhancement of this wildlife resource requires careful study and management.

Accurate and timely information regarding habitat conditions is essential to an effective intensive management program. This must include data concerning spatial distribution, areal extent, and degree of interspersion of current and potential wildlife habitat types. To be of optimal utility, an inventory of this scope should be computer based and, in addition, be capable of being up-dated at regular intervals.

In Kansas, visual evidence indicates that increasing amounts of various wildlife habitat types are being destroyed or physically changed in order to allow for more economically profitable land uses. Despite this observation, it has been impractical, to date, to collect data such as that cited above on a statewide basis. The only intensive inventories of habitat have been conducted on public land near state lakes and reservoirs, or on other land where a local problem has been recognized. Areas covered are usually not in excess of several sections. A much more extensive inventory is needed.

A statewide habitat and/or land-use inventory would allow the monitoring of short-term and long-term changes in the habitat and would be used by the wildlife manager to pinpoint areas in need of attention from the standpoint of habitat management. The inventory would give the manager an overview of the land-use categories prevailing within his particular region of the state, thus providing him with a tool for better management planning. With this type of information it will be possible to orient wildlife management programs around specific environmental changes, perhaps before such changes constitute a real problem. It would be a real and new advantage to be able to recognize early stages of change in wildlife habitat status.

Conventional photography and some other types of imagery acquired from high altitude aircraft and spacecraft appear to be satisfactory data bases for the type of inventory discussed heretofore. These "remote sensing" techniques seem suited to both the expansive spatial nature of the data itself and the rather specific informational requirements of the Kansas Forestry, Fish and Game Commission.

It is the purpose of this paper to review the degree to which certain remote sensing techniques may contribute to a statewide inventory of wildlife habitat in Kansas. More specifically, this report reviews the results of an investigation into the application of high altitude color infrared aerial photography to such an effort.

THE USE OF REMOTE SENSING TECHNIQUES IN A WILDLIFE HABITAT INVENTORY

"Remote Sensing" is the term used to describe the gathering of information about an object or area without having the measuring device in physical contact with the entity of interest. Though other types of sensors exist, the nature of the data required for an inventory of wildlife habitat dictates that this discussion be limited to instruments which produce an image and can be operated from air or spacecraft platforms.

Sensors of this variety measure and record electromagnetic energy either reflected from or emitted by objects at or near the earth's surface (see R. Colwell, et al, 1963). Individual sensors generally detect and record energy in one or, at most, a few "bands" of the electromagnetic spectrum (see Figure 1). Sensors may be classed as either "passive" or "active" depending upon their mode of operation. Passive sensors (e.g. cameras) detect and record energy reflected or emitted under natural conditions, energy originating from the sun. Active sensors generate their own energy, transmit it towards the object or area of interest and record the "echoes". Side-looking Airborne Radar is the most common of this type of remote sensor (see Scherz and Stevens, 1970; National Academy of Sciences, 1970 for more detailed discussion of sensors).

The capabilities of individual sensors to detect and record information in different spectral bands gives each advantages in identifying and mapping certain objects or conditions which tend to be more "visible" in some bands than in others. In addition, most sensors may be operated from either air or space platforms at varying altitudes with resultant unique spatial and cost properties (e.g. with camera systems

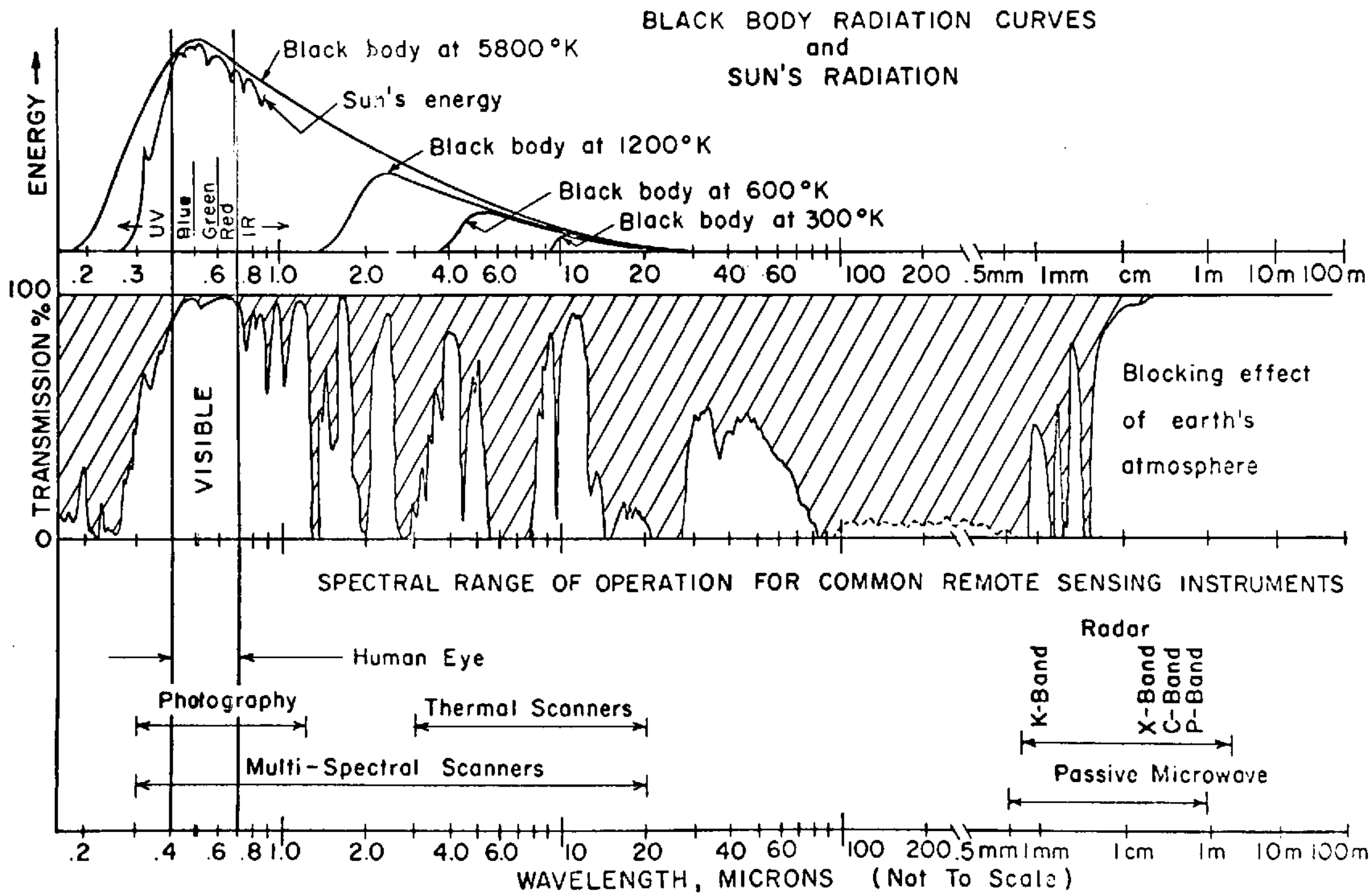


FIGURE 1. THE ELECTROMAGNETIC ENERGY SPECTRUM
Source, Scherz and Stevens, 1970.

it is generally true that the higher the altitude, the greater the areal coverage per frame of imagery and the lower the cost per unit area). The sensor-platform systems listed in Table 1 are briefly evaluated with respect to their utility for a statewide wildlife inventory below.

