ASSESSMENT OF WETLAND RESOURCES

Manual for a Workshop

John G. Lyon
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Michigan Sea Grant College Program
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Summary

This manual is intended to provide an introductory look at uses of aerial photography for collection and analysis of wetland information. Obtaining information is difficult due to access limitations, short field seasons, and potential wildlife disturbance. To fulfill information needs concerning their location and variety, consideration is given to inventory and change detection techniques. In essence, this is a short review of capabilities of aerial photography for assessing wetland resources.

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PART I : INTRODUCTION

Why are Wetlands Important?

Wetlands are often considered low-value land as they ordinarily cannot be used for most construction or agricultural activities. Lately, pressure to drain wetlands to provide land for urban or industrial development has increased. Wetlands are often located between water bodies and land, prime areas for second homes or cabins, commercial harbors or other industry dependent upon water transportation. These multiple uses often result in conflict.

The activities mentioned above are valid uses of wetland areas. The problem is choosing the right place for each activity without jeopardizing their valuable qualities. Because of this conflict, there is a need for better wetland information to guide planning processes.

In the past few years, the value or wetlands as wildlife and plant habitat has become important. Wetlands are very productive natural areas and their productivity can equal that of an intensively managed agricultural field.

Many wetlands are productive without such management, producing fish and wildlife for our use and enjoyment. It is estimated that major Great Lakes wetlands contribute 32,000 ducks and 1.8 million pounds of fish to the annual production. Some forested wetlands can produce extensive amounts of wood and fiber. Other wetlands may be used for berry production, such as cranberries, or for peat mining.

Besides the products we enjoy and use from them, wetlands serve people in the following ways:

As floodwater retention areas, wetlands trap excess water from rains, reducing the extent of high waters. They act as a water regulator often reducing flood damage to human-made structures. Other wetlands along large lakes buffer the shore against damaging storms.

As filters and purifiers of water, wetlands have an ability to trap sediments and nutrients that would otherwise flow into lakes and streams creating pollution. They serve as a natural buffer between sediment-laden waters coming from uplands and clean waters of rivers and lakes. As groundwater recharge areas, some wetlands act to replenish and purify supplies.

All these roles played are the free work of a natural system. In the absence of wetlands, humans must perform these roles through construction of stormwater retention ponds or wastewater treatment plants. The alternative is to suffer the consequences of polluted water, storm and flood damage, as well as diminishing sportfish and game habitat.

Why Is Aerial Photography Valuable?

Concerns over potential wetland conflicts are shared by land owners, commercial interests, and resource managers, as use of coastal areas is intense. To adequately manage wetland resources for multiple use requires timely information. Among the questions asked by resource managers are: How many wetlands are there, how large are they, where are they, and how do they change over time?

Obtaining wetland information is difficult, due to access limitations, limited field seasons, and potential plant and wildlife disturbance during field work. Because of this, interest in aerial photography as an aid to wetland inventory is high.

Many states, including Michigan, have employed aerial photography and satellite imagery to inventory and monitor coastal wetlands. Utilization of such data sources, particularly color infrared aerial photography, allows managers to achieve their information goals in a timely fashion.

Aerial photography provides a cost effective method of mapping wetlands. The aerial perspective helps to reduce the amount of field work, and enhances the inventory process by sensing resource characteristics which often go undetected by ground observers. Large inventories can be completed in a short period, allowing ground observers to concentrate their attention on problem areas.

An obvious use of this data is to separate wetlands from other land uses. This can be accomplished with satellite imagery or aerial photography. For large regional delineation jobs, however, satellite imagery often proves to be the most economical.

In addition to mapping wetlands, it is possible to separate large areas into categories based on the proportions of wetland types. This provides an area-by-area inventory without visiting each site. This kind of information can be a valuable input to more detailed surveys, as it provides an estimate of wetland quantities.

For inventorying wetlands, it is desirable to detect a variety of vegetation communities characteristic of these lands, and determine their boundaries. Within an area, it is necessary to know plant species composition to distinguish wetland type. Photo interpretation of color infrared imagery can provide this information, along with field work.

