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FIRST COMPREHENSIVE SYMPOSIUM ON THE PRACTICAL APPLICATION OF EARTH RESOURCES SURVEY DATA

VOLUME II-B

SPECIAL SESSION PRESENTATIONS

COASTAL ZONE MANAGEMENT
STATE AND LOCAL USERS
USER SERVICES

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER

TM X-58168

NASA Earth Resources Survey Symposium

VOLUME II-B

SPECIAL SESSION PRESENTATIONS

Coastal Zone Management
State and Local Users
User Services

PREFACE

The first comprehensive symposium on the practical application of Earth resources survey data was sponsored by the NASA Headquarters Office of Applications from June 9 to 12, 1975, in Houston, Texas. The Lyndon B. Johnson Space Center acted as host.

This symposium combined the utilization and results of data from NASA programs involving Landsat, The Skylab Earth resources experiment package, and aircraft, as well as from other data acquisition programs.

The primary emphasis was on the practical applications of Earth resources survey technology of interest to a large number of potential users. Also featured were scientific and technological exploration and research investigations with potential promising applications.

The opening day plenary session was devoted to papers of general interest and an overview. The following 2½ days were devoted to concurrent discipline-oriented technical sessions and to three special sessions covering State and Local Users, Coastal Zone Management, and User Services. These special sessions were structured to provide governmental and private organizations with a comprehensive picture of various applications in the management and implementation of remote-sensing data use in their own programs. The concluding day was a summary with selected state, international, and technical session papers, summaries of significant results from special and technical sessions, and an overview of Federal agency and international activities and planning.

Volumes I-A, I-B, I-C, and I-D contain the technical papers presented during the concurrent sessions. Volume II-A contains the opening day plenary session and the concluding day summary sessions. Volume II-B contains the special sessions. Volume III contains a summary of each session by the chairman and session personnel and provides an overview of the signi nt applications that have been developed from the use of remote-sensing data. Volume III also includes the conclusions and needs identified during the individual sessions and workshops.

This book consists primarily of edited transcripts of verbal presentations and audience interaction. As much as possible, all contributors were given an opportunity to review their transcripts; however, some final editing was necessary to achieve clarity and a uniform format. Editing guidelines also included preservation of each author's terminology and individual style, considered by the coordinator to be an integral part of the reports. Care was taken to retain the meaning and emphasis; however, where any inadvertent alteration may have occurred, the coordinator assumes full responsibility.

Opinions and recommendations expressed in these reports are those of the session members and do not necessarily reflect the official position of NASA.

Olav Smistad
Symposium Coordinator

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COASTAL ZONE MANAGEMENT

C-1. Status of Coastal Zone Management Techniques

E. Lee Tilton, III[a]

I shall try to describe some technical aspects of marine resources and coastal zones, and I hope we will begin a dialog that starts relating some of our technical capabilities to some of our needs. Let me begin with a definition. The entire area that we are discussing is included in a discipline called marine resources. Marine resources really means everything in the oceans and coastal zones that pertains to water having any detectable salinity, or salty water. It includes physical, chemical, and biological processes; both dead and living organisms; and just about everything off the coast and as far in from the coast as that saltwater might affect occurrences on land. That is the coastal zone, which we are going to work up to. My purpose here is to present a very nontechnical description of the techniques that are in development, the potential techniques that we have coming along to help solve some of the problems. We hope that a number of you in the management business or the political business will think along with us to try to start relating to each other because, as technologists, we have learned that we really must communicate with the people who need the information while we are developing the techniques.

What do we really want to know in marine resources? We want to know what makes the Earth tick — the fluid part of the Earth — not the hot part in the center, but the cold part on the surface. We need information, not just data, in a form that people who are trying to make decisions can use. Some of the techniques for obtaining such information are not very well developed; they are just in their infancy. Others are ready to be, at least, tested or very nearly so. I'll try to point that out.

We will proceed from a technique development situation into an application situation, which is the coastal zone business. I would like to suggest an approach to provide some continuity. Some of you have read the book by Desmond Morris called "The Naked Ape." I believe he had an interesting approach in trying to look at the behavior of the human being. That is really what we want to do: to look at the behavior of the Earth. Morris suggested that if you walked into a room and saw a human corpse on a dissecting table, and that was the first time you had ever seen a human being, analysis would be difficult. How would you decide what made him look like he does and so on?

I suggest that we do the same thing here. Let's back off from the Earth and approach it much as a space traveler would and see where we get. I guess the first thing we would look at is the shape. It is round obviously, but is it really round or is it not quite so round? We have some measuring techniques that are important right now scientifically, but as these techniques are developed and applied, they will become very important with regard to navigation. We are talking about measuring the very minute changes in the shape of the Earth. We would like to do that to an accuracy of about 10 centimeters. That is pretty fine, but that is what we need to do to improve our present day navigation systems, which will help our transportation and our prediction of tides. I think we all have a pretty good feel for the importance of all that.

If we now descend in our spaceship to a lower altitude, we become more aware of the true shape of the Earth. What does it look like right at the surface? Is it

[a]NASA Earth Resources Laboratory, Bay St. Louis, Mississippi.

rough or smooth? Does it have waves? Has it an atmosphere? Does the wind blow? Which way is it blowing? We would certainly like to know about the wind. Again, the applications are in the area of weather prediction and transportation to make our transportation routes more efficient. We have something that is starting to look promising for measuring wind direction. We have established a relationship between windspeed and some parameters called apparent temperature and scattering coefficients. The more we learn about such paremeters, the more we are going to be able to remotely measure things like windspeed, which we can then use as information to solve other kinds of problems. We can also start to determine wind direction, and that is also very important, even to you people who like to go sailing on the lake.

We are on the surface now, and we see that if we had some techniques, we could learn a little more about what is happening on the surface of this Earth we are trying to understand. We might note, if we have the right sensors, that some parts of the ocean are cooler than others. We have techniques for actually taking a picture of the temperature of the oceans. Why do we want this information? Well, we can start talking about thermal effluents from powerplants and the relationship of temperature in the ocean to the management and assessment of our commercial fish resources. We can start talking about current boundaries and which way the oceans are circulating. Those are important data. What is the status of the technique? It is well developed. We can measure temperature from aircraft or satellites probably to within 1° C. Thus, we have learned a little bit more about the surface.

Another parameter of interest for which we have limited knowledge is circulation. Water circulation is of obvious importance because of its relationship to transportation, to distribution of nutrients around the Earth, to commercial fisheries, to sediment transport, and so on. Those are all important factors in making decisions. We are trying to develop remote-sensing techniques to measure circulation, but we don't want to oversell these techniques. Although we can infer some facts about circulation, we cannot measure it directly. Why is circulation important? Again, we can go back to the effluents. Where is an acid dump going to end up? How is sand transported along the shores?

Another important parameter for getting to know this Earth a little bit better is color. While we are sitting on this big ocean and moving around the ocean, we might also notice that sometimes the color varies when we go from one place to another. Colors are rather strange. Frankly, color is our most puzzling problem right now. Such factors as the physics, the chemistry, and the biology of the ocean all influence the color. Unfortunately, we cannot see color through clouds. We must persevere with this problem. We must try and try again; and we are making progress, slowly but surely. There are some qualitative things we can do right now with color. We can relate it to the distribution of fishes in some cases; and sometimes, we can see through the water to determine what is under it.

That leads me to my next step here in this tour of the Earth. We might even look below the water and find that there are little things down there. There are phytoplankton, zooplankton, and fish swimming around. In our survey of what makes the Earth tick, we would certainly like to remotely measure some of these things that are under the water. The things that make water so enigmatic, as opposed to land, are that it is dynamic and three dimensional. When we look at the water, we see the effects of this three-dimensional environment; and we would like to have information about the third dimension from the depth. We even have some techniques under development that might help us to do that. This area is very important to the commercial fisheries people. Cold water coming up from the depths of the ocean tends to provide the right environment for phytoplankton to grow and bloom, to feed small fish that feed larger fish. If we can measure things like phytoplankton by looking at water color, then we might be able to predict productivity and availability of some of the commercial and sports fishing resources. We might even move closer to the coast and take a look at what the sportsmen do and what they worry about. We also worry about the sportsmen; we are concerned about how quickly they can find fish and where they can find them. I am sure that, scientifically, the nature of the game-fish distribution will reveal other facts about living marine resources. If we do enough experiments, then we can start to understand the relationships between the fish and the environmental parameters that we can measure. We are not going to find fish from satellites, but we can measure the other parameters. If we know enough about those relationships, we can tell what the fish are doing. That is an inference technique.

Let me digress and talk about something that is important when we collect any kind of data on the oceans. We stated that the ocean is dynamic and that it varies three dimensionally and with time. The timeliness of data is important. People are going to make decisions based on information that we give them, and they must have the information in a timely fashion. Conditions can change overnight; therefore, it is important that we get the data quickly. We are working on those problems also.

Let us go a bit nearer the coast and talk about bathymetry. That is important also because of the transportation problems, the presence of shoals, and the relationship of water depth to some living marine resources. We can start with some accuracy measuring the depths of the water.

We will continue on our journey a little closer to shore and find that as we near the coastline and prepare to enter a river, the water we see is different from ocean water. It is muddier. Another parameter that we are interested in is sediment; we want to know how it is transported, how it fills the harbors we build, how it is eroded from the shores. Such knowledge certainly has a lot to do with how we might zone our coastal areas, whether or not we want to build houses there, and so on. Some techniques for measuring sediment are being developed. Using some new digital techniques, we can now start measuring quantitative levels of sediment. Right now, we can do it on a given day, usually, but to extend that to the next day is somewhat difficult.

As we move inland, still inspecting the Earth, if we put a finger in the water and taste it, we find that the water is not quite as salty as it was out on the ocean. A technique for remotely measuring salinity in the coastal areas is available. We can measure salinity levels from 10 to 35 parts per thousand in water having temperatures higher than 20° to 30° C. There are some problems with the technique. We have to fly low, we have to avoid land masses, and the water must be warm. The technique does represent a beginning, however, and is being used currently in some cooperative evaluation programs in the State of Louisiana. The shrimp season and the relationship of shrimp productivity to temperature and salinity distributions along the Louisiana coast are being studied. By this means, the optimum time to open the season can be chosen. Even though the technique is unsophisticated, it is already a useful tool in the coastal zone.