Aerial cameras record on film reflected electromagnetic energy in the visible and near-visible wavelengths (Figure 1). Conventional black and white (panchromatic) film records the intensity of reflection of visible light in various tones of grey. Color film records hue rather than simply grey tone. Infrared films allow imaging of reflected energy having slightly longer wavelengths than are visible to the human eye. On black and white infrared film the intensity of reflection of this near-infrared energy is registered in shades of grey. False color infrared films portray reflected infrared energy in shades of red, and other visible colors in shades of blue and green (not necessarily their true colors). Multiband cameras or camera clusters photograph a single area, splitting up the visible and near infrared energy collected into several spectral bands (e.g.- red light, green light, infrared) each of which is recorded on a separate portion of film.

Each of these systems has advantages and disadvantages insofar as a wildlife habitat inventory is concerned. Black and white films are, for instance, less costly than color both to acquire and process. Normal color films, on the other hand, provide the added information of hue which often aids in interpretation, and color infrared films assist, likewise, in the analysis of infrared imagery. Infrared imagery in general can provide information not obtainable from normal panchromatic or color photography. The intensity of reflection of near infrared energy from vegetation is related to the type, quality, vigor and maturity of the flora and, thus, an interpreter can frequently acquire information regarding these attributes. Multiband photography is generally more expensive and somewhat more complex to interpret than other camera-film systems discussed, but has the advantage of allowing the interpreter to view the same object in several discrete bands.

Photographic imagery may be collected from various altitudes ranging from very low flying light planes or helicopters to spacecraft. Although certain camera systems and films may allow some adjustment, in general the higher the altitude flown, the lower the resolution of the imagery (i.e. the larger an object must be to be seen).

TABLE 1. SENSOR-PLATFORM SYSTEMS EVALUATED

Sensor	Platform
Aerial Photography	
Camera - Panchromatic (black and white) film	Aircraft
Camera - Color film	Aircraft
Camera - Infrared film	Aircraft
Camera - Multiband	Aircraft
Camera - Multiband	Skylab
Scanners	
Multispectral scanner	Aircraft
Multispectral scanner	Earth Resources Technology Satellite (ERTS)
Thermal IR scanner	Aircraft
Radar	
Side Looking Airborne Radar	Aircraft

A trade-off, however, is the fact that low flying aircraft collecting imagery of great detail capture very little area within each frame of film. Thus, low altitude missions can become quite costly if data is to be collected over sizeable areas. It may often be advantageous when inventorying a large area to use a multistage sampling technique employing space or high altitude imagery as the data base supplemented by increasingly higher resolution photography over smaller sample areas and culminating in ground data collection at selected points (Langley, 1969; Driscoll and Francis, 1971).

Several other imaging sensors besides cameras may be mentioned. Multispectral scanners collect and record information in discrete bands, similar to multiband camera systems, but often over a broader spectrum from visible to emitted thermal infrared wavelengths (Figure 1). This data is collected electronically, not photographically, though images may later be produced. Thermal infrared scanners detect and record emitted infrared energy in the thermal part of the electromagnetic spectrum only. Side-Looking Airborne Radar (SLAR) beams pulses of microwave energy toward the ground and records the "echo" in image form.

Though it does produce an image, the thermal infrared scanner, detecting essentially differences in temperature, appears to have little application for habitat inventory. SLAR imagery, while having significant utility in areas such as geology, at present does not offer the advantages of some other sensors for medium to large scale land-use mapping. Aircraft mounted multispectral scanners are relatively expensive and require rather sophisticated processing and interpretative techniques. Though other sensors presently appear more suited to habitat inventory, the development of the multispectral scanner deserves attention.

The four band multispectral scanner mounted in the presently orbiting Earth Resources Technology Satellite (ERTS-1) is an exception, as it appears to have potential immediate use in a habitat inventory, at least for non-detailed information. Its chief advantages are (1) the large area covered in each frame of imagery (approximately 115 miles on a side) due to the 570 mile altitude of the orbiting platform, (2) the inexpensive cost of the imagery and (3) the similarity of certain image products to conventional photography. The main disadvantage of the ERTS imagery is its low resolution of about 300 feet. Still it may be useful, since this imagery is currently available for the same location every 18 days, weather permitting.

It may be mentioned while discussing space platforms that the photographic multiband imagery obtained from Skylab does not appear to be useful since the orbiting station will be only a temporary fixture and, furthermore, very little, if any, imagery has been obtained over Kansas.

For the immediate future, then, an aircraft mounted camera system seems to be the most viable option for a habitat inventory. High altitude flights (40,000-65,000 ft.) are believed to be the optimal mode for data collection. The advantages of high altitude photography include (1) large areal coverage on each frame (about 170 square miles at 45,000 ft. with a six inch focal length camera and a nine inch by nine inch film format), (2) commercial availability and (3) high resolution (detail apparently sufficient for habitat inventory). While photographs taken at lower altitudes show greater ground detail, many more of these images would be required to cover a given area, and, thus, costs would rise. Color or color infrared film would probably be significantly advantageous over black and white films. The cost and increased complexity of interpretation of a multiband system are not believed necessary to obtain the information required for a wildlife habitat inventory.

In sum, it appears that high altitude color or color infrared photography will be most advantageous for a statewide habitat inventory. Nine inch film rather than 70 mm or other film formats is probably preferable. Flights it appears should be conducted in mid-late spring or autumn when differentiation of land-useage is most likely to be greatest. Two or more flights during the growing season may produce valuable added information, but it is believed at present that these would be a luxury. Multistage data could be quite valuable and, indeed, ground truth on a limited basis would be essential. ERTS imagery, for the reasons discussed earlier, may be useful as a secondary resource for providing information on broad scale phenomena and for detection of change in land-use over a period of time.

A TEST OF HIGH ALTITUDE IMAGERY IN JEFFERSON COUNTY, KANSAS

In order to assess more fully the utility of high altitude imagery as a means to inventory wildlife habitat in Kansas, a pilot study was conducted. The objectives of this study were to determine habitat parameters to be measured, to define the capabilities of the remote sensing system to provide this information, and to develop techniques for data extraction, manipulation, and presentation. An attempt was made to develop all data and techniques in the context of potential utility to the primary users - wildlife management personnel. Furthermore, all data and procedures were designed to be suitable for computer storage and processing at a later date.

High altitude imagery is available over only selected areas of Kansas at present. The most recent photography, acquired by the National Aeronautics and Space Administration (NASA) on March 21, 1973, provided good quality coverage of several areas across the state. It was suspected that March was not the best time of year for interpreting habitat, since some important land-use classes are difficult to distinguish during the period of vegetal dormancy. Nevertheless, we were prompted to begin our work utilizing this imagery as our data source. The recent date of the photography, its good overall quality, and, especially, the fact that we could immediately acquire copies of the color infrared photography on loan from the Kansas Geological Survey were important factors in this decision. Ordering imagery would have caused a delay of several months in the program. Furthermore, we felt that techniques developed for extracting and manipulating data from the March photography could be transfered to more optimal imagery as it was received. We concurrently ordered more optimal imagery flown by NASA in early autumn 1969 with several types of films to be evaluated at a later stage in the project.