Information Obtainable From Photography

As we review the uses of these data for wetland assessment, it is useful to consider those attributes of aerial photography that make it useful as a information source. One valuable characteristic is the vantage point from which an area of interest can be evaluated. Many resource types can not be seen when standing on the ground itself. Black and white, color, and color infrared photography can show patterns of plant density and type within wetland areas. While some of the differences apparent on aerial photography might be visualized by standing at the wetland edge, the distributions of the patterns would not be seen, and are difficult to map from the ground.

Secondly, aerial and space photography provide a view of a large portion of the earth's surface at one time. This helps the interpreter visualize objects in relation to their surroundings. For example, satellite imagery, taken from 500 miles above the earth displays highways as well as other cultural patterns. The relationship between agricultural land, urban centers, and transportation facilities, are apparent and can be visualized from one image.

Thirdly, aerial photographs provide a permanent record of conditions as they exist at one point in time. This aids in understanding changes that are taking place.

Another advantage stems from the fact that very accurate measurements of ground areas and elevation differences can be made from aerial photos. If a person is familiar with the geometric relationships in aerial photography, it is possible to make measurements which are closely related to ground measurements. Conventional wetland area estimation procedures involve expensive mapping efforts and much time-consuming collection of ground data, and thus have not been repeated with any regularity. Quicker and less-expensive aerial photographic methods for making wetland area estimates make annual updates feasible.

For example, monitoring change is a valuable use of aerial photography. As an example of these capabilities, an assessment of St. Clair Flats wetlands in lake St. Clair was completed. The area formerly supported 18,000 acres of wetlands. By 1973 the wetland area had been reduced to 5,000 acres. To determine exact change in a smaller portion of the area, historical photographs from the years 1938 and 1974 were examined. Analysis of the data revealed a loss in wetland area from 5600 in 1938 to 5000 in 1974. Of this loss 400 acres were converted to residential use and 200 acres to channel construction (Roller 1977).

To maintain wetlands and their important qualities requires careful management based on resource data. Several types of information are useful. These include:

A) the extent of flooding and the associated change in wetland acreage.

B) the presence and extent of vegetation which can provide some protection from shoreline erosion.

C) knowledge of adjacent land use which affects wetland areas.

These information needs can be met through interpretation of aerial photography.

PART II : SELECTED TECHNIQUES AND INFORMATION

The following section considers some techniques for assessment of wetland characteristics. Specific topics include: A) An examination of the value of vegetation communities for mapping wetlands. B) A description of the energy flow profile involved in aerial photography is provided to foster better understanding of characteristics of aerial photography. C) A brief look at some practical applications illustrated by a photointerpretation key for coastal wetlands.

Vegetation Communities As Indicators

Wetlands are dynamic ecosystems, characterized in terms of hydrology, vegetation and soils, but difficult to map by traditional means. This is partly due to water level fluctuations and their effect on plant species composition. In addition, a field visit yields only a single record of species composition and lake level, and the observer's view of the area is restricted.

Recent mapping approaches have focused on wetland boundary determinations by vegetation, rather than actual water level. This approach is common to most states that have undertaken wetland inventories. This is because inundation surveys are prohibitively expensive and time-consuming. In addition, biological wetland boundaries have more ecological significance than an arbitrary elevation with respect to current water levels.

Vegetation communities are an important indicator of wetland condition, for plants respond to many environmental parameters. Factors such as flooding, topography, pH, turbidity, and underlying soil type govern the species composition of the vegetation community. A plant's abundance, and location in a wetland are determined by its tolerance to these variables. Often the change in vegetation community type is a gradual one, with overlapping zones of species which tolerate slightly different depths and durations of flooding. Hence, apparent differences can be used to divide wetland vegetation into communities, which indicates a general hydrological regime.

Although the occurrence of isolated species is of little significance, large stands of characteristic species have been shown to be indicators of soil moisture, conditions of sedimentation, and topography. Definition of these relationships allow managers, within limits, to use wetland community distribution to interpret the significance of these site characteristics.

Aerial photography provides a vertical view of wetland communities, such that the above characteristics can be employed to map wetlands. Good results are achieved with this approach. Many wetland vegetation communities exhibit distinct shapes, and have particular reflectance characteristics in the near-infrared and red portions of the spectrum. Because vegetation growth patterns are related to local environmental factors such as flooding and water depth, changes in vegetation composition can indicate wetland boundaries. Such changes are evident on aerial photography as different textures and tones.