We have a digital quantitative technique for measuring land area and water area and for measuring shoreline length. We are fairly confident in the accuracy of the measurements now. Some actual evaluations are being performed in application areas. We are rather excited about that technique because it is working, it is developed, it is there to be used, and it is inexpensive.

Moving again a bit farther inland, we go into the marsh. The marsh has a lot of different elements that make it alien; we cannot go in and look at it too easily. We are concerned about marshland because it controls, to a large extent, the productivity along the coast. We worry about erosion and other factors changing shape and form. We worry about salinity intruding into the marsh because, with such an intrusion, the vegetation changes from fresh to salt. And while the vegetation is dying, the mudflats erode and all kinds of bad things happen. The vegetation is a useful indicator of the status of a marsh. By observing the vegetation in a marsh and using some digital techniques to classify vegetation types, we can learn something about it. We are finding that, in some ways, plants are probably just like people. They prefer a certain kind of environment; some plants like saltwater and/or salt mud and other plants do not. If we learn to distinguish the plants that do have an affinity for salt and those that do not, and if we can classify the plants, we can say "That is a freshwater marsh" or "That is a saltwater marsh." How does such knowledge help? Now, we can start not only delineating the boundaries in the coastal zone (what are the wetlands, which is a big concern right now), but we can also tell the salinity on the boundaries. Furthermore, if we are adept at analyzing the geometry of these pictures, we can lay next year's picture on top of this year's picture and determine the changes. We can see if the marsh is becoming more saline or fresher, and that tells us a lot about when we should dig canals and when we should not. Leveeing has brought about great changes.

These are all remote-sensing techniques that can help us understand the environment. These and other techniques that are being used and evaluated right now will be discussed in the coastal zone management presentations.

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C-2. Panel: Information Needs — Perceived and Real — for State Decisionmakers

A. R. (Bube) Schwartz,[a] Chris Spirou,[b] William Kier,[c] and Michele Tetley[d]

SCHWARTZ: As a state senator, I represent Galveston County and that part of Harris County in which the NASA Lyndon B. Johnson Space Center (JSC) is located. My district also runs down the coastline from High Island on the Bolivar Peninsula to the middle of the Corpus Christi ship channel. That is about half the linear distance of the Texas coast. I probably represent more coastline generally than any other state senator in the United States. In addition to that, it seems like most of the problems in Texas are located in my senatorial district, which is the kind of place where a politician never can get very comfortable because the voters move in and out so fast that one really cannot get that well acquainted.

Politicians dealing with scientists are not really very well accepted. That is part of what we are talking about when a person like me comes to you to describe the overview of what we are doing in coastal zone management and why indeed we need the scientists, why an elected public official from a state senatorial district concerns himself with scientists as a practical matter. We are indeed interested in what scientists do, if we can learn what scientists do. And if we are able to learn what scientists do — if they are willing to tell us — then we are interested, if we can understand it. We have an old saying in the Texas Senate that we apply when one person rides another into the ground trying to get him to explain his bill on the floor. The exasperated senator will finally say, "Senator, I can explain it to you, but I cannot understand it for you."

It might do well for scientists to understand that too. Politicians sometimes require more explanation than other people in terms of translation. The NASA is in a business that does require communications.

In 1972, the Congress passed a Coastal Zone Management Act, which shows great concern for the states of these United States. That act was passed and implemented by Congress before there was an outcry against land use management. Land use management is the anathema of chambers of commerce, because chambers of commerce believe that if one has land, he must sell it to somebody. If it is under water, then he must dry it out before he sells it, but he still must sell it. And if it is going to be under water tomorrow, like some Houston land, that is all right; he can promise that somebody will build a levee around it. And then he can go to the government and ask to have a levee built.

The coastal zone management program is a functional program that has been funded. All 30 coastal states, including the Great Lakes states, have now qualified in that program and each is functioning. Texas is in its second year of the program and attempting to use the benefits.

I happen to be the elected national chairman of the Coastal States Organization, which represents every coastal state in the United States. And we are designees by the governors of our states for the purpose of translating the coastal zone goals and needs of those states to the Congress and to the Federal establishment, which is no small job for state people.

Here in Texas, I am amazed at the complexity of coastal zone management and our needs over the years. How does a Texas legislator learn what there is about the coastal zone that one might want to manage? The fact is that we grope around and fall in and out of state agencies and hope that we can come up with some things that somebody has done that tells us what needs to be done. I became interested in the coastal zone about 6 years ago, and I was surprised to learn that there is an organization at the University of Texas (UT) called the Bureau of Economic Geology. The bureau has done an outstanding job, beginning with some mapping and

[a]Texas State Senator, Galveston, Texas.

[b]New Hampshire House of Representatives, Concord, New Hampshire.

[c]Senate Office of Research, Sacramento, California.

[d]National Oceanic and Atmospheric Administration, Washington, D.C.

geological surveys on the Texas coast. (I had always believed that geologists were principally in the business of finding oil and gas.) I learned that the Bureau of Economic Geology, as a practical matter, was 10 years in advance of the Texas Legislature (and, for that matter, of national bodies) in terms of determining the coastal zone needs of Texas and tracking the transformations that were taking place. What they lacked most were money and scientific data, which they had to assemble in large part with money they had obtained from the educational facility they represented. Some of the things simply had to be done, if Texas indeed were going to have ultimately a decent coastal zone program.

When I first came in contact with the satellite remote-sensing program, it became very obvious that this program ought to be related to all our needs in Texas and that, if there was a state that needed any kind of a scientific exchange, Texas was that state. We developed and finally Texas A. & M. University became a Sea Grant institution; the Bureau of Economic Geology was funded properly through the legislature to continue much of its good work; the UT Marine Science Institutes began to develop; the UT Biomedical Institute developed at the UT Medical Branch in Galveston; and so on.

So we have a scientific community that does relate to legislative process to a limited extent. My plea to you is that, whatever you are doing and whatever you are about to do, relate it to us in some way. It is nice of you to let some of us come to you. By and large, scientists think that legislators and politicians are difficult to reach and to inform. If you have ever tried to teach us anything, you understand how difficult it is for us to translate the facts to other politicians so that the necessary projects that you conceive, that you think are important, can be funded. So that is where we are and that is the framework in which we have to operate. You can do nothing unless you are funded to do it.

With that general view of our relationship and why we are here, I give you the minority leader of the New Hampshire Legislature, Chris Spirou.

SPIROU: I am glad to be with you, to share my experience with you. How do we relate to one another, whether in coastal zone management or selling pictures, or whatever? I had had very little contact with the scientific world, and very little contact with coastal zone management until one day 2 years ago, when Aristotle Onassis announced that he was hoping to build a 500 000-barrel/day refinery at Durham, New Hampshire. The people around Durham were upset. And all at once, the legislature's attention was shifted from how many deer we are going to have and how much fish we are going to take to "save our shores." And the battle began. Those of us who were decisionmakers had very little knowledge.

Did we have any planning? Did anybody know how we were going to put that in? Where were the state industries? What legislative enactments did we need? What were the processes of siting a refinery? No one knew anything about it. The legislature had to make a decision. The decision was not one of the scientific world but one of the political world.

As far as I am concerned, the Durham, New Hampshire, experience is the biggest failure of people attempting to site a plant of this type in the history of the world. They spent $500 000 and accomplished nothing because they did not obtain enough advance information.

Even the gypsies in the old country knew how to do that. Before they came into a town to make a few dollars reading palms, they would send a scout undercover and check out Chris Spirou. What are his problems? What is happening in his life? Then, a week later, the gypsy queen would come by to read my palm. And she knew all about me. She said there was a check coming from the United States. A few days later, a check arrived. I was fooled, because I thought she had read my palm. I didn't realize she even had scouts checking the postal service. Onassis failed to have a good scouting report, so he didn't find out how to convey his message to those who had to make the final political decision.

The final determination was not made on the basis of how many barrels of oil were going to be produced, nor on what plans had already been made. The decision was made on a very practical political consideration: whether or not the governor and the political system of the State of New Hampshire would want to circumvent the home rule provision we had in the laws. If someone wanted to put a racetrack in any town in the State of New Hampshire, or if someone wanted to sell beer in any town in the State of New Hampshire, he first had to get the consent of the local people by a referendum. We asked, "Why can't we do the same thing about a refinery?" Then we required it in a law; so the vote on the floor of the House was not whether or not there would be a refinery, but whether or not a refinery should be put in the town of Durham without the consent of the residents. No legislator was going to vote against that. The night before that vote, we held a town meeting day statewide and we made sure that when the governor (who heavily supported the refinery) said, "This is the question before the town meeting: Should we have a refinery in the State of New Hampshire?", somebody would rise and say, "I want to make an amendment to that." That amendment was, "Provided the people of that town where the refinery is proposed have an opportunity to vote whether or not they want it." In all, 223 towns voted to have a refinery, but 223 people rose with an amendment. The town people could never vote against an amendment like that.

So the next day, instead of having a refinery for the State of New Hampshire, we had a referendum saying that a refinery will be built if the people of the town where the refinery is being proposed vote on it. When they did, it was 4 to 1 against and the refinery proposal failed.

Now back to remote sensing. I understand that NASA has this unique technology and wants to apply it to the United States of America and perhaps to other places. But I am not an expert on remote sensing. I am only an expert – in a little way – in the political system we have, and I would like to advise you who are going to be participants of this application of remote sensing. Here is how I would go about it if I were you. First and foremost, your expertise and knowledge are not useful when you are talking to politicians. It serves the purpose for you to be prepared, but there is a different mechanism between your preparation and your ability to prepare me. Unless you understand how you can prepare me to understand what you are trying to explain to me, you fail. You can bring the best pictures, the best experiments, the best analysis, but if I have a different agenda than you have, if I am not listening to you, if I am pressured by another group, I am going to move that you be indefinitely postponed. And 13 seconds later, nearly everybody says "aye" and the rest say nothing and your plan is gone.

You go back and tell your friends, "It took him 15 seconds to kill a thing I have been trying for 5 years to accomplish. They just rejected it outright, didn't even give me an opportunity to testify. I went all the way up to New Hampshire, sat down before the committee, and they never listened to me." It happens every day at every statehouse from Washington to New Hampshire. Sometimes, there is no relationship between your information and my ability to grasp it, to understand it, and to apply it.