A 27 square mile area in Jefferson County, Kansas was selected as a test site for development of interpretation and data handling techniques (Figure 2). The high altitude coverage of this area was of good quality. Additionally, the area contained a diversity of habitat types interspersed in a variety of situations, was close enough to our research facilities at, respectively, Lawrence and Valley Falls, Kansas to allow ground checking when needed, and was substantially covered by low altitude photography flown by the Kansas State Highway Commission almost concurrently with the high altitude flight, thus providing quite valuable "ground truth".

The color infrared imagery acquired (Figure 3) was photographed from an altitude of approximately 65,000 feet above mean sea level (or about 64,000 feet above ground level in Jefferson County). Each original film transparency measured nine inches on each side, had a mean scale of about 1:127,000 and covered an area of approximately 300 square miles. Although imagery flown commercially would not normally be obtainable at this altitude, techniques developed for use on this photography would be transferable to imagery acquired at 40,000 - 50,000 feet.

Figure 2

JEFFERSON COUNTY, KANSAS STUDY AREA

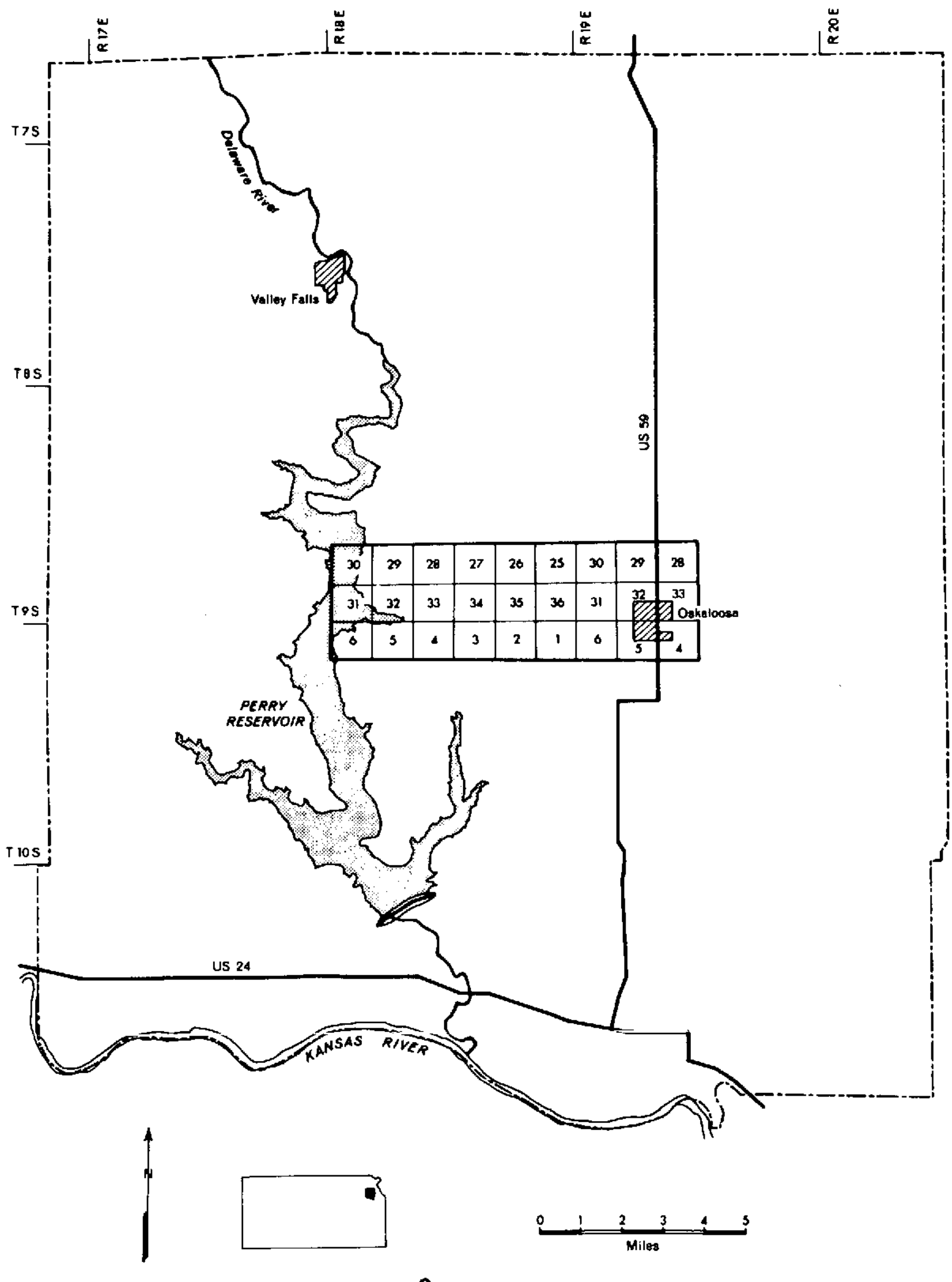


Figure 3 Color infrared image of test site area, Jefferson County, Kansas

The habitat/land-use classification adopted was based on an assessment of informational requirements of the Forestry, Fish and Game Commission and the capability of the imagery to provide such data (Table 2). It was felt that the land-use categories selected could be interpreted from the photography with reasonable accuracy and efficiently recorded, and that they would be of value in management programs.

Land-use data was compiled using a 10 acre unit as the basic areal element. It was believed that this unit would be adequate for compiling statistical information useful for management, could be suitably employed with the imagery available, and would provide a basis for computer storage of data at a later time. Every square mile section of the study area contained 64 10-acre cells, each referenced to the northwest corner of the section for consistent accuracy of location.

Color infrared transparencies of the study area were rear projected onto glass mapping planes and enlarged to a scale of 1:24,000. At this scale land-use was much easier to interpret and map, and, in addition, this was the scale of U.S. Geological Survey maps which we were using as a collateral resource.

Homogeneous units of land-use were outlined on transparent tracing material and identified. Ground truth checks indicated satisfactory identification overall. Roads, some residences, and drainage information were derived from the U.S.G.S. maps. A 10 acre grid was superimposed on the mapping base and data was transfered cell by cell to specially prepared recording forms (Appendix I).

These forms will serve a dual function. They allowed manual tabulation of data during this pilot study, but, later, will also facilitate computer programming of the information. Each of the 64 rows on the data form represents one 10 acre cell, each number in the row a land-use type. There was a separate form for each square mile of the study area.

The dominant land-use within each cell (that covering 50% or more of the cell area) was recorded along with other land-uses which were present, but not dominant. With the exception of linear features, residences and small ponds, no land-use occupying less than one acre of the cell was registered. In some instances cells were equally dominated by two or three land-uses, none occupying more than 50% of the cell area; these were marked as co-dominates.