Energy Flow Profile

To successfully implement aerial photography for wetland assessment, additional detail on data collection is helpful. Aerial photographs are nearly instantaneous records of energy upwelling from the terrain and water surfaces "photographed." Most of the energy recorded originated at the sun and was reflected from terrain and water features. That portion of the reflected energy that reaches the camera is what the camera system records. The amount and spectral distribution of light reaching the camera from plants can be altered by atmospheric conditions such as cloud cover, haze, suspended particles, as well as the reflectance characteristics of the wetland. These variables affect the wetland community's color or tone on photographic images, and the variations can be employed to distinguish communities. To better interpret texture, tone and color changes on photography, it is desirable to establish some familiarity with the energy flow profile.

Solar energy forms a continuous spectrum of radiations that vary in intensity from one part of the spectrum to another. Peak radiation occurs in the visible spectrum where we refer to the energy as light, but significant amounts of ultraviolet and infrared energy are also received from the sun. The high intensity of radiation permits selective filtering in the visible and infrared regions and provides opportunities for enhancing certain types of image detail.

A generalized energy flow profile for a camera system mounted in an orbiting satellite is shown in figure 1.

Energy radiated by any source must travel across a distance before reaching a camera. Energy must flow through spatial debris and atmospheric components before it enters the camera filter and lens system. Energy travels to an object and that portion of the energy that is reflected, then travels on towards the camera. Several factors alter the light spectrum and light intensity, these include:

Ozone. In the upper atmosphere, energy from the sun

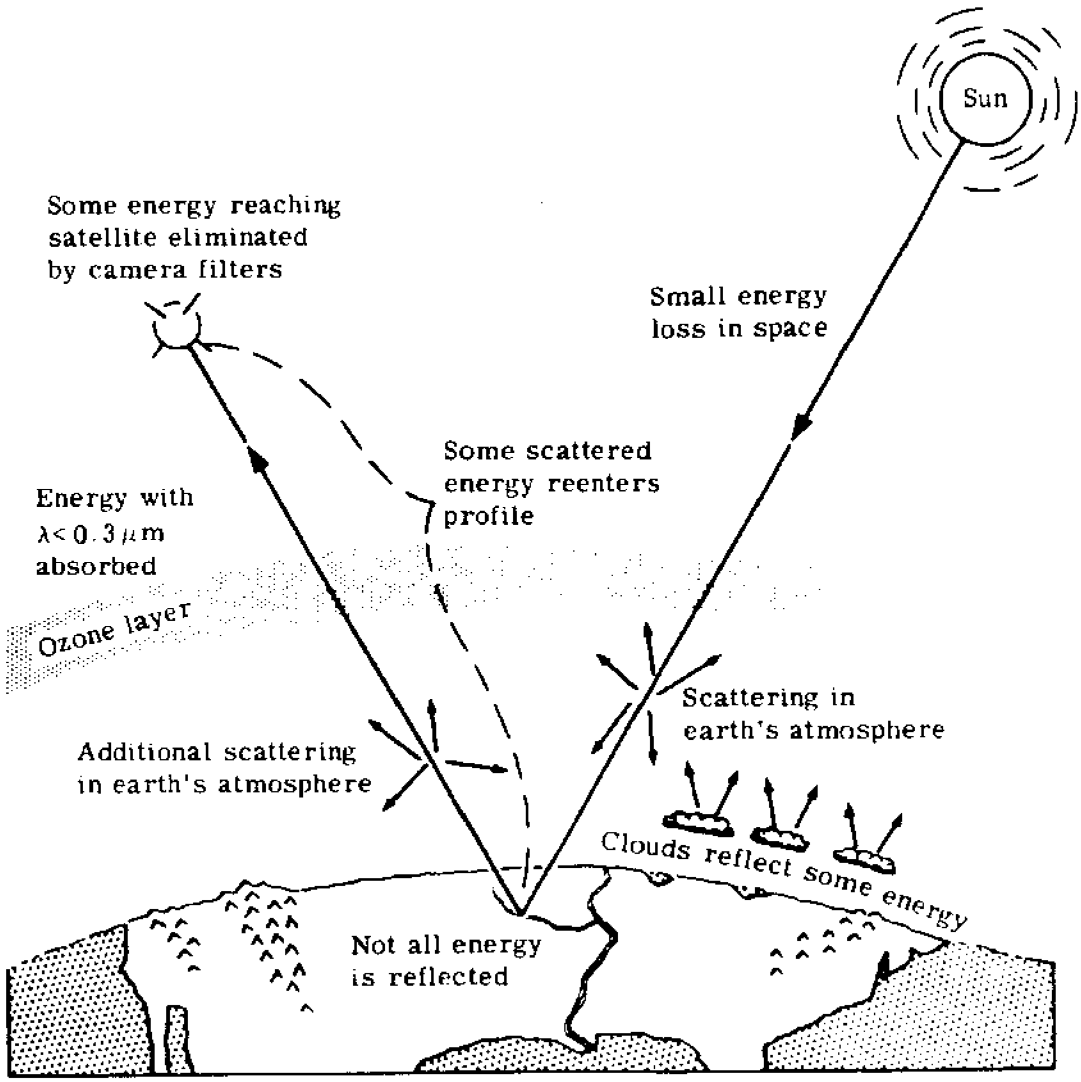

Figure 9. The Energy Flow Profile for a Camera System in an Orbiting Satellite

encounters a layer of ozone, a molecular oxygen that is opaque to energy with wavelengths in the ultraviolet (<300 micrometers).

Water. Water in the atmosphere produces an effect referred to as haze and is a major factor in atmospheric attenuation of solar energy. Water droplets refract light much as a prism. Shorter wavelengths are refracted most and this scattering, or haze effect, declines rapidly at wavelengths longer than 475 micrometers.

Reflection at the object. Energy striking an object may be absorbed, transmitted, or reflected but energy reflected from an object may pass back through the atmosphere and space, and if a camera is placed in the right position the camera may intercept some of this reflected energy. In most cases, reflected energy is the energy that produces the photographic record.

Smoke and smog. These conditions can completely obscure an area but result in energy loss from the profile even when less severe. Small amounts of smoke in the air scatter incoming energy with the magnitude of the effect controlled by chemical composition and size of the smoke particles.

Before leaving this stage of the energy flow profile, stop and consider what has happened to the energy incident upon the atmosphere. Some of it has been absorbed and is lost from the profile. Some has been scattered and apparently lost but could reenter the profile on a more-or-less random line. This scattered energy is predominately of the shorter visible wavelengths and can be considered "noise" if it actually enters the camera. The energy that successfully negotiates the obstacle course from source to object undergoes further modifications on reflection at the object.

Objects differ in their reflectivity. Some produce specular reflections and some diffuse reflections. Moreover, each type of object reflects some wavelengths more strongly than others. Thus, the nature of the object controls both the quantity and quality of light reflected from it. An understanding of reflectance characteristics of objects that are shown in aerial photography is a help in photointerpretation.

Path from object to camera. Energy reflected from terrestrial objects must pass through at least some of the atmosphere, and possibly into space, before reaching our camera. This part of the energy flow profile includes the same attenuating factors that influenced the incoming solar radiation. The reflected energy will reach the camera with a lower intensity than it had as it left the surface of the reflecting object. This attenuation increases with increasing atmospheric travel and is a more severe obstacle in high altitude than low altitude photography.

Filters. Filters can eliminate several of these problems, and are used to produce a definite effect on the energy flow profile. They are thin, selectively transparent materials that absorb energy at some wavelengths and transmit energy at others. They are essentially subtractive and cannot add energy to the profile. The "haze-filter" commonly used in aerial photography is virtually opaque to energy with wavelengths shorter than 500 micrometers and is called a minus-blue filter. Its function is to minimize the attenuating effects of scattered blue light, by absorbing this light.

Wetland Photointerpretation

Several factors involved in the energy flow profile act to create variation on the photography. Wetlands with reflectivity differences have differences in photographic color or tone. Wetlands with different species composition exhibit dissimilar textures. Recognizing these characteristics can aid in wetland mapping.

Several characteristics of coastal wetland types, such as those described below, can be used to identify and map seven wetland types from false-color-infrared photography. Several elements of the energy flow profile interact to produce these characteristics.

A) Submergent Wetland Beds. These are identified as irregularly shaped, dark toned patches on the photography, or as pinkish tones where tops of the plants are near the water surface. It should be noted that submerged beds are temporary and are difficult to observe on photography. Ground work should be conducted to verify interpretation.

