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For Multidisciplinary Research

on the Application of Remote Sensing

to Water Resources Problems

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Research Funded Under Grant #NGL 50-002-127

August, 1977 - July, 1978

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I. INTRODUCTION

This is the progress report for "Multidisciplinary Research on the Application of Remote Sensing to Water Resources Problems," NASA Grant NGL 50-002-127 during 1977-78 (for the period August 1977 through July 1978) at the University of Wisconsin-Madison. The research team was directed by Professor James L. Clapp, as part of the Environmental Monitoring and Data Acquisition Group of the Institute for Environmental Studies. (Since December 1978 the research has been directed by Professor Ralph W. Kiefer).

Lineage of this research effort is traced to the NASA Institutional Grant to the University of Wisconsin in 1968. Research was focused in 1969 on "Studies on the Use of Remote Sensing in Problems of Monitoring Earth Resources." In 1970 the effort entitled "Multidisciplinary Research in Space and Engineering" developed interest in the specific areas of water quality, watershed management, surface parameters of large water bodies, mixing zones for effluents discharged into streams, and hydrogeology. Since 1971 these areas have been explored in research entitled "Multidisciplinary Research on the Application of Remote Sensing to Water Resources Problems."

STRUCTURE OF THIS REPORT

Section II of this report concerns the remote sensing of sediments and associated non-point-source pollutants in lakes. Three areas of research are involved: sediment concentrations, mixing and water chemistry, and sources of sediments.

Section III reports on other applications of remote sensing to water resources problems that were funded wholly or in part by this grant.

Section IV covers associated projects to which this project bears an interdependent relationship, which were funded from other sources.

Section V is a summary of institutional information about the project, as requested by the Technical Officer.

Section VI lists publications emerging from work in this project during 1977-1978.

MAJOR EVENTS DURING THE 1977-78 YEAR

Major changes in management of the project occurred during 1978. Principal Investigator James L. Clapp left the University at the end of November 1978 to become Dean of Engineering and Physical Sciences at the University of Maine, Orono. The University of Wisconsin has requested the concurrence of NASA in the appointment of Professor Ralph W. Kiefer, Acting Director of the Environmental Monitoring and Data Acquisition Group, and Professor, Department of Civil and Environmental Engineering, as Principal Investigator. He is managing the project at this time, continuing the work proposed for this year (1978-79), and preparing a proposal for next year (1979-80) that will take into account the action of NASA terminating this project in July 1981.

Since 1977 the focus of this research effort has been the remote sensing of non-point-source pollutants. Commencement of the work in some areas has been dependent on the results of certain portions of the early investigations. Digestion of results of sampling, diver's observations, and imagery from 1977 now indicate that the relationship between image density and vertical distribution of sediments is so unpredictable that the application of remote sensing in this area is more limited than expected. For this reason, some of the tasks originally proposed should not be undertaken at this time. Present research on sediment concentration, mixing, and water chemistry will be completed, but we do not expect to commence additional investigations in these areas.

RELATIONSHIP WITH THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

After several years' experience with lake classification by remote sensing through its association with this project, the Wisconsin Department of Natural Resources proposed an operational program to cover all the lakes in the State. Such a program at this time would require funding from outside the state government. Discussion with NASA personnel through the Goddard Space Flight Center gave some hope that NASA funding could be directed to this program. A small part of the demonstration project is being carried forward this year through funds from the Goddard Space Flight Center, but this will be enough only for the data extraction phase. In the near future, we will reassess actual needs of the Wisconsin DNR and will appraise possibilities of new research directions with them.

NEW DIRECTIONS

Among the associated projects, the application of techniques for digital analysis of photographic imagery to medical research, described in the section on autoradiograms of electrophcresis gels, page 46, may indicate a large area of application that could be explored. By the use of digital image-analysis techniques adapted from our remote sensing research, it is possible to reduce significantly the time required for analysis of photographic materials. Investigation into other possible areas of application will also be made.

II. NON-POINT SOURCE POLLUTION

CONCENTRATION OF SEDIMENTS

Professor Frank Scarpace
Linda Kalman, Research Assistant

The goal of this portion of the research was to determine how photographic imagery and, ultimately, satellite imagery are affected by various types and concentrations of sediment in lake water. The specific goals of this sub-project during the year were: (1) to analyze the imagery acquired during the summer of 1977, (2) to develop a workable method of correcting lens falloff in photographic imagery, (3) to further develop a radiative transfer model for the atmosphere, and (4) to acquire further data on other lakes, in cooperation with the Wisconsin DNR.

Analysis of 1977 Imagery and Acquisition of New Data

Data Acquisition. As a continuation of the research started in 1977, photographic flights and water sampling events were planned for late spring and early summer, 1978. Two improvements over 1977 methods were introduced: (1) new filters were used, and (2) ambient light level was recorded. To increase the signal-to-noise ratio on the film, interference filters with 30 nm instead of 10 nm bandpass and allowing 50% instead of 40% peak transmission were obtained for aerial photography. A digital-readout Gamma Scientific radiometer was purchased for use in monitoring ambient light levels during the sampling missions. This instrument provided the power supply and readout for a portable flux sensor. The instrument package could be easily transported and used to monitor incident light at the sampling site. In 1977 we had used monitoring facilities based on the Meteorology Building at the University, 6.7 km from the test site.

Photographic flights and water sampling were resumed in late spring and early summer of 1978. One short sampling event was conducted on May 16, 1978 over Middleton Bay, after heavy rains. Due to severe overcast for two days following the rain, the plume had nearly disappeared by the time sampling began. Photographic imagery was acquired with the new narrow band filters under moderate overcast. Preliminary analysis of the data for suspended solids shows little variation in sediment concentration. Images of the sediment-laden water also lack variation.

A second sampling event was conducted in June 1978 after severe rains. Since the macrophytes had not grown to large size yet, the plume spread out over nearly one third of Lake Mendota. Since the plume moved and dissipated, a smooth gradation from heavy sediment to clear water was observed. When the 1977 events occurred, macrophyte growth in Middleton Bay was thick enough to prevent much dissipation or movement of the plume.

A sampling mission and photographic flight were conducted during the event. Since only one boat was available, a limited number of water samples were taken. Light transmission and suspended-solids measurements were performed.

Color imagery, as well as the black and white narrow-band imagery, was obtained. Since light-leak problems plaguing earlier photography were eliminated, the images appear to be of excellent quality and will probably be useful for analysis. Preliminary sampling results indicated that a good range of sediment concentrations was included.

A third photographic flight mission was flown in August 1978 over the north end of Green Lake, in Green Lake County, Wisconsin. Green Lake is a very large, deep, clear, oligotrophic lake, sampled to obtain measurements of relatively clear water to contrast with the Middleton Bay runoff data. On the day of sampling, however, a moderate sediment plume was present in Green Lake. Water sampled ranged from extremely clear to moderately turbid. Ambient light levels were measured at the site, and water transparency data were obtained.

The water samples were later analyzed for suspended solids and chloryphyll content. Although the imagery is otherwise flawless, much sun glitter is present due to windy conditions. Scattered overcast also created a variety of light levels, which may create problems during analysis.

The imagery obtained from the June and August events will be analyzed in 1979.

Data Analysis. A limited portion of the imagery acquired during summer 1977 over Middleton Bay was analyzed. Images taken July 19, 1977, with the 600 nm (red) filter were digitized and corrected to log exposure data. The images were corrected for lens falloff using data acquired during experiments performed at the Johnson Spacecraft Center. (A summary of the lens-falloff study is presented in the next section of this report.) Changes in ambient light levels were determined by analyzing the changes in exposure of grey objects (roads and parking lots) from one frame to another. Significant changes in exposure were found over the three-hour time span covered by the photography. The exposures calculated for the water samples were corrected to account for the changes in incident light.

Using the corrected exposures a plot of exposures vs. concentration of suspended solids was obtained (Figure 1). The plot illustrates one of the basic problems in the sampling data. During the runoff event, macrophytes in the bay were extensive enough to restrict the outward movement of the plume. The plume, therefore, remained essentially intact and motionless during the week of the runoff event. Sediment loads inside the plume were very high, 90 to 110 mg/L, while sediment loads outside the main plume ranged from 5 to 50 mg/L. Absence of sediment loads between 20 and 90 mg/L indicated a sharp gradient at the edge of the plume.

Using the plot in Figure 1, a classification of suspended-solid load was made for two images, one taken at 9:50 a.m., July 19, 1977, and the other taken at 12:20 p.m. on the same day (Figures 2 & 3). Four classes were named; main plume, no data, edge of plume, and clear water. The boundaries of these classes are shown by the dashed vertical lines in Figure 1. The main plume was easily determined by its high exposure values. The "no data" class was the range of exposure values not found on the images, assumed to correspond to the values of suspended solids between 20 and 90 mg/L. The boundary between edge of plume and clear water was somewhat arbitrarily chosen. Low correlation between exposures and suspended solids for values between 5 and 20 mg/L may be due to noise in the exposure data and uncertainties in the suspended-solids measurement.

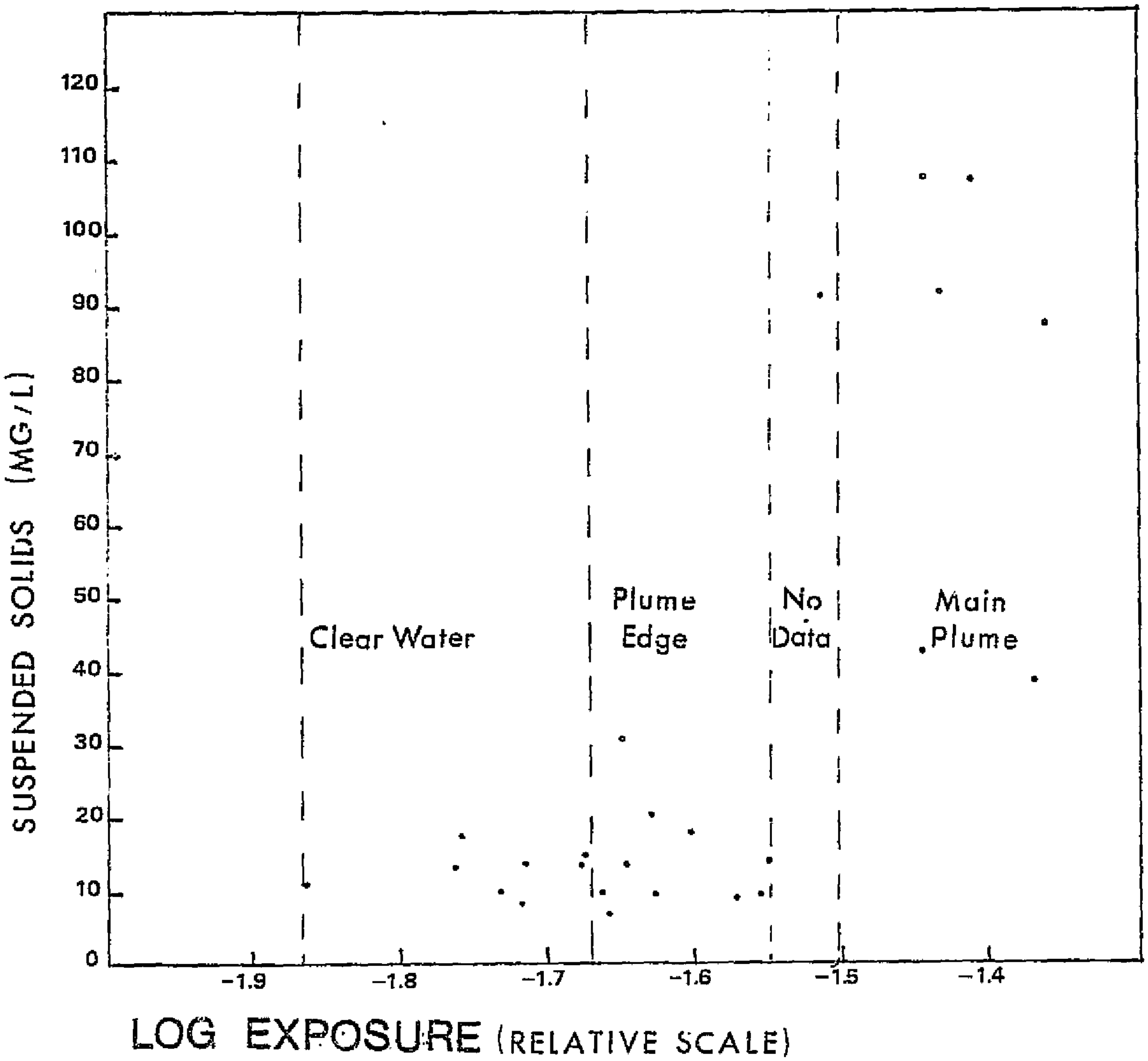

Figure 1. Plot of-suspended sediment load vs. corrected relative log exposure values. Dashed lines show the division of the data into four main categories:

Main Plume: This category contains data points with log exposure values between -1.3 and -1.505, corresponding to suspended sediment loads above 90 mg/L.
No Data: Very few image pixels were found with log exposure values between -1.55 and -1.505. These exposure values are assumed to be correlated to suspended sediment loads above 40 mg/L. The lack of data in this range indicates a steep gradient at the edge of the main plume.
Plume Edge: This category primarily represents data points found just outside the main plume boundary, where slight diffusion may have occurred.
Clear Water: This category contains data obtained at the ends of the sampling lines farthest from the main plume. It represents the "background" suspended sediment load of the ordinary lake water.

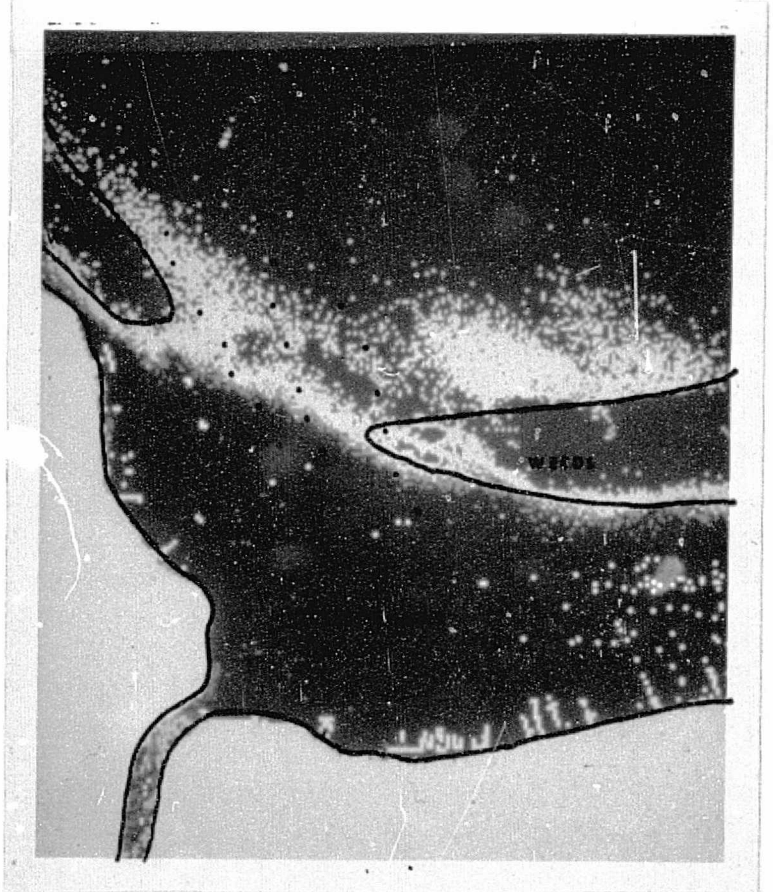

Figure 2. Color classification of Middleton Bay during the July 1977 runoff event. The original image was taken at 9:50 a.m. July 19, 1977, narrow-band filter, 600 nm. Exposure bounds for each class are shown in Figure 1.

Figure 3. Color classification of Middleton Bay during the July 1977 runoff event, from an original image taken at 12:20 p.m., July 19, 1977, 600 nm narrow band filter.

Code: BLUE=clear water; YELLOW=plume edge; LT.ORANGE=no data; ORANGE-RED=main plume, DOTS=sampling locations

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The classifications shown in Figures 2 and 3 were made by producing transparencies from each of the categories of densities defined in Figure 1, and viewing them together on a multichannel viewer. The figures are prints of color photos of the screen of the viewer.

As can be seen by examining the color classifications (Figure 2 and 3), the plume boundary remained extremely sharp and was largely defined by the extent of the weed beds. The transition zone between 20 and 90 mg/L ('no data' class), the orange area at the boundary of the weed bed, is approximately 5 m wide. Since the sampling locations, shown by the black dots, are approximately 33 m apart, the transition zone could easily be missed during sampling. The 9:50 a.m. image shows a slight diffusion of the plume past the weed beds (the yellow area). Although the 12:20 p.m. image seems to indicate more diffusion, this is more likely an effect of the increased sun-glitter.

A streamer from the main plume did move past the weeds over the three-hour period by flowing through a channel created by weed-harvesting machines. In Figures 2 and 3 this streamer is located in the upper-left portion of the main plume.

Visual inspection of images obtained two days later, July 21, 1977, indicates that the plume was confined by the weed beds and merely sank into the weeds rather than dissipating through the water. Suspended-solids data from July 21 confirm this, indicating that the extremely sharp gradient between fairly clear and very turbid water still existed.

Because correlation between data from July 21, 1977, and July 19, 1977, is low, further analysis of the 1977 data is being postponed until analysis of the June and August 1978 data has been studied.

Lens Falloff Study

Preliminary analysis of the July 1977 runoff imagery showed the images to be subject to extreme lens falloff, of the order of $\cos^{15}\theta$ rather than the customarily assumed $\cos^{3}\theta$ relationship. To obtain meaningful exposure data from the images it was necessary to correct for the lens falloff. Literature describing investigations of the nature of lens falloff indicates that it could be affected by lens aperture, focal length, design, and, possibly, the addition of a filter in front of the lens. We considered the lens falloff effect to be significant enough in analysis of imagery to warrant a detailed investigation of the falloff for the lenses used.

Using facilities at the Johnson Spacecraft Center, electronic-scan field-irradiance measurements were made for our Carl Zeiss Distagon, 40 mm F/4.0, and Carl Zeiss Planar 80 mm, F/2.8 lenses. Scans were performed on all the lenses, with a variety of F-stop and filter combinations. The data were later analyzed to determine the effect of lens focal length, aperture, or filter on lens falloff. The results indicated that for lenses of a given focal length or design, the falloff does not change significantly between similar lenses. The addition of filters in front of the lens changes the lens falloff function a small amount, while a change in aperture can lead to drastic changes in lens falloff. The large falloff observed for the runoff imagery appeared to result from the use of a large aperture, F/2.8, rather than from the interference filters. The values published by Hasselblad for a 'typical' lens did not match our particular lenses very well.

At the Johnson Spacecraft Center, photographic images of the source used for falloff analysis were also obtained. Several of these images were analyzed to see how well the photographic data could be used to determine lens falloff. The results indicated that generally the lens falloff functions determined from the photographic data reproduced the results from the scan data to within 5%, except at the corners of the images. Since the corners of the images are rarely used in our work, photographic determination of falloff might be as useful as scan data. These results inspired further attempts to measure lens falloff.

Images of clean, lightly travelled roads were obtained for a variety of lens aperture-filter combinations. The lens falloff was calculated by computing the change in exposure of the road image across the frame format. Falloff functions obtained for these images also matched the scan results to within 5%, excluding the format corners. This method for determining lens falloff is a simple and practical one, and can be used with reasonable success when access to a facility such as the Johnson Spacecraft Center is not available.

The results of the lens falloff study will be presented at the A.S.P. convention, March 1979, in Washington, D.C. (Kalman and Scarpace, 1979).

Radiative Transfer Modelling

During the winter and spring of 1977 the development of a radiative transfer model was begun, to predict how the energy detected by aerial sensors changes with sediment concentration and vertical distribution. Two models were proposed to represent the water and air regimes.

During 1978, the Delta-Eddington model, used to calculate fluxes in the water, was developed. The results of the model were checked by running Monte Carlo simulations with the same input parameters. This helped to define the limitation under which the model could be used.

A model using a doubling algorithm was proposed to treat the air layer. It was felt later that a more suitable and less costly model could be obtained using a Neumann solution to the radiative transfer equation. This model has been programmed, and checked for internal consistency. The results of the model have not been checked with existing published results.

MIXING AND WATER CHEMISTRY

To determine relationship between remotely sensed data and the concentration and movement of sediment in the water, consideration had to be given to vertical mixing and the dynamics of plumes, and to chemical processes within and around plumes. The following three sections report on work focused on sediment fingers, thermal fronts, and water chemistry.

Sediment Fingers

Professor Theodore Green
John Schettle, Research Assistant

Non-point source pollution is a significant environmental problem in Wisconsin, due many times to the large amount of feedlot runoff during storms. This sediment-laden water then usually enters rivers, and finally lakes. Here it settles to the bottom. There is great interest in this final bottom distribution.

Remote sensing can tell us the "surface" distribution of such muddy water in lakes (i.e., the position and extent of the plume entering via a river). However, the settling and final deposition on the bottom must be inferred from the remote measurements by hydrodynamic reasoning. To do this, we must understand the processes involved. This was the reason for the work described below, which was part of the large study on non-point source pollution.

In many cases, the inflowing muddy water is also warmer than the lake water. This is usually true in spring, when winter fertilizing can also lead to heavy sediment runoff. Often, due to its higher temperature, the muddy river water is even lighter than the cold lake water. In this case, the phenomenon of double diffusion, well known in the oceans (where salt replaces our sediment), is very likely to be an important part of the sedimentation mechanism.

In double diffusion, an overlying layer of warm, salty water, which is lighter than the underlying cold, fresh water, will still move downward, mixing with the fresh water and displacing it. This happens because heat is transported much faster than salt, so that a small intrusion of salt water from above cools rapidly, but retains its salt. It is then heavier than the surrounding fresh water, and continues to sink, forming a "salt finger".

Early laboratory experiments by Houk and Green (1973) confirmed the rather obvious conjecture that sediment fingers do occur. However, the effect of interfacial shear between the two layers on inhibiting sediment finger formation is unclear, and has not been fully resolved by salt-finger studies. This effect is probably very important in our case, as the warm, muddy water is spreading over the lake water, and a large velocity difference exists at the bottom of the muddy layer, where fingers are expected to form.

The experiments were conducted in the tank shown in Figure 4. Warm, muddy water was allowed to spread over colder, clear water by lifting the gate shown. Temperatures and sediment (taconite tailings, clay, and fluorescein) concentrations were measured, and photographs of the resulting surface plume taken at 15-second intervals. These photographs were projected onto a wall, and various measurements made.

Sediment fingers did form as expected, Figure 5. However, their concentration varied markedly over the plume. The fingers were most active farthest from the front of the plume. This is in agreement with previous ideas of high shears limiting fingering activity.