I want to know more about the area that is called the seacoast of New Hampshire, and not in such a traumatic situation as I had last year. I want to know what its value is, what is there, why it is there, and how it is going to affect the future of my state, or the future of the State of Washington or of Colorado. Whether I am in Washington or in the New Hampshire Legislature, I need to have that information.

You can convince me, my colleagues, or anybody else. You can convince me that I know enough about my state, about my nation, and this is the right thing to do based on data you gave me. You also have to learn that I might just vote against that. Even though you are convinced that you have me convinced, that I have enough knowledge now that I would make no other decision than what you have concluded is the just and right decision, I may vote the other way. You just have to learn to come back the next day and try all over again in another way. The considerations that I have to take into account when I vote might be some that you have never seen, heard, or anticipated. So learn the political process, both the benefits and the headaches, and I think we can work together in understanding both of our roles.

I need to know as much as I can about scientists, remote sensing, and expertise and technical papers that come through my desk every day, which I can only read by title. Somebody comes up with a bill 50 pages long and somebody says, "Mr. Speaker, I move that we read it by title only." That is what I do with the messages you send me. But if somebody follows that up and seeing me someplace, he can say, "You know, I sent you a paper concerning remote sensing. Have you been able to read it? Can I talk to you at some point about it?" Know the policymakers and you will get results. So learn the subject matter, not only the one that you are technically expert on, but learn the subject matter that you want to apply to the political system, whether it be the selectman in Durham, New Hampshire, or the President at the White House. Then we can apply remote sensing much better.

TETLEY: Senator Schwartz asked me to discuss the types of information that the states were requesting of me and of our office as they prepare their planning programs. I found, examining my past 2 years of information requests, that not many states had come to me and requested remote-sensing data. I think I have found, through talking to the states using it, that they are going directly to NASA or are going to commercial groups for their remote sensing. I do have a feel, however, for the types of information the states need that I think remote sensing could be used for.

We are both a land and water use planning organization. We have one foot in the water and one foot on the land. That is a very dynamic interface and is one that is difficult to manage. Lee Tilton was talking about the wet side of our problem. We also have some fairly major problems on the dry side. I do not really feel, from what I can see promulgated through the satellite material, that it is very helpful to the states at this point. They are really involved in looking closely at the zoning problem. I think that it will take some iterations on the part of NASA to come up with some useful material in that area.

I was heartened to hear some of the things Lee was discussing on the water side about temperature, turbidity, and these sorts of information. As many of you probably know, each of the states has to conduct an assessment of its coast and this includes the living resources in the water, sediment transport, erosion, and critical areas. A lot of the new techniques that Lee was explaining I think can be applied towards surveying these problems. One major problem is erosion. We hear this most frequently from the Great Lakes, but the states are all either suffering from erosion or, in the case of the Houston area, from subsidence. I think this is an aspect of remote sensing that can be used by the states fairly well. The scale of the low-flight material, I think, is going to be a lot more useful as the states pull together their identifications of problems. I think in the long term, the satellite material will be the most useful, once the states develop their management plans, in monitoring water quality and long-term changes.

One of the things states have to identify before they can begin their management are the boundaries of their coastal zone. Several of the things Lee mentioned will be helpful here. One of them is the vegetation line; this is one of the ways a state can draw its boundary, the difference between the saltwater and freshwater vegetation. One of the problems with using this particular type of boundary is that it is a changing one. Once again, Landsat information would be helpful. It would show over time how this was either receding or advancing. One of the other ways that the states are going to probably be establishing boundaries will be the political boundaries, which will not show with remote sensing, but I think it can be applied.

We are working in NOAA to help the states in some of their mapping problems, and developing a mapping handbook. It is a joint venture between the National Ocean Survey and the U.S. Geological Survey, with sort of gentle guidance from the Office of Coastal Zone Management. When they began the handbook, they surveyed the states and asked what kinds of information they wanted on these maps that, if the money is there, will eventually be put together. Right now, we are just putting together a handbook. The types of things the states said they needed included information on offshore structures, so they would have information for siting pollution; in other words, the dumping and the land runoff, sewage outfalls, and this sort of thing. Here, remote sensing will be very handy. For the living resources, the land and water inventories of commercial species, Lee mentioned that in identifying plankton blooms and water temperature, they could fairly accurately assess where fish might be. This is valuable for the states and certainly for the fishermen there. The states wanted some ideas about the physical changes over time. Here, the periodicity of the satellite data will be very helpful, although it is on a scale that will be useful probably only on the long term. I think they will need low-flight remote-sensing data to establish their base, particularly for such things as erosion and (for instance, in the Great Lakes) the seasonal lake levels and the change of the lake levels over time, with the accompanying either accretion or erosion. A foot here and there can make a lot of difference, and you cannot pick that up from the high-flight material. Basically, they also wanted to be able to establish a fairly good socioeconomic base on these maps for use in their land use zoning. I do not know whether or not the remote sensing will be able to help except on the low-flight imagery. They also need the flood-plains information and the bathymetry in the nearshore areas. In establishing their critical areas, they will need low-flight material in the beginning. I think in each one of these cases, the scales will probably differ. In some cases, the large scale will be sufficient. We will not be able to have just the one size and apply it straight across the board.

As NASA moves more deeply into Earth resources, certainly in working with coastal zone managers, it is first going to have to understand what coastal zone management is. It must understand who the users are and what they need. I think NASA is not necessarily going to be able to fit the states into what it now has. We have 30 states and 4 territories, and each one of those programs is different. They are approaching their problems differently. They have different types of coastline and shore problems. I really believe that as the states get further into their planning process, they will begin to know the kinds of data they need.

Although the act was signed in 1972, we did not receive our funding and did not hand out our first grants until early last spring. So states have really only been involved for a little over a year; they are now coming in for their second-year grants. This first year has been, for the most part, a gearing up for the planning and management process. Some of the states, such as Louisiana and Florida, are using remote sensing now. Other states, I am sure, will follow as their plans reveal the types of information that the remote sensing can provide. I think probably that NASA and those of you in the remote-sensing business are going to have to do a bit of individualized door-to-door selling to the states. In those areas where you do not have a program, I would recommend coming to Washington or going to the states looking at their programs under section 305, the planning section of the act. Look at their proposals and see what they are, what they propose to do, and identify those areas in which remote sensing could be used. Particularly identify those where remote sensing can do the job better than any other measurement method.

There is, as you may realize, not that much money in those grants. States are not necessarily always going to actively seek out NASA for remote sensing as a panacea for their problems. It is probably going to be up to you people to identify those areas in which you can be of most help and go sell the states the program.

KIER: This panel deals with informational needs of decisionmakers, real and perceived. I am going to try to be painfully honest here and deal with some facts, which I will flag, and some perceptions, which I will also identify as just that and we can discuss those later. I am a staff person with the California State Senate. I was at one time a fisheries research scientist. However, I left hard science some time ago, about the time remote sensing appeared on the scene. In California, the Federal Government was just beginning to use infrared remote sensing of ocean surface temperatures toward some predictive work on commercial fishing. I was delighted to learn that this good work continues. That was, by the way, a good piece of work. The state and Federal folks jointly managed to steer the California abalone fleet toward what turned out to be a bumper year. And that is the kind of remote-sensing payoff that can and should score with the decisionmakers.

Fact number one: I do not know anything about remote sensing. I commandeered a double armload of State of California paperwork on the subject and plowed through it on the way to Houston and such time as I have had here. I searched through inches of paper and could not find a kernel. I could not find where all the coordination and all the committees were doing anybody any good. My perceptions, then, are that remote sensing is a piece of technology that has been developed, for the most part, by the Federal Government, which has made it available, not to decisionmakers, but to technicians in California who have treated this as though it were worth what they paid for it — nothing; and that, after a decade of talking about it, we have made very little application.

The fact is that, after a diligent search, I could find no evidence that the State of California had ever consciously committed dollar one to any remote-sensing venture. Some applications have been made in California, essentially with what we might call laundered money. The Department of Water Resources of the State of California is represented at this conference. I have not met the gentleman who will present this paper, but I understand that the remote-sensing data utilization is represented in the Department of Water Resources budget as though it were photographic support or graphic arts. So think about that. In the California Department of Transportation, there is, I discovered only this morning, an Office of Geometronics. As best I can determine, it warehouses 9-by-9 photographs for purposes yet undetermined. I did manage this morning to go over and hear a former employee of the University of California describe how remote-sensing data are used in predicting the spread rate of wildland fires. And I was so impressed that I followed Jim to breakfast and met a couple of his former university colleagues. We talked about the importance of turning the decisionmakers on to remote sensing, which these three young fellows were so turned on to themselves. I found out enough from them to reinforce the impressions I got in going through the paperwork. They had had contact with the various coordinating committees of the executive branch in Sacramento, but nothing had come of it.

The memo writers and committee formers have gotten in between the kind of hands-on technicians I was having breakfast with and the people that I work for, the politicians. So we explored this notion of getting my employers turned on to the use of this kind of information for the problems they deal with. And maybe that is what I can do for the State Senate as the inside man for technicians who think they have a product that the legislature needs.

They identified several things they were doing and I said, "No, I don't think that I could get my employers to sit still long enough to listen to all of that." But, I said, "Here is what is coming down in Sacramento. We have a brouhaha going just now on forest practices. We have a governor who is convinced the country is in an economic decline and he is going to have to have a big surplus in the state general fund before he turns loose of buck one, but at the same time, he is determined to identify new job opportunities. So let's take all these factors and put them together." We came up with the fact that the information that two of these University of California fellows were working with concerns the potential capability of forest land presently on stock. What I know is that the California State forester would like just a little bit of money from the legislature to renovate the Division of Forestry nurseries. Some new technology for mass producing seedlings at much lower unit cost has been developed. So, I say, let's utilize this remote-sensing data to identify (at very little cost, hopefully) those sites capable of being restocked. Then we have to get ourselves a politician or two from these potential forest improvement areas and begin to build up tarbabv and get the legislature's paw stuck to it by getting a very modest appropriation – a very, very modest appropriation, not to create something, but really to call up information that is already available to show how we are going to get those new seedlings out there. I forgot to mention the fact that the State Division of Forestry has been approached by these university researchers and has shown very little real interest in remote-sensing applications in state forest management. So, here, we have the ingredients of an application which is of modest cost. I want to make it perfectly clear that this scenario is one that can be played out.