B) Floating-leaved Beds. These are characterized by bright pink tones, and flat features when viewed stereoscopically. Pond and water lilly patches often appear white. Difficulty can be encountered in separating free-floating forms, such as duckweed, from those that are attached, such as water lily.

C) Emergent Wetlands. These communities are variable in species composition and color tone on infrared photography, making generalization difficult. They can be detected by their proximity to water/land boundaries. In spring and late fall, these areas appear like submergent beds, as dark patches.

D) Fresh meadows. These are commonly found on less-frequently flooded sites. Shrubs and woody plants plants are few and the smooth texture of meadows is a clue. Their color changes with the growing season, flooding and with variation in grass species combinations.

E) Shrub Wetlands. These are identified on the photography by their rough texture. Most of the shrub species are not tonally unique, so it is hard to differentiate between them. An exception is the low growing shrub, Leatherleaf, which has a distinct rust color on false-color-infrared photography.

F) Forested Wetlands. Full grown stands of trees are not difficult to identify, but there may be a problem in separating wetland trees from upland trees. Stereoscopic viewing, use of topographic information, and location of features such as roads and houses can aid interpretation. Ground investigation may be necessary to precisely define the forested wetland boundary.

G) Separating Deciduous and Coniferous Forested Wetlands. In the reflective infrared, green foliage is more reflective than most other objects, and broadleaved species are more reflective than conifers. Shadows of individual needles are quite dark, for conifer needles are nearly opaque. Broadleaved foliage is highly transparent in the infrared, and shadows of such leaves are not as dark as the shadows of conifer needles. Since the illumination in shadows of opaque objects is primarily blue (from diffused sky light), conifer crowns with their dark shadows usually appear much darker than broadleaved trees in longer wavelength spectral bands. The distinct broadleaved/conifer contrast of infrared imagery results from this relationship. This is valuable for locating wooded wetlands as they are often dominated by coniferous trees.

Seasonal Differences

When spring and fall photography are compared, striking differences in overall color are obvious. The spring imagery has more intense reds than fall photography which tends to be pale or brownish. Most differences are due to plant aging and seasonal change in the species making up the community. The seasonal vegetation change from spring to fall was detectable as change in photography color, saturation, and texture.

Seasonal effect can be exploited. On winter photography, leaves are gone from deciduous plants and evergreen plants are readily identified. Leaf-off photography also permits more accurate delineation of drainage patterns, especially though forested areas--providing streams are not ice and snow covered. When winter photographs are supplemented with growing season photographs, evergreen and deciduous canopy and understory can be separated and several deciduous classes identified.

Plant age can also affect the image color of wetland communities. For example, wild rice (Zizania aquatica) produces a medium-pink false-color image in the spring, but an almost white reflectance in the fall due to the presence of reproductive culms, weathering, and discoloring of the leaves, which become chloretic in the fall. Seasonal variations in growth rate among species are extremely important when observing photographs taken in different times of the year. With the knowledge of what species are present in the plant communities and their life cycles, predictions can then be made as to which species is most likely to dominate at different times of the growing season. Because of differences in growth rates, seasonal decline, plant stature, and habitat, annuals and late perennials may become the dominant species as the season progresses.

Seasonal change illustrates the need for acquiring imagery from several seasons to provide accurate wetland estimates. For general cases, it is advantageous to obtain information from all available sources.

Formats and Data Types

Many types of data can provide useful wetland information. Existing maps, photographs, and local histories can be used as supporting data to assist in verifying interpretations of aerial photographs from prior years, such as those available from the U.S. Department of Agriculture, are especially useful. Although this photography is almost always black-and-white rather than color, much valuable information can be derived from it. When rainfall and lake water level information are available, old photography can provide insight into hydrologic regimes of wetland systems.

Planned use of multiple data sources can be very cost-effective. When LANDSAT data are used as a first stage in the inventory process, most major and many lesser boundaries can be quickly mapped. High altitude or low altitude aerial photography can then be used to fill in more detailed information, and field checking concentrated in areas of greatest value, or in areas where type boundaries are most questionable. This mix of data sources is a good one for the following reasons: LANDSAT data is inexpensive to acquire and process in comparison with other forms of remote sensing data. Even though the level of detail that can be obtained is not great, the most valuable types of wetlands (those covered by open standing water, or riparian vegetation) can be generally detected and delineated. Wetlands that are too small to resolve as detectable units in LANDSAT data can be added when conventional aerial photography is interpreted during the second stage of the inventory. With the use of LANDSAT in the first stage, the need for photo data collection and interpretation, and field work, are greatly reduced.