The shear was estimated from the deformation of the fingers--a convenient flow tracer. We found that fingers disappeared for Richardson numbers below

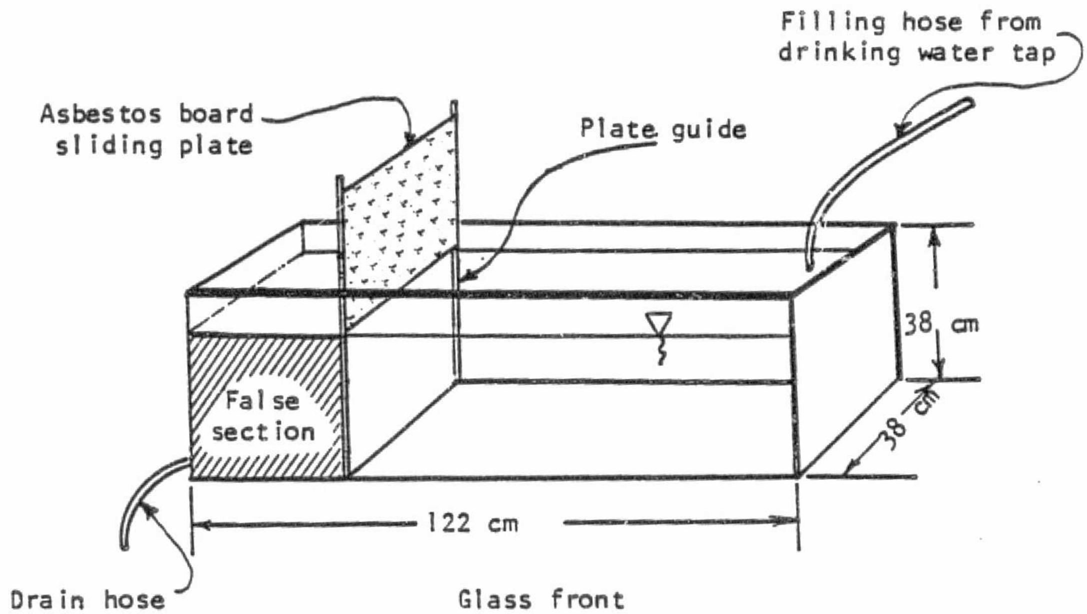

Figure 4. Sketch of Laboratory Tank.

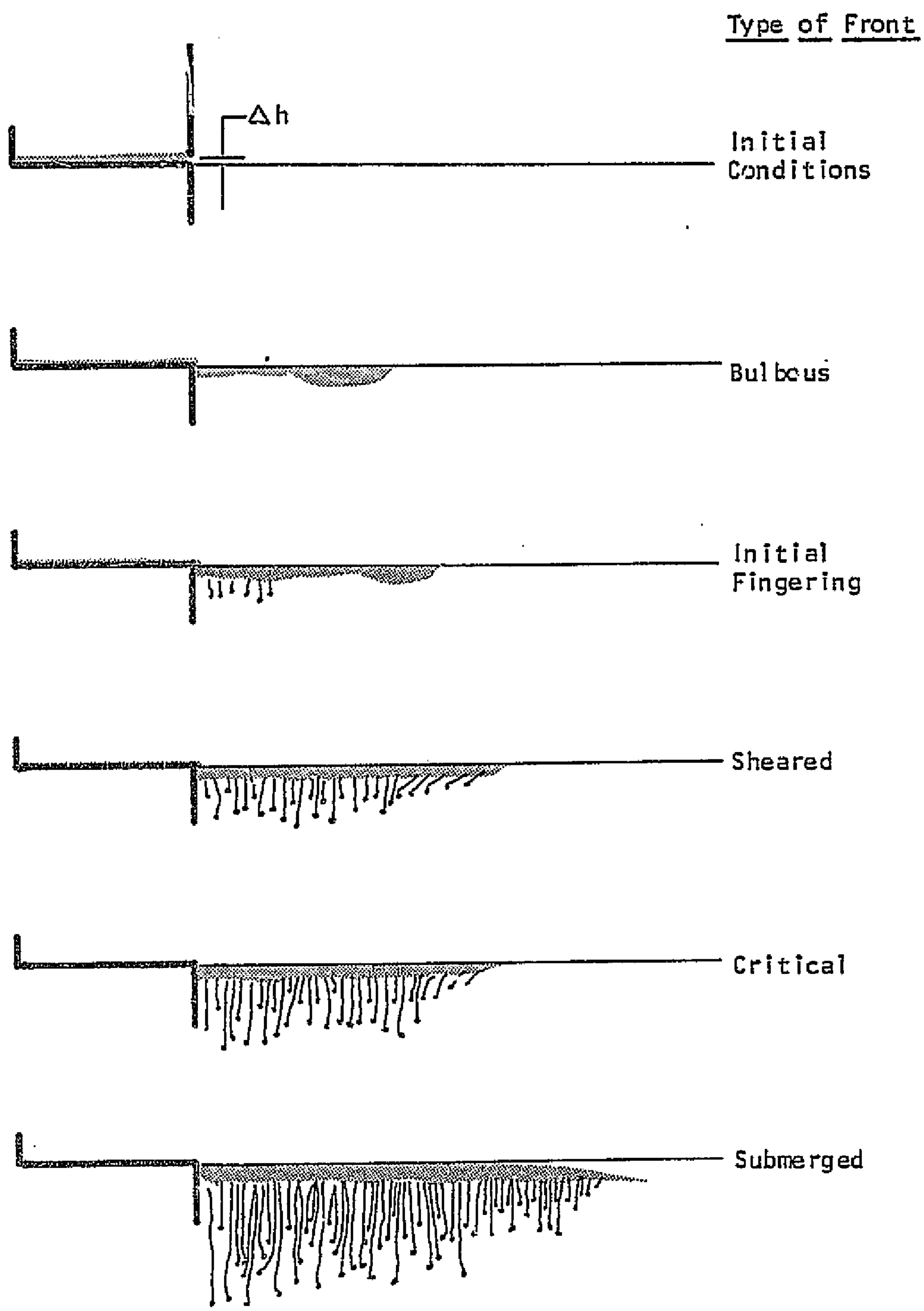

Figure 5. Progression of the plume front.

6,000, and remained for Richardson numbers above 13,000. Here, the Richardson number is defined by

$$Ri = \frac{-g\Delta\rho/N}{\rho(\Delta U)^2/d^2}$$

where g is gravity
ρ is density of the lower, fresh water
d is an average finger length
ΔU is the change in horizontal velocity over the average finger length
$\Delta\rho$ is the density difference between the two layers
N is the depth of the upper layer

The experiments also confirmed the finger descent rates found by Houk and Green (1973), gave a relation between the depth H and length B of the bulbous "head" of the plume ($H \sim 0.1B$), and gave insight into changes in plume spreading velocity associated with the onset of fingering (the velocity decreased more slowly after fingering started). Variations in sediment size did not have much effect on the results. Downward sediment transport rates due to the fingering are much larger than those due to Stokes settling.

We also attempted to document the existence of fingers in Lake Mendota, by diver photography. The attempt failed - either fingers were absent, or the water was so disturbed by boats, divers, and instruments (and waves?) that the fingers were disrupted.

The results will be submitted as a research note to an appropriate journal. It should be noted that personal communications have shown workers in sedimentation to be quite interested in the fingering process.

Future work will be oriented more toward field observations, perhaps using an artificial source of muddy water. A major concern is the effect of wave-induced turbulence on finger formation, descent, and transport rate.

Thermal Fronts in Cooling Water Discharges

Professor John Hoopes
Vahid Alavian, Research Assistant

Many models have been developed that predict the behavior of heated water discharges in a cold body of water. Even some of the very sophisticated models, however, are unable to fully predict all the natural phenomena that may occur as a result of the interaction between a warm discharge and a cold ambient.

One of the least understood phenomena associated with such discharges is the occurrence under certain conditions of a series of alternating bands of warm and cold water in the far field of the discharge. This phenomenon, generally referred to as "Thermal Fronts," is frequently observed in the thermal images of heated discharges of various sizes and types. A modelling effort has been undertaken to investigate the nature and behavior of the thermal fronts as a further step in better understanding the mixing processes associated with dilution and dissipation of heat added to bodies of water.

A laboratory model capable of simulating the field conditions in the near and far fields of warm water outfalls was designed and constructed for experimentation. The model allows control of discharge parameters (i.e., temperature rise above ambient and rate and velocity of discharge), outfall geometry (i.e., size and shape), and ambient conditions (i.e., stagnant or moving) over a wide range.

Experiments were carried out in the model for the purpose of identifying the significant parameters involved in the formation, propagation, and dissipation of thermal fronts. The first series of experiments was conducted in a stagnant ambient and resulted in thermal fronts symmetrical about the outfall centerline. The second series of experiments involved a uniform flow of ambient, normal to the outfall centerline. The discharge plume in this case was bent in the direction of the ambient flow after the momentum of the discharge was reduced to that of the ambient flow. This led to thermal fronts asymmetrical with respect to the outfall centerline.

Investigation of thermal fronts in the laboratory required, among other things, a record of temperatures and velocities in each experiment. Sensitive, small, fast-responding thermistor probes were developed specifically for this study. These probes are capable of sensing small velocity and temperature changes in the flow field without distorting the mixing process. Four such sensors were built: two for velocity and two for temperature.

A portable thermal imagery system was used for recording the time history of the entire flow field, allowing tracking of thermal fronts. This system consists of a liquid-nitrogen-cooled scanning camera and a series of processor-display units capable of providing a dynamic image of the surface temperature pattern, including color-coded isotherms. Dynamic images showing the thermal fronts were photographed at known intervals during each experiment for analysis.

The temperature and velocity data obtained from the thermistor probes were digitized and statistically analyzed to determine the possible presence of dominant frequencies of large scale periodic motions (i.e., thermal fronts). Selected frames of the thermal imagery were digitized using a scanning densitometer. The film densities were then converted to absolute temperatures, using calibration equations.

The digitized data were displayed and transformed to power spectra using various programs available through the Enviornmental Monitoring and Data Acquisition Group library. A sample frame and its digitized version are shown in Figures 6 and 7. A sample surface-temperature power spectrum is shown in Figure 8.

The data anlaysis portion of the study has taken place since September 1978. Interpretation of these results, including comparison with analytical models of thermal fronts, is in progress. The results of this study will be presented in a Ph.D. thesis by Vahid Alavian in May 1979.

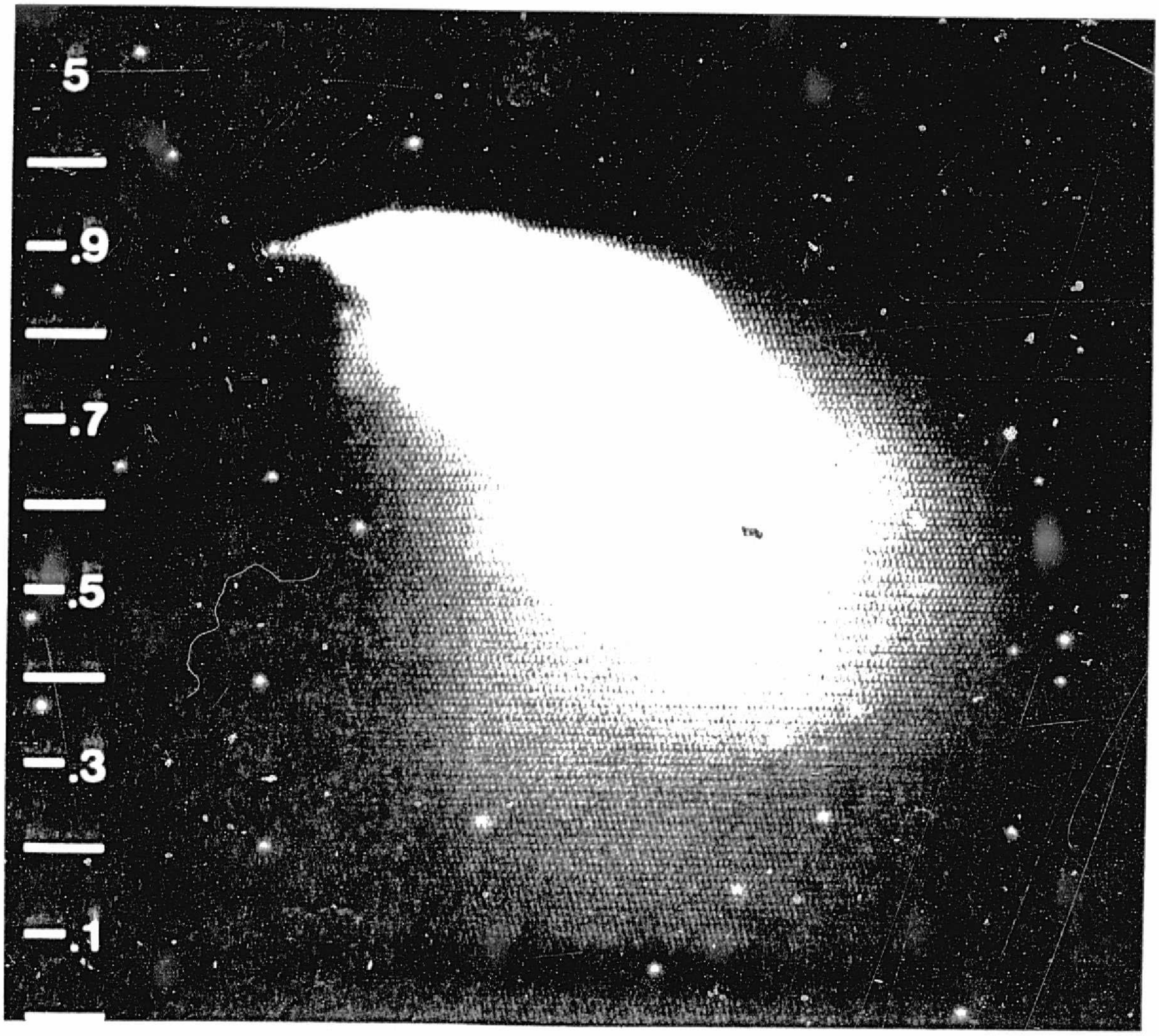

Figure 6. Surface Thermal Image for Laboratory Run 1.

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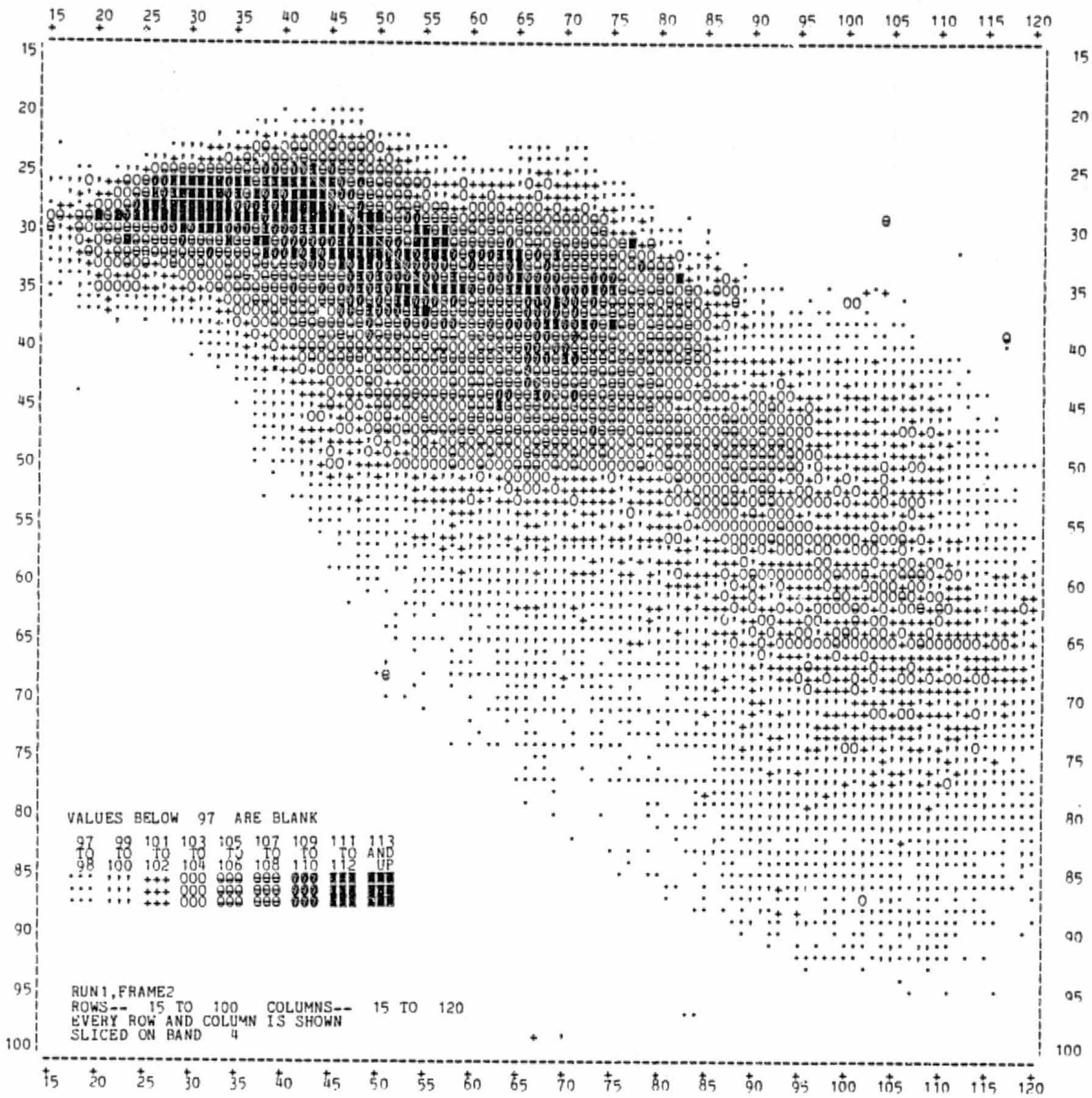

Figure 7. Digitization of Surface Thermal Image for Laboratory Run 1.

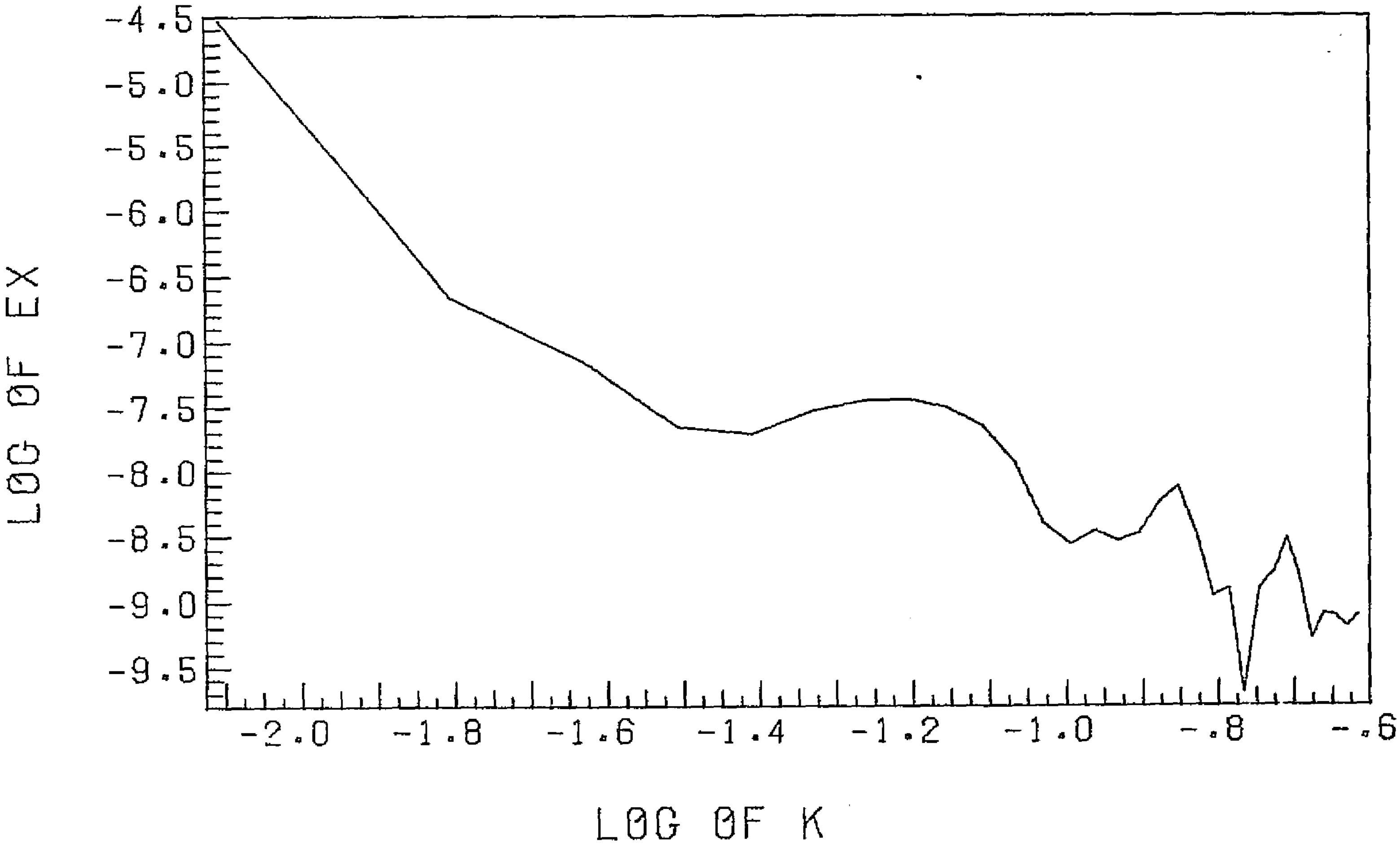

Figure 8. Surface Thermal Power Spectrum Run 1 T = 10 Sec

Water Chemistry

Professor Anders Andren
Barry Verdegan, Research Assistant

Introduction. Phosphorus in surface runoff waters may be transported in a dissolved or particulate form. At the creek - lake interface much of the particulate P may become available for uptake by aquatic nuisance plants. The goal of the water chemistry group is to quantitatively relate the plume processes of dilution, sedimentation, P release, and uptake in order to provide a firmer basis from which to make management decisions. Baseline data regarding P specification and plume variability are lacking. Efficient monitoring methodologies need to be developed and process models of runoff plumes need to be constructed.

Methods. The 1976-1977 Progress Report describes the monitoring methods used during 1977. Four additional plumes were monitored during the spring and summer of 1978 following similar guidelines, though on smaller scales. Two of the four events, May 16 and June 19, were also monitored by remote sensing techniques. Water samples collected at the mouth of Pheasant Branch by the USGS during the June 19 event were analyzed to test the assumptions used in developing a conservative species model.

Each water sample was analyzed in the laboratory for 13 water quality parameters. Two physical parameters, turbidity and suspended solids (SS), and four phosphorus fractions, i.e. dissolved reactive phosphorus (DRP), total dissolved P (TDP), acid extractable P (AEP), and total P (TP), were measured. The remaining seven parameters, potential tracer species, are conductivity, chloride, sulfate, calcium, magnesium, sodium, and potassium. The methods used in the analyses are described in our 1976-77 progress report and Standard Methods for the Examination of Water and Waste Water, 14th. ed. (1974).

Results. In the previous report it was noted that the plumes were found to be extremely variable in both time and space. The 1978 results confirm this finding. This makes it necessary to use modeling techniques to study P transport.