I am dazzled by what I have seen and heard here. But, despite my semiscience background, I do not really comprehend what I see and hear, although I suspect it cost a lot of money and, therefore, it does not make much sense right now, in terms of California's lowered expectations. I am sure I have now made the point that we must apply remote sensing in exquisitely selective ways at practically no cost at all and we must solve some real-life problems for decisionmakers; that is how decisionmakers are going to understand the application of remote sensing to real-life problems.

We did not wait for NOAA money to launch our coastal planning effort. We started early in 1973 as a result of a popular voter initiative which came on the heels of 4 years of legislative deliberation. That plan has evolved to the point where it has been subject to 31 public hearings conducted by the California Coastal Zone Conservation Commission. It is being shaped up, spruced up, polished up for presentation to the legislature. The involvement of remote sensing in the preparation of that California coastal plan was virtually nil. That is a fact. The only application, to my knowledge, was in the identification of coastal wetlands, comparing the existing situation to the earliest Federal mapping to get some kind of trend data. The plan contains 183 specific recommendations. It includes a recommendation, for example, that the state exercise control in perpetuity of a band of the coastline that is generically described as a wet sand vegetation line. First, we must have a baseline determination as to what that is. That control line, or whatever, is going to have to relate to people's property and is going to have to give these decisionmakers the capability of seeing whose ox is getting gored. Legislators will express principle and deliver some good policy. But if people who are important to them are losing by some change in public policy, look out. We have to be able to deal with this land use data in various clinically clear and exquisitely precise ways. The point here is that it is less important to decisionmakers to know that only 0.4 percent remains of the original whatever-it-is that was once dominant along the marshes of the California coastline. They want to know whose backyard the remaining plant species or whatever is in.

That is where we are in the coastal planning process in California. The people spoke in 1972 and said they wanted coastal zone planning and implied that they wanted coastal zone management. The mission of that management plan has been evolved; that evolution at this point unhappily coincides with what the governor, union leaders, builders, bankers, and so forth in California perceive as a very dire economic situation. We're going to have (1) a terrible time selling that plan to the legislature and (2) the legislators are probably going to find comfort in the fact that many of the Californians who voted for that plan in 1972 are currently on the shorts, or out of work, or know somebody who is, and those voters don't care about the kind of environmentalism they were espousing in 1972. The pendulum swings back and forth.

I think all of us should strive for some continuity. We went environmental in 1972, a little bit too antienvironmental in 1975; a little bit fat on remote sensing perhaps in 1972, and a little bit too slim in 1975. And the name of the game is finding these real-life applications of the things that we generate and evolve in order that these very human decisionmakers can see how they relate to solving real problems for real people.

SHERMAN: It kind of seems like it has been you versus us. I am one of those technocrats. But we are in this thing together to seek out solutions. When we go in and legislation is created, often the people involved in technology or in the operational program end up with the responsibilities, but we don't have authority. How do we set up communication? It is you telling us the general problem areas that you face, so that your priorities can be established in a meaningful way, so that agencies can be created to address those problems and have the responsibility and authority to do it.

KIER: One of the really tough things for me, in dealing with state legislators, is that business of communicating. Communications typically are passing a guy in the hallway or giving him counsel in a nanosecond because there just is no time; communication is all of that fluff and stuff in the padding and the bureaucratic language that just take up time and lose the typical legislator's interest absolutely. I began to realize how condensed my counsel had to be. There was not time for all those qualifications that scientists are so apt to use to hedge. My typical communication with decisionmakers gets down now to, "Hey, this is good stuff," or, "That's a turkey," or, "That's a way to go." That is the kind of information a lot of their decisionmaking is done on: counsel from people they respect and rely upon. That is the way it is. Legislators just do not have time to digest the paper that comes across the desk because the volume is unbelievable, just plain unbelievable.

As an agency bureaucrat, you cannot legitimately call up the chairman of the House Ways and Means Committee and say, "This is Jack and I think that NOAA's budget in this area should be increased by $3 million." There may be a way to get around that by encouraging people outside the agency who have the interest and the ability to communicate one-on-one with legislators. There are people in the scientific community who have those scientific and political skills who are able because of their positions in society to get one-on-one with legislators or who are so into their thing that they don't bother about the normal niceties. We are having an experience in California right now with just one such person who is totally and very productively involved in aquaculture. Trying to get that man money through normal budgeting procedures that involve the University of California is like trying to jam wet yarn through a keyhole. A university just takes that money and scatters it all over creation. This guy just came to Sacramento and went around the halls and, because he happened to have the dual skill, he sold his program. The legislature is finding a way to give his program the emphasis in funding that it deserves.

TETLEY: Jack, you asked the decisionmakers to articulate their needs to the suppliers. I think that you will find in many cases remote sensing is a new animal to the states and until they know what it can do for them, they are not going to be able to come and articulate their needs. It is really going to take a selling job.

SPIROU: I probably would have never heard of coastal zone management if somehow someone hadn't heard from me first. We may be able to develop a good program in New Hampshire in terms of coastal zone management, using remote sensing and putting all those techniques into application. Somebody championed the cause in that legislative body: that is what it takes.

TETLEY: Regarding coastal zone management, communication is the key – involving Federal, State, and local people. Until effective information and communications networks are set up, we won't go anywhere.

SPEAKER: I want to ask a question directly about that communications problem. I will preface it by talking about something which happened in New Jersey. New Jersey had an investigative contract with NASA in the Department of Environmental Protection. It involved coastal zone management and inspection of use of wetlands using Landsat photographs. Out of this investigation evolved a semioperational use of the satellite data. The department was able to send inspectors to specific areas to check land use to make sure it conformed to the Wetlands Act of New Jersey. When that investigation contract ended, the state then had to look to its own sources. The Department of Environmental Protection put in a budget of $10 000, which was a rather small budget, but the New Jersey Legislature voted it down. Now, this to me is an example of something which perhaps happens in a lot of states. The question I have is: Is this not symptomatic of something which is very much more fundamental? It is not just the communications problem, but it is the relationship between the Federal Government and the states, in terms of what the Federal Government should do and what the states should do. And isn't it true that this has not been defined?

SPIROU: I think there is a general anti-Federal establishment attitude that state people display, particularly the executive branches, because of the way the Federal Government has worked in the past, going directly to cities and towns with Federal funds. The states don't have any control on the patronage of the money.

TILTON: It sounds to me like the case you describe in New Jersey was what is known as improper technology transfer. We need 2 to 3 years of working with an organization, whether it is a state or another Federal agency, before we understand their problems and they understand ours. Typically, to take a project and show people how they can use products and then walk out the front door is just about useless. You must carry it all the way through. In some cases, you must hire their people for them, train them until that thing is working in their building with their people for a year or more, and you gradually phase out. But unless you can do that, unless you can tell them what it is going to cost them, it is just useless. We found that out the hard way, but I think there are some examples in the program that at least tend to show the criteria for success in this technology transfer.

RICHARD: I'm Dan Richard from NASA Headquarters and I guess I ought to start by saying that I'm not a technical person. I guess what bothers me is Michele Tetley saying that we cannot really know what the state needs are, that the state cannot identify those needs. In the state and local users session at this symposium, one of the conclusions was that they had to identify their problems, because otherwise this technology is just going to look like so many more toys. We are trying to develop it for people to use and to tie it to some identified need at the state level. If the resolution from Landsat satellites is not adequate for coastal zone management, we need to know that. We could then just go out for high-resolution aircraft data or something like that, which might better serve those involved in coastal zone management. So it is very difficult for technical people to come and say, "We would like to develop technology to meet your needs," when the nontechnical people cannot seem to define their needs in such a way that we can do that.

TETLEY: I think in the coming months we will see the states coming up with a much better idea of their needs. This first year has been spent gearing up; now, they are really getting their teeth into planning and looking forward to the implementation of those plans. The various needs are beginning to surface, setting the boundary of the coastal zone, for instance, or the identification of critical areas. These are things that we know in the national office from the number of telephone calls and state trips to Washington. We know that these are going to be real problems. I do not see that the states are going to be beating a path to your door unless they can see that you can do something for them quickly and cheaply. We have the same problems trying to identify the needs before they get on the threshold of needing the information. It is awfully easy to have hindsight in something like this. Coastal zone management is a brand new approach to planning. We have learned a lot from some of our mistakes and also from our successes. Just looking at the act and the guidelines will give you a fairly good idea of the types of information the states are going to need. Some of the states, through other programs, have already identified or surveyed particular areas; others have not. So it is not going to be clear cut across the country. I think as I tried to pull together everything I could think of that would be applicable, I realized that relationships between NASA and the Office of Coastal Zone Management are practically nil at the Washington level. If we establish liaisons at the national level, the state relationships will follow more easily.

RICHARD: We are not sitting back waiting for the states to beat a path to our door. We have a program called the States Visits Program, in which we have been trying to go out to various state agencies and talk to them and have some kind of interchange to see if there are some possibilities there. Would NOAA be willing to encourage states to look at remote sensing as a tool for management if you were convinced that it had great potentials?

TETLEY: The word "encourage" is a little bit sticky. The states are basically on their own as to how they approach each of the planning and management elements. When states come to me with a particular information problem, I refer them to those individuals in the government or in private organizations who I think can help them. Heretofore, we have not pushed the states in any one direction. That is not the stance that the office has taken, and probably will not take. If we at the national level understand your capability and the types of expertise that you can provide the states, then when a state says it needs to know what the offshore currents are, I would add to my list: "Check with NASA; find out what they have in their remote-sensing programs and maybe that will help you." It would be one of a list of things I would recommend. The more we understand what you are doing, the better we can pass the information on to the states. Encouraging them and pushing them is not something to do.