TABLE 2 LAND USE CLASSIFICATION - KANSAS WILDLIFE HABITAT INVENTORY

A. URBAN AND BUILT-UP LAND

Residential, both farmsteads and urban including business and built-up areas
Extractive, mining
Roads
Utilities and communications

B. AGRICULTURAL AND GRASSLAND

Cropland
Hayland
Pastureland
Windbreak types: grove, orchards, bush fruits, horticultural areas
Burned land
Mature grass
Grass and forbs
Mature grass and shrubs (less than 50% shrub cover)
Mature grass and trees (less than 50% tree canopy cover)

C. WOODLAND AND EDGE

Deciduous woods
Evergreen woods
Mixed woods
Brush
Brush and trees-similar to hedgerows (e.g. riverine, drainage locations)
Hedges
Fence rows

D. WATER

Reservoirs
Lakes (over 10 acres)
Larger ponds (3-10 acres)
Smaller ponds (0-3 acres)
Streams and waterways
Marshes and rainwater basins

E. BARREN LAND

Sand
Exposed rock
Salt flat
Other

Secondary information was collected with regard to selected habitat types. For each 1/16 mile of hedgerow, river or road located, a value of 2 was given. If this feature occurred on the cell boundary, each 1/16 mile was given a value of 1. This provided a means for tabulation of lengths of linear features. Additionally, the number of ponds was recorded for each cell, and ponds and lakes 3 acres or larger overlapping adjacent cell boundaries were recorded so as to prevent double counting during calculation of statistical information.

WILDLIFE HABITAT STATISTICS AND GRAPHICS

Various statistical parameters were tabulated from the completed data forms. These fell into four general categories: area estimates, linear measurements, counts of discrete habitat elements, and statistics of frequency or habitat interspersion. This information can be summarized for successively larger areal units as required. For wildlife habitat administrative purposes, information grouped by one or more counties, or the entire state, might be most useful, whereas, for management purposes, information for areas as small as the 10 or 40 acre size cell might be of more utility. The Kansas Forestry, Fish and Game Commission is likely to most frequently require data summarized for areas of 10, 40, and 160 acres, 1 and 36 square miles, and entire counties.

The following representative examples of statistics were primarily tabulated for single square miles and then summarized over the entire 27 square mile study area. Calculations could be made, however, for areas as small as 10 acres, as large as the entire state (were data available), or for any intermediate multiples of 10 acres.

Table 3 presents an example of acreage estimates computed as percentages of each square mile covered by land uses dominant in any 10 acre cell. Some habitat types that were present in a section, but never dominant, are, of course, not represented in the table. Table 4 presents an example of three habitat categories that can be described in linear terms. These rarely, if ever, dominate a cell, but provide information important in wildlife management. As in the previous example, the linear extent of these types is computed for each square mile and totaled for the study area. An average per square mile was also calculated. Table 5 presents an example of how some information is suited for simple counts and may be summarized for the entire study area.

Location \ Land Use	Residential, Business, & Other Built-up Areas	Extractive	Transportation	Active Cropland	Hayland	Pastureland	Grass, Uncropped	Grass and Forbs	Grass and Shrubs	Grass and Trees (Savanna)	Deciduous Woods	Brushland	Brush and Trees (Linear)	Reservoirs	Lakes (Over 10 Acres)	Large Ponds (3-10 Acres)	Total Per Section
T9S R18E Sec 25				8.6	34.4	22.4		23.2		6.2	5.2						100
26				15.6		21.9	0.8	21.9	4.7		35.2						100
27			1.6	14.6	10.2	12.2		0.8			60.7						100
28			5.5	19.5	7.0	18.0					47.7	2.3					100
29			1.3	10.9	18.8	32.0	0.5				34.9					1.6	100
30					7.6						16.1			76.3			100
31			7.8		10.7		0.5				3.6			77.3			100
32			1.6		13.8	22.7	13.8				14.1			34.1			100
33			2.9	13.5		25.0	6.5				51.3					0.8	100
34				7.8	1.6	47.9	9.1				32.3					1.3	100
35				14.1		32.8	2.3	10.2		0.8	31.2		8.6				100
36				27.3	5.5	22.4		6.2		3.6	34.9						100
T10S R18E Sec 1				29.4	1.6	8.3	6.0	5.2			48.7					0.8	100
2				18.8	18.0		4.4	1.0	2.1		55.7						100
3				8.3	8.6	26.3	3.1				53.6						100
4				8.6	3.6	18.0	20.8				48.4					0.5	100
5				5.2	3.6	28.1	5.2				57.8						100
6		2.0			14.1	1.6	7.0				52.7	2.0		20.3		0.4	100
T9S R19E Sec 28	3.1			25.0	2.1	9.4	3.1	26.3			31.0						100
29				36.5	8.6	18.0	7.0	13.8			16.1						100
30	0.8			14.8	12.5	38.3		3.1		11.7	17.2		1.6				100
31				24.7	24.2	0.8	6.8	2.1	7.6		33.9						100
32	24.2					21.9	22.7	8.6		5.5	16.4					0.8	100
33	8.8				25.0	36.2	2.1	6.2	2.9	2.1	16.7						100
T10S R19E Sec 4	5.5			12.0	27.1	14.6		21.9		3.1	15.9						100
5	25.2				2.3	16.1	4.7	18.8	8.6		19.5		0.8		3.9		100
6				3.9	12.5	35.7	3.9	0.8	2.9	3.1	35.7					1.6	100
Entire Study Area	2.5	0.1	0.8	11.8	10.1	19.6	4.8	6.3	1.0	3.4	30.8	0.2	0.4	7.7	0.1	0.3	100

Table 3. Percent Coverage of Dominant Land Use Categories.

Location	Roads (Miles)	Hedgerows (Miles)	Streams & Rivers (Miles)
T9S R18E Sec 25	2.0	2.6	1.2
26	1.7	0.7	1.0
27	3.3	-	2.7
28	2.3	0.6	2.4
29	6.5	1.3	1.2
30	0.4	-	0.1
31	2.4	0.1	-
32	2.2	1.0	0.6
33	2.9	0.2	1.6
34	2.6	0.1	1.6
35	1.8	1.8	1.9
36	1.3	2.2	1.5
T10S R18E Sec 1	1.8	0.3	2.9
2	1.2	1.2	2.9
3	3.0	1.2	1.5
4	2.8	1.4	1.6
5	1.6	0.8	1.2
6	5.7	0.3	0.8
T9S R19E Sec 28	2.9	1.3	2.2
29	2.3	0.6	2.9
30	2.8	0.5	2.1
31	2.4	1.4	2.9
32	2.4*	1.2	1.4
33	2.5*	0.5	1.1
T10S R19E Sec 4	2.0	2.5	2.2
5	2.8*	0.6	1.6
6	1.9	1.3	2.0
Total (All Sections)	67.5	25.7	45.1
Average/Section	2.5	0.95	1.67

*Portions of section lies in city limits of Oskaloosa where streets were not tabulated.

Table 4. Miles of Roads, Hedgerows, and Streams.

	Reservoirs	Lakes (Greater than 10 Acres)	Large Ponds (3 - 10 Acres)	Small Ponds (0 - 3 Acres)
Number of Water Bodies	1	3	25	119
Average Number of Water Bodies/Section	0.04	0.11	0.93	4.41
Number of Sections Occurring in	6	2	17	26
% Sections	22.2	7.4	63.0	96.3

Table 5. Number of Water Bodies in Study Area.

A fourth type of information deals with the presence or absence of habitat types in whatever size area we care to examine. Table 6 shows one method of summarizing this type of data into a variation of the "Interspersion Index". The index is simply a measurement of the mixture of different habitat types within any given area. In this example, grassland, woodland, cropland and water bodies are the habitat features considered and a 40 acre cell size is utilized. Each time one of these four categories was found present (not necessarily dominant) in the 40 acre cell it was given an index value of "1". Each 40 acre cell thus had a maximum possible value of 4, each 1/4 section, 16, and each square mile, 64. In this example it should be noted that index values for sections in which "built-up areas" were present are somewhat depressed. Figure 4 graphically portrays the average interspersion value for each 40 acre cell summarized by 1/4 sections and square miles, and the total index value for each square mile based on the 40 acre cells. Those cells having the higher index values have the greatest diversity based on the four land-use categories considered and may be better habitat for wildlife requiring a highly interspersed environment incorporating the four habitat types used in this example.