Conservative species models have been used to study long term plumes. However, the initial assumptions may not apply to transient runoff plumes. Strictly speaking, the source waters should be of constant concentration for this type of model to apply. After flow-weighting the results of the analyses of the June 19 creek samples, it was found that variability in concentrations for Cl, Mg, and NA were less than analytical error. In the outer edges of the plume, SO_4, Ca, and K variability due to source concentrations were also reduced. Highly significant correlations between the measured parameters in each event suggests that a conservative species model can be adapted to the study of transient runoff events.

Several factors limit the use of the model. The model is valid only in the parts of the plume representing the high SS and outward areas of the plume. Nearshore areas may represent baseflow waters in which the tracer species may be present at elevated concentrations. The model can be useful in relating the in-plume processes to one another, however, it cannot be used to estimate absolute P loading. Because of the dynamic state of the plume, it is not possible to sample the plume at a time when all of the P is in the lake and in its final form.

To investigate the possibility of P desorption, AEP, DRP, and SS data were transformed to form Langmuir-type, adsorption isotherms. Figure 9 is the isotherm for July 21, 1977. Two distinct trends are evident. In one case, particulate P (gamma) varies independently of DRP. In the second case, gamma is dependent on DRP. The gamma-DRP relationship suggests that desorption is occurring.

The geographic distribution of the data represented in Figure 9 indicates that the trends are real. The DRP independent data were obtained from the region described as "main plume" in the "sediment concentration" section of this report. The remainder of the data were obtained from sampling sites in the outer areas of the plume. Particle sizing suggests that the main plume is composed of much larger particles than are found in other areas. It appears that when extensive macrophyte beds are present, two distinct regions exist in the plume. The main plume region is characterized by the highest sedimentation rate and hence the greatest P removal. In the outer areas, dilution and P desorption are more important in determining the distribution of P between the various P compartments.

The containment effect of macrophyte beds is shown by comparison of Figure 10, a photograph taken on July 19, 1977, and Figure 11, taken on June 19, 1978. On July 19 the beds were well established while on June 19 the beds were undeveloped. Though the events were of comparable magnitude, the July 19 plume was confined to an area about 200 m from shore, but the June 19 plume covered most of the western basin of Lake Mendota.

Use of only surface data oversimplifies the picture of the actual SS transport. The "sediment concentration" section reports width of the "no data" class as 5 m at the surface. Subsurface samples indicate that the band is about 70 m wide. As long as remotely sensed data are limited to surface waters, their application to plume studies will be limited.

The results of this study suggest several interesting management considerations. Macrophytes appear to be useful in reducing the P loading to a lake by increasing sedimentation rates in the plume. It is not known, however, if the sedimented P remains in the sediments or if it is pumped back into the lake. Since increased sedimentation means that more dredging may be required, the tradeoffs will have to be considered in making decisions whether or not to harvest the macrophyte beds.

Remote sensing was used in this study to confirm conventionally collected data and to locate irregularities in the plume structure. Further, remote sensing was the only practical way to study the plume over time periods as long as hours or days, and to obtain data in areas which could not be sampled due to cost, time, or labor constraints.

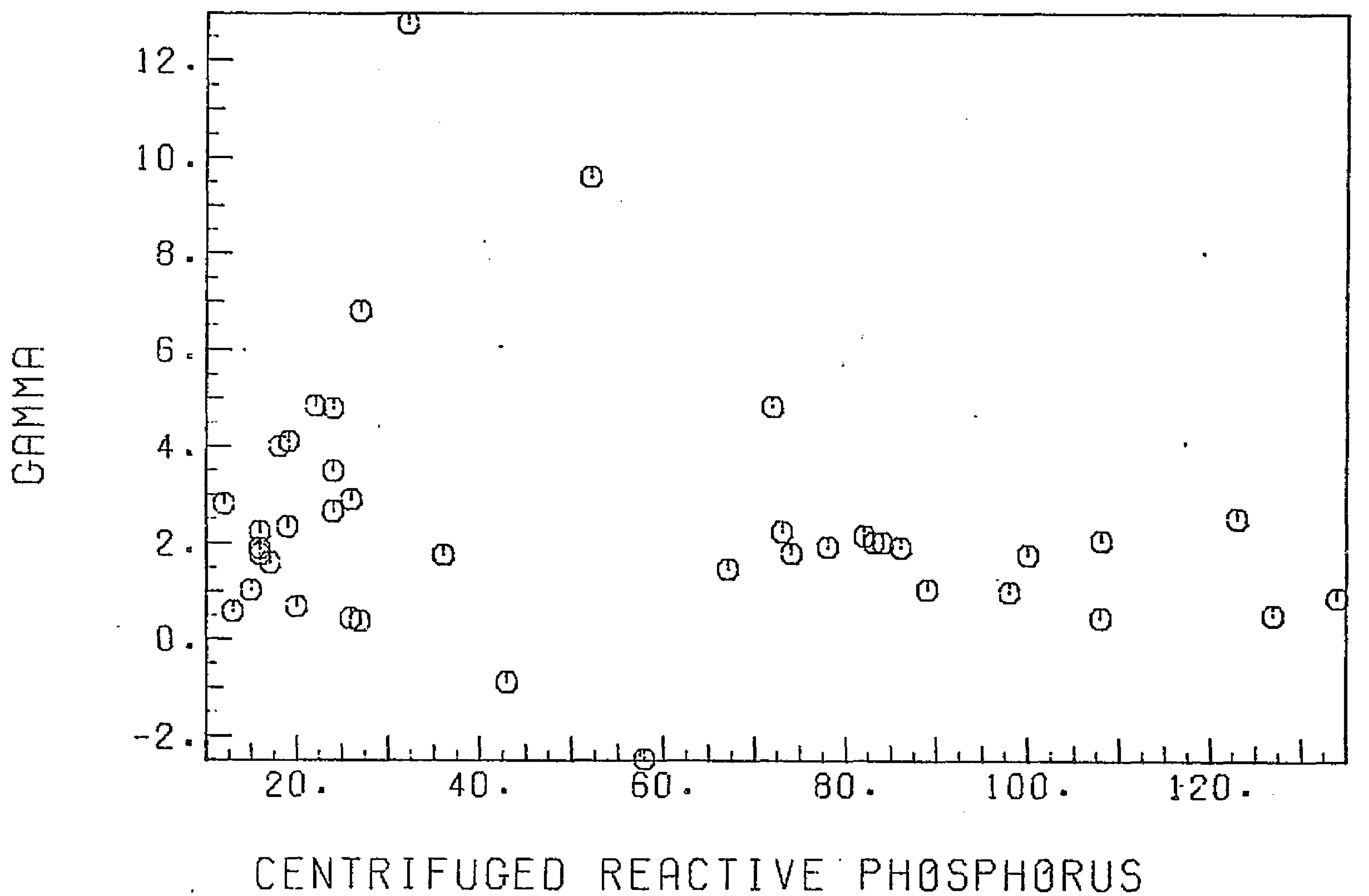

Figure 9. Isotherm for July 21, 1977 (Particulate-Dissolved Phosphorus Relationships)

Figure 10. Photo July 19 showing containment of sediment plume by macrophytes.

Figure 11. Photo June 19 showing spread of plume when macrophyte bed is absent.

The greatest limitations of the techniques are the restrictions of the data to surface waters and the dependence on ground truth for calibration. In plumes with sharp boundaries, such as in 1977, it is not possible to collect the samples needed to calibrate the technique. This limitation is probably important in studies including small lakes with quick runoff events and a high probability of having macrophyte beds.

More detailed information regarding the progress and finds of the Water Chemistry group will be found in an M.S. thesis by Barry Verdegan which is expected to be completed by June 1979.

SOURCES OF SEDIMENT

Introduction

In the proposal for research during 1977-78, the Sources of Sediment group formulated the following seven research objectives:

1. Continue testing of soil detachment and transport models.

2. Modify an existing model or develop a model to simulate sediment transport from upland and channel areas to basin outlet.

3. Expand data base for testing sediment source area locations and governing parameters and for model validation.

4. Test the reliability and effectiveness of various interpretative techniques to determine land cover and sediment source data.

5. Evaluate USDA-SCS soils information and test the utility of aerial imagery for soils mapping.

6. Study the utility of various space-platform sensors for data collection.

7. Select a site for an intensive study during 1978-79 of one of the watersheds adjacent to the Inland Lake Renewal site.

Constraints and new opportunities were encountered by the Sources of Sediment group which resulted in some reformulation of research objectives.

A primary goal of the group's research, as listed in the research objectives, was to develop a detailed sediment transport and yield model for the Pheasant Branch Watershed and to utilize and evaluate alternative remote sensing techniques for collecting the land cover data needed by the model. Since the major emphasis during 1977-78 was on the development of runoff/erosion models (sediment yield models), sediment transport modelling received only minor attention. A new research opportunity was the realization that remote sensing data collection could eliminate the need for extensive field work in watershed studies using the Universal Soil Loss Equation (USLE).

Continue testing of soil detachment and transport models. During 1977-78 a field study was undertaken to investigate sources and yields of sediments from a small area (sub-basin) of the Pheasant Branch Watershed. The objectives of this study were: (1) to delineate hydrologic and sediment source areas using ground and aerial photographic observations; (2) to monitor sediment and water runoff for selected precipitation events; (3) to correlate sediment source areas and yields to storm and runoff characteristics, basin physiography, land use and conservation measures; and (4) to model the sediment and water runoff.

A 15 hectare area in the northwestern part of the 6136 ha Pheasant Branch Watershed was selected for this study. This subbasin was picked because it was small enough to allow measurement of the desired parameters with a limited amount of equipment and manpower, and because it exhibited a variety of land uses and crop types (approximately 8 1/2 ha of hay, 3 1/2 ha of corn, 2 1/2 ha of woods, 1/2 ha of farmstead), slopes, and slope lengths (slopes up to 20 percent). Since the two culverts draining the subbasin have sufficient capacity for a combined discharge of about 3.4 m^3/sec, well over the 100-year storm event, all discharges from the subbasin could be measured or accurately estimated.

Precipitation was measured at one location with two gages. Runoff was continuously recorded at the subbasin outlet with a specially designed and calibrated wier, and in the cornfield with a standard H-flume. Sediment samples were gathered using single stage and continuous samplers at three sites in the subbasin. Soil moisture was measured in the field at up to nine different locations, two to three times per week. A topographic map of the subbasin was drawn from a land survey conducted in this study.

Information from the topographic map, soils information from the Dane County Soil Survey, and precipitation data were used to generate sediment yield and runoff with SCS methods and the LANDRUN model (hydrologic and soil loss model developed by V. Novotny, Marquette University, and used in the Menomonee River IJC Project and in the Washington County Project). These models' results were compared with field measurements. Color infrared aerial photographs (taken in 1977) were anlayzed for determining hydrologic source areas.

Details of this study are given in the report by Nettum (1978), which is summarized below.

The single-stage sediment samplers (which were used to sample the rising limb of the hydrograph) proved to be inexpensive, easy to construct and install, and to give accurate results. The continuous (flow-through) samplers sampled at the time of the falling limb of the hydrograph, however, because they trapped sediments during the time of the rising limb, they indicated sediment concentrations for the falling limb of the hydrograph which were too large. Soil moisture measurements made in the field with the "Speedy Moisture Tester" showed that this device is a relatively fast and reliable method for identifying hydrologic source areas.

Small scale (1:60,000) aerial photographs taken in the spring and summer, 1977, were examined for evidence of hydrologic source areas. No aerial photographs were taken during this study. The 1977 photographs did not lend themselves to quantitative analysis of a small area on the ground because the spot size on the densitometer was too large. Tonal patterns were observed in areas where source areas were expected, but it was not possible to apply Ishaq's method (Ishaq, 1974) of identifying hydrologically active areas using these photographs.

The SCS method and LANDRUN model gave poor and erratic estimates of runoff and sediment yield in most cases. LANDRUN was not able to account for the location (within the subbasin) of different land uses. For example, if input values indicated runoff from the corn field (west side of subbasin) LANDRUN would predict runoff reaching the subbasin outlet. Actually runoff from the corn field was often absorbed by the much higher infiltration capacity of the hay field downslope. Better measurements of sediment yield, sampling the whole hydrograph, are needed to test LANDRUN properly. For all but one storm, the SCS method gave runoff estimates closer to measured values than the LANDRUN model, particularly for small flows. The SCS soil-loss estimates are based upon the same method as in the LANDRUN model.

Modify an existing model or develop a model to simulate sediment transport from upland and channel areas to basin outlet. Data contained in the computer geo-information system derived from the U.S.G.S. topographic maps, USDA-SCS soil survey information, and airphoto interpretation of NASA RB-57 imagery were listed in the 1976-1977 Progress Report. The following data, derived from airphoto interpretation of 70 mm imagery acquired specifically for this project, have since been added:

Hay	April 1977
Barn Agricultural Soils	April 1977
Hay	August 1977
Hay	August 1977
Corn	August 1977
Oats	July 1977
Impervious Surfaces	September 1977
Open Lands	September 1976
Forested Lands	September 1976
Open Water	September 1976
Predominant Cover	September 1976

In addition to these data, the subwatersheds within the Pheasant Branch Watershed have been delineated on a cell-by-cell basis. These subwatershed boundaries will be added to the Pheasant Branch Data Bank to permit retrieval of data at that level.

Test the reliability and effectiveness of various interpretative techniques to determine land cover and sediment source data. With regard to land cover data, several activities have been conducted. Results and comparisons of airphoto interpretation of crop type and land/water classes are discussed in the paper, "Application of Remote Sensing to Estimating Soil Erosion Potential," by Morris-Jones and Kiefer (1978). In summary, the following results were obtained.

(1) Manual photointerpretation techniques and aerial photographic data sources were successful in gathering all of the types of land use/land cover data necessary for estimating soil erosion potential. Multiple-date coverage and film of the most appropriate type were necessary to gather crop type information.

(2) Land use changes occurring within the watershed (i.e. increase in urban cover, and decrease in rangeland, forest land and crop land) were monitored with NASA high-altitude color infrared photos and medium-altitude color photos; and

(3) A comparison of crop-type data collected from medium-altitude color and color infrared airphotos acquired during the 1977 growing season with field-survey information gathered during a 1975 USLE study revealed a decline in oats and an increase in corn.

The Universal Soil Loss Equation (USLE) is designed to assess long-term annual average soil loss within watersheds. Remote sensing methods can be used to quantify two of the five factors which comprise the USLE, the cropping management (C) factor and the erosion control practice (P) factor.

Details of the techniques developed to quantify the USLE with remote sensing as a data source are given in the attached papers by Morgan, et al. (1978), Morris-Jones and Kiefer (1978), and Morris-Jones, Morgan and Kiefer (1978). The findings detailed in these papers are summarized below.

Comparison of the experimental 1977 USLE study, which employed remote sensing data-collection methods, with the traditional 1975 USLE study based primarily on field-survey methods yields the following results and conclusions:

1. Airphoto interpretation was successful in gathering all of the basic land use/land cover data needs associated with the C and P factors. In the 1975 traditional USLE study, the C factor value was 0.200 and the P factor value was 0.79. Our 1977 experimental study resulted in a C factor value of 0.197 and a P factor value of 0.78.

2. Similar values for long-term annual average soil loss were predicted with each study. An erosion rate of 1.46 $kg/m^2/yr$ was predicted by the traditional study while the experimental study predicted a value of 1.51 kg/m^2yr.

3. Remote sensing-data collection techniques were less labor intensive than the traditional methods based primarily on field studies. Approximately 50 hours were required to complete the study with remote sensing methods while 93 hours were required with the traditional methodology.

4. Acquisition of aerial photography results in a permanent record of land cover conditions in the watershed at the time of overflight but increases costs associated with data sources. A minimum of three overflights at a total expense of approximately $600 was required to conduct the study in our test-site watershed.

5. Since the R, K, and LS factors change very slowly over time, soil loss rates can be periodically reassessed by collecting new C and P factor data. Since remote sensing methods provide accurate and efficient methods for collecting C and P factor data, changes in soil erosion rates can be periodically monitored with efforts limited to remote sensing data collection.

Stereoscopic-airphoto-interpretation techniques to identify potential hydrologically active source areas based on terrain analysis were developed and applied in the Pheasant Branch Watershed. Plans have been established for an experiment involving in-the-field verification of presence or absence of source areas and acquisition of airphotos. This experiment will probably be conducted in the spring of 1979 following a major storm.

Evaluate USDA-SCS soils information and test the utility of aerial imagery for soils mapping. A comparison of the interim and final soils maps of the Pheasant Branch Watershed was conducted after the recent publication of the final soils maps.

This comparison revealed that the geographic referencing of the interim soils map was poor. Since the soils data contained within the Pheasant Branch Data Bank were collected from the interim soils map, a decision has been made to recollect the soils data from the final soils map. No attempt has been made to evaluate the potential for improving interpretation of soil boundaries through utilization of color and color infrared imagery.

Study the utility of various space-platform sensors for data collection. The following types of land use/land cover data must be collected in order to quantify the USLE: (1) urban land, crop land, range land, forest land and miscellaneous; (2) seasonal plowing and residue management practices; (3) crop types; and (4) erosion control practices (e.g. grass waterways, strip cropping).

The potential use of space-platform sensors is limited at this time by several problems:

(1) identification of erosion control practices requires very high resolution data, not possible with sensors now available;

(2) identification of erosion control practices is dependent upon a pattern-recognition capability exceeding that of present computer interpretation techniques; and

(3) since data must sometimes be acquired during a specific time period of limited duration, cloud cover could restrict the utility of satellite data if coverage is not sufficiently frequent.

Select a site for an intensive study during 1978-79 of one of the watersheds adjacent to the Inland Lakes Renewal site. Alternative sites have been discussed but a decision regarding whether or not to initiate another major experiment has not been made.

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III. OTHER APPLICATIONS OF REMOTE SENSING

ATMOSPHERIC CORRECTIONS

Professor Frank L. Scarpace
James Verdin, Research Assistant

A project involving the use of multi-band imagery to correct the Landsat imagery for atmospheric effects has been proposed for a number of years. Again no imagery has been acquired coincident with a Landsat pass since either aircraft unavailability, snow cover, or cloud cover prevented the operation. No funds have been used this year for this portion of the study. Efforts have been made during the fall of 1978, and will be made during the spring of 1979, to acquire the requisite imagery.

A graduate student is currently investigating the transformation between photography and Landsat imagery and, when the multi-band imagery has been acquired, the study will proceed. Other methods of atmospheric calibration have been investigated in conjunction with the project funded by the Tennessee Valley Authority.

POSITION DETERMINATION FOR REMOTE SENSING WITH THE HASSELBLAD 500 EL/M

Professor Paul Wolf
Terry Risse, Research Assistant

Introduction. Radiometric interpretation and classification of photographic imagery have provided a useful means of analyzing remote sensing data. The question remaining to be answered is "How can the radiometric data from the photography and the actual ground position be related?" While this is easily done with a mapping camera, the expense of such a camera can be prohibitive and the accuracy attainable is not needed for many remote sensing projects.

At the present time a great deal of radiometric interpretation is carried out using 35 and 70 mm non-metric cameras. We utilize the Hasselblad 500 EL/M in much of our work. This research represented an attempt to calibrate one of our Hasselblad cameras and to evaluate its accuracy in low order metric work for remote sensing.

Both a 40 mm (Distagon) and an 80 mm (Planar) lens were calibrated using a terrestrial calibration field developed at the University of Wisconsin and then tested for application in remote sensing projects.

Camera Calibration. Camera calibration was performed based on the techniques and computer programs developed by Wolf and Loomer (1975). Further work was done in documenting procedures and identifying potential problems and desirable improvements in the process.

For conversion of the camera to metric use, a fiducial system necessary to identify photo coordinates was established. Glass flash plates were exposed in the cameras to record a stable undistorted image of the fiducials for measurement.

Calibration was performed using the McArdle Laboratory target range. The process combined a known exposure station and known coordinates of building window corners with their measured photo coordinates to perform the calibration. Collinearity equations were used to adjust the focal length, principal point offsets, and orientation angles to best fit the photo coordinates to the control.

Experience gained in the calibration procedure for this project pointed out several problems and raised questions for future study. The primary problem encountered was the poor quality fiducial marks as well as the difficulty in seeing them in dark areas of the photos.

The major question to be answered is that of the stability of the calibration over time and the effect the removable magazine may have on subsequent work. Unless the calibration is relatively constant, a method of calibration for each use must be developed.

Field Testing. To test the camera we used a ground network which formed a strip of seven photos with targeted control in the classic locations. The area used was the Bong Test Area established by the Wisconsin D.O.T. in 1971. Two strips of photographs were obtained, one for the 40 mm lens and one for the 80 mm lens.

By calculating the exposure station location and orientation and using it along with known ground positions in the collinarity equations, photo coordinates of the known positions can be found. This technique can be very useful in remote sensing correlation studies where the film density corresponding to a particular ground sample must be measured. This process has been tested unofficially at UW-Madison with a non-calibrated camera and was successful enough to encourage further work in the area.

A second useful tool in remote sensing densitometry involves placing readings of a particular interest or classification into the ground system given their photo coordinates in conventional overlapping photography. To test this, polynomial strip adjustments on two strips (one for each lens) were performed using control points at the center and ends of the strip. Computed control coordinates for withheld points were then compared with actual field control values.

Conclusion. Results documented within this report, though limited, indicate the feasibility of analytical photogrammetric uses of the Hasselblad 500 EL camera. In spite of the removable magazine and problems with mediocre fiducial marks, resulting accuracies were sufficient for many remote sensing applications. Indications point to possible accuracies of 100 micrometers in determining photo coordinates and 1/800 to 1/1000 of the flying height if determining ground control by strip adjustment.

Additional testing would be valuable to determine the effects of:

1) time change on calibration
2) camera disassembling and reassembling on calibration
3) film curvature on calibration effectiveness and resulting accuracy

and to improve:

1) fiducial mark quality
2) definition of fiducial positions using glass plates

Users must be cautioned, however, that definition of photo coordinates to 25 micrometers cannot be done to a high degree of confidence. 50 micrometer accuracies might reasonably be expected in analytic work if the indications of this test are valid and some system improvements result.

COMPUTER PROGRAM DEVELOPMENT

Dr. Lawrence T. Fisher, Program Coordinator

Computer programs for general purpose image analysis and classification have been developed over the last several years. Our package of programs has reached a satisfying level of maturity. There are now about 80 programs in the package, all designed around a common file structure.

Programs are in five main categories. One group allows file generation from a variety of sensors--Landsat, scanning densitometer tapes, or thermal scanner. A second category produces output of filed data. This category includes routines to create line printer "shade prints," to create high-quality color separations for recording on the film writer which is part of the scanning densitometer, or to produce tapes in a format easily used by other computers. This latter program has allowed us to perform several film scans for other universities and agencies. A third category of programs transforms data sets in various ways, including decomposition into principal components, texture transformation, scale alteration, or smoothing. A fourth category allows selection of training areas for supervised classifiers and gives us methods to judge and edit these. Histograms, bar graphs, scatter diagrams, and statistics calculators are available to aid in training-set understanding. Statistical cleanup and training set merging, deletion, and reordering are possible for editing purposes. Finally, the fifth category includes classifiers. These include inexpensive "box" programs and two different implementations of maximum likelihood classifiers.

All of our programs have been designed around the Madison Academic Computing Center's Univac 1110 machine, and they are therefore specific to Univac hardware.