When new photography is desired of relatively small areas, the need can often be met with 35mm photography obtained from a light aircraft. Both normal-color film, and false-color infrared film are available at good photo stores. You can "do-it-yourself" if you want to, and obtain nearly the same kind of data as do more sophisticated systems.

The 35mm aerial photography system is practical as a resource monitoring tool from the standpoint of: resource data collection capabilities, modest cost of operation and operational feasibility under normal field and weather conditions. In our ongoing study of wetland inventory in Emmet county, Michigan we used color film, and six species of emergents were readily identified. In addition, the presence and density variations of submergents could be detected when normal color photography was supplemented with color infrared. Pond borders could be more accurately mapped, delineation of some species type boundaries was improved, and better detection of overshadowed emergents was possible.

County soil maps are another valuable bit of supporting information. Based on extensive field work, the overall level of mapping detail is very good. Lakes and ponds of less than one-half acre in size are frequently identified on county soil survey maps, and wetlands may be effectively mapped by soil survey data.

County soil maps may be used as a ready-made base map for wetland resource delineation. Many major wetland boundaries can be identified from the soil maps and addition wetland resource information can be added analysis of new, or existing, aerial photography with selected field checking. The principal disadvantage associated with use of soil maps as the base for a wetland inventory is that these maps are frequently outdated.

Wetland Mapping Errors

In any mapping activity there is a possibility of error. As a result, mapping exercises frequently have residual errors.

Wetland categorization errors occur when a wetland unit is misclassified. Wetland commission errors are caused by incorrectly assigning a wetland classification, when the area is not a wetland. Wetland omission errors, where a wetland is not located, are common and several varieties occur.

A) Omission due to scale of photography: This occurs along canals or drainage ditches where the wetland vegetation is about 5m wide on the ground. This type of error would not result in misclassification of a significant amount of wetland acreage.

B) Omission due to agricultural activities such as cattle grazing and mowing in wetlands: Errors of this type resulted in drawing boundaries more conservative than field checking demonstrates. These activities change the total character of a wetland so that the area appears more like upland. Stereoscopic viewing helps in sites with there is a significant change in topography between wetland and upland.

C) Omission errors involving transitional wetlands: The problem occurs when upland and marginal wetland plant species are combined. Part of the successional process from wetland to upland is invasion of marginal wetlands by upland species. Technically the area is wetland due to soil moisture characteristics and predominance of wetland dependent plants. However, the unique species composition provided by this mixture may lead to photointerpretion errors.

CONCLUSIONS

The objectives of this manual are to provide some familiarity with aerial photography and how to employ it for identification of wetland resources. From this material it is possible to conclude that:

A) A variety of wetland types can be rapidly identified and mapped, allowing detailed field work to be directed at problem areas.

B) Multiple data sources can increase mapping accuracy.

C) Use of aerial photography is a cost-effective approach to wetland inventory.

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ADDITIONAL REFERENCES

For those wishing to pursue things further, these references will be helpful.

Anderson, J., E. Hardy, J. Roach, and R. Witmer, 1976. A Land Use Classification System For Use With Remote-Sensor Data. U.S.G.S. Prof. Paper 964, 28 pp.

Carter, V., 1978. Coastal Wetlands: Role of Remote Sensing. Coastal Zone '78. Amer. Soc. Civil Eng., San Francisco, CA, March.

Cowardin, L., F. Golet, and E. LeRoe, 1977. Classification of Wetlands and Deep-Water Habitats of the United States. J. Sather, ed., U.S. Fish and Wildlife Serv., Wash. D.C.

Deely, D., R. Anderson, C. Dorigan, J. Morrow and W. Brown, 1975. Wisconsin Wetlands Inventory-Pilot Mapping Program. Earth Sat. corp., Washington D.C.

Department of Natural Resources, 1977. A proposed Program for Michigan's Coast. Div. Land Res. Programs, Lansing, MI., April.

Enslin, W. and R. Hill-Rowley, 1977. Guide to Aerial Imagery of Michigan. Agri. Ext. Serv., Michigan State Univ. 80 pp.