SPIROU: I have a different approach to this. I think that NOAA should be one to encourage or discourage, when it can pass on information, because the capabilities you have is a very important question related to how states are going to make a decision. If I were advising a governor or planning to deal with coastal zone management directly related to me as a policymaker, I would call in NASA and say, "I got a grant from NOAA and I have some responsibilities to fulfill so I can hustle that money out. Now, I need some more information to know what to do with an application." I'm going to ask you and I'm going to recommend to the governor that we get people up to the statehouse from your office. But first, I have to know about you; I have to feel our relationship to you; I need something about coastal zone management.

PIERCE: I would like to ask the representatives what their overall feeling is of the total value of the scientific input that they need for the Coastal Zone Management Act. What areas are weak? What areas are strong?

KIER: First, I don't have any feelings at all for the precise kind of data needed to bolster that coastal plan. Second, are there real-life problems for which we have no hard data in California? The answer is definitely yes. We are currently staring down the gun barrel. The Federal Government is poised to release 1.5 million acres of California offshore oil and gas exploration production. If the drilling program proceeds, we have not the foggiest notion of what the onshore impact is going to be. The sale puts the information gathering and analysis burden on California as it is now, and we are trying to put that burden back on the Federal Government. I would say the hotspot on the California coastline today is the Federal offshore drilling program.

TETLEY: I would say the major gap in information right now is the onshore impact of the accelerated offshore drilling schedules that are proposed. This has been a very hot issue. We do have information, particularly in the Gulf of Mexico, but drilling there was done over a long period of time. It has become so much a fabric of the economy in the area that there is no way we can compare it to the accelerated buildup. As far as the other types of technology or information gaps, I think for the most part the technology is already there. It is just finding out which technology to apply where. And our job at the national level is to identify the sources of information and pass this information on to the states so that they do not have to reinvent the wheel. Each state has a different personality regarding its particular needs.

MILLER: I'm John Miller from the University of Alaska. Mr. Spirou, I number myself among those who are hoping to learn from some of your comments about being able to communicate and understand political realities. Mulling over some of your comments, I have one politically oriented question. I appreciate your comments about the importance of the referendum regarding the Durham refinery proposal. How far in your view do you think the local referendum concept can be wisely taken? For example, clearly, a city the size of Durham makes a strong case. Suppose we are talking about a powerplant (nuclear or otherwise) and three farmers would like to sell their property to the developer. Naturally, it is going to impact maybe 10 or 15 farmers in the area. In this instance, their rights surely are as vested as those of the Durhamite, but they carry far less political clout. How, in your view, should something like this be handled?

SPIROU: I am a regionalist, you know. Originally, I believed in a concept of planning for energy resources. If everything was normal and we started talking about America being self-sustaining and everybody fulfilling their responsibilities to produce energy, I would have sat down willingly with Massachusetts, Vermont, Maine, and everybody else, laying out the agenda as to how we go about it. But I was not given an opportunity to do that. What side do I choose? I had to make some very fast decisions. So we all changed around, and those who were regionalists became local-referendum oriented, and the governor, who ran as a local-referendum-oriented person, changed the other way and said this has regional and statewide ramifications. In this particular case, a referendum was okay. If it had been allowed to evolve logically, I would have never taken that position. It was a reaction position in the absence of anything other than reaction. It was the only way we could have stopped the nonsense of just putting in a refinery with no studies, no discussions, simply because there was an energy crisis. That doesn't mean it was the logical thing to do or the right thing to do. And it was not the thing I would have done given the opportunity to sit down with those who had the technical expertise to convince me that, "Yes, we can have it there," and tell me, "This is going to be the impact it is going to have," and "No, we don't need a 500 000-barrel refinery; a 200 000-barrel would be equally effective." Or there are other alternatives. It was a reactionary thing, and it happened that way.

SWETNICK: There was a recent meeting of the Outer Continental Shelf Resource Advisory Board, which is composed of Government representatives and state representatives. There was some concern on the part of several states as to their lack of involvement in planning the offshore program. And at the same meeting Assistant Secretary of the Interior Hughes reported to this board that there was going to be a meeting of the coastal zone governors to resolve this. What are the political implications when the governors then have to relate to the state legislatures?

SPIROU: In my opinion, the responsibility of the Department of the Interior or of the Department of

Commerce or anybody else is understanding the ultimate responsibility that rests with the legislative body. We have gone too far in keeping legislative leaders uninformed about what is happening in the executive branch. Until the executive leaders understand that legislative leadership needs to be a coequal partner in this process of decisionmaking, we are going to find agreements between governors going down the drain. Those people had better talk to the legislative leaders before they make an agreement because they are going to have another conflict afterwards between the two branches if they don't. We are a check and balance on one another. If the governor is going to be informed, I have to be informed also.

PIRIE: I am Doug Pirie, Corps of Engineers in San Francisco, and I am very interested in the State of California. I have some logs that I keep because I often get questions about who uses all of this NASA aircraft imagery. I have on my log State of California Navigation, Ocean Development, Department of Transportation, Environmental, Fish and Game, State Lands Commissioner, and on and on. People would have to actually use this in planning, and they are. And they are using NASA imagery flown by JSC and by NASA Ames Research Center. That should not be overlooked.

KIER: That does not refute my point that the California Legislature has made no conscious or deliberate investment or involvement in remote sensing. You may be getting it to some technicians in state agencies, but that does not assure any continued interest in applying remote sensing to solving problems in California.

PIRIE: This may be true. However, I think you will find this is going to be almost a grassroots-type action. In instances where people are getting used to using remote sensing, they are going to demand that heads of state agencies, who are in a position to say where funds should be spent, get heads of departments who understand what is happening with remote sensing. Then, these people can be coordinators between NASA and the state.

KIER: Your point is well taken. Part of the New Jersey dilemma was the question, "Shouldn't the role of the state and Federal agencies in this remote sensing be defined?" And I was thinking, we'll have another committee and we'll define the roles and responsibilities and we'll have another inch of paper that decisionmakers won't read. The role will be defined exactly the way that you described: on a project-by-project, real-life basis.

When Dan Richard indicated that Lee Tilton is involved in a program of going out to the states and assessing the needs for information, I was conjuring up in my mind Federal involvement in a series of sessions with California program managers. These sessions would for the most part be involved with trying to produce a product that would convince a legislator that this is good stuff. And I was speculating on the possibility of the Federal people ever stumbling across a very real problem, for example, the decline of dungeness crab in northern California. We suspect we have an industrial pollution problem in the San Francisco Bay area. But along the north coast, evidence has just materialized that crabs in very juvenile stages are affected by silt outflows. That silt adhering to their young bodies provides an excellent medium for disease organisms to grow.

PIRIE: As you may know, we do have studies in San Francisco Bay, which is being used as a classic for sediment distribution and all the ramifications of it. This study is not necessarily pointed toward remote sensing, but we *are* using remote sensing with that study. I don't think that fact has ever been publicized either.

KIER: One of the things I am doing here is looking at aquaculture to answer some questions the legislature is dealing with. Getting the California market crab industry back on its feet involves interest from two or three different directions. My point is, it is highly unlikely that a quick trip to California by Federal folk would reveal that real-life data requirement. That problem just happens to be very important to the dean of the California Senate. He is the kind of man who, because of immediate direct interest in a problem affecting the people of his district, could well be the champion of the kind of data that provide part of the answers – in this case, concerning market crab decline.

TETLEY: I am heartened by the fact that you say there is a grassroots movement in California to use remote sensing. This is probably the way it is going to have to go, the lower echelons using it and convincing their bosses and heads of agencies that it is valuable. These grassroots are the very people that are the constituencies that Chris worries about, and I would think that they would be able to convince the legislators, too.

SPIROU: I don't believe in spontaneous grassroots. I am a product of grassroots neighborhood involvement, and I do not think there is anything spontaneous about it. If a private company, for example a computer company, had given 15 agencies in the State of New Hampshire a helping hand in sorting out their little problems one way or another, you know what would have happened. Somehow there would have been some money in the budget. The company that is going to get it is the one who already has friendly relations with everybody around. You have to ring your own bell if you want others to start ringing with you. Just because you have provided technical assistance, if you have not reached Kier and the people he works with, you are not going to get in the budget ever. Or if you do, it's going to be too long from now.

CARTMILL: I am Bob Cartmill from NASA, and I have a question for the legislative people that is just a little bit different from how you sell to the legislature. I think you may need us more than we need you, because the solutions to these problems are going to have to be technological solutions. I think all we really need to do is find a political mechanism to help solve very real technological problems. There is, for instance, an energy shortage in this country, and passing this law or that law isn't going to make that go away. If technology provided the offshore platforms which caused the pollution, then I'm afraid the only solution is going to be some technology to control that pollution. Do your constituents really feel concern for the energy crisis, or do they think it is all made up?

SPIROU: Yes, there is an energy crisis, and I do agree that we have to solve it technologically. The confrontation between the technological sector and the political sector has to happen. The pressure has to accumulate. Nobody is going to come from ground level and start screaming for a nuclear plant he doesn't understand. The people of this country are right now in a survival stage. They want to know how they are going to feed their families, what their kids are doing, what's happening to their wives or their husbands. Generating energy is the last thing they think about until their utility bill goes up. A real grassroots movement to build a refinery or a generating plant is just not going to happen. Powerplants are not on their agenda. So you are going to have to find the mechanism someplace between you and me and then get the people feeling comfortable that this is the number one item on our agenda.

CARTMILL: If I understand your remarks, you are not really feeling an urgency about this situation that apparently a lot of people feel. Maybe this is true with gasoline at 60 cents a gallon. Will it be true at a dollar a gallon? How about $2.50 a gallon?

SPIROU: I'm expecting those glasses and dishes to come back. This time, the oil companies will be giving them at $1.50 a gallon and 700 percent profit, so you're going to have an incentive to buy that gasoline. They are expecting you. I have 14 glasses; I needed 20. I am still hoping to get the other six. And I still want the Tony the Tiger doll because I missed him. So, how are you going to convince me there is an energy crisis?

CARTMILL: Maybe when they start plowing fields with horses instead of tractors. Maybe there isn't an energy crisis, but if there is, the results will be felt.

SPIROU: I am not convinced as a state legislator. Not one bit.