A variation of this interspersion index involved a simple count of all land-use categories found to be present in each 10 acre cell. In Table 7 this information is summarized for 40 acre cells and for each square mile of the study area. The index value for each section is shown in Figure 5. Again, the higher the number, the greater the diversity of habitat.

A third means of computing a statistic of interspersion (potentially the best method) could involve the selection of certain habitat categories on a strictly biological basis. By imposing weighted values on selected land-use elements, an estimate of present or potential quality of habitat with respect to certain species could be made. For example, the presence of certain types of grass, crops, etc. might be given a higher value than the presence of large ponds when considering a particular species of wildlife. Although this statistic was not calculated in this pilot study, it appears that it may be useful both in evaluating and managing wildlife habitat.

Location \ Grid Cell	AB12*	AB34	CD12	CD34	Subtotal	AB56	AB78	CD56	CD78	Subtotal	EF12	EF34	GH12	GH34	Subtotal	EF56	EF78	GH56	GH78	Subtotal	Grand Total per Section	Grid Cells Bu
T9S R18E Sec 25	3	2	2	2	9	3	3	2	3	11	3	2	3	3	11	3	3	4	3	13	44	
26	4	3	2	3	12	3	2	4	3	12	3	3	3	3	12	3	3	3	4	13	49	
27	4	3	4	2	13	2	4	3	4	13	3	3	1	3	10	4	4	3	2	13	49	
28	3	4	3	3	13	2	3	2	3	10	3	3	3	2	11	3	3	3	1	10	44	
29	3	2	3	3	11	2	2	3	3	10	3	3	4	4	14	3	4	4	4	15	50	
30	1	1	1	1	4	1	3	1	3	8	1	1	1	1	4	2	3	3	2	10	26	
31	2	2	1	1	6	3	3	1	2	9	1	1	1	1	4	1	1	1	3	6	25	
32	3	3	3	3	12	2	3	3	2	10	2	3	2	2	9	3	3	2	3	11	42	
33	2	4	3	4	13	3	3	3	3	12	3	1	3	2	9	3	3	3	2	11	45	
34	2	3	3	3	11	3	3	4	4	14	3	3	3	2	11	3	3	3	2	11	47	
35	3	4	2	3	12	4	3	4	3	14	3	3	3	4	13	3	3	3	2	11	50	
36	3	3	3	3	12	4	4	4	3	15	3	3	4	3	13	3	4	3	4	14	54	
T10S R18E Sec 1	3	3	3	4	13	4	3	4	4	15	4	4	2	4	14	4	3	3	3	13	55	
2	4	3	4	3	14	4	3	4	4	15	2	3	3	3	11	4	4	3	3	14	54	
3	4	4	4	3	15	3	3	3	3	12	3	3	3	3	12	3	3	3	3	12	51	
4	2	3	2	2	9	3	3	4	4	14	3	2	4	3	12	2	3	3	2	10	45	
5	3	3	3	2	11	3	2	2	3	10	2	4	3	3	12	3	4	2	4	13	46	
6	2	3	3	2	10	3	3	3	3	12	3	2	3	2	10	3	3	2	3	11	43	
T9S R19E Sec 28	4	3	3	3	13	3	3	4	3	13	3	4	3	Bu	10 Bu	4	4	4	4	16	52	1
29	3	4	3	4	14	4	4	4	2	14	4	3	4	2	13	4	3	4	3	14	55	
30	3	3	3	3	12	3	3	3	3	12	3	2	2	3	10	3	4	4	4	15	49	
31	3	3	3	4	13	4	4	4	2	14	3	3	4	3	13	4	4	3	4	15	55	
32	3	2	3	3	11	2	3	Bu	3	8 Bu	3	2	3	3	11	Bu	Bu	Bu	Bu	Bu	30 Bu	5
33	2	3	2	3	10	3	2	2	3	10	Bu	3	Bu	Bu	3 Bu	2	2	3	Bu	7 Bu	30 Bu	4
T10S R19E Sec 4	Bu	Bu	3	3	6 Bu	4	3	3	2	12	Bu	3	4	3	10 Bu	3	3	3	4	13	41 Bu	3
5	3	2	3	2	10	Bu	Bu	Bu	Bu	Bu	3	3	3	3	12	Bu	3	3	Bu	6 Bu	28 Bu	6
6	2	3	3	3	11	3	4	3	2	12	3	3	2	3	11	3	3	3	3	12	46	

Bu Indicates Built-up Area.
* Indicates Grid Cell Coordinates of Four 10 Acre Cells (eg. A1, B1, A2, B2).

Table 6. Interspersion Index Values Based on the 40 Acre Cell Size Using Four Major Groups of Land Use Categories.

					R18E	R19E			
1.00 2.00 a. 26 b. 1.62 1.00 2.50	2.75 2.50 50 3.12 3.50 3.75	3.25 2.50 44 2.75 2.75 2.50	3.25 3.25 49 3.06 2.50 3.25	3.00 3.00 49 3.06 3.00 3.25	2.25 2.75 44 2.75 2.75 3.25	3.00 3.00 49 3.06 2.50 3.75	3.50 3.50 55 3.44 3.25 3.50	3.25 3.25 50 3.47 Bu 4.00	
1.50 2.25 25 1.56 1.00 1.50	3.00 2.50 42 2.63 2.25 2.75	3.25 3.00 45 2.81 2.25 2.75	2.75 3.50 47 2.94 2.75 2.75	3.00 3.50 50 3.12 3.25 3.50	3.00 3.75 54 3.38 3.25 3.50	3.25 3.50 55 3.44 3.25 3.75	2.75 Bu 30 2.73c. 2.75 Bu	2.50 2.50 30 2.50c. Bu Bu	T9S
2.50 3.00 43 2.69 2.50 2.75	2.75 2.50 46 2.88 3.00 3.25	2.25 3.50 45 2.81 3.00 2.50	3.75 3.00 51 3.19 3.00 3.00	3.50 3.75 54 3.38 2.75 3.50	3.25 3.75 55 3.44 3.50 3.25	2.75 3.00 46 2.88 2.75 3.00	2.50 Bu 28 2.80c. 3.00 Bu	Bu 3.00 41 3.15c. Bu 3.25	T10S

a. Average interspersion value of 40 acre cells in 160 acre unit.

b. Average interspersion value and total count (maximum index value = 64) for 40 acre cell size in square mile (640 acres).

c. Indicates average interspersion value for portion of square mile that deletes 40 acre cells having 10 acre cells that were either dominated or codominated by the category - residential business, or other built-up areas (Bu).

Figure 4. Interspersion Index Values for Sections of Study Area Based on Presence of Cropland, Grassland, Woodland, and Water Bodies within Each 40 Acre Cell.