Jaworski, E. and N. Raphael, 1978. Fish, Wildlife and Recreational Values of Michigan's Coastal Wetlands. Michigan Department of Natural Resources, 209 pp.

Lyon, J., 1978. An Analysis of Vegetation Communities in The Lower Columbia River Basin. Proc. of the Pecora Symp. on Application of Remote Sensing to Wildlife Management. Sioux Falls, S.D., October, 8 pp.

Lyon, J., 1979. Remote Sensing of Coastal Wetland and Habitat Quality of the St. Clair Flats, Michigan. Proc. 13th Int. Sym. Remote Sensing Env., Ann Arbor, MI., April.

Lyon, J. and T. George, 1979. Vegetation Mapping in the Gates of the Arctic National Park. Proc. Amer. Soc. Photogrammetry, 45th Ann. Con., Washington, D.C., March.

MLUCRC, 1976. Michigan Land Cover/Use Classification System. Division of Land Resource Programs, Michigan Department of Natural Resources, Lansing, 66 pp.

Montheith, T. and E. Jarecki, 1978. Land Cover Analysis For the United States Great Lakes Watersheds. Great Lakes Basin Commission, 55 pp.

Ohio Dept. Nat. Res., 1974. Ohio Wetlands Inventory, Final Report. Div. Wildlife, September.

Olson, C.E., 1979. Elements of Photointerpretation. Fifth ed., School of Natural Resources, Univ. Michigan, Ann Arbor, 80 pp.

Roller, N., 1977. Remote Sensing of Wetlands. Env. Res. Instit. of Mich., Ann Arbor, MI., Report no. 193400-14-T, 88 pp.

Roller, N. and J. Colwell, 1978. Wetland Inventory and Condition Evaluation Techniques. Proc. of the Pecora Sym. on Remote Sensing in Wildlife Habitat Assessment, Sioux Falls, S.D., October.

Sellman, A., I. Sattinger, L. Istvan, W. Enslin, W. Meyers, and M. Sullivan, 1974. Remote Sensing in Michigan for Land Resource Management: Waterfowl Habitat Management at Point Mouillee. Environ. Res. Instit. Mich., 193400-1-T.

Shaw, S. and C. Fredine, 1956. Wetlands of the United States. U.S.F.W.S., Circ. 39, 67 pp.

Shima, L., R. Anderson, and V. Carter, 1976. The Use of Aerial Color Infrared Photography in Mapping the Vegetation of a Freshwater Marsh. Chesapeake Science 17:74.

Tilton, D., R. Kadlec and B. Schwegler, 1978. Characteristics and Benefits of Michigan Great Lakes Wetlands. Spec. Rep. to the State of Mich., Univ. of Mich.

APPENDICES

Appendix 1 : Sources of Existing Imagery

State and county imagery is available from several sources. A list of local photography is included from the Enslin and Hill-Rowley (1977) publication.

COUNTY

Soil Conservation Service office. Select imagery at the local office and order from:

Cartographic Division
SCS, USDA
Hyattsville, Maryland 20782

SCS, USDA
1405 S. Harrison Rd.
East Lansing, MI. 48823

STATE

The Michigan Department of Natural Resources has recent (1978) coverage of the entire state at 1:24,000-scale. An index of coverage is available on request, and imagery can be inspected in Lansing.

Sherman Hollander
Remote Sensing
Land Resource Programs
Michigan DNR
Lansing, MI 48909
Phone: (517) 373-3328

The Michigan Department of State Highways and Transportation as recent coverage of many counties and selected areas. This includes color-infrared imagery. The imagery may be viewed in the photogrammetry section in Lansing.

Environmental Liaison Section
State Highways Bldg.
Lansing, MI 48904
Phone: (517) 373-0146

For a listing of coverage of several varieties and over large areas, the EROS Data Center of the U.S Geologic Survey is helpful.

EROS Data Center
Sioux Falls, S.D. 57198
Phone: (605) 594-6511, ext. 151

Others sources of photography include regional councils of government and corporations.

Abrams Aerial Survey Corp.
124 N. Larch St.
Lansing, MI 48901

Environmental Research Institute of Michigan
P.O. Box 618
Ann Arbor, MI 48107
Phone: (313) 994-1200