KIER: I think that is the short answer for California as well. You in Houston live in an oil town; unemployment is low in the community. Oil is good for Texas and Texas likes oil. The average Californian doesn't have the same opinion of oil companies. Unemployment is at 10 percent in California. The people's sense of urgency lies elsewhere. People don't understand how jacking up the price of gasoline is supposed to solve the energy problem. People react to crises as they hit them at home. It is just not hitting at home, in a way that people comprehend it as an energy issue. It is not the nature of folks to engage in long-term solution evolution. That's not to say the issue cannot and ought not to be exploited. I've done it myself. I drafted a $10 million recreation trails program, which is speeding its way through the California Legislature. And the urgency of it as I framed it is to devise a network of bicycle trails off highways in California because of what I claim to be a burgeoning number of Californians who are forced to bicycle rather than drive to work because of the alleged energy crisis. And you'll recall the hullabaloo in California when the well blew out in the Santa Barbara Channel and oil folk became bad guys overnight. That same Santa Barbara community voted, on one of these local referendums, approval of a new refinery in Santa Barbara County. I'm sure that oil company is getting advertising copy ready to explain how people of Santa Barbara have faced up to the energy crisis. It was not that at all. It was undoubtedly concern over jobs and a lot of hard lobbying by construction trade unions.

TETLEY: I do not think that the locals are as worried about technology as they are about their own backyard. Until they can understand how coastal zone management or land use or any of the planning and management programs are going to affect them and what they are going to gain they are not going to worry about the little ins and outs of existing technology.

WORLEY: My name is David Worley. I am with the Coastal Marine Council in Florida. I have been a coastal planner for 4 years. We have been actively engaged in remote sensing in our program. There are a couple of points I would like to try to put forth in terms of coastal zone management and remote sensing. We have a multiple program requirement. The concept of coastal zone management is very involved, in terms of all data acquisition and dat. dissemination. It depends entirely on your program design from the local to the state level, and also on your Federal requirements. To meet these requirements, you must have a multiple program as far as data collection and dissemination. Michele mentioned about getting into the local level. We have been with the local 4 years; that has not been the problem. The problem is political expediency. It is going to be a problem both with the coastal zone management program and remote-sensing application because you get down to the question: How much information does the political decisionmaker really want? If you can get the local people involved, you won't have any problems. But it is a process that will take time, particularly with a new program. When NOAA goes into these areas, it should find out how far along the local people are, particularly in program design and trying to get help in instrumentation. But if these local people do not go back to the legislative process and get their own elected officials to support the program, then nothing is going to happen.

TETLEY: I agree it has to be done from both sides because a legislator is not going to move unless his constituency is obviously going to be positively affected by it, and he is not going to know how they feel unless they already understand the problem.

N76-26649

C-3. Applications of Remote-Sensing Technology to Environmental Problems of Delaware and Delaware Bay

D. Bartlett,[a] V. Klemas,[a] W. Philpot,[a] and R. Rogers[b]

In addition to my work with the State of Delaware wetlands inventory, I also pursue research in digital processing of multispectral data. I have been associated with the state coastal zone management project, and I participated in the formulation of regulations for the management of Delaware wetlands. Therefore, I not only provide data, but I am also a first-order user of some of those same data. Although our major research interest at Delaware is in the analysis and interpretation of Landsat and Skylab data, when called upon to apply remote sensing to a particular problem, we rarely rely solely on orbital imagery. We have never intended, nor has NASA, that orbital platforms should replace all other forms of information gathering, remote sensing or otherwise, for any application. In almost all cases, we envision the application of Landsat technology as part of an integrated system of data gathering, including lower altitude remote sensors and other sources of information.

Our applications of remote sensing are divided into those concerned with water, which I shall discuss first, and those concerned with more or less dry land. First, the State of Delaware and the National Science Foundation, through its research applied to national needs program, have supported the development in Delaware of a computerized model of predicted oil slick movement within the bay. Delaware Bay is the largest petroleum marshaling area on the east coast; it handled about 87 million tons of petroleum products in 1973, and that figure has increased quite a bit in the 2 years since. Thus, the States of Delaware, Maryland, New Jersey, and Pennsylvania are understandably concerned about the movement of oilspills.

Once a spill has been reported, the input requirement at a computer terminal includes the size, the location, and the time of the spill; the nature of the oil; and the weather forecast, particularly wind conditions and unusual tidal conditions. With this input, the console has the output capability to display the oil slick movement as a function of time and to display the spatial oil slick probability on an average monthly basis. With this information, one can determine where a slick is most likely to come ashore. Engineers and oceanographers who worked on this project first thought they could simplify things considerably by assuming that because an oil slick, for the most part, floats on the surface, they need only worry about those phenomena affecting surface water circulation in two dimensions. From their preliminary tests, however, they discovered that they could not rely upon this assumption because of the presence of structures that they termed "fronts" (ref. 1). A front is defined as the surface expression of the convergence of two water masses, usually sediment-laden fresher water and clearer oceanic water. Figure 1 illustrates a front and the sharp interface that occurs between two such water masses. One component of the motion of the water masses is convergence, and one water mass at the point of convergence goes down underneath the other. Usually, the more saline, therefore denser, oceanic water goes underneath. As the two converge, they bring floating material with them; as one mass slides under the other, the material is trapped along the boundary (ref. 2) and moves about quite differently than if it were affected simply by winds and tides in a strictly two-dimensional sense. These become three-dimensional structures in the sense that they continue below the surface. Figure 2 is an example of this type of behavior. It is a drawing made from low-altitude ultraviolet photography showing oil slicks in the lower part of Delaware Bay shortly after a spill had

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[b]Bendix Aerospace Systems Division, Ann Arbor, Michigan.

Figure 1.– Aerial photograph of coastal and oceanic water masses converging along a "front" on the western shore of Delaware Bay.

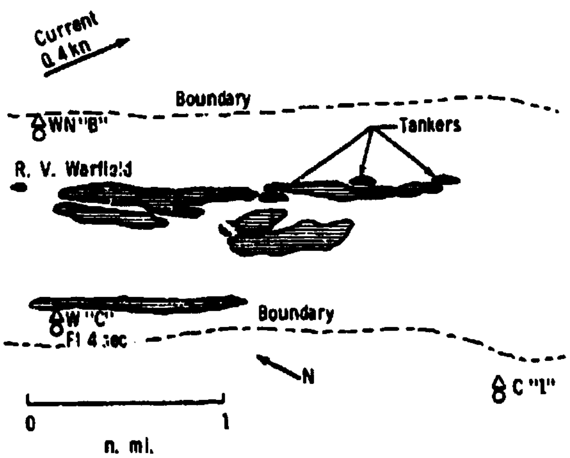


Figure 2.– Map of distribution of small oil slicks interpreted from a low-altitude ultraviolet photograph. Symbols and numbers identify specific buoy locations.

occurred, about 10:30 a.m. Figure 3 shows the spill at 3:00 p.m. on the same day. The slicks now are oriented longitudinally along the long axis of the bay, and the sinuous pattern that is characteristic of something trapped along one of the fronts is apparent. The

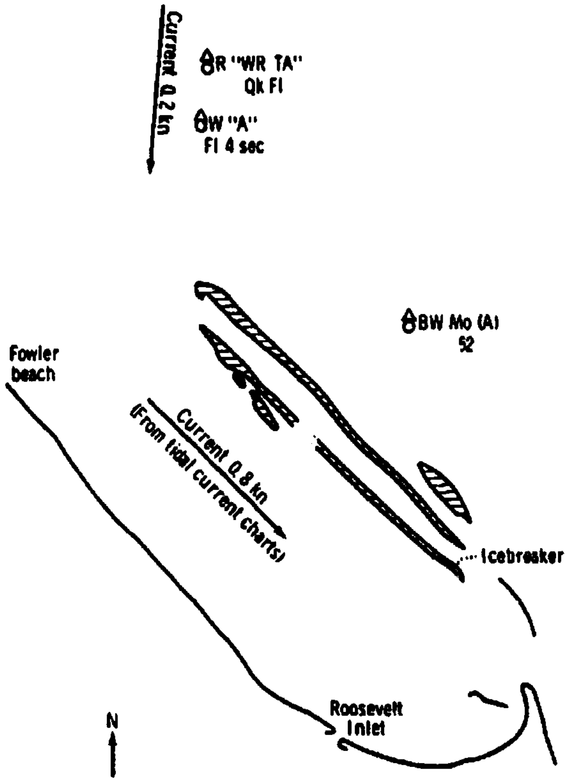
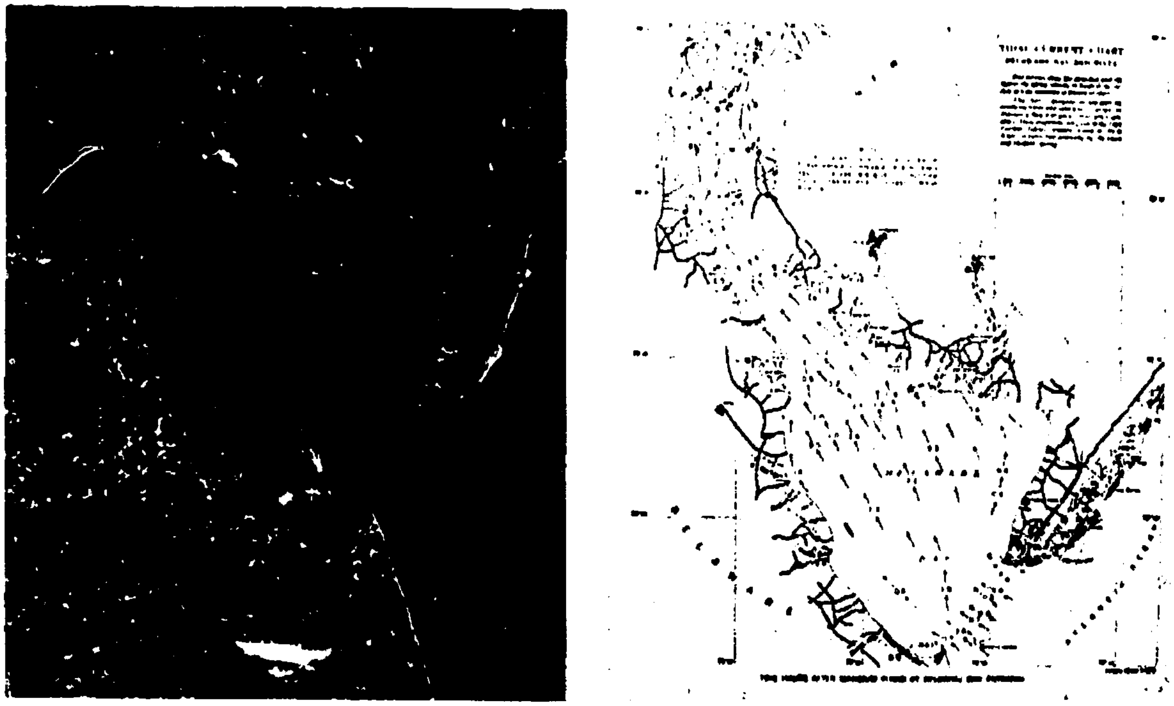


Figure 3.– Map of distribution of oil shown in figure 2 after 4.5 hours, showing entrainment of oil in coastal fronts at a scale of 1:80 000.

dispersal of the slick and its gross movement about the bay are considerably different from what one would predict if the presence of the convergent fronts were ignored. Fortunately, these fronts occur in relatively low numbers and in characteristic locations in the bay, depending on the tidal stage. They also are large enough to be easily seen in Landsat imagery (ref. 3).