Location \ Grid Cell	AB12*	AB34	CD12	CD34	Subtotal	AB56	AB78	CD56	CD78	Subtotal	EF12	EF34	GH12	GH34	Subtotal	EF56	EF78	GH56	GH78	Subtotal	Grand Total per Section
T9S R18E Sec 25	12	11	10	8	41	9	6	11	11	37	11	10	10	18	49	11	11	11	14	47	174
26	10	10	9	8	37	12	8	16	14	50	7	8	11	10	36	10	8	12	11	41	164
27	12	8	12	8	40	6	8	10	16	40	10	14	4	9	37	14	15	11	5	45	162
28	9	11	9	12	41	10	8	8	9	35	9	11	11	9	40	14	14	12	5	45	161
29	9	13	13	17	52	13	11	7	11	42	13	13	13	14	53	11	12	11	13	47	194
30	4	4	4	4	16	4	8	4	9	25	4	4	4	4	16	6	6	7	9	28	85
31	6	6	4	4	20	10	12	4	11	37	4	4	4	4	16	4	4	4	6	18	91
32	17	14	15	15	61	12	14	10	14	50	7	14	5	6	32	15	11	6	8	40	183
33	8	12	11	10	41	8	9	5	12	34	12	4	12	8	36	8	10	10	12	40	151
34	9	12	10	14	45	8	8	15	12	43	13	12	10	11	46	10	11	12	11	44	178
35	10	11	9	13	43	12	18	15	13	58	15	12	13	14	54	18	14	12	9	53	208
36	14	18	14	14	60	11	12	10	13	46	13	7	13	9	42	6	17	7	15	45	193
T10S R18E Sec 1	17	11	11	10	49	14	8	16	16	54	13	13	7	9	42	14	7	8	9	38	183
2	16	14	14	12	56	13	11	10	14	48	9	11	10	13	43	11	10	12	9	42	189
3	17	11	15	12	55	15	14	7	10	46	20	11	12	10	53	12	9	13	9	43	197
4	9	12	10	8	39	12	10	11	14	47	13	10	15	16	54	12	17	14	13	56	196
5	10	6	14	11	41	9	7	7	7	30	10	20	9	12	51	11	11	9	13	44	166
6	5	8	11	16	40	7	12	11	13	43	13	16	9	16	54	15	16	15	18	64	201
T9S R19E Sec 28	18	13	17	7	55	12	13	16	14	55	8	11	Bu	12	31 Bu	12	11	18	Bu	41 Bu	182 Bu
29	12	14	11	18	55	14	18	11	7	50	14	8	10	10	42	12	11	12	11	46	193
30	12	14	13	8	47	13	16	8	14	51	11	12	11	11	45	9	12	11	16	48	191
31	11	14	11	17	53	13	12	14	9	48	14	17	13	9	53	14	14	9	17	54	208
32	14	8	17	17	56	6	12	Bu	15	33 Bu	12	7	10	17	46	Bu	Bu	Bu	Bu	Bu	135 Bu
33	9	14	11	9	43	8	10	13	11	42	Bu	12	Bu	Bu	12 Bu	10	10	17	Bu	37 Bu	134 Bu
T10S R19E Sec 4	Bu	Bu	16	10	26 Bu	10	18	10	11	49	Bu	12	15	13	40 Bu	11	16	19	12	58	173 Bu
5	17	13	14	14	58	Bu	Bu	Bu	Bu	Bu	12	14	10	12	48	Bu	14	14	Bu	28 Bu	134 Bu
6	8	13	12	12	45	15	15	14	6	50	9	14	9	14	46	10	10	9	10	39	180

Bu Indicates Built-up Area.

*Indicates Grid Cell Coordinates of Four 10 Acre Cells (eg. A1, B1, A2, B2)

Table 7. Interspersion Index Value Based on the 40 Acre Cell Size Using All Land Use Categories.

R18E | R19E

85	194	161	162	164	174	191	193	182 Bu*	
91	183	151	178	208	193	208	127 Bu	134 Bu	T9S
201	166	196	197	189	183	180	134 Bu	173 Bu	T10S

*Bu Indicates Built-up Area. Index totals are for all cells on the section excluding cells dominated or codominated by the category residential, business, or other built-up areas.

Figure 5. Interspersion Index Values for Sections of Study Area Compiled by Summing All Categories Present in Each 10 Cell Area.

Though the statistical calculations above were accomplished manually, all could be done automatically by computer. In a computerized system it would also be possible to produce digital maps. Figure 6 is a simulation of one type of digital output that might be of value to the wildlife manager. On this map is shown the distribution of dominant and co-dominant habitat types in each 10 acre cell for four square miles of the study area. Of course, any one or more land-use elements may be mapped individually whether they are dominant or not. Figure 7 illustrates the distribution of deciduous woodland, again over four sections of the study area. Other maps could be produced showing cells in which hedgerows or rivers occur, or cropland is present, for example. Maps and tabular information would, no doubt, often be used together to optimize their utility. Both would be available for areas of any multiple of 10 acres.

The statistical and cartographic examples presented above are only samples of the types of output that could be derived from a habitat inventory based on a cellular system such as has been described. Other potentially significant data products would, of course, be available to satisfy individual user requirements.

EVALUATION OF THE SYSTEM AND PROJECTION OF FUTURE WORK

Although results of this pilot study appear encouraging, several difficulties were encountered. It is suspected that in some instances misinterpretations of land-use occurred. As most trees were defoliated in the photography used, brush was sometimes confused with deciduous woodland. Grass, grass and forbs, and grass and shrubs were probably subject to some inaccuracies of interpretation also. Nevertheless, the limited ground truth available supported most identifications. Inaccuracies which did occur may be attributable to (1) the fact that the photography used was not acquired at the optimal time of year for discrimination of certain land-use categories, (2) the unavailability of detailed contemporaneous ground truth, (3) the possibility that some land-use categories can not be discriminated on the imagery and should be combined into a single category within the land-use classification, (4) the complexity of the landscape in the test area, or (5) error on the part of the interpreter which may be related to any of the factors mentioned heretofore. Imagery acquired at a more optimal time of year (e.g.- late Spring or early Summer) and accompanied by adequate ground truth would, no doubt, promote improvement in interpretation.

Figure 6

DOMINANT AND CO-DOMINANT LAND USES IN FOUR SECTIONS OF JEFFERSON COUNTY STUDY AREA

(Simulated digital map)