Use of a general purpose multitasking system has constrained us to use of batch processing or timesharing with slow (120 character per second or less) data links. This, together with high first cost, has prevented us from using modern technology image processing techniques; this constraint gradually became more and more insufferable. Fortunately, funds became available from the University and from NASA late in 1978 which allowed resolution of this problem.

The University's Space Science and Engineering Center (SSEC) has been developing image processing systems for several years, largely for meteorological needs. These systems, named McIDAS (Man-computer Interactive Data Access System) include terminals with color-video displays, operator consoles, image memory, and a controlling microcomputer. The terminals operate in conjunction with a medium sized computer located close enough that high speed communication is possible; one host computer can service several terminals provided none demands unusual amounts of computation. Normally, a Harris/6 machine serves as the host.

Extensive software has been developed for McIDAS. Much of it is specific to the needs of meteorologists, but a large amount is general in nature and would be usable for any image processing.

Because of the availability of hardware and software support, the Environmental Monitoring and Data Acquisition Group (EMDAG) decided to obtain its own McIDAS terminal, which is now under construction with completion expected by the summer of 1979. Provisions are being made to share a Harris/6 computer which is being bought by the Department of Meteorology, largely to serve as a data link to other large computers involved in data modeling.

Some of our existing programs will no longer be needed when the terminal begins operating. Most, however, will have to be converted. This involves conversion to a new file structure and operating system, a different word length, and much more limited memory, so it is expected to be rather difficult.

Some of the conversion may be possible earlier. Plans are being made to transport many of our routines to a CDC-based system at the University of Minnesota. Some of the translation questions which will be answered there are expected to ease the later conversion of the same routines to the Harris.

DIGITIZATION OF THE THERMAL SCANNER

Dr. Lawrence T. Fisher, Program Coordinator

EMDAG has done extensive past research using a Texas Instruments RS-18a thermal scanner. Data were acquired on analog magnetic tape and later digitized on the ground. In early 1978 the analog tape recorder wore out. Head and capstan drive motors needed replacement at very high cost. Since the recorder was the largest contributor of noise in the system, it was decided instead to replace it with acquisition-time data digitization and on-board digital recording. A block diagram of the new system is shown in Figure 12. It is designed around an Intel microcomputer and uses some data transfer electronics developed for another purpose by the Space Science and Engineering Center.

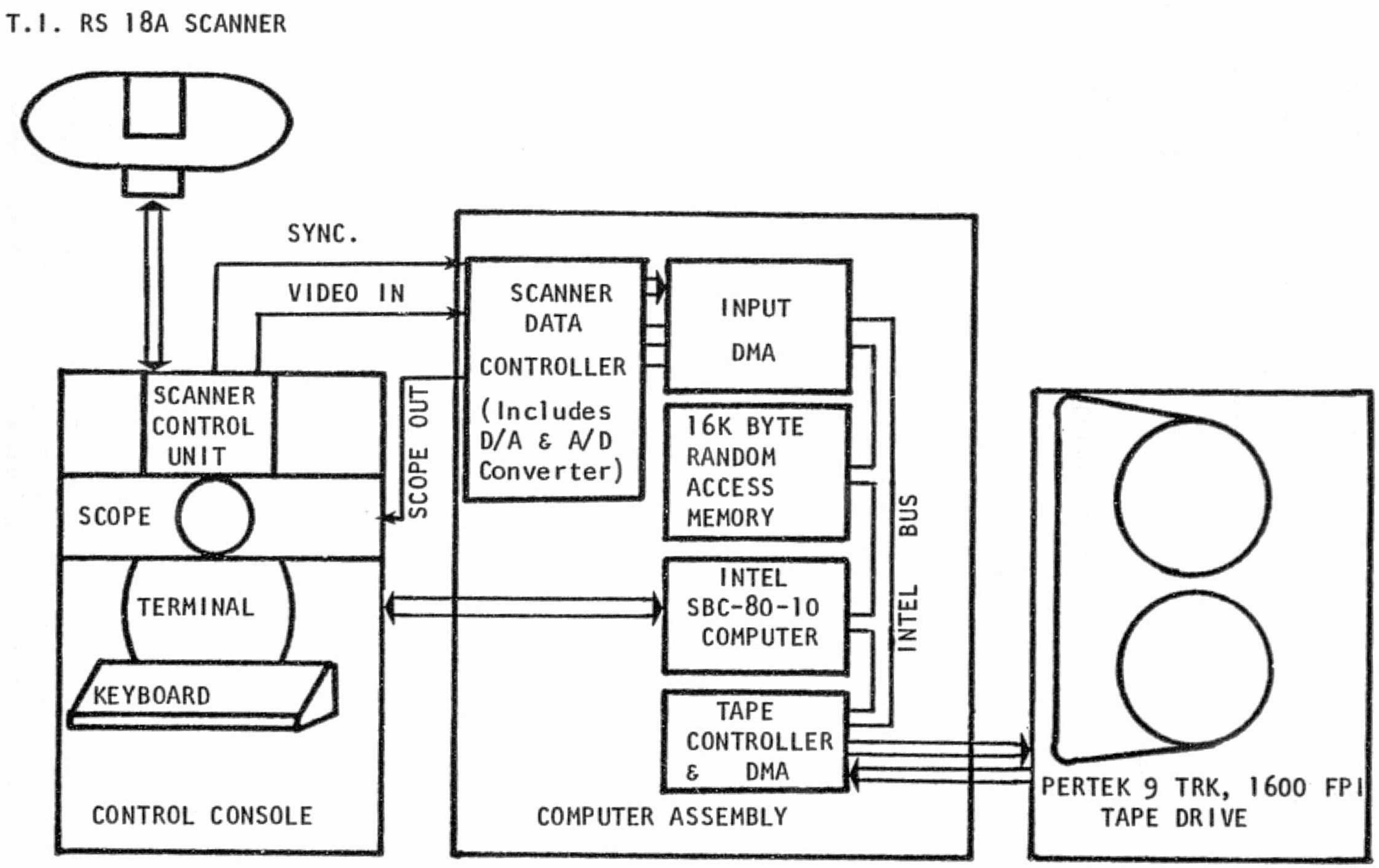

Figure 12. Thermal Scanner System, Block Diagram

SURVEY OF POTENTIAL USERS OF DIGITAL FILM PROCESSING

Warren J. Buchanan, Jr., Research Assistant

Remote sensing has often been "accused" of being a strictly research-oriented technology, with little relevance to operational needs. However, descriptions of resource inventory and management needs and practices seem consistent with some of the described capabilities of remote sensing, particularly digitized film analysis. It appears that digitized film analysis could be an appropriate technology for resource inventory and monitoring, but may be suffering through a time lag between development and general acceptance by some user community.

The reasons for this lag are essentially unknown. White (1977) suggests several possibilities:

1) the capabilities of remote sensing have been overstated and oversold;

2) the capabilities of remote sensing are unknown or unappreciated;

3) the best applications of remote sensing have not been fully developed yet;

4) users tend to stick to traditional technologies and resist new ones; or,

5) sophisticated remote sensing techniques are expensive substitutes for traditional inventory methods.

This study was intended to determine which of the above factors indeed hindered the acceptance and application of digitized film analysis. A questionnaire was mailed to 484 resource managers and surveyors thought to be actively involved in resource inventory and monitoring. The recipients were fairly evenly divided among federal, state, and private agencies.

Aside from asking why remote sensing might not be used, several questions were directed toward actual users to determine what advantages were enjoyed with remote sensing, what are good applications, and what are the disadvantages.

Methods

Two main considerations in sending out the survey were:

1) in what form should the questions be asked, and

2) to whom should the questions be directed.

Although only one previous survey was found with any similarity to the present effort (Center for Development Technology 1976), the methods and coverage of this earlier survey were quite different. The earlier survey consisted of personal interviews with known remote sensing users in a five-state midwestern region and stressed the use of Landsat. The present survey used a standard questionnaire mailed to resource managers and surveyors nationwide without prior knowledge as to their use of remote sensing.

Questionnaire. The format of the questionnaire was styled according to the advice of the Center for Survey Research at the University of Wisconsin, Madison (Harry Sharp, personal communication, March 1978). This format emphasized well-spaced lines and answers that could be simply checked off to facilitate response (Figure 13). The questions were purposely limited to both sides of a single page so the survey would appear brief. A cover letter explained the reasons for the survey and introduced the basics of digitized film analysis. A stamped, self-addressed return envelope was also enclosed to encourage responses.

Recipients. The list of 484 recipients comprised federal and state public agencies, private non-profit conservation groups, and for-profit environmental consulting firms. The National Wildlife Federation's Conservation Directory was the source for all addresses of the public agencies and most of the non-profit conservation groups. The remaining addresses were taken from a computer listing of environmental consulting firms by the U.S. Army Corps of Engineers.

The number of recipients was fairly evenly divided among these four groupings. All federal agencies and national conservation groups that seemed to possibly conduct natural resource inventories were included in the survey. Half of the states were sampled by splitting the nation into six regions and alphabetically selecting half the states in each region. Consulting firms were selected on the basis of having a relatively large contract load and staff of environmental scientists. Addressees were generally not specific individuals but were usually offices because it was thought that offices were less transient than people.

Summary of Results and Conclusions

Response. Of the 484 surveys sent, 177 were returned after five weeks for a response rate of 37%. Surprisingly, the state agencies responded at a rate of 51%, slightly better than the 37% response from federal agencies. Consulting firms and conservation groups had paltry return rates of 25% and 13%, respectively. It was expected that the public agencies would feel more obliged to respond than private organizations, but the magnitude of the difference was unexpected.

In real numbers, 177 state agencies were contacted and 90 responded; 156 federal agencies received questionnaires and 57 returned them; 20 out of 79 consulting firms responded; while 10 of the 75 non-profit conservation groups replied.

Types of Resource Inventory. General-land resource mapping was the most common type of inventory; quantification of resources was less common. Crop inventory and stress detection were performed least by the survey audience. In performing their respective inventories, the more frequently cited problems were expense, labor intensity, and lack of time. Problems to which remote sensing has often been considered a solution, such as data manipulation, inaccessability of study areas, or orientation on the ground were less frequently mentioned.

Dear Resource Manager or Surveyor:

The following survey is to provide information for a research project on remote sensing (particularly digitized film analysis) conducted at the University of Wisconsin-Madison. Aside from developing new applications of this technology, we are interested in the perceptions of possible users. Your cooperation in taking a few minutes to answer these questions is greatly appreciated. Feel free to pass this along to anyone in your organization you fell may more appropriately address these questions. The individual returns will be strictly confidential. Please write or call if you have any questions, wish additional information, or would like to recieve a copy of the results.

1. WHAT TYPES OF RESOURCE INVENTORIES ARE DONE BY YOU OR THOSE YOU SUPERVISE: (CHECK ALL THAT APPLY)

   ____land resource mapping ____land resource quantification ____water resource quantification

   ____water resource mapping ____wetland inventory ____forest inventory ____cropland inventory

   ____stress detection ____other________________________ ____none--PLEASE RETURN QUESTIONNAIRE

2. WHAT RESOURCE INVENTORY TECHNIQUES ARE USED BY YOUR ORGANIZATION?

   ____on-site gound surveys ____landowner surveys ____manual photo interpretation ____digitized film

   ____satellite data ____multi-spectral scanner ____thermal scanner ____literature review ____none

   ____other ________________________

3. ARE THESE INVENTORIES DONE IN-HOUSE, BY CONTRACT, OR BOTH?

   ____in-house ____contract ____both

4. WHAT PROBLEMS DO YOU HAVE FULFILLING YOUR RESOURCE INVENTORY NEEDS?

   ____expense ____labor-intensity ____inaccuracies ____storing and retrieving data ____overlaying data

   ____access to study areas ____lack of expertise ____lack of time ____orientation on ground ____none

   ____other ________________________

5. WHICH INVENTORY TECHNIQUES DO YOU COMMONLY ASSOCIATE WITH THE TERM "REMOTE SENSING"?

   ____Landsat or ERTS satellite ____aerial photography ____thermal scanner ____multi-spectral scanner

   ____digitized film ____on-site photography ____x-ray ____radar ____photogrammetry ____none

   ____other ________________________

6. WHAT APPLICATIONS OF REMOTE SENSING ARE YOU AWARE OF?

   ____land resource mapping ____land resource quantification ____water resource mapping ____water resource quantification ____wetland inventory ____forest inventory ____cropland inventory

   ____stress detection ____none ____other________________________

(OVER)

Figure 13. Questionnaire Sent to Survey Recipients.

7. WHAT APPLICATIONS OF REMOTE SENSING WOULD YOU OR YOUR ORGANIZATION BE INTERESTED IN?

____land resource mapping ____land resource quantification ____water resource quantification

____water resource mapping ____wetland inventory ____forest inventory ____corpland inventory

____stress detection ____none ____other ______________________________________

8. IF REMOTE SENSING IS OR COULD BE USED BY YOUR ORGANIZATION FOR RESOURCE INVENTORY, WHAT IS THE SMALLEST AREA ON THE GROUND YOU WOULD NEED RESOLVED?

____square foot ____square yard ____ten square yards ____100 square yards ____acre ____unknown

____other ________________________________

9. WHAT APPLICATIONS OF DIGITIZED FILM ANALYSIS ARE YOU AWARE OF?

____land resource mapping ____land resource quantification ____water resource quantification

____water resource mapping ____wetland inventory ____forest inventory ____cropland inventory

____stress detection ____none ____other ______________________________________

10. WHAT DO YOU SEE AS THE MAIN REASONS DIGITIZED FILM ANALYSIS IS NOT USED?

____lack of in-house familiarity ____poor substitute for present methods ____access to computer

____cost of computer services ____access to film digitizer ____cost of digitizer ____cost of purchasing or developing software ____finding ground locations ____no relevant applications

____unknown ____other ______________________________________

11. IF DIGITIZED FILM ANALYSIS IS USED BY YOUR ORGANIZATION, IS IT A SUPPLEMENT OR HAS IT REPLACED PREVIOUS INVENTORY TECHNIQUES?

____replaced previous techniques ____supplement ____not used

12. WHAT DO YOU SEE AS POSSIBLE ADVANTAGES OF DIGITIZED FILM ANALYSIS?

____less expensive ____faster ____less labor-intensive ____more accurate ____data can be overlaid

____easy data sotrage and retrieval ____potential for data enhancement ____economy of scale

____none ____other ______________________________________

13. WHAT DO YOU SEE AS POSSIBLE DISADVANTAGES OF DIGITIZED FILM ANALYSIS?

____more expensive ____slower ____more laborious ____inaccurate ____unwieldy data handling

____none ____other ______________________________________

(optional) SIGNED ______________________________________

(optional) POSITION ______________________________________

ORGANIZATION ______________________________________

Figure 13. (continued)

Awareness. Most of the possible responses listed to test respondents' awareness of various remote sensing techniques were properly associated with the term "remote sensing." However, there was great disparity among the frequency of responses; Landsat was the most frequent, even more than conventional aerial photography, while digitized film analysis was among the least frequent. All respondents were aware of at least one remote sensing application. At least 60% of respondents were aware of every application. Interest levels toward remote sensing were lower than awareness levels, although interest in quantitative applications was proportionally higher than their respective awareness levels.

Resolution. A one acre resolution cell was the most popular choice. Over half the respondents required a resolving power of 100 square yards or better. It was felt that several respondents unfortunately misunderstood the concept of a ground resolution cell.

Awareness of Digitized Analysis. The awareness levels for applications of digitized film analysis were about half those of remote sensing in general. These awareness levels were proportionally equal among groups of respondents. The reasons given for nonuse of digitized film analysis stemmed mainly from lack of familiarity, inaccessibility, and cost. Few respondents indicated negative opinions of digitized film analysis, such as it's being a poor substitute or irrelevant. Nearly 15% used digitized film analysis, the greatest proportion at the federal level.

Advantages and Disadvantages. Possible advantages of digitized film analysis included largely efficiency of data gathering and manipulation. Relatively, respondents thought that digitized film analysis would be less expensive or more accurate. Correspondingly, the most common disadvantages were expense and inaccuracies. A large portion of responses admitted insufficient knowledge of digitized film analysis to judge the advantages or disadvantages.

This technology may have some advantages for certain specified applications (especially resource quantification, signature extensions, and data manipulations). These applications appear to interest some of the possible user audience. Undoubtedly digitized film analysis will gradually gain greater acceptance by those whose inventory problems and needs coincide with ascribed advantages of this technique.

Conclusions. The thought that digitized film analysis is suffering through a time lag between development and acceptance as an operational tool is supported by the data on lack of awareness. Although the stated advantages are important considerations for many in the survey aduience, the disadvantages of expense and inaccuracy are also important. Since expense was the most important problem currently experienced in resource surveys, the feeling that digitized film analysis is too expensive will probably always be its greatest detraction. Inaccessibility to the technology and lack of familiarity can be overcome simply through further applications, demonstrations, and documentation.

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IV. ASSOCIATED PROJECTS

Associated projects share technology with the NASA Project but are funded from other sources.

REMOTE SENSING APPLIED TO THE IDENTIFICATION OF WETLAND VEGETATION

Professor Ralph W. Kiefer
Professor Frank L. Scarpace
Sarah Wynn, Research Assistant

From 1971 to 1978 the Wisconsin Power and Light Co., the Madison Gas and Electric Co., and the Wisconsin Public Service Corp. with the U.S. Environmental Protection Agency funded a study of the impact of siting a two-unit, 1000 megawatt coal-fired generating station in a 1600 hectare wetland.

Aerial photography has been obtained on a nearly monthly basis since 1971, covering the period of construction and a three year period after the initiation of of operation. 1971-1974 aerial photographs were 35 mm color and color infrared. 1975-1978 photographs are 70 mm color and color infrared at scales ranging from 1:10,000 to 1:40,000. Detailed vegetation maps have been prepared from an extensive (four year) field survey effort and from human photo interpretation.

The principal impact on the wetland vegetation is due to the extensive leaking of the 200 hectare cooling lake built on a portion of the original wetland. Groundwater influx to the remaining wetland has increased by a factor of six, floating up and eroding much of the peat mat. Surface water levels are now consistent throughout the yar. In addition, groundwater temperatures are now out-of-synchronism with the normal temperature fluctuations by four to eight months. The result of these changes is widespread destruction of the peat mat and an accompanying change of wetland species from shallow water perennials to more hydrophytic species in some areas and weedy annuals in others.

Both human photo interpretation and extensive ground sampling data have been used to trace vegetation changes over time (Wynn & Kiefer, 1978).

APPLICATION OF REMOTE SENSING TO THE ANALYSIS OF FISH HABITAT

Warren Buchanan, Research Assistant

Assessment of the environmental impact of a coal-fired electric generating station in Columbia County, Wisconsin required analysis of the extent of fish habitat in a section of the Wisconsin River adjacent to the plant site. An inventory of potential pike spawning areas in the section of the Wisconsin River bordered by the Petenwell and Prairie du Sac dams was prepared by manual photo interpretation of 70 mm color infrared transparencies taken from an altitude of 3,350 m. A series of 180 images along 12 flight lines was taken on 9 September 1977 at a scale of 1:62,500.

The first step in the analytical process was preparation of a base map on which to trace the photo interpretations. Because the photo scale approximated that of the standard U.S. Geological Survey (15-min) topographic quadrangle maps, transparent mylar copies of the U.S.G.S. maps were used as base maps. Each photo was placed under the transparent base map and vegetation areas were transferred to the base map.

An experienced photo-interpreter identified the resources on the imagery. Ground checking of mapped wetland classes revealed an excellent correlation between photo-interpretation and actual vegetation types. From the infrared photographs the following wetland classifications were delineated.

1. Deep Water Sedge Meadow. The deep sedge meadows consist of lake sedge (Carex lacustris), bulrush (Scirpus spp.), and bluejoint grass (Calamagrostis canadensis and C. inexpansa) with some colonies of cattail (Typha supp.) mixed in. Other floating and emergent aquatic marcophytes that often occur in deep water sedge meadows include arrowhead (Sagittaria supp.) and burreed (Sparganium eurycarpum). A deep water sedge meadow is most clearly distinguished by the inundation that is usually evident throughout the year.

2. Shallow Sedge Meadow. This category is dominated largely by either tussock sedge (Carex stricta) or bluejoint grass. Forbs such as aster (Eupatorium spp.) are occasionally prominent. Cattail is fairly common as is reed canary grass (Phalaris arundinacea). Shallow sedge meadow, as the name implies, has a less hydric moisture regime than deep sedge meadow. There are generally long periods during the growing season when the water table is somewhat below the surface.

3. Emergents and Deep Water Floating Macrophytes. This category includes deep water species floating or scarcely emerging above the surface. Floating mats of duckweed (Lemna supp.) frequently cover stagnant open water between other vegetation. Large mats of arrowhead (Sagittaria spp.), water lily (Nymphaea sp. and Muphar sp.), or pondweed (Potamogeton spp.) often compose this vegetation type, which is often associated with the borders of open bodies of water.

4. Cattail. Monospecific stands of cattail are separated on the maps if large enough to outline.

5. Reed Canary Grass. This densely grown monospecific vegetation type often occurs along water courses or in regularly shaped plantations.

6. Bluejoint Grass. This species seldom occurs in large pure stands and is an indication of a fairly undisturbed wetland community.

7. Drained Wetland. A growth of weedy forbs and shrubs often indicates ditching and dessicated conditions. Typically, remnants of the original vegetation type are found under the weeds.

8. Shrub Carr and Swamp. Dogwood (Cornus stolonifera), spiraea (Spirea alba), or willow (Salix interior) are the most common constituents of shrub carr. Lowland tree species of willow, silver maple (Acer saccharimum), aspen (Populus tremuloides), or green ash (Fraxinus

pennsylvanica) are commonly interspersed or occur as solid stands of lowland forest.

9. Mixed Vegetation. Vegetation complexes too detailed to separate by individual boundaries were combined and labeled by predominant types. For example, complexes of shrub-cattail-sedge meadow were fairly common.

Areas for each vegetation class were quantified using a Hewlett Packard Model 9107A digitizer and calculator. Comparison of pike spawning areas on the plant site with other spawning areas allowed us to draw some conclusions about the importance of the plant site to the Wisconsin River fishery.

Results. Wisconsin River wetlands were grouped into 13 major areas of potential northern pike spawning habitat. Because no field data exist to show if these actually were utilized for spawning, the comparison of spawning areas was determined solely by whether suitable vegetation types were evident by infrared aerial photography. This comparison shows the wetland area on the plant site (bordered by Duck Creek on the north, Rocky Run on the south, and the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks on the east) to be only a small percentage of the total wetland between the Petenwell and Prairie du Sac dams. Only 13.1% of the deep water sedge meadow and 0.5% of the shallow water sedge meadow areas are on the station site. Other areas with substantial deep and shallow sedge meadow areas are upper Duck Creek, upper Rocky Run Creek, Powers Creek and its tributaries, and Lodi Marsh.

Although we know from our fyke netting that the Rocky Run A and B areas are not important spawning grounds, they were included in the analysis to avoid biases. Since they appear suitable on the basis of aerial photography (the only technique used for judging other sites where no fish survey data existed), it would have been unfair to exclude them. Information provided by the Wisconsin Department of Natural Resources indicates that the Lodi marsh is not used as a pike spawning ground either. If these areas are eliminated from the comparison, the station site contains 22.5% of the deep-water sedge meadow and 0.8% of the shallow-water sedge meadow. The relative importance of the generating station wetlands would probably increase if fish survey data for other marshes were available.