Figure 4(a) is a Landsat image of Delaware Bay acquired during floodtide; several fronts are visible in the upper portion of the bay parallel to the shore. Figure 4(b) is a tidal current chart provided for comparison. This figure is indicative that the scale of Landsat imagery makes identification of huge features much easier than if lower altitude sensing were used. We have approximately 20 good sets of Landsat imagery of Delaware Bay at different tidal stages showing the instantaneous distribution of these fronts over the entire bay. Programming the characteristic location of these fronts during different tidal stages and under different wind conditions should make the oil slick model an even more accurate and efficient tool.



(a) Landsat image.

(b) Tidal current chart.

Figure 4.– Landsat-1 image (band 5) of Delaware Bay and tidal current chart for tidal stage corresponding to time of Landsat overpass.

We are also using Landsat imagery in a project that requires monitoring an offshore waste disposal site. Figure 5 is a Landsat image acquired immediately after the dumping of iron acid wastes roughly 40 nautical miles off the Delaware coast; dispersal has not yet begun. The sinuous pattern is produced simply by the movement of the barge dumping the waste. Figure 6 is a digitally enhanced image taken from the same data; it shows a little more structure within the plume. Denser areas are denoted by red, less dense areas by dark green, and general oceanic water by light green. Because the acid was dumped at a time we specified (a given time after a Landsat overpass), we can study the movement of the plume and its dispersal through time. As I mentioned, we do not rely exclusively on orbital imagery; an extensive conventional water sampling program is also part of the project, and the current data obtained by tracking the spill visually through time with Landsat imagery are supplemented by data acquired using disposable, radio-signal-emitting drogues that are tracked from shore (ref. 4). The latter technique, of course, is a type of remote sensing, although it is not accomplished from the air.

Our major project on land has been inventorying the Delaware tidal wetlands at a variety of scales. Figure 7 shows the general purpose mapping of the wetlands and the plant species within them at a scale of 1:24 000 (ref. 5). The information was interpreted from color and color-infrared photography acquired by an NASA aircraft flying at an altitude of 60 000 feet. Figure 8 was done at a scale of 1:2400, 10 times larger than the scale of the previous study, and the wetland boundaries and the species identifications are drawn directly on black-and-white enlargements of the photographs used for interpretation. Figure 9 shows a more comprehensive inventory of cover types generated from Landsat digital data (ref. 6). The variety of color-coded cover types is oriented toward an inventory of coastal wetlands but also includes agricultural and barren land categories.

All of the categories involved were interpreted in approximately 3 days by use of computer equipment developed for this purpose by the Bendix Aerospace

Systems Division. It was possible to distinguish the three primary vegetative communities present in the wetlands as well as related categories around and within the wetlands. The accuracy of identification has been determined to be greater than 85 percent for all categories and greater than 90 percent for all but two of the categories. By comparison, the U.S. Bureau of the Census regularly encounters errors of 5 to 10 percent when doing regional inventories of agricultural land use areas.

We are investigating ways of correcting Landsat data for effects of the atmosphere between the ground target and the Landsat, and we hope this work will allow us to conduct an even more detailed and accurate survey. The success of this endeavor has encouraged us to explore an application by which potential impacts of offshore oil and gas development on the coastal environment of Delaware could be identified. The idea is to examine Landsat images of areas in which development has already occurred or is currently taking place, such as Louisiana, Alaska, and southern California, and to identify characteristic features such as storage and marshaling areas, petroleum-related industrial activities, transportation networks, and docking areas. All of these features should be large enough to be seen at Landsat scales, and the hope is that by examining patterns of development in other areas, the potential impact on the Delaware coast can be anticipated. As with other projects, the orbital data will be supplemented with low-altitude aircraft photography, maps, or other data.

We believe that orbital data must be used in conjunction with other sources in almost any operational project. Orbital data are, of course, the newest and thus the least proven of the various remote-sensing tools; however, the acceptance of our work -- which was accomplished largely through the use of platforms at orbital altitude -- by such diverse and applications-oriented organizations as the State of Delaware, the Environmental Protection Agency, and private industry is encouraging.

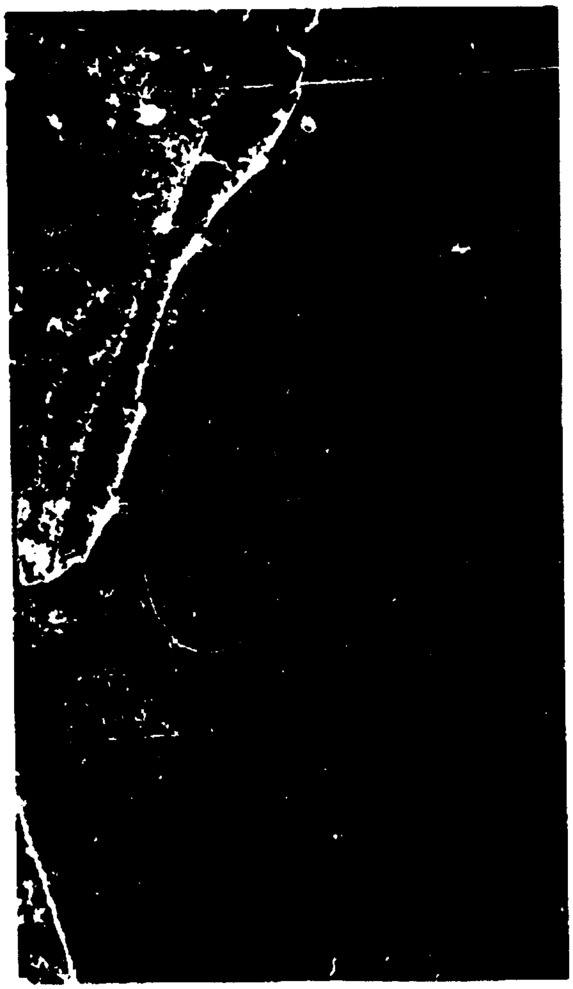


Figure 5. Landsat-1 image (band 5) showing location of acid waste dump, the fishhook-shaped plume in the lower center. The dump area is in the North Atlantic Ocean, approximately 40 nautical miles off the Delaware coast.

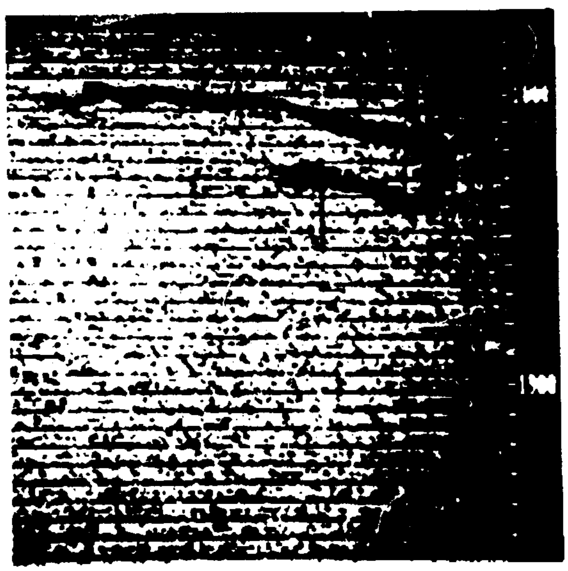


Figure 6. Digital enhancement and enlargement of the data in figure 5, showing structural features of the acid waste plume.