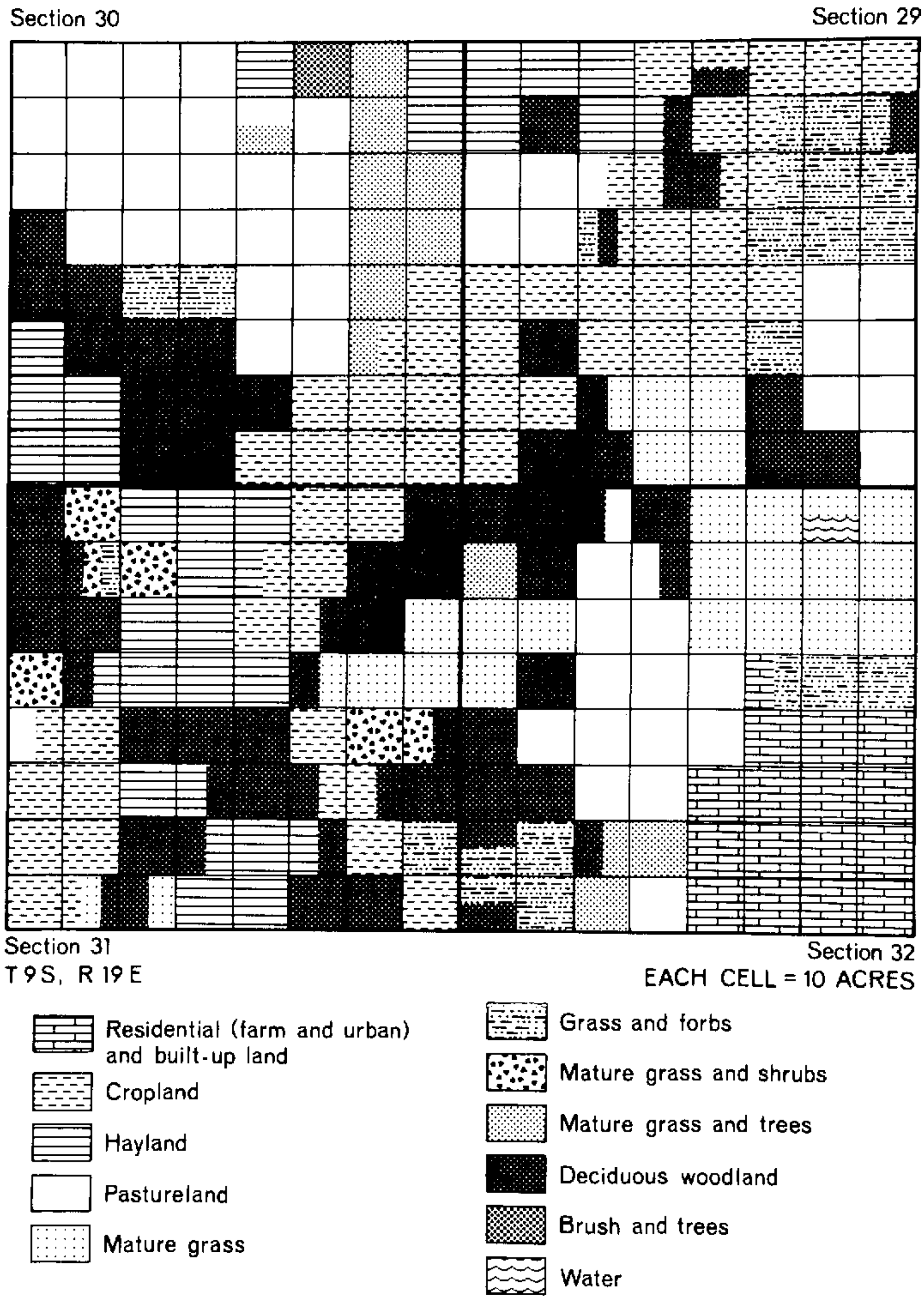
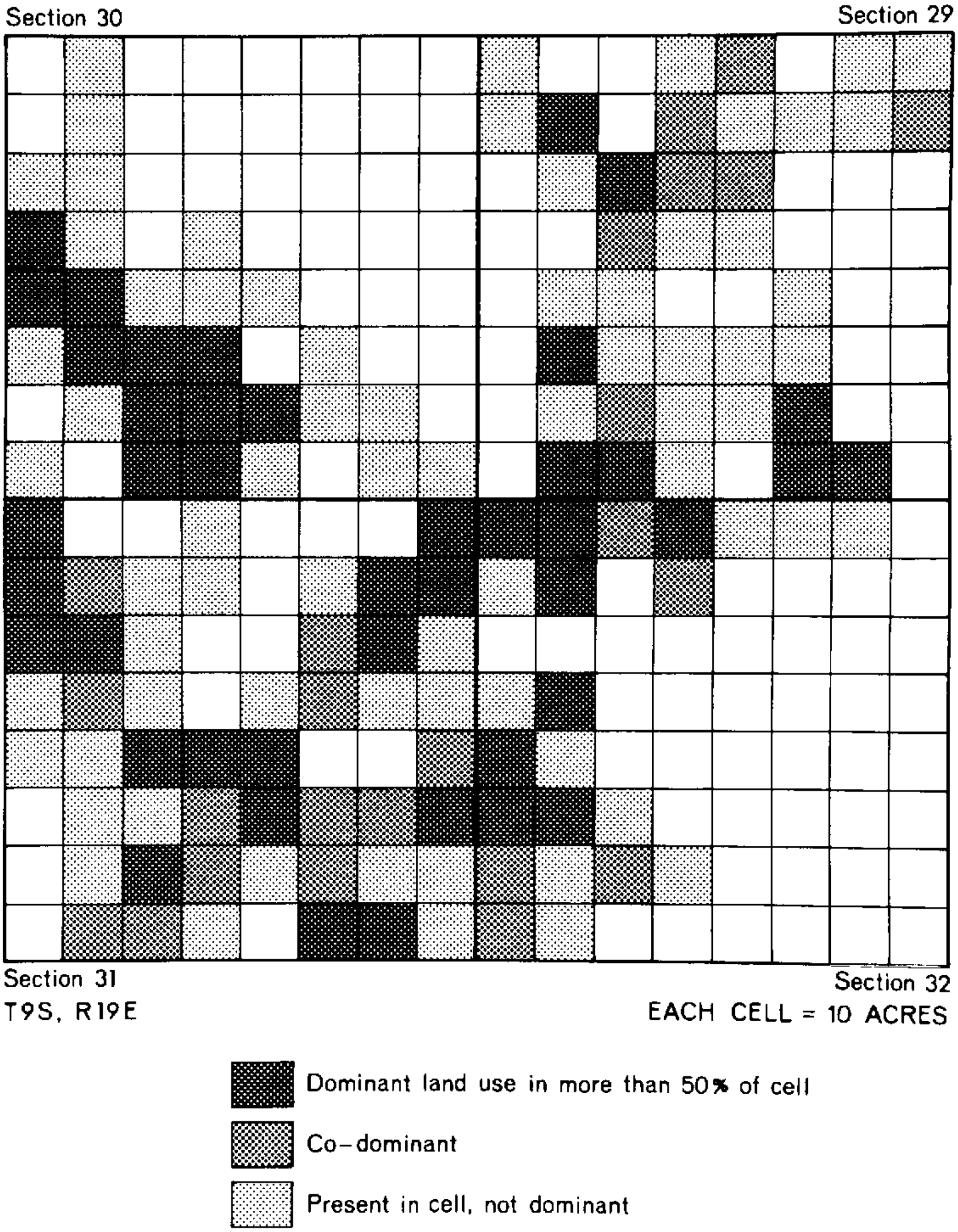


Figure 7

DISTRIBUTION OF DECIDUOUS WOODLAND IN FOUR SECTIONS OF JEFFERSON COUNTY STUDY AREA

(Simulated digital map)



While a cell based system of interpretation and data recording is advantageous from the standpoint of computer programming, it does suffer from some inaccuracy. Because of the technique of recording dominant and co-dominant land uses within minimum areal units of 10 acres, some errors are introduced in calculations of acreages and other statistics. Acreages smaller than 10 acres cannot be estimated accurately.

Modifications to the system of habitat inventory should aid in ameliorating many of these problems. Efforts to improve and augment the inventory system are proceeding. Automated and computer techniques are being examined to speed interpretation, data recording, and statistical manipulation. These procedures should help increase accuracy in certain phases, as well, by allowing smaller acreages to be delineated perhaps through means other than a cell system.