MAPPING OF THE SHEBOYGAN MARSH

Professor Ralph W. Kiefer
Professor Frank L. Scarpace
Bruce Quirk, Research Assistant

The remote sensing group was involved in two small mapping projects last year. One involved a continuing study on mapping the vegetation in Sheboygan Marsh which has been ongoing since 1975. This project involves using digitized photography (original scale of 1:120,000) with a ground resolution of 6 meters.

Training set data were extracted and a classification of the vegetation types was accomplished using our elliptical classifier. A color-coded thematic representation of the vegetation types can be found in Figure 14. The other

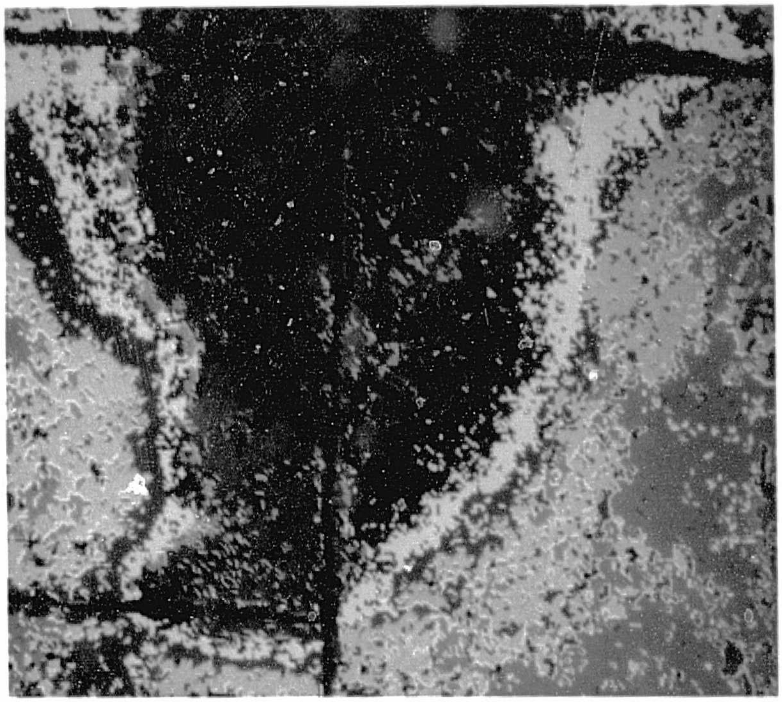

Figure 14. Smoothed computer classification of Sheboygan March from a NASA CIR image taken on 31 July 1974 at an altitude of 18,288 m AMT, (scale 1:120000). A pixel size of 6 m^2 (19.685 ft^2) was used in mapping the following 12 land cover categories.

Land cover catagory	Color on print
1. Water	Blue
2. Deep Water Emergents	Dark Green
3. Sedges and Grasses	Dark Blue
4. Reeds	Dark Brown
5. Shrubs and Forbs	Light Blue
6. Sedges, Grasses and Forbs	Pink
7. Agricultural Fields	Light Brown
8. Upland Hardwoods	Red
9. Shrubs	Yellow
10. Cattails	Light Purple
11. Shallow Water Emergents	Green
12. Lowland Conifers	Cyan

project involved helping Professor T. Lillesand of the University of Minnesota (funded on another NASA project) classify a number of wetlands in Minnesota. Both of these projects involve very small budgets.

CLASSIFICATION OF INLAND LAKES FROM LANDSAT

Dr. Lawrence T. Fisher
Professor Frank L. Scarpace
Mr. Ron Martin and Mr. Kenneth Holmquist, Wisconsin DNR

Introduction

This project aims to use Landsat data acquired at intervals throughout a growing season to provide multidate statistical information to classify eutrophication levels in inland lakes throughout Wisconsin. It has been reported in past annual reports. Progress has unfortunately been slower than hoped because of funding difficulties.

Progress During 1978

The Wisconsin Department of Natural Resources (DNR) was very interested in this project at the beginning of the year, and were cooperating with the University on a large-scale test. This involved analysis of three Landsat scenes (early, mid and late summer of 1976) from Southeastern Wisconsin and another three covering the north central part of the state. Department funds were provided to obtain data and to support two full-time people. One, Mr. Ronald Martin, is a permanent DNR employee. The other, Mr. Kenneth Holmquist, was an ex-graduate student from the Remote Sensing Group. He had been involved in the Lake Eutrophication Project from its beginning, and had earned his Master's Degree by his research on classification techniques. When he left the University, he was employed as a Limited Term Employee by the DNR.

Negotiations were begun with the Applications Technology Branch of NASA's Goddard Space Flight Center (GSFC). After several visits by GSFC people, a proposal was prepared by DNR and the University soliciting GSFC support for the project. GSFC, vitally interested in fostering use of Landsat within state agencies, was apparently extremely interested. This was the only large scale Landsat applications project active in Wisconsin, and there seemed to be agreement that it was imperative to continue it.

Further discussion indicated, however, that the whole project could not be funded by GSFC at this time. Subsequent to a show of continued interest by GFSC, a smaller proposal (under $10,000) has been submitted by the University. This amount is not sufficient to acquire data and perform data extraction and classification for the entire state, and certainly will not allow adequate field checking and classification verification. This component of the work was considered essential by the DNR before the technique could be considered operational.

The DNR is unable to participate to any large extent in the smaller project as contemplated. They have agreed to allow Mr. Martin to participate in an advisory role to assist University researchers, and it may be possible to use DNR funds to acquire a limited amount of Landsat data.

Intentions now are to use GSFC funds to pay a University Project Assistant and to provide computer funds to extract as much Landsat data as possible from 1976 tapes. A few tapes are already available; some others may be available through GSFC, and a limited number of others will be purchased. This data extraction process will no doubt reveal errors in the computer files which describe the 3,000 lakes in the state; corrections and updates will be made as required.

Data extracted will be archived for future research in lake classification. They will also be used as far as possible for the originally intended purpose--to classify the state's lakes. Additional funding, however, will be essential to accomplish this.

No further computer programming or file development is anticipated beyond error correction and routine maintainance. Data extraction programs have been extensively tested and appear to be satisfactory. Classification programs are less refined and could no doubt be improved, but this will not be done now. Similarly, program and procedure documentation is needed but must be deferred.

Earlier conversations with GSFC people revealed a strong interest in adapting the techniques and programs developed here to operate on GSFC machines so that they could be used for other regions. At this time, it is not clear whether GSFC retains this interest.

Publications

Two papers, Fisher, et al. (1978) and Scarpace, et al. (1978), were presented at the 1978 ASP/ACSM Convention in Washington. Both of these have been accepted for publication in Photogrammetric Engineering and Remote Sensing although the publication date has not yet been announced.

A DNR report "Remote Sensing as a Mechanism for Classification of Wisconsin Lakes for Trophic Condition" is in preparation.

Figure 15 displays a news item about this project from a recent GSFC newsletter.

TROPHIC CLASSIFICATION OF TENNESSEE VALLEY RESERVOIRS

Professor Frank L. Scarpace
Jeff Fox, Tom Lo, and Bruce Quirk, Research Assistants

During the summer of 1978, the Tennessee Valley Authority funded a small study to investigate the feasibility of using Landsat imagery to predict the trophic condition of a number of reservoirs within their service area.

Ground calibration data used for the study were collected by the Environmental Protection Agency during the 1973 National Eutrophication Survey (NES) at 35 reservoirs in the TVA area. These data were subjected to cluster and principal component data transformations. A single trophic-state index for each reservoir was derived. Water quality characteristics selected as trophic indicators were: chlorophyll, conductivity, total phosphorus, total organic nitrogen, the inverse of the Secchi disc depth, and the yield of an algal assay procedure.

REFLECTIONS

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Wisconsin Tests Software for Multidate Landsat Data Extraction

by Betsy Middleton

A software package to accomplish multidate Landsat data extraction for a lake water-quality monitoring program is being tested on a statewide basis by the Wisconsin Department of Natural Resources (DNR) and ERRSAC. Ron Martin of DNR is working with ERRSAC on the project. The software package was written under the direction of Dr. Larry Fisher and Dr. Frank Scarpace of the University of Wisconsin.

The water quality project is ERRSAC's first step in assisting the State of Wisconsin in developing multidisciplinary, multiagency statewide Landsat applications.

Figure 15. Report on Lake Classification from Landsat.

Landsat Multispectral Scanner (MSS) data from four different dates were extracted from computer tapes using the digital analysis programs developed at the University of Wisconsin. Pixels representing reservoir water were extracted from the surrounding land matrix by using a band 7 mask between 0 and 3. Descriptive statistics to include mean, variance, and ratios between bands were calculated.

Significant correlations (>0.8) between the MSS statistics and many of the trophic indicators were found. Regression models were developed to predict reservoir eutrophication from the MSS data. Using the MSS data, R squared values between .85 and .98 were found when predicting the trophic-state index.

To illustrate the spatial variations within reservoirs as well as the relative variations between reservoirs, a table-look-up elliptical classification was used in conjunction with each reservoir's trophic state index to classify each reservoir on a pixel-by-pixel basis. A color-coded thematic representation was then produced on our Optronics P-1700 photo-write unit.

Atmospheric Corrections. A number of different corrections to the Landsat imagery for differing atmospheric conditions were attempted. The first scheme used the clearest water and a bright object to scale the Landsat data. This method has been reported in previous annual reports (see 1976-77 report). The other method used to correct the Landsat data involved calculating the histogram for the entire Landsat scene. The low and high values were used to scale the data within the scene. Neither method worked with total satisfaction.

Investigations are continuing this year. A complete report of these activities can be found in a technical report published by the Tennessee Valley Authority which is titled: "Trophic Classification of Tennessee Valley Area Reservoirs Derived from Landsat Multispectral Scanner Data," authored by D. Meinert, D. Malone, A. Voss and F.L. Scarpace.

CROP YIELD STUDY

Professor Frank L. Scarpace
Tom Lo and Tom Mace, Research Assistants

A small study was funded by Argonne National Laboratory to investigate the relationship between crop (soybean) yield and information recorded on an aerial image. 70 mm color and color infrared images of soybean test plots fumigated with sulfur dioxide were acquired on eight dates. Imagery from two of the dates (1 August and 22 August, 1977) was scanned on our P-1700 densitometer. These data were corrected to absolute log exposure values.

Using these data, soil patterns were classified into 18 classes using a supervised-maximum-liklihood classifier. After the classification was color-coded, a print was produced. The classes closely resembled the USDA soils map but contained much more detail. A preliminary ground calibration verified the patterns produced by the computer classification.

Data were extracted from the digitized image and correlated with yield values derived from ground sampling within the test plots. Very good correlation was found between plant damage and the exposures derived from the magenta and cyan layers of the color imagery acquired on both dates analyzed. R squared values for the regression ranged between .86 and .93.

We believe this technique was very successful for site specific determination of soybean yield.

COMPUTER ANALYSIS OF TWO DIMENSIONAL ELECTROPHORESIS GELS

Dr. Lawrence T. Fisher, Program Coordinator

Introduction

An extension of computer methods for analysis of remotely sensed data has provided a method of addressing an important problem in medical image processing. Researchers at the McArdle Laboratory for Cancer Research at UW-Madison were confronted with the need for methods to quantitatively measure concentrations of proteins on two-dimensional electrophoresis gels. Equipment and techniques obtained and developed by the Remote Sensing Group with the support of NASA proved applicable. Although very different in origin, the analysis problem is quite similar to problems encountered in remote sensing and photogrammetry.

Electrophoresis is a relatively new method for separation of proteins in complex organic materials. The process begins with the preparation of a sample of material--liver cells in this case--composed of many proteins, in which some fraction of certain atoms has been replaced with radioisotopes. Both C^{14} and S^{38} have been used as active materials in samples prepared for this project; both are emmitters of Beta particles with energies of around 250 Kev. The sample is placed in a thin capillary and subjected to a strong electric field for several hours. Individual molecules in the sample migrate along the capillary to positions of equilibrium determined by the number of free electrons in molecular outer rings. This process (a "one dimensional electrophoresis") provides a first level of separation. After this, the partially separated sample is removed from the capillary and allowed to settle vertically over a gel, largely under gravitational influence but also driven by electric fields. Separation in this direction is primarily determined by molecular weight.

With two independent mechanisms separating molecules, individual proteins tend to isolate themselves into specific and discreet regions of the final gel. Concentrations of particular proteins can therefore be monitored by observing concentrations of radiation from particular areas.

Visualization of protein concentrations can be accomplished in several ways: chemical staining can be used, producing a papayrus-like material with colored stains. Alternatively, the gel could, in principle, be scanned with very small radiation sensors. The prevailing method, however, is exposure of film. This can be done either by use of an intervening photoemitting material (such as is conventional for most radiographic films), or by direct exposure of films to the radiation emitted by the radioisotopes in the gel. This technique--autoradiography--has been used to produce the images used for analysis in this project.

Figures 16 and 17 are reproductions of two electrophoresis autoradiograms, formed from rat liver cells. Figure 16 is a control sample from normal cells; Figure 17 was produced from hormone-treated cells. These are reduced in size: the original films were approximately 10 x 23 cm.

Analysis Objectives

A glance at Figures 16 and 17 will show that the electrophoresis technique can give repeatable results. There are clearly many spots or proteins which appear in about the same position on both gels. Many of them evidently have about the same size and density on both gels. Some, however, are clearly stronger or weaker on the after-treatment gel than on the control gel, presumably because of effects of the hormone. This sort of subjective observation, of course, is a very limited form of analysis. Quantitative methods were needed; these implied some form of machine-assisted processing.

First, it was essential to be able to measure amounts of protein present in each spot. Second, comparisons of similar spots on different gels were needed: which of these showed greater or less concentrations after treatment, and what were the relative amounts? Third, there had to be a way to effectively overlay corresponding spots on two related gels. Fourth, a means was needed to allow simplified and concise tabulation and documentation of protein quantities and variations of quantities between gels.

Early analysis methods (O'Farrell, 1975) included cutting out and weighing spots from gels to estimate radiation quantities. Comparison of spots on similar gels was done by mechanical overlays and hand prepared tracings.

Approaches to Analysis

Computer analysis was clearly needed to provide analysis with any degree of accuracy. This demanded that images be converted to computer compatible form, which first prompted McArdle Laboratory researchers to seek us out. Prof. Van R. Potter of the Department of Oncology has long had assocaitions with the Institute for Environmental Studies; through these he learned that the Remote Sensing Group made extensive use of a scanning microdensitometer. Our group has also had a large amount of experience in developing and using programs for image analysis and classification. Since some of the display, interaction, and feature-recognition problems inherent in the electrophoresis gel problem were akin to problems in remote sensing, it seemed reasonable to extend and develop programs for this new need.

Measurement of amounts of protein can be accomplished by calculating integrated optical densities of spots, provided care is taken to compensate for film background levels, exposure nonlinearities, and variations in exposure, processing, and scanning. Before the spot integrations can be done, however, it is essential to have methods to locate coordinates of interesting spots. This implies that some sort of interactive computer analysis is required.

An image processing system such as McIDAS (at the U.W. Space Science and Engineering Center) or one of several commercially available systems would have allowed swift generation of a high resolution grey scale image, probably with means to rapidly switch from control to after-hormone gels. Spot positions could easily be marked with joystick-controlled cursors. Such a system, unfortunately, was not available to us, since McIDAS facilities

Figure 16. Control Electrophoresis Autoradiogram (rat liver cells.)

Figure 17. Electrophoresis Autoradiogram of Rat Liver Cells After Hormone Treatment.

were fully committed to the Global Atmospheric Research Project's World Weather Experiment. In the next few months we hope to obtain our own McIDAS terminal, but until then other, cruder, approaches must be used.

A Tektronic Model 4015 graphics terminal was available, connected to the UW-Madison Academic Computer Center (MACC) Univac 1110 computer by a relatively slow transmission line (120 characters/second). This terminal is mainly intended for line vector graphics, but is has a grey scale option which allows relatively good image generation. Good images, however, demand very large amounts of data; this is costly and very time consuming. Therefore, only one-sixteenth of the available resolution is used, resulting in fairly crude images.

Operators can interact with data either by keyboard commands or by use of a position-marking cursor.

Programs were developed to exploit the capabilities of the terminal as well as possible. Replicas of the scanned gels are displayed as crude gray scale images such as Figures 18 and 19. Two different images can be shown simultaneously. These can show all or any part of the scanned data. Small areas can be isolated and enlarged for detailed analysis by pointing the cursor to an area of interest.

Considerable attention was paid to operating efficiency and to creation of a flexible yet simple command structure. Image generating subroutines were produced to optimize character transmission so that images could be created without long transmission delays. Other subroutines were generated to take advantage of cursor reading and vector or symbol generating capabilities. A command language was evolved to allow operators to place the program in any of several different operating modes--display, integration, coordinate transformation, etc.--by simple and logical single letter commands.

Data Conversion. Transformation of film images to computer compatible form was an essential first step. The Optronics, International scanning microdensitometer provided the mechanisms to accomplish this. Density samples are taken at 100 micrometer intervals, yielding 100 samples per square millimeter, far in excess of requirements. These samples (recorded on magnetic tape) are sampled and reformatted to produce mass storage (disk) files at the UW-Madison Academic Computing Center. The data conversion process ordinarily discards three of every four data points, retaining a sample for every 200 micrometers square. Sample values are directly proportional to film density.

A mass storage file format was designed to allow efficient packing and retrieval of data, and a conversion program was developed to translate data from the rather cumbersome magnetic tape format produced by the scanner to the new format. This program also, optionally, produces a line printer picture of the gel which is helpful for approximate location of spots. A histogram of all scanned data can also be printed; this is very useful to help interpreters set display thresholds in the analysis program so that sufficient detail is shown while avoiding slow and unneeded transmission of image data for background areas.

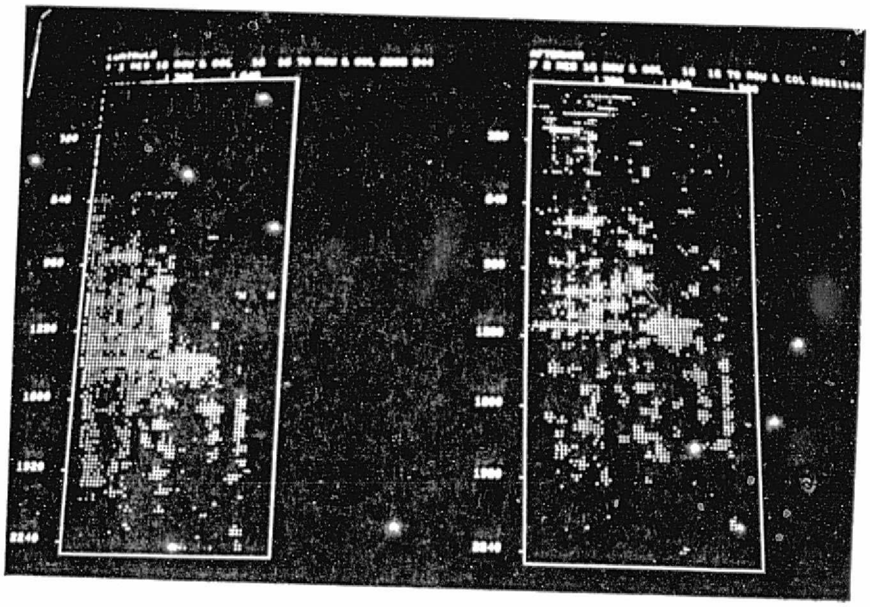

Figure 18. Grey scale display of two scanned electrophoresis gels.

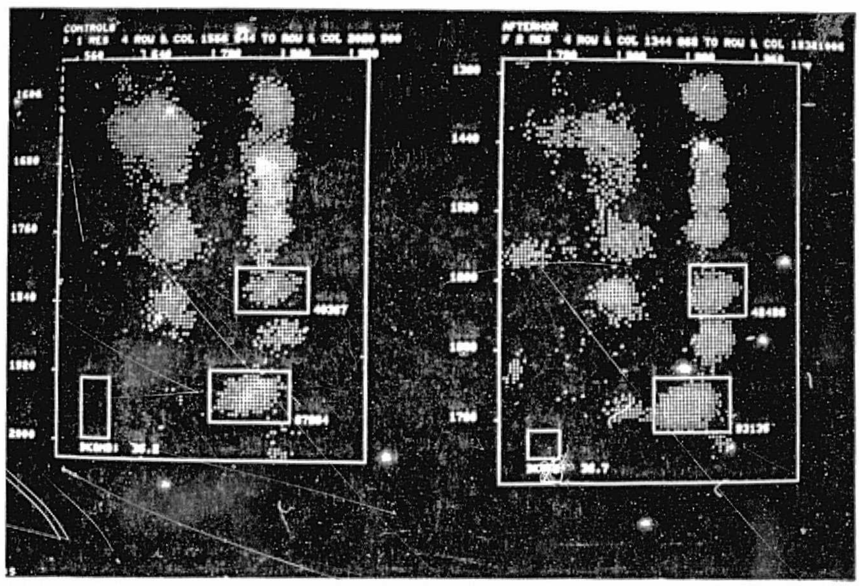

Figure 19. Detailed display of portions of the images displayed in Figure 18. Rectangles and numbers are integrated regions and integration results.

Integration Method. Measurement of protein quantities can be accomplished by measuring the total amount of radiation present in a spot. This must be an integrative process rather than a simple measurement of radiative flux density because a broad but diffuse spot may contain the same amount of protein as a small, dense one. Film exposure is related to flux density but is subject to a number of nonlinearities and error sources which must be considered:

1. Film densities in general are not linear functions of exposing flux. Curves such as Figure 20 generally describe the relationship.

2. Variations in exposure time, temperature, film emulsions, and processing chemicals can all contribute variations which alter the density-flux characteristics.

3. The scanning densitometer nominally produces output values which are directly proportional to film density over a range of three orders of magnitude (or 3D, where D is a base 10 logarithmic measure of amount of transmitted light). However, there will inevitably be some variation in scanner calibration from day to day and the output-density relation will not be precisely linear.

4. Film base materials and emulsions have non-zero density which varies signficantly from film to film, probably due mostly to processing and chemical variations.

Two different integration algorithms are presently being evaluated, differing in the way in which background and fog corrections are made. In one (called "I-Mode" integration), a rectangular region is specified by marking two opposite corners on a displayed image, using the cursor. This rectangle should be selected sufficiently far from the surrounded spot that its border lies in regions of background density. A density correction grid is then calculated using values found along the top, bottom and sides of this rectangle to estimate what background density levels would be present if the spot were not there. Values actually present are corrected by subtracting a background value from the correction grid.

Figure 21 illustrates the procedure. Its advantage is that variations in background level--streaking, for instance--can be eliminated fairly well, and that background correction is automatic.

In some circumstances I-Mode integration is unsuitable. If two spots are close together, density values may not drop to background levels between spots. An abnormally high background grid would result, as illustrated in Figure 22. This would result in overcorrection and thus in improperly low calculations of integrated density. For this circumstance a second integration mode called "J-Mode" is available. Here, a region of the operator's choosing is processed to obtain a background value. This region is generally selected in a spot-free region near spots of interest so that its average value is likely to be representative of backgrounds around the spots themselves.

A new technique is being explored to cope with nonlinear film density versus flux characteristics. Small tablets of C^{14} material of carefully controlled

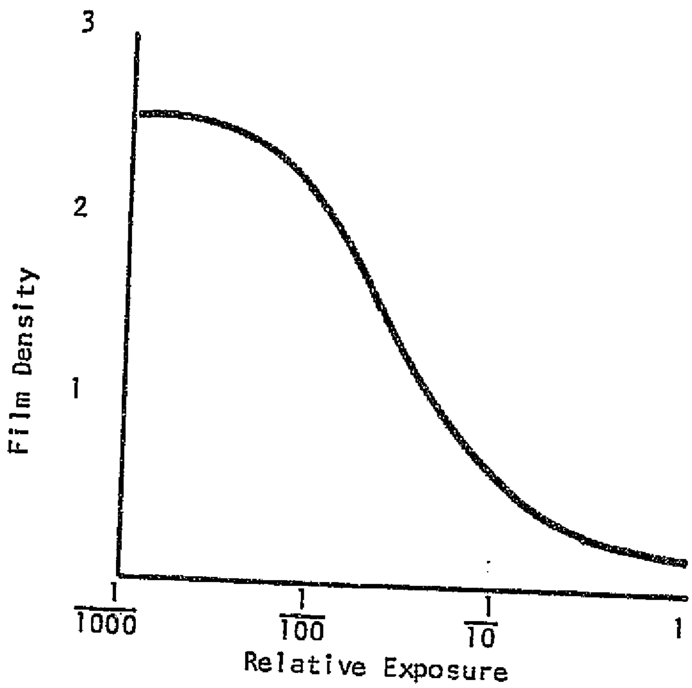

Figure 20. Typical density-exposure characteristics for films.

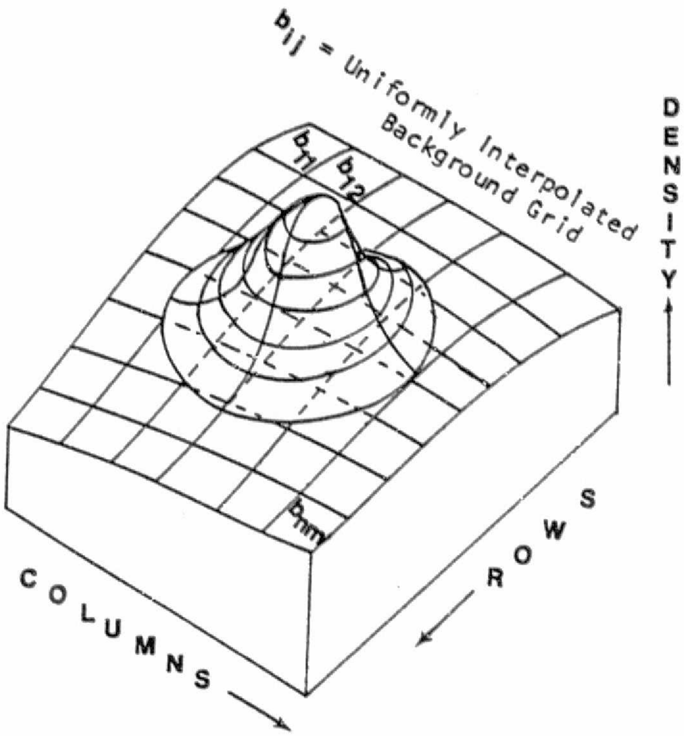

Figure 21. Generation of background correction grid for spot integration ("I - Mode").

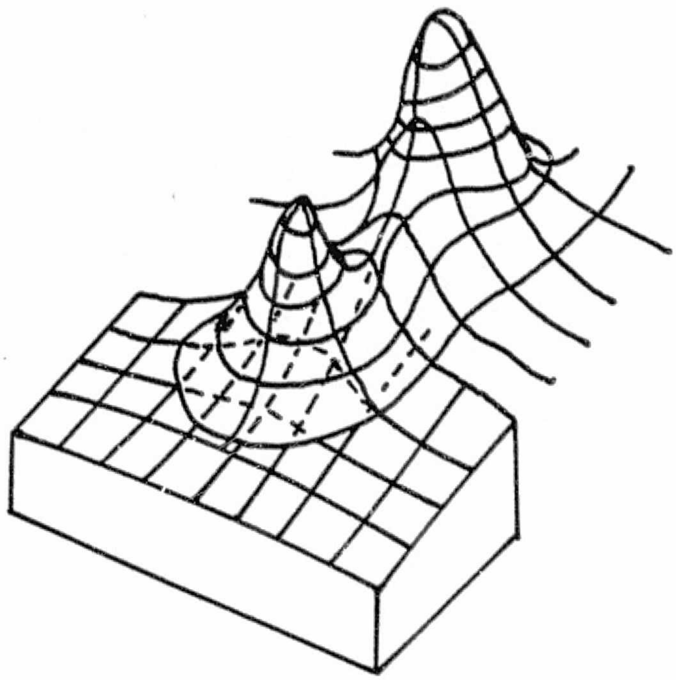

Figure 22. Improper distortion of background grid caused by nearby spots.

concentrations have been prepared. Four of these tablets, with relative concentrations of 1, 2, 4 and 8 (referenced to an arbitrary scale) units of radiation will be placed next to films while they are being exposed to the original gels. Film densities will be sampled in these calibration regions to produce a table in main memory relating film density to radiation content. It is hoped that this technique can compensate for exposure and processing variations.

Figure 23 shows some preliminary results relating film density (as sensed by the scanning densitometer) to concentration of C^{14} in the calibration standards, using film exposure times of from three to eight days.

Geometric variations between gels are sufficiently great that some form of coordinate transformation is required to relate positions on one gel to those on another. The problem is very closely related to standard coordinate transformations encountered in photogrammetry and cartography, and solutions to those problems are applicable here.

When performing coordinate transformations on photographs, it can usually be assumed that the two images differ only by offsets, rotations and scale differences. All of these differences are linear, and can be modelled by an affine transformation of the form

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

where x and y are coordinates on one image, u and v are coordinates on the other, and the a_{ij}'s and b_i 's are constants. The a_{ij}'s and b_i 's can be calculated by standard regression methods incorporating least-squares adjustments provided three or more common points are known.

Distortions affecting electrophoresis gels are likely to be very nonlinear. Gel thicknesses may be nonuniform. Viscosities of gels may differ. Temperature changes, variations in electric field potential, or any number of variables may induce slight but significant variations. Thus, if one gel were to be truly mapped to the same coordinates used on another, the mapping function would of necessity be a complex nonlinear warping function. This would be hard to model and would also require knowledge of a large number of common points to satisfy all of the variables in the mapping function. However, linearity can reasonably be assumed in a small region, as shown in Figure 24. Therefore provision is made in the program to select three or more common match points from displays of portions of two films, and a least-squares adjustment is performed to fit an affine transformation to that region.

The mapping function is always used by internal bookkeeping procedures in the program to relate positions on the after-treatment image to those on the "navigation test" feature of the program to evaluate mapping accuracy. This calculates the estimated position on one image from any specified cursor position, and plots a small cross at the new point. If mapping accuracy is not suitable, new match points can be entered at any time.

Outputs. Permanent recorded output was considered essential to supplement the interactive displays. Therefore (unless rejected by an operator's option), a

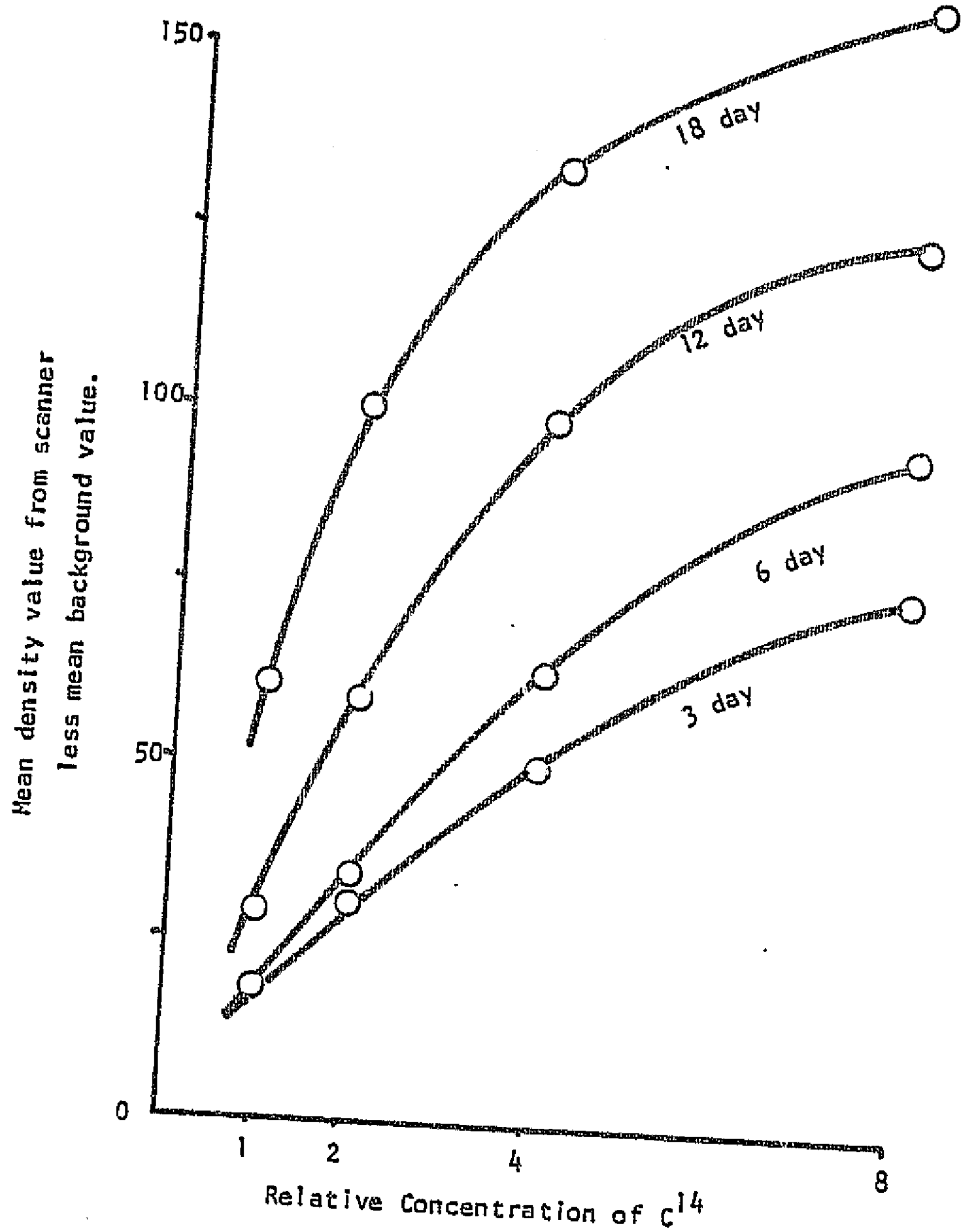

Figure 23. Film densities resulting from C^{14} standard samples exposed for 3, 6, 12, and 18 days.

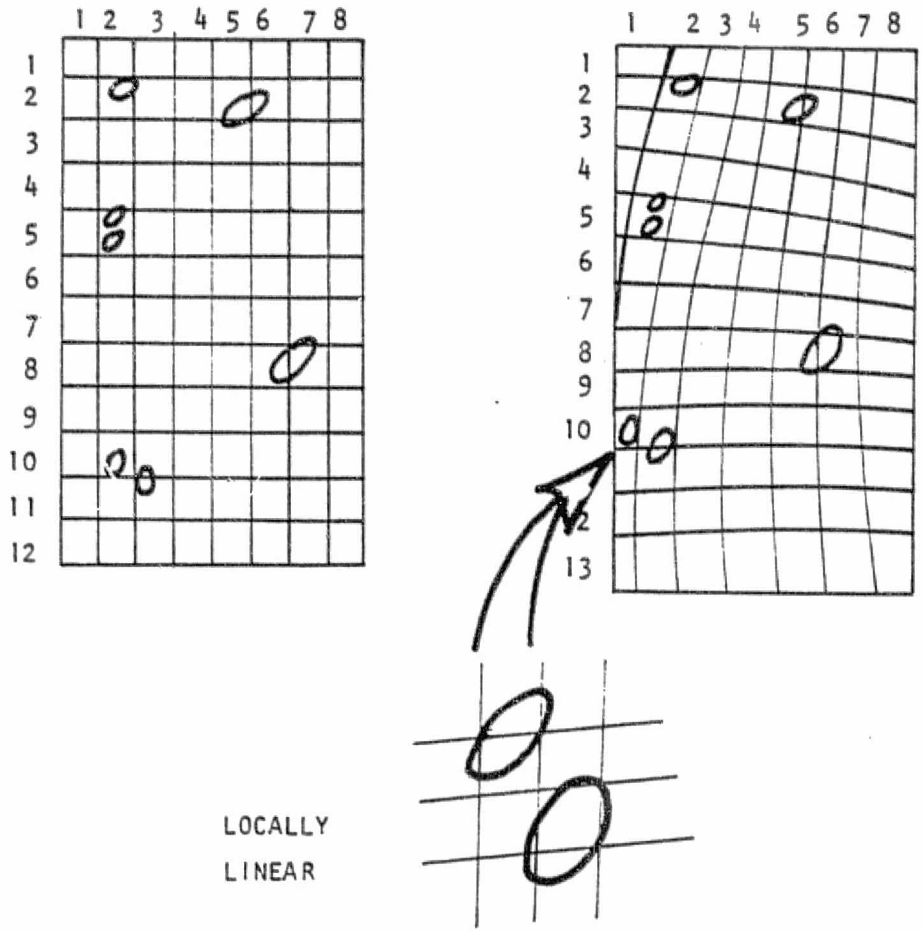

Figure 24. Hypothetically non-linear coordinate relationships approximated locally by Affine models.

printed output file is produced as operation progresses. Line printer output is physically generated at the end of an interpretation session. It lists all commands given to the program, replicates images which were displayed, identifies all match points which were specified, and summarizes tests of the mapping function. When integration is done, specified rectangles are entered in the printer version of the image as well.

Results of integrations are maintained in the computer's main memory as long as an evaluation session lasts. Positions of rectangles as well as calculated integrals are stored. In addition, a coarse location for each spot is calculated in the following way: a grid of approximately 40 columns by 60 rows is effectively laid over the control image; each cell in the grid is 4 mm square. If an integration is done on the control image, the center of the specified rectangle is used to directly calculate a grid zone for the spot. If an integration is done on the after-treatment image, its center position is mapped by the mapping function in effect at that time to produce an estimated corresponding position on the control side. This position is used to determine a zone position for the integral.

When the program terminates, all integrals are sorted by their zones and printed. A tabulation of the entire zone map is also produced.

Most gels are too complex to process in a single interpretation session. Therefore interpreters may store integration results from a session on a small cataloged-and-saved mass-storage file. When recalled as another session begins, these integrals are read back into main memory, and processing can continue from there. Another small program is planned which will allow editing of information in this file to adjust zone locations, delete redundant points, etc. This program will be developed in the next few months.

Future Development

Researchers from McArdle Laboratories are now being trained to operate the analysis programs, and their reaction to the method has been favorable. It is expected that several sets of gels will be prepared in the next few months, and that use of the procedure will be fairly heavy.

Prospects are good that other users can be found, either within the University or at other institutions in the Midwest. We intend to seek outside funding to continue development of this work.

LOWER ST. CROIX RIVER STUDY, USER/RESOURCE CONDITIONS

Professors Robert H. Becker, Ralph W. Kiefer, Bernard J. Niemann, Jr., and Frank L. Scarpace

Funded by the Minnesota-Wisconsin Boundary Commission, the Minnesota Department of Natural Resources and the Wisconsin Department of Natural Resources, this project was designed to study the Lower St. Croix River to determine best management for its recreational use.

Objectives were to review relevant research, develop and refine user surveys, develop and validate a resource survey and monitoring program, and to develop management alternatives.

Remote Sensing was a part of a large, coordinated effort. 35 mm imagery was acquired with two motorized Nikon F, 250 exposure cameras. In conjunction with user surveys, photos were used to compare user perceptions of river use with actual use. Thirty nine low-altitude flights were made in 1977 between May 31 and September 5.

Photos were analyzed to indicate numbers of boats on the river, activities and destinations of boats, relation of water level to boating use, and to provide a summary of the resources present along the river during the recreational season.

When conclusions from this study were submitted to the Minnesota-Wisconsin Boundary Commission, they were received with strong support. Management practices based on the study are being carried out. Commission members accept this application of aerial photographs as an important tool when used in conjunction with such a survey.

A similar study, funded by the Corps of Engineers, is being made in 1979 for an adjacent section of the Mississippi River.

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Fisher, L.T., F.L. Scarpace, and R. Thomsen. Multidate Landsat lake quality monitoring program. Photogrammetric Engineering and Remote Sensing. Accepted for publication.

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O'Farrell, P. 1975. High resolution two-dimensional electrophoresis of proteins. J. Biol. Chem. 250, No. 10.

Scarpace, F.L., K. Holmquist, and L. Fisher. Landsat analysis of lake quality for statewide lake classification. Photogrammetric Engineering and Remote Sensing. Accepted for publication.

Wynn, S.L. and R. W. Kiefer. 1978. Color and color infrared 70 mm aerial photography as a monitoring tool for assessing vegetation changes in a large freshwater wetland. Proceedings of the 7th. Annual Remote Sensing of Earth Resources Conference. Tullahoma, Tennessee.

V. SUMMARY OF PROJECT ACTIVITY

PROJECTS CONDUCTED WITH GRANT FUNDS

PROJECTS	DATES	ACTION/DECISION
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES: Medium-altitude black and white, color and color infrared aerial photographs of plumes of sediment in Lake Mendota were acquired and analyzed, along with extensive ground data on the sources, mixing, chemistry, and concentrations of sediments to assess the utility of remote sensing for measuring and monitoring this kind of pollutant.	1976-79	In progress; early analysis indicates limited application
ATMOSPHERIC CORRECTIONS FOR SATELLITE IMAGERY: Simultaneous low-altitude and Landsat imagery will be related to determine a means of correcting satellite imagery for atmospheric effects.	1976-78	In progress; several attempts have not yet produced needed data.
POSITION DETERMINATIONS FOR REMOTE SENSING WITH THE HASSELBLAD 500 EL/M: Tests were made to determine if the camera could be calibrated for low order position determination.	1977	Limited use for low-order position determination is possible.
COMPUTER PROGRAM DEVELOPMENT: Software for digital analysis of data from a scanning densitometer, thermal scanner, or Landsat have been developed. Conversion to a color terminal and self-contained computer is now contemplated.	1977-78	Conversion of programs will start in 1979.
CONVERSION OF THERMAL SCANNER TO DIGITAL OUTPUT: The RS-18A thermal scanner is modified to allow direct conversion of output to digital form.	1978-79	Scanner operational in spring 1979. Reliability and simplicity improved.
SURVEY OF USE OF REMOTE SENSING BY ENVIRONMENTAL REGULATORY AGENCIES AND INTERESTED GROUPS. Queried 500 persons in Federal, State, regional, and private agencies on possible uses of remote sensing in their concerns.	1978	Results reported in student thesis.

ASSOCIATED PROJECTS

These projects share technology with the NASA project, but are funded from other sources.

PROJECT	DATES	FUNDING AGENCY	ACTION/DECISION
REMOTE SENSING APPLIED TO THE IDENTIFICATION OF WETLANDS VEGETATION: Medium altitude, color infrared imagery used to detect changes in communities of vegetation in a wetland next to an electrical generating station.	1975-78	E.P.A.	Recommended as a tool for monitoring wetlands.
REMOTE SENSING APPLIED TO THE MEASUREMENT OF FISH HABITAT: Medium altitude, color infrared imagery used to identify and measure the areas suitable for fish habitat on a stretch of the Wisconsin River.	1978	E.P.A.	Recommended as a tool for assessing fish habitat.
MAPPING OF VEGETATION TYPES IN SHEBOYGAN MARSH: From high-altitude color infrared imagery (1:120,000) maps of the vegetation types in a wetland are being prepared, and compared with field data.	1977-78	U.W.	Technical paper will present this method, with limitations for operational use.
CLASSIFICATION OF INLAND LAKES FROM LANDSAT: Wisconsin DNR with cooperation from University researchers, proposed statewide program to classify lakes by trophic status. Small part of program now funded by NASA through GSFC.	1976-79	NASA-GSFC	Small start made; full program uncertain.
TROPHIC CLASSIFICATION OF TVA RESERVOIRS: Landsat imagery used to determine trophic class of TVA reservoirs.	1978	TVA	Technique under consideration by TVA for regular use.
CROP YIELD STUDY: Low altitude imagery analyzed to assess the relationship of soybean yield to measurements of film density, in connection with a larger study by Argonne National Laboratory.	1977-78	Argonne National Laboratory	This type of imagery shows great promise in crop yield measurement.

PROJECT	DATES	FUNDING AGENCY	ACTION/DECISION
ANALYSIS OF AUTORADIOGRAMS OF ELECTROPHORESIS GELS: Digital film analysis is used to analyze films produced by radiation from sections of livers of rats to determine molecular structure of protein in the organ, as part of research on cancer.	1978-79	McArdle Laboratory, NIH	Technique now being appraised.
TRAINING OF ENERGY LOSS AUDITORS: This energy extension service of the U.W. made use of the thermal scanner and personnel trained in its use to train persons in the understanding of radiative heat transfer and the value of insulation materials.	1978	U.W. Extension	Program being imitated in other areas of the state.

PROJECTS LISTED BY COOPERATING AGENCY

Federal

U.S. Geological Survey
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES

Tennessee Valley Authority
ATMOSPHERIC CORRECTIONS FOR SATELLITE IMAGERY
TROPHIC CLASSIFICATION OF TVA RESERVOIRS

Environmental Protection Agency
REMOTE SENSING APPLIED TO THE IDENTIFICATION OF WETLANDS VEGETATION
REMOTE SENSING APPLIED TO THE MEASUREMENT OF FISH HABITAT

NASA - Goddard Space Flight Center
CLASSIFICATION OF LAKES FROM LANDSAT

Argonne National Laboratory
CROP YIELD STUDY

National Institutes of Health
ANALYSIS OF AUTORADIOGRAMS OF ELECTROPHORESIS GELS

State

Wisconsin Department of Natural Resources
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES
ATMOSPHERIC CORRECTIONS FOR SATELLITE IMAGERY
REMOTE SENSING APPLIED TO THE IDENTIFICATION OF WETLANDS VEGETATION
REMOTE SENSING APPLIED TO THE MEASUREMENT OF FISH HABITAT
MAPPING OF VEGETATION TYPES IN THE SHEBOYGAN MARSH
CLASSIFICATION OF LAKES FROM LANDSAT

Wisconsin Geological Survey
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES

Regional

Southeast Wisconsin Regional Planning Commission
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES

Dane County Planning Commission
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES

Local

City of Middleton
REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES

PROJECTS LISTED BY SOURCE OF IMAGERY

Landsat Imagery

REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES
ATMOSPHERIC CORRECTIONS FOR SATELLITE IMAGERY
MAPPING OF VEGETATION IN SHEBOYGAN MARSH
CLASSIFICATION OF LAKES FROM LANDSAT
TROPHIC CLASSIFICATION OF TVA RESERVOIRS

High Altitude Imagery

MAPPING OF VEGETATION TYPES IN SHEBOYGAN MARSH

Medium Altitude Imagery

REMOTE SENSING OF SEDIMENTS AND ASSOCIATED NON-POINT SOURCE POLLUTANTS IN LAKES
POSITION DETERMINATIONS FOR REMOTE SENSING WITH THE HASSELBLAD 500EL/M
REMOTE SENSING APPLIED TO THE IDENTIFICATION OF WETLANDS VEGETATION
REMOTE SENSING APPLIED TO THE MEASUREMENT OF FISH HABITAT

Low Altitude Imagery

ATMOSPHERIC CORRECTIONS FOR SATELLITE IMAGERY
CROP YIELD STUDY

OTHER FUNDING RECEIVED

Other funding received, related to the capabilities generated by this grant. These amounts are not auditable, since in some cases they represent portions of larger grants based upon our estimate of the cost of that part related to remote sensing.