More optimal imagery will be used and its utility evaluated. Color and color infrared photography acquired over Douglas County, Kansas in early October, 1969 is presently being examined with respect to (1) the relative advantages of natural color and color infrared imagery for habitat classification (2) the value of autumn imagery as opposed to the March photography used in the pilot study, and (3) the utility of stereoscopic coverage in delineating habitat/land use information.

Furthermore, the National Aeronautics and Space Administration (NASA) will fly additional high altitude photography over parts of Kansas during the period May 15 - June 15, 1974. This flight will consist of a transect across the state and will provide coverage of natural environments substantially different than that analyzed in Jefferson County. It is believed that this imagery will be acquired at a near optimal time of year. The photography will be thoroughly evaluated with respect to its utility for wildlife habitat inventory as compared to previously examined imagery, and the degree to which pre-existing procedures developed for northeast Kansas may be applyed to other environments in the state.

Costs involved in a statewide habitat inventory are only now being assessed. Preliminary estimates (Appendix II) of flight and photographic costs do not include interpretation, data processing, or data storage. These costs will be formally ascertained as interpretative and data processing procedures are refined.

In addition to the efforts cited heretofore, a concurrent investigation of the utility of ERTS imagery and digital information for broad scale habitat assessment is being undertaken. Both manual and automatic interpretative techniques are being examined. Preliminary results indicate that ERTS may be a valuable resource for providing data on regional habitat conditions.

CONCLUSIONS

It appears that two remote sensing systems may be of substantial value for an inventory of wildlife habitat in Kansas. High altitude photography provides both large areal coverage and high ground resolution, and seems to be a suitable data base from which detailed habitat information may be extracted. ERTS imagery and digital output may be useful for regional survey of contemporary habitat conditions and for monitoring change.

This investigation demonstrates that high altitude photography can be utilized as a data resource from which habitat information can be extracted using a grid cell method. A cell technique provides a basis for both manual and computer storage and manipulation of data. Statistics of area and habitat interspersion, linear measurements, and digital maps are some of the products which may be derived from information gathered and stored in a cellular manner.

Efficiency and overall value of the system probably can be improved substantially through the use of automated techniques which aid image interpretation, and computer storage, processing and output procedures. Incorporation of automated techniques and optimal imagery into the system should accelerate data extraction and output, and improve accuracies throughout. ERTS merits increased attention with regard to its capabilities for broad scale habitat inventory. As further studies are concluded, and modifications and improvements are made in the procedures presented in this investigation, it is believed that the value of remote sensing to a statewide wildlife habitat inventory of Kansas will be considerably enhanced.

APPENDIX I

SAMPLE WILDLIFE HABITAT DATA RECORDING FORM

WILDLIFE HABITAT DATA RECORDING FORM

KEY TO LAND USE CATEGORIES

URBAN AND BUILT-UP LAND

1 Residential (farm and urban including business)
2 Extractive, mining
3 Roads
4 Utilities and communications

AGRICULTURAL AND GRASSLAND

6 Cropland
14 Hayland, species unknown
20 Pastureland
21 Windbreak types: grove, orchards, bush fruits, horticultural areas
22 Feed lot operations
24 Burned land
25 Mature grass
26 Grass and forbs
27 Mature grass and shrubs (less than 50% shrub cover)
28 Mature grass and trees (less than 50% tree canopy cover)

WOODLAND

32 Deciduous woods
33 Evergreen woods
34 Mixed woods
35 Brush
36 Brush and trees – similar to hedgerows (e.g. riverine, drainage locations)

WATER

37 Reservoirs
38 Lakes (over 10 acres)
39 Larger ponds (3-10 acres)
40 Smaller ponds (0-3 acres)
41 Streams and waterways
42 Marshes and rainwater basins

BARREN LAND

43 Sand
44 Exposed rock
45 Salt flats
46 Other barren lands

EDGE

47 Hedges
48 Fence row

COUNTY ____________________ INTERPRETER ____________________

TOWNSHIP ____________________ INTERP. DATE ____________________

RANGE ____________________ IMAGERY DATE ____________________

SECTION ____________________ IMAGERY TYPE ____________________

CELL

A1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

A8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

B8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

C8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

D8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

E8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

F8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

G8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H3 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H6 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H7 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

H8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

APPENDIX II

PRELIMINARY COST ESTIMATES

KANSAS HIGH ALTITUDE PHOTOGRAPHIC MISSION

ALLAN C. BOCK, President
DEAN B. HANSEN, V. Pres
WM. R. SEESTROM, V. Pres

Mapping Specialists
Since 1922

Mark Hurd
AERIAL SURVEYS, INC.

TELEX: 290-474
CABLE: MARKHURD

345 PENNSYLVANIA AVENUE SOUTH, MINNEAPOLIS, MINNESOTA 55426 • Telephone (612) 545-2583

IN REPLY, REFER TO: E-5329 December 20, 1973

Mr. James W. Merchant
The University of Kansas
Space Technology Center
2291 Irving Hill Drive--Campus West
Lawrence, Kansas 66044

Dear Mr. Merchant:

In response to your letter dated December 12, the following information is furnished.

We would guess the cost per square mile could range from \$2.50 to \$5.00. Dependent upon your requirements, there are many factors involved in such a project and we would be most happy to discuss these various aspects at your convenience. It has been our experience that high altitude photography is uniquely separate from conventional photography and has its own set of problems. Therefore, as you say this information will have to be "cursory" at best.

Thank you for considering Mark Hurd and we hopefully look forward to being of further service.

Very truly yours,

MARK HURD AERIAL SURVEYS, INC.

Robert E. Sporrong

Robert E. Sporrong
Technical Representative

RES/lp

Enclosure: Brochure

OUR 50th YEAR 1922 1972

WESTERN DIVISION OFFICE: 5760 DAWSON AVENUE, GOLETA, CALIFORNIA 93017 — TELEX: 658-425
CARIBBEAN OFFICE: P.O. BOX 10117, SANTURCE, PUERTO RICO 00908 — TELEX: 365-250

MURRAY-McCORMICK
AERIAL SURVEYS, INC.

AERIAL PHOTOGRAPHY AND PHOTOGRAMMETRIC SURVEYS

December 19, 1973

Mr. James W. Merchant
Research Scientist
The University of Kansas Space
Technology Center
2291 Irving Hill Drive, Campus West
Lawrence, Kansas 66044

Dear Mr. Merchant:

Murray-McCormick Aerial Surveys has been providing high altitude jet photography for three years for a variety of clients.

At the present time our files do not include any photography of the state of Kansas.

A very rough estimate of cost for 82,050 ~~acres~~ sq. mile would be approximately $165,000.00 or $2.00 per ~~acre~~ sq. mile.

If you would supply me with an outline map of the state showing the limits of photography and the approximate time of year the photography would be required, it would be possible to make a more definite answer.

Enclosed is a copy of our brochure and a 251 Form for your information. If may be of interest to you to know that we have just acquired Continental Engineers of Denver and we are offering full photography and mapping services from that office also.

Yours very truly,

Murray-McCormick Aerial Surveys, Inc.

Dan Radman

Dan Radman
Vice President

DR:km

Enclosures

REFERENCES

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CRINC LABORATORIES

Chemical Engineering Low Temperature Laboratory

Remote Sensing Laboratory

Flight Research Laboratory

Chemical Engineering Heat Transfer Laboratory

Nuclear Engineering Laboratory

Environmental Health Engineering Laboratory

Information Processing Laboratory

Water Resources Institute

Technology Transfer Laboratory