Federal Agencies

U.S. Environmental Protection Agency	$42,000
Tennessee Valley Authority	$ 5,000
Argonne National Laboratory	$ 5,000
National Institutes of Health	$ 5,000

State Agencies

University of Wisconsin-Madison	$ 7,800
Wisconsin Department of Natural Resources	$ 3,500

COMMERCIAL SPIN-OFF FROM THIS RESEARCH PROJECT

Contracts are being let for acquisition of black and white aerial imagery. 1:20,000 scale in 1978 and 1979 under the Department of Administration-State Planning Office. Wetlands will also be recorded through color infrared imagery. The program is entitled the "Wisconsin Unified Aerial Photographic Acquisition." Private contracts will total $167,000 for this program. Decisions leading to this program were either influenced by, or illucidated by the remote sensing project at the University of Wisconsin.

EDUCATIONAL ACTIVITIES

Briefing for the Wisconsin Department of Natural Resources, with staff members from Goddard Space Flight Center, on possibilities of a program for classification of Wisconsin Lakes from digitized Landsat imagery held in the fall, 1977.

Professor Kiefer participated in planning for remote sensing activities for all State agencies, as a member of the State of Wisconsin Interagency Wetlands Mapping Advisory Committee.

EDUCATIONAL ACTIVITIES (Cont.)

Remote sensing courses offered on campus and number of students enrolled.

Course Number	Credits	Course Name	Frequency of Offering	Typical Enrollment per time offered	Typical Number enrolled/year
CEE/IES-552	3	Remote Sensing of the Environment	Twice/year	45	90
CEE 554	3	Fundamentals of Remote Sensing	Once/year	15	15
CEE 555	3	Airphoto Interpretation	Twice/year	25	50
IES/CEE/LA 556	3	Remote Sensing Image Interpretation	Twice/year	15	30
CEE 659	3	Remote Sensing Data Analysis	Once/year	15	15
IES 655	3	Environmental Monitoring Practicuum	Alternate years	20	10
IES 656	3	Environmental Monitoring Practicuum	Alternate years	20	10
IES/CEE 920	3	Environmental Monitoring Seminar	Twice/year	15	30
CEE 351	3	Photogrammetry for Non-Engrs.	Once/year	30	30
CEE 356	3	Photogrammetry	Twice/year	30	60

NOTES: 1. Numerous courses dealing with advanced photogrammetry, surveying and cartography are also offered.

2. M.S. and Ph.D. degrees with an emphasis in Remote Sensing can be earned in either the Department of Civil and Environmental Engineering or the interdisciplinary Environmental Monitoring Program.

Faculty and research assistants involved in this program:

1977	7 faculty	7 research assistants
1978	7 faculty	6 research assistants

AGENCY CONTACTS:

Federal

U.S.G.S. - Water Resources Division, Wisconsin
Warren Giebert, Staff Scientist

E.P.A. - National Environmental Research Laboratory - Duluth
Dr. Gary Glass, Research Chemist

State of Wisconsin

Department of Natural Resources
John M. Cain, Chief, Water Quality Planning Section
John G. Konrad, Chief, Special Studies Section
Jerome R. McKersie, Chief, Water Quality Evaluation Section
Francis Schraufnagel, Chief, Water Quality Division

Department of Administration
Allen H. Miller, Chief, State Planning Bureau

Wisconsin Geological Survey
Meredith Ostrom, State Geologist
Arthur Ziegler, State Cartographer

TRAFFIC TO THE REMOTE SENSING GROUP

Requests for imagery - Landsat, high or low altitude	50 per year
Requests for aid in interpreting imagery	15 per year
Contacts by citizens seeking applications of remote sensing	10 per year
Contacts by state and regional agencies for applications of remote sensing	15 per year
Contacts by students or faculty for application of remote sensing to other research or courses	40 per year

GRADUATES OF THIS PROGRAM:

R. Steven Fratoni, Planner, Natural Resource Data Management Study, New England Water Basins Commission, Boston, Mass

GRADUATES (Cont.)

Kenneth Holmquist, Remote Sensing and Photogrammetry Section, Tennessee Valley Authority

Warren Buchanan, Wisconsin Department of Natural Resources, Madison, WI

James Nettum, Consulting Engineer, R.W. Beck and Assoc., Seattle, Washington

VI. PUBLICATIONS EMERGING FROM THIS PROJECT

Adams, M.S., F.L. Scarpace, J.P. Scherz, and W.J. Woelkerling. Assessment of aquatic environment by remote sensing. Univ. of Wisconsin Institute for Environmental Studies Report No. 84. 1977. 235 p.

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Green, T., J. Hoopes, F. Scarpace, J. Villemonte, and R. Madding. Measuring effluent plumes. Proc. of the ASCE Conference on Hydraulic Research. Aug. 1978.

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Morgan, K.M., G.B. Lee, R.W. Kiefer, T.C. Daniel, G.D. Bubenzer, and J.T. Murdock. Prediction of soil loss on cropland with remote sensing. J. of Soil and Water Conser. November-December 1978.

Morris-Jones, D.R., and R.W. Kiefer. Application of remote sensing to estimating soil erosion potential. Proc. of the 7th Annual Remote Sensing of Earth Resources Conference. Tullahoma, Tenn., March 1978.

Morris-Jones, D.R., K.M. Morgan, and R.W. Kiefer. Remote sensing as a tool for estimating soil erosion potential. Proc. of Canadian Remote Sensing Conference, Vancouver, British Columbia, August 1978.

Scarpace, F., L. Fisher, and K. Holmquist. Landsat analysis of lake quality for statewide lake classification. Proceedings of the Spring Convention of the American Society of Photogrammetry, March 1978.

Wynn, S.L., and R.W. Kiefer. Monitoring vegetation changes in a large impacted wetland using quantitative field data and quantitative remote sensing data. Proc. of the 4th Joint Conference on Sensing of Environmental Pollutants. New Orlenas, LA. November 1977.

Wynn, S.L., and R.W. Kiefer. Color and color infrared 70 mm aerial photography as a monitoring tool for assessing vegetation changes in a large freshwater wetland. Proc. of the 7th Annual Remote Sensing of Earth Resources Conference. Tullahoma, Tenn., March 1978.

APPENDIX I

CHAPTER II OF THIS THESIS

APPLICATIONS OF DIGITIZED FILM ANALYSIS AND PERCEPTIONS OF POSSIBLE USERS

BY

WARREN J. BUCHANAN, JR.

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

(Land Resources)

at the

UNIVERSITY OF WISCONSIN-MADISON

1978

ABSTRACT

A questionnaire was mailed to 484 resource managers and surveyors thought to be actively involved in resource inventory and monitoring. The purpose was to survey possible user perceptions as to inventory problems and practices, use and awareness of remote sensing, and interest in digitized film analysis.

The response rate was 37%. General mapping surveys were most common; although quantification of resources also attracted a moderate amount of interest. Expense, labor intensity, and lack of time were the most common inventory problems.

Dititized film analysis was employed in 5% to 14% of resource inventories. Use and awareness of digitized film analysis was considerably less than that of manual air photo interpretation, ground surveys, or Landsat data. Perceived advantages of digitized film analysis were linked mainly to efficiency of data gathering and manipulation. Disadvantages included expensiveness and inaccuracy.

The thought that digitized film analysis is suffering through a time lag between development and acceptance is supported by data showing low awareness of this technique. The attributes wherefrom digitized film analysis may provide advantages over other inventory techniques, namely resource quantification, efficiencies of time and labor, and data manipulation, are of interest to a sizeable portion of the survey audience. However, until these advantages are repeatedly verified, demonstrated, and documented, the growth of this technology will probably be gradual at best. Problems such as unfamiliarity or inaccessibility can be overcome simply by increasing awareness of existing facilities. The acceptance of digitized film analysis will always be hindered by its perceived disadvantages: expense and inaccuracy.

I. INTRODUCTION

The preceding chapter presented the results of investigating several applied aspects of digitized film analysis as a resource inventory tool. However, the discussion of this technology would not be complete without addressing its potential as perceived by potential users: those who administer and perform resource inventories.

Remote sensing has often been "accused" of being a strictly research-oriented technology, with little relevance to operational needs (White 1977). However, descriptions of resource inventory and management needs and practices (Amir 1976, Garlauskas 1975, Leopold et al. 1971, and Mitnick and Weiss 1974) seem consistent with some of the described capabilities of remote sensing, particularly digitized film analysis (Boyer 1973, Carneggie 1969, Cooper 1964, Cummings and Jayroe 1973, Dirschl and Dabbs 1972, Heyland 1972, Joyce and Higer 1973, and Yost and Wenderoth 1971). It appears that digitized film analysis could be an appropriate technology for resource inventory and monitoring, but may be suffering through a time lag between development and general acceptance by some user community.

The reasons for this lag are essentially unknown. White (1977) suggests several possibilities:

1) the capabilities of remote sensing have been overstated and oversold;

2) the capabilities of remote sensing are unknown or unappreciated;

3) the best applications of remote sensing have not been fully developed yet;

4) users tend to stick to traditional technologies and resist new ones; or,

5) sophisticated remote sensing techniques are expensive substitutes for traditional inventory methods.

This portion of the study was intended to determine which of the above factors indeed hindered the acceptance and application of digitized film analysis. A questionnaire was mailed to 484 resource managers and surveyors thought to be actively involved in resource inventory and monitoring. The recipients were fairly evenly divided among federal, state, and private agencies.

Aside from asking why remote sensing might not be used, several questions were directed toward actual users to determine what advantages were enjoyed with remote sensing, what are good applications, and what are the disadvantages.

II. METHODS

Two main considerations in sending out the survey were:

1) in what form should the questions be asked, and

2) to whom should the questions be directed.

Although only one previous survey was found with any similarity to the present effort (Center for Development Technology 1976), the methods and coverage of this earlier survey were quite different. The earlier survey consisted of personal interviews with known remote sensing users in a five-state midwestern region and stressed the use of Landsat. The present survey used a standard questionnaire mailed to resource managers and surveyors nationwide without prior knowledge as to their use of remote sensing.

A. Questionnaire

The format of the questionnaire was styled according to the advice of the Center for Survey Research at the University of Wisconsin, Madison (Harry Sharp, personal communication, March 1978). This format emphasized well-spaced lines and answers that could be simply checked off to facilitate response (Figure 13, page 34). The questions were purposely limited to both sides of a single page so the survey would appear brief. A cover letter explained the reasons for the survey and introduced the basics of digitized film analysis. A stamped, self-addressed return envelope was also enclosed to encourage responses.

The content of the survey reflects the collaboration of several EMDAG personnel. Both general questions on inventory needs, procedures, and problems, and more specific questions on digitized film analysis are included.

The first few questions are intended to determine the nature of the respondents' inventory practices and needs. The remaining questions are meant to discover respondents' perceptions of remote sensing as an inventory tool Specifically, these questions deal with user awareness of various remote sensing technologies, applications, perceived advantages and disadvantages. The reasons remote sensing is not used are addressed. The survey questions whether non-use stems from lack of expertise, costliness, inaccessability, inappropriateness, or traditional resistance.

B. Recipients

The list of 484 recipients comprised federal and state public agencies, private non-profit conservation groups, and for-profit environmental consulting firms. The National Wildlife Federation's Conservation Directory (Decker 1977) was the source for all addresses of the public agencies and most of the non-profit conservation groups. The remaining addresses were taken from a computer listing of environmental consulting firms by the U.S. Army Corps of Engineers (1977).

The numbers of recipients were fairly evenly divided among these four groupings. All federal agencies and national conservation groups that seemed to possibly conduct natural resource inventories were included in the survey. Half of the states were sampled by splitting the nation into six regions and alphabetically selecting half the states in each region. Consulting firms were selected on the basis of having a relatively large contract load and staff of environmental scientists. Addresses were generally not specific individuals but were usually offices because it was thought that offices were less transient than people.

C. Data Handling

Because of the survey format and the nature of the questions, the results are handled by simply tallying the responses in each category. Data are summarized in terms of respondents' resources available to meet these needs. An overall tally is also compiled.

It is recognized that further dividing the respondents by discipline, such as foresters, range managers, cartographers, etc., would have provided interesting and worthwhile details; however, the respondents' identities were seldom so distinct.

III. RESULTS AND DISCUSSION

A. Level of Response

Of the 484 surveys sent, 177 were returned after five weeks for a response rate of 37%. Surprisingly, the state agencies responded at a rate of 51%, slightly better than the 37% response from federal agencies. Consulting firms and conservation groups had paltry return rates of 25% and 13%, respectively. It was expected that the public agencies would feel more obliged to respond than private organizations, but the magnitude of the difference was unexpected.

In real numbers, 177 state agencies were contacted and 90 responded; 156 federal agencies received questionnaires and 57 returned them; 20 out of 79 consulting firms responded; while 10 of the 75 non-profit conservation groups replied. The latter two cohorts probably are sized insufficiently to lend much strength to any inferences which may be drawn from the data. Perhaps the low level of response in itself suggests that interest in remote sensing, including digitized film analysis, is not rampant among these entities.

Of the 177 respondents, 13 replied that they did not conduct resource surveys and, as requested, returned the questionnaire without further response. This leaves essentially 164 respondents who actually might employ remote sensing techniques.

B. Responses to the Questionnaire

Tables 1 to 13 present the tallies for each response as divided among federal agencies, state agencies, consultants, private conservation groups, and overall totals respectively.

1. Types of Resource Surveys

Overall, land resource mapping surveys are the most common sort (73% of respondents), while 46% perform water resource mapping surveys. Wetland inventories (52%) and forest inventories (55%) are more often performed than water resource surveys (Table 1). Relatively few of the respondents are involved in cropland inventory (30%) or stress detection (21%).

The breakdown of resource survey types among federal agencies, state agencies, and conservation groups proportionally followed the overall tallies fairly closely. Consulting firms are generally involved in more types of surveys. Generally, quantitative surveys were less numerous than mapping surveys.

2. Resource Inventory Techniques

As stated in the first chapter, on-site ground surveys and manual photo interpretation are the traditional and most common inventory techniques. This was amply illustrated by the questionnaire returns with those two responses being over twice as frequent as any other response except for literature reviews (Table 2). Somewhat surprisingly, more surveys employ satellite data (45%) than those that contact landowners for survey information (37%). Besides satellite data and manual photo interpretation, other remote sensing are used relatively seldom. Slightly more than 26% of respondents use multi-spectral scanners (some of which may be redundant with Landsat responses), while about 14% of respondents use thermal scanners

Table 1. Types of resource inventories performed (number/percent responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
land resource mapping	38 70.4	57 69.5	19 95.0	5 62.5	119 72.6
land resource quantification	34 63.0	44 53.7	16 80.0	3 37.5	97 59.1
water resource mapping	28 51.9	34 41.5	11 55.0	2 25.0	76 46.3
water resource quantification	22 40.7	34 41.5	10 50.0	6 75.0	72 43.9
wetland inventory	29 53.7	39 47.6	15 75.0	3 37.5	86 52.4
forest inventory	33 61.1	43 52.4	11 55.0	3 37.5	90 54.9
cropland inventory	18 33.3	21 25.6	9 45.0	2 25.0	49 29.9
stress detection	11 20.4	17 20.7	5 25.0	1 12.5	34 20.7
none	3 5.6	8 9.8	0 0.0	2 25.0	13 7.9

others: buildings, recreation facilities, rangeland mapping, natural areas, climatology, geologic faults.

Table 2. Resource inventory techniques used (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
on-site ground surveys	54 100.0	74 90.2	17 85.0	4 50.0	149 90.9
landowner surveys	18 33.3	34 41.5	7 35.0	1 12.5	61 37.2
manual photo interpretation	51 94.4	65 79.3	17 85.0	5 62.5	138 84.1
digitized film	10 18.5	10 12.2	2 10.0	1 12.5	23 14.0
satellite data	24 44.4	34 41.5	12 60.0	3 37.5	73 44.5
multi-spectral scanner	19 35.2	18 22.0	5 25.0	1 12.5	43 26.2
thermal scanner	12 22.2	7 8.5	4 20.0	1 12.5	24 14.6
literature review	27 50.0	49 59.8	16 80.0	4 50.0	96 58.5
none	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0

others: aerial surveys, digitizer table

Table 3. Surveys done in-house, by contract, or both (number/percentage response).

	federal agencies	state agencies	consulting firms	conservation groups	overall
in-house	20 37.0	43 52.4	12 60.0	2 25.0	77 47.0
contract	2 3.7	1 1.2	0 0.0	1 12.5	4 2.4
both	32 59.3	38 46.3	8 40.0	5 62.5	83 50.6

Table 4. Problems fulfilling inventory needs (number/percentage response).

	federal agencies	state agencies	consulting firms	conservation groups	overall
expense	36 66.7	65 79.3	10 50.0	6 75.0	117 71.3
labor intensity	26 48.1	35 42.7	8 40.0	1 12.5	70 42.7
inaccuracies	18 33.3	24 29.3	5 25.0	1 12.5	48 29.3
storing and retrieving data	18 33.3	26 31.7	5 25.0	1 12.5	50 30.5
overlaying data	11 20.4	16 19.5	2 10.0	1 12.5	30 18.3
access to study areas	11 20.4	10 12.2	2 10.0	1 12.5	24 14.6
lack of expertise	12 22.2	17 20.7	1 5.0	0 0.0	30 18.3
lack of time	23 42.6	35 42.7	7 35.0	2 25.0	67 40.9
orientation on ground	3 5.6	8 9.8	0 0.0	1 12.5	12 7.3
none	3 5.6	6 7.3	3 15.0	1 12.5	13 7.9

others: identifying needs, adequate technology, lack of photo coverage, coordination, no computer, historical data.

Table 5. Inventory techniques commonly associated with remote sensing (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
LANDSAT	54 100.0	78 95.1	19 95.0	6 75.0	157 95.7
aerial photography	49 90.7	64 78.0	17 85.0	7 87.5	136 82.9
thermal scanner	35 64.8	54 65.9	16 80.0	6 75.0	111 67.7
multi-spectral scanner	40 74.1	52 63.4	15 75.0	5 62.5	112 67.7
digitized film	20 37.0	23 28.0	7 35.0	2 25.0	52 31.7
on-site photography	13 24.1	20 24.4	9 45.0	2 25.0	45 27.4
x-ray	11 20.4	15 18.3	5 25.0	2 25.0	33 20.1
radar	28 51.9	32 39.0	12 60.0	3 37.5	74 45.1
photogrammetry	30 55.6	38 46.3	9 45.0	2 25.0	79 48.2

others: passive microwave, radio-telemetry

Table 6. Awareness of applications of remote sensing (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
land resource mapping	54 100.0	80 97.6	20 100.0	7 87.5	161 98.2
land resource quantification	39 72.2	59 72.0	20 100.0	7 87.5	125 76.2
water resource mapping	50 92.6	68 82.9	20 100.0	6 75.0	144 87.8
water resource quantification	39 72.2	50 61.0	20 100.0	6 75.0	115 70.1
wetland inventory	45 83.3	68 82.9	20 100.0	7 87.5	140 85.4
forest inventory	49 90.7	76 92.7	20 100.0	7 87.5	152 92.7
cropland inventory	46 85.2	68 82.9	20 100.0	7 87.5	141 86.0
stress detection	38 70.4	47 57.3	16 80.0	5 62.5	106 64.6
none	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0

others: archeological sites, wildlife census, fire control, rangeland production climatology

Table 7. Interest in applications of remote sensing (number/percentage responsés).

	federal agencies	state agencies	consulting firms	conservation groups	overall
land resource mapping	42 77.8	65 79.3	17 85.0	4 50.0	128 78.0
land resource quantification	37 68.5	49 59.8	14 70.0	4 50.0	104 63.4
water resource mapping	34 63.0	46 56.1	9 45.0	4 50.0	93 56.7
water resource quantification	35 64.8	43 52.4	13 65.0	6 75.0	97 59.1
wetland inventory	33 61.1	47 57.3	15 75.0	3 37.5	98 59.7
forest inventory	38 70.4	58 70.7	14 70.0	3 37.5	113 68.9
cropland inventory	23 42.6	32 39.0	12 60.0	3 37.5	70 42.7
stress detection	21 38.9	34 41.5	13 65.0	1 12.5	69 42.1
none	3 5.6	3 3.7	1 5.0	2 25.0	8 4.9

others: buildings, range inventory, archeological sites, geologic faults, wildlife census, recreation areas, fire control, energy analysis

Table 8. Smallest resolution cell needed (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
square foot	9 16.7	9 11.0	0 0.0	1 12.5	19 11.6
square yard	7 13.0	11 13.4	4 20.0	0 0.0	22 13.4
ten square yards	12 22.2	11 13.4	7 35.0	2 25.0	32 19.5
100 square yards	9 16.7	8 9.8	5 25.0	2 25.0	24 14.6
one acre	24 44.4	38 46.3	2 10.0	2 25.0	66 40.2
unknown	2 3.7	12 14.6	4 20.0	1 12.5	19 11.6

others: .1 acre, .25 acre, .5 acre, 3 acres, 5acres, 10 acres.

Table 9. Awareness of digitized film applications (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
land resource mapping	29 53.7	38 46.3	11 55.0	4 50.0	83 50.6
land resource quantification	24 44.4	26 31.7	10 50.0	4 50.0	65 39.6
water resource mapping	18 33.3	30 36.6	7 35.0	4 50.0	59 36.0
water resource quantification	22 40.7	25 30.5	7 35.0	4 50.0	58 35.4
wetland inventory	23 42.6	30 36.6	9 45.0	4 50.0	66 40.2
forest inventory	26 48.1	32 39.0	10 50.0	3 37.5	71 43.3
cropland inventory	23 42.6	31 37.8	9 45.0	3 37.5	66 40.2
stress detection	17 31.5	17 20.7	6 30.0	2 25.0	42 25.6
none	19 35.2	36 43.9	5 25.0	4 50.0	64 39.0

others: thematic mapping

Table 10. Reasons digitized film unused (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
lack in-house familiarity	30 55.6	46 56.1	12 60.0	1 12.5	89 54.3
poor substitute	9 16.7	7 8.5	0 0.0	1 12.5	17 10.4
computer access	12 22.2	23 28.0	1 5.0	2 25.0	38 23.2
computer service cost	16 29.6	29 35.4	2 10.0	1 12.5	49 29.9
digitizer access	17 31.5	36 43.9	10 50.0	2 25.0	65 39.6
digitizer costs	17 31.5	35 42.7	7 35.0	1 12.5	60 36.6
software costs	19 35.2	35 42.7	6 30.0	1 12.5	61 37.2
ground registration	2 3.7	0 0.0	0 0.0	0 0.0	2 1.2
no relevant applications	5 9.3	6 7.3	1 5.0	0 0.0	12 7.3
unknown	7 13.0	16 19.5	3 15.0	3 37.5	30 18.3

others: unreliable, strictly research tool, poor resolution, impractical
no contractors, inaccurate

Table 11. If used, is digitized film analysis a supplement or replacement technique (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
supplement	10 18.5	9 11.0	2 10.0	1 12.5	22 13.4
replacement	0 0.0	1 1.2	0 0.0	0 0.0	1 0.6
unused	44 81.5	72 87.8	18 90.0	7 87.5	141 86.0

Table 12. Possible advantages of digitized film analysis (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
less expensive	6 11.1	14 17.1	5 25.0	1 12.5	26 15.9
faster	22 40.7	26 31.7	10 50.0	1 12.5	59 36.0
less labor intensive	23 42.6	27 31.7	8 40.0	2 25.0	61 37.2
more accurate	6 11.1	15 18.3	4 20.0	1 12.5	26 15.9
overlay data	12 22.2	21 25.6	9 45.0	1 12.5	43 26.2
data storage and retrieval	21 38.9	26 31.7	7 35.0	2 25.0	56 34.1
data enhancement	18 33.3	30 36.6	7 35.0	1 12.5	54 32.9
economy of scale	0 0.0	9 11.0	8 40.0	1 12.5	18 11.0
none	6 11.1	4 4.9	1 5.0	2 25.0	13 7.9
unknown	13 24.1	30 36.6	4 20.0	2 25.0	49 29.9

others: greater resolution

Table 13. Possible disadvantages of digitized film analysis (number/percentage responses).

	federal agencies	state agencies	consulting firms	conservation groups	overall
more expensive	20 37.0	22 26.8	9 45.0	3 37.5	54 32.9
slower	4 7.4	5 6.1	0 0.0	0 0.0	9 5.5
laborious	4 7.4	3 3.7	0 0.0	0 0.0	7 4.3
inaccurate	13 24.1	13 15.9	7 35.0	1 12.5	34 20.7
unwieldy data handling	9 16.7	12 14.7	2 10.0	0 0.0	23 14.0
none	4 7.4	1 1.2	1 5.0	1 12.5	7 4.3
unknown	15 27.8	39 47.6	4 20.0	1 12.5	59 36.0

others: poor substitute, unreliable, defining data needs, resolution, acquiring photos, calibrations, poor for small jobs, bad presentation, precludes subjectivity.

or digitized film analysis. Although not exceptionally popular, the 14% level of usage is more than what was expected for digitized film analysis. This must be tempered with the knowledge that the introductory information enclosed with the survey explained that the intent was especially directed at sampling the potential utility of digitized film. Users of this technology may be more likely to respond than nonusers, thus oversampling the users relative to nonusers. If the assumption is made that all users of digitized film analysis reached by the survey indeed returned the questionnaire, then the percentage of users in relation to the survey audience drops to about 5%. This is an overly conservative assumption, but the truth probably lies somewhere between 5% and 14%. Users were distributed among all types of respondents; however, a larger proportion of federal agencies use digitized film analysis (19%).

3. Who Performs Resource Inventories

Nearly all of the respondents perform their own resource inventories (Table 3). Slightly over half use contractors in addition to their in-house efforts. Only 2% rely soley on contractors. These results show that at least some capacity for performing resource inventories exists at almost all organizations reached. Some capital outlay and operating expenditures must be channeled toward maintaining or enhancing these capabilities.

4. Problems Fulfilling Resource Inventory Needs

Whatever level of financial support is presently allocated for resource inventories, this level seems inadequate to most respondents (Table 4). Expense, with 71% of the responses, was cited as the main problem in fulfilling resource inventory needs. This is 70% more often than labor intensity or lack of time, the next two frequent choices (43% and 41%, respectively).

The problems for which remote sensing has traditionally been advanced as a solution were among the less frequent problems. Because digitized film analysis provides a computer-based system of data management, the facilities to store, retrieve, and overlay data are considered among the positive attributes of this technology. However, these specific operations were not considered problems by most respondents. This either means that these operations are already performed routinely, or that these operations are simply not desired. Since the vast majority of respondents use on-site surveys or manual photo interpretation, it seems likely that the aforementioned advantages of digitized film are inconsequential to most resource managers or surveyors. Furthermore, access to study areas was an infrequent problem. Therefore, the need for "remote" sensing is reduced.

For the sizeable minority who expressed having problems with data manipulation and access to study areas, remote sensing in general, and digitized film analysis specifically, may be useful.

5. Inventory Techniques Associated with Remote Sensing

It was desired to learn what awareness of remote sensing and digitized film analysis was extant among resource surveyors and managers (Table 5). A simple approach to this was to inquire what remote sensing techniques the respondents are familiar with. Although only half as many respondents actually used satellite data (Landsat) as used aerial photography, more respondents identified Landsat as a remote sensing technique than aerial photography (96% versus 83%). This question relied perhaps too much on the semantics of the term "remote sensing." It was interesting that digitized film was among the least frequent responses (32%) suggesting a very low level of awareness.

6. Awareness of Remote Sensing Applications

Respondents were highly aware of most remote sensing applications (Table 6). Land resource mapping, forest inventory, wetland inventory, water resource mapping, and cropland inventory were applications that over 80% of respondents were aware of. Even the least known application, stress detection, had been encountered by over 60% of the audience. Everyone who returned a questionnaire was aware of at least one application.

7. Applications of Interest

Besides determining the awareness level of respondents for remote sensing in general, the level of interest was also sampled (Table 7). The level of interest was about 70% of the level of awareness. Proportionally, the responses were somewhat dissimilar to the responses on types of inventories performed (Question 1) and the awareness levels (Question 6). Quantification of land and water resources and stress detection aroused more interest relative to simple mapping surveys than in the previous questions. This interest in resource quantification suggests that the utility of remote sensing may lie in this direction.

8. Resolution Needed

This question was intended to discover the greatest resolving power needed by resource surveyors (Table 8). It was hoped that some insight may be gained into the utility of digitized film analysis (which can have very fine resolution) as opposed to inventory techniques such as Landsat with resolution cells of 1.1 acres. Unfortunately, it is suspected that several respondents misunderstood the concept of a ground resolution cell.

Over twice as many respondents (48%) indicated a ground cell of one or more acres as the smallest needed, compared to the number of respondents needing any one of the smaller resolution cells of 100 square yards or smaller. Whether these responses were prejudiced by any commitment to Landsat is unknown. Many soil scientists suggested that one to five acres was the smallest resolution cell needed to map soils because that is the size of their smallest map unit. In fact, soil mapping requires much finer resolution. It appears that some respondents interpreted the question as asking what was the smallest area on the ground they have to investigate as a single study area, even though investigating a single study area with a grid would require resolution cells much smaller than the study area itself. It seems somewhat inconceivable that resource managers would be willing to have all the information in an entire acre averaged over a single cell except for the grossest kind of inventory effort.

The second most popular choice was 10 square yards (20%), approximately equal to the optimal cell size described in Chapter 1 for detailed resource mapping. Nearly equally popular were the resolution cells sized 1 square foot, 1 square yard, and 100 square yards. In total, 52% of those returning the questionnaire replied that they needed a resolving power better than the 1.1 acre cell afforded by Landsat. A higher proportion of state agency personnel (46%) were satisfied with a one acre ground cell than federal (44%), consultants (10%), or conservation groups (25%).

9. Awareness of Digitized Film Applications

The remaining questions dealt strictly with digitized film analysis. The first of these asked essentially the same question on awareness of applications as Question 6. This technology enjoyed slightly less than half as high an awareness level as remote sensing in general (Table 9). Just about as many respondents were totally unaware of digitized film applications as were aware of any one application. The proportional awareness levels among applications was about the same as for remote sensing in general. Approximately half of the respondents in each of the four categories were aware of some digitized film application; the level of awareness was equal among these groups.

10. Reasons Digitized Film Analysis Unused

Lack of familiarity was the most common reason (54%) that digitized film analysis is not used (Table 10). The next frequent reasons all related to the inaccessibility and costs of a digitizer and necessary software (37-40%). Only 10% indicated that digitized film analysis was a poor substitute for their present techniques; 7% felt there were no relevant applications for their needs; and only 1% replied that ground registration was a problem. Many respondents stated that they did not know why digitized film was not used (18%). Most alternative responses cited the unreliability of this technology as one of the main hindrances. A greater proportion of state agencies cited costs and inaccessability as problems than did federal agencies.

11. Digitized Film as Supplement, Replacement, or Unused

This question was intended mainly to discern whether users of digitized film analysis had entirely replaced their prior inventory techniques with it or were using it as a supplement. Additionally, this question proved a good tally of users versus nonusers (Table 11). Only one respondent has replaced previous techniques with digitized film analysis for resource inventories. Nearly 13% used digitized film analysis as a supplement (this checks with the tally for Question 2). Again, this percentage of users probably overestimates reality. Almost half these users were in federal agencies (10 out of 54 returns), compared to 9 out of 82 returns at the state level.

12. Advantages of Digitized Film Analysis

Many of the advantages attributed to digitized film analysis involve ease of data manipulation and the efficiencies gained therefrom (Table 12). The two most common answers were that lower labor intensity was anticipated and inventory time would be reduced. Data storage and retrieval, data enhancement, and the ability to overlay data were nearly equally frequent as replies. The least expected advantages were that digitized film analysis would be less expensive, more accurate, or would enjoy an economy of scale. A rather large percentage (30%) of replies stated that the advantages were unknown.

13. Disadvantages of Digitized Film Analysis

A plurality of those responding to this question (59 out of 164) had no opinion on possible disadvantages (Table 13). Nearly as many (33%) felt that it would be more expensive than their present techniques. The next greatest problem expressed was the fear of inaccuracy (21%). A lesser disadvantage cited was unwieldy data handling, whereas few thought it would be slower or more laborious.

It seems from these responses and those of the previous question that many respondents lack sufficient knowledge of this technology to express an opinion on its advantages or disadvantages. Those that did express an opinion reinforce the ideas that digitized film analysis facilitates data manipulation, is therefore faster and less laborious, but costs more. Several additional opinions were expressed indicating that diversion of funds and set-up expenses were an important hindrance.

IV. SUMMARY AND CONCLUSIONS

A questionnaire was mailed nationwide to 484 resource managers or surveyors representing federal agencies, state agencies, consulting firms, and non-profit conservation groups. The rate of response was 37%. The questionnaire was intended to survey perceptions of those performing resource inventories as to the utility of remote sensing techniques including digitized film analysis.

Specifically, the survey covered the types of resource inventories performed, problems encountered, awareness of and interest in various remote sensing applications, needed resolution, awareness of and interest in digitized film analysis, and opinions on the advantages and disadvantages of digitized film analysis.

General land resource mapping was the most common type of inventory; quantification of resources was less common. Crop inventory and stress detection were performed least by the survey audience. In performing their respective inventories, the more frequently cited problems were expense, labor intensity, and lack of time. Problems to which remote sensing has often been considered a solution, such as data manipulation, inaccessability of study areas, or orientation on the ground was less frequently mentioned.

Most of the possible responses listed to test respondents' awareness of various remote sensing techniques were properly associated with the term "remote sensing." However, there was great disparity among the frequency of responses; Landsat was the most frequent, even more than conventional aerial photography, while digitized film analysis was among the least frequent.

All respondents were aware of at least one remote sensing application. At least 60% of respondents were aware of every application. Interest levels toward remote sensing were lower than awareness levels, although interest in quantitative applications was proportionally higher than their respective awareness levels.

A one acre resolution cell was the most popular choice. Over half the respondents required a resolving power of 100 square yards or better. It was felt that several respondents unfortunately misunderstood the concept of a ground resolution cell.

The awareness levels for applications of digitized film analysis were about half those of remote sensing in general. These awareness levels were proportionally equal among groups of respondents. The reasons given for nonuse of digitized film analysis stemmed mainly from lack of familiarity, inaccessibility, and cost. Few respondents indicated negative opinions of digitized film analysis, such as it being a poor substitute or irrelevant. Nearly 15% used digitized film analysis, the greatest proportion at the federal level.

Possible advantages of digitized film analysis included largely efficiency of data gathering and manipulation. Relatively less respondents thought that digitized film analysis would be less expensive or more accurate. Correspondingly, the most common disadvantages were expense and inaccuracies. A large portion of responses admitted insufficient knowledge of digitized film analysis to judge the advantages or disadvantages.

As noted in Chapter 1, this technology may have some advantages for certain specified applications (especially resource quantification, signature extensions, and data manipulations). These applications appear to interest some of the possible user audience. Undoubtedly digitized film analysis will gradually gain greater acceptance by those whose inventory problems and needs coincide with ascribed advantages of this technique.

The thought that digitized film analysis is suffering through a time lag between development and acceptance as an operational tool is supported by the data on lack of awareness. Although the stated advantages are important considerations for many in the survey audience, the disadvantages of expense and inaccuracy are also important. Since expense was the most important problem currently experienced in resource surveys, the feeling that digitized film analysis is too expensive will probably always be its greatest detraction. Inaccessibility to the technology and lack of familiarity can be overcome simply through further applications, demonstrations, and documentation.

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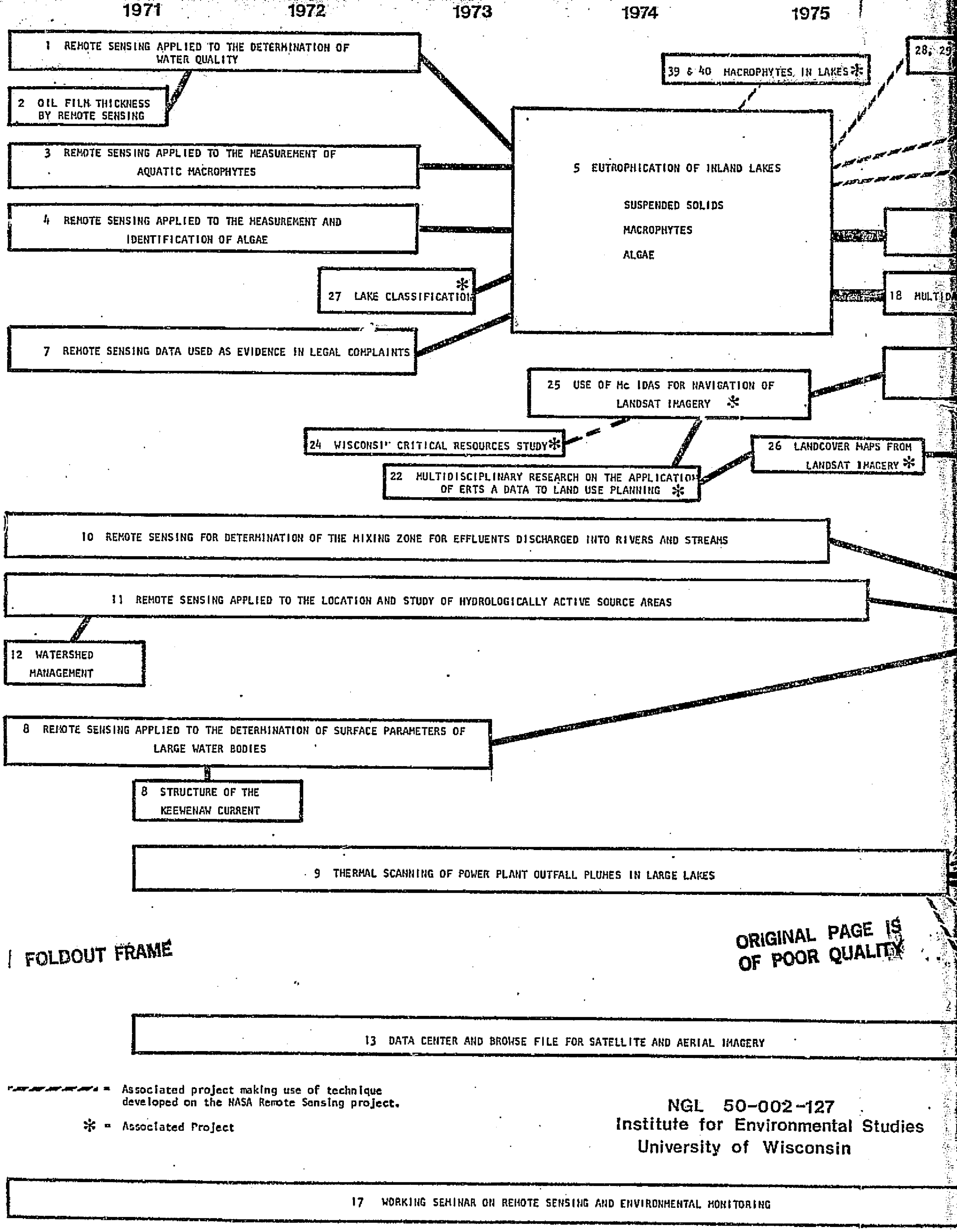
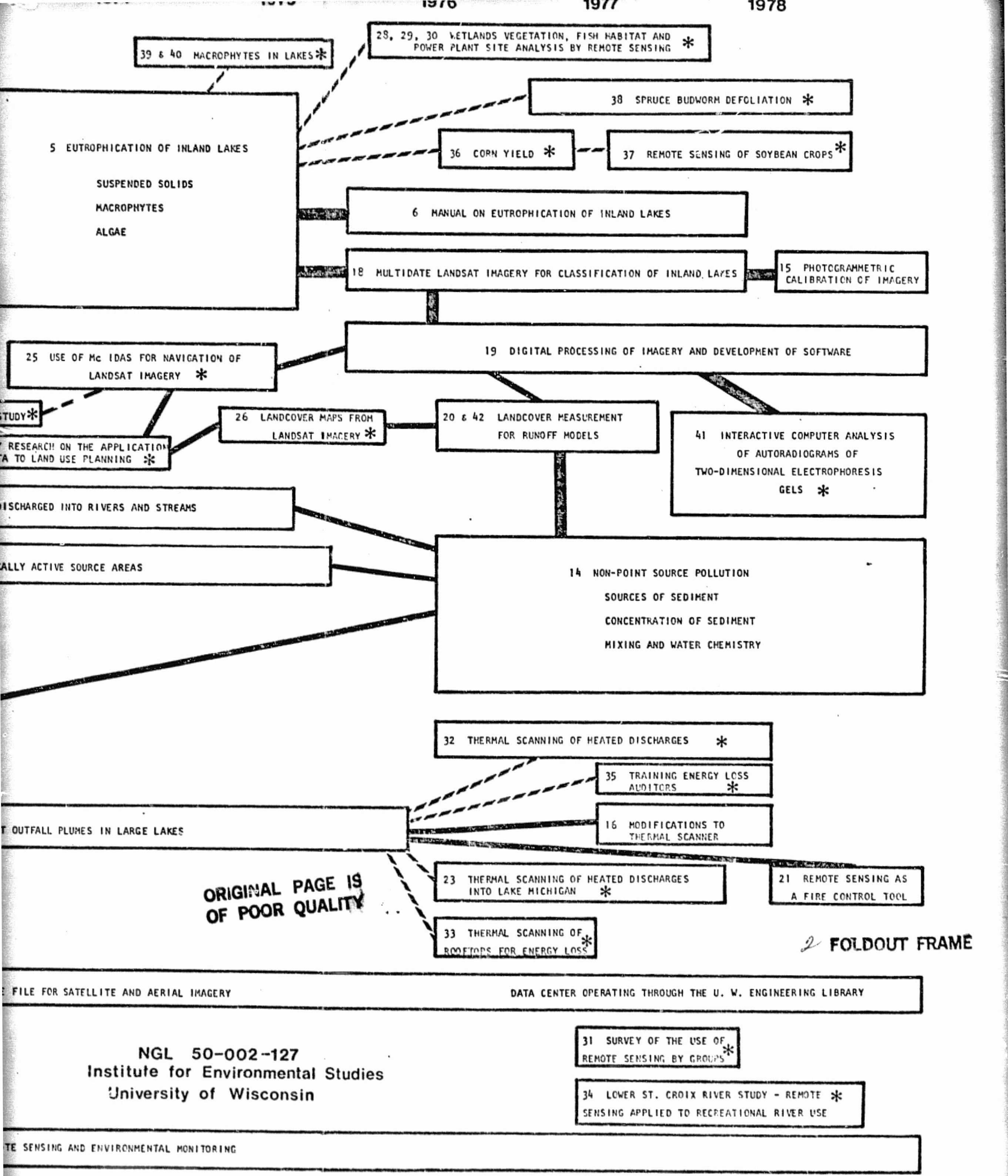
APPENDIX II

Graphic Summary of the Development of Projects During the Course of This Grant

C-2


1971
1972
1973
1974
1975
1 REMOTE SENSING APPLIED TO THE DETERMINATION OF WATER QUALITY
2 OIL FILM THICKNESS BY REMOTE SENSING
3 REMOTE SENSING APPLIED TO THE MEASUREMENT OF AQUATIC MACROPHYTES
4 REMOTE SENSING APPLIED TO THE MEASUREMENT AND IDENTIFICATION OF ALGAE
27 LAKE CLASSIFICATION *
7 REMOTE SENSING DATA USED AS EVIDENCE IN LEGAL COMPLAINTS
39 & 40 MACROPHYTES IN LAKES *
28, 29
5 EUTROPHICATION OF INLAND LAKES
SUSPENDED SOLIDS
MACROPHYTES
ALGAE
18 MULTIDI
25 USE OF Mc IDAS FOR NAVIGATION OF LANDSAT IMAGERY *
24 WISCONSIN CRITICAL RESOURCES STUDY *
26 LANDCOVER MAPS FROM LANDSAT IMAGERY *
22 MULTIDISCIPLINARY RESEARCH ON THE APPLICATION OF ERTS A DATA TO LAND USE PLANNING *
10 REMOTE SENSING FOR DETERMINATION OF THE MIXING ZONE FOR EFFLUENTS DISCHARGED INTO RIVERS AND STREAMS
11 REMOTE SENSING APPLIED TO THE LOCATION AND STUDY OF HYDROLOGICALLY ACTIVE SOURCE AREAS
12 WATERSHED MANAGEMENT
8 REMOTE SENSING APPLIED TO THE DETERMINATION OF SURFACE PARAMETERS OF LARGE WATER BODIES
8 STRUCTURE OF THE KEEWENAW CURRENT
9 THERMAL SCANNING OF POWER PLANT OUTFALL PLUMES IN LARGE LAKES
13 DATA CENTER AND BROWSE FILE FOR SATELLITE AND AERIAL IMAGERY
= Associated project making use of technique developed on the NASA Remote Sensing project.
* = Associated Project
NGL 50-002-127
Institute for Environmental Studies
University of Wisconsin
17 WORKING SEMINAR ON REMOTE SENSING AND ENVIRONMENTAL MONITORING



2 FOLDOUT FRAME

NGL 50-002-127
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