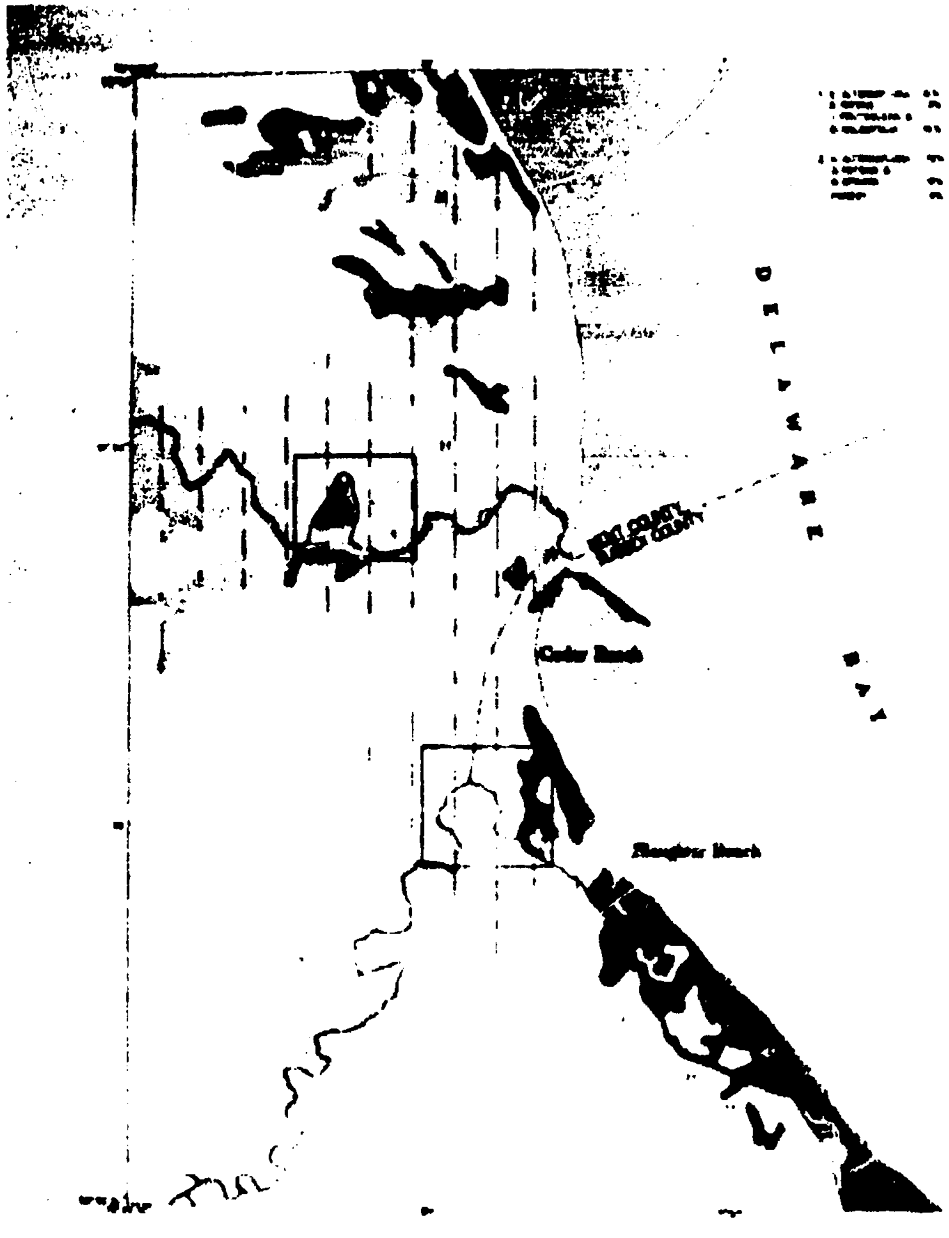


Figure 7. Wetland vegetation distribution map at a scale of 1:24 000. Colors denote various wetland plants, and white indicates upland or beach material that is not included in the wetlands.

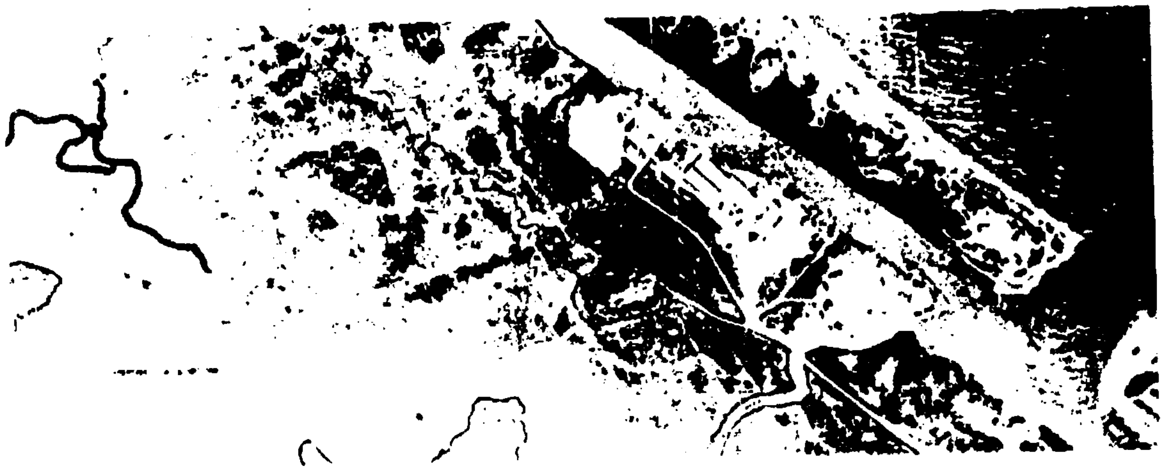


Figure 8.– State of Delaware wetlands inventory photographic sheet, showing wetland/upland boundary (heavy line) and vegetation boundaries (thin line). Roosevelt Inlet is in the lower right portion of the figure.

Figure 9. Coastal land cover map generated by supervised digital analysis of Landsat-1 multispectral scanner data.

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N76-26650

C-4. California Nearshore Surface Currents

Douglas M. Pirie[a], Michael J. Murphy[a], and J. Robert Edmisten[b]

INTRODUCTION

Characteristics of nearshore surface currents along the California coast contribute in large measure to the economy of California and also provide unique recreational and esthetic experiences for the citizenry. The impacts of oceanic current variations on the fishing and resort industries are well known. Less understood are the problems encountered in coastal engineering due to the lack of good data on nearshore currents that affect littoral transport as well as other coastal parameters.

During the "oceanic period" from July to November, the southward-flowing California Current dominates the nearshore current patterns. Commencing about the middle of November and extending to mid-February, the Davidson Current, a northward-moving countercurrent, is the dominant inshore transporter of water and suspensates. The phenomenon of upwelling is prevalent during the period from the middle of February to the end of July. Thus, every year along the coast of California, there are the three successive current seasons: the oceanic, the Davidson, and the upwelling. This paper is a discussion of the nature of these nearshore currents. In addition, the capabilities of various remote-sensing platforms and systems for providing methods of monitoring the coastal processes associated with the current seasons of California are demonstrated herein.

GENERAL OVERVIEW AND RESULTS OF PREVIOUS INVESTIGATIONS

Remote Sensing of Surface Currents

With the advent of quality films and multispectral imaging systems for both aircraft and satellites, remote-sensing techniques have gained widespread acceptance and use in studies of coastal processes. The Landsat provided for the repetitive acquisition of high-resolution multispectral imagery of the Earth surface. With respect to nearshore currents, Landsat permitted synoptic, repetitive coverage having acceptable resolution capability for detecting current directions and horizontal distribution, upwellings, current blockages, offshore movements, gyres, and sediment sources (ref. 1). In addition to the Landsat data, imagery from NASA U-2 high-altitude aircraft and from medium-altitude NASA Earth observation aircraft has been used for coastal current evaluation.

Use of the 0.5- to 0.65-micrometer band of the electromagnetic spectrum provides the best definition of nearshore and offshore currents that carry suspended sediments. The suspensates act as current pattern tracers and originate primarily from riverine discharges, estuarine flushing, and shore erosion. Satellite and aircraft systems have provided imagery of the structure of large coastal and lacustrine plumes associated with sediment-producing areas in many parts of the world. During periods of little or no runoff, especially in southern California, the lack of appreciable quantities of suspended materials acting as tracers makes detection of sea and coastal processes difficult.

To obtain maximum information from transparencies and computer tapes, enhancement techniques for expanding density ranges have been applied. It is also possible to use multichannel computer processing to enhance water density differences between the various multispectral channels and thereby enhance suspended sediment and current features. Analysis of available Landsat imagery, U-2 aircraft photography, low-altitude aircraft imagery, and sea-truth data has resulted in generalized monthly current patterns along the coast of California (ref. 1).

[a]U.S. Army Corps of Engineers, San Francisco, California.

[b]U.S. Army Corps of Engineers, San Rafael, California.

Nature of Nearshore Currents

Although a fully integrated picture of all factors influencing the nearshore surface currents along the coast of California has yet to be developed, the most important force imparting motion to the surface waters is known to be wind. As described by Sverdrup, there is generally a clockwise current circulation in the North Pacific Ocean caused by the strong westerly high-latitude winds, which move the waters eastward, and the trade winds farther south push the waters westward in a return flow. The California Current lies at the eastern, southward-flowing side of this Pacific Ocean circulation pattern. The current flows southeastward between one cell of high atmospheric pressure to the west and another cell of high pressure on the landward, eastern side. Winds over the California Current are generally from the north and the west. These winds are strong when the two high-pressure cells are close together and intense. Conversely, winds are weak when the cells are farther apart and moderate. Both these cells are weakest in winter. The high to the west moves northward in spring and summer as it grows slightly stronger. In the fall, it weakens and moves southward. The low-pressure cell over the land is a semipermanent feature with a wider range of seasonal variations. Changes in the strength and location of the cells cause seasonal changes in the winds along the California coast. From spring to fall, the main component of the winds is northerly; in the winter, this northerly component either weakens or reverses.

Other forces that affect the ocean waters are pressure gradients, Coriolis effects, and gravity. They produce geostrophic flow, or gradient currents, which result from the action of gravity flow outward from topographic bulges of water found primarily at the center of surface wind gyres. Differences in the level of the sea produced by low-density water overlying denser water, especially if a sharp interface exists between the water bodies, induce slope currents. During the fall and winter months, river discharge quantities, particularly in northern California, are of sufficient magnitude to cause slope currents.

Description of California Current

The California Current system is a part of the general clockwise circulation of the North Pacific Ocean. At high latitudes, the waters move eastward under the influence of the "roaring forties," and near the coast of North America south of the Aleutian Islands, they divide into branches. The smaller part turns northward into the Gulf of Alaska, and the larger part turns southeastward to become the California Current. The water that is transported south by the California Current is cooler than the waters farther offshore. This current, with a usual speed of less than 0.25 m/sec, is modified by upwelling, solar heating, river discharge, and exchange with estuaries and embayments as it traverses the shoreline of western North America. As it nears latitude 25° N, it begins to turn westward and its waters become part of the westward-flowing North Equatorial Current. On the inshore side of the current, numerous variations of the circulation occur. A permanent counterclockwise eddy, the Southern California Countercurrent, is found inside the submerged peninsula that extends southeast from Point Conception and that includes Santa Rosa Island, San Nicolas Island, and Cortes Bank (ref. 2).

Oceanic and Upwelling Seasons

Along the coast of California, winds from the north and the northwest prevail during the spring and summer months. The nearshore, southward-flowing surface waters are turned from their movement along the coast to a direction offshore. The waters that move offshore are partly replaced by colder waters from below. This replacement is known as upwelling and is important because of the surfacing of waters rich in nutrients. These nutrients support the abundant and diverse biological activity in the coastal waters.

The period of strongest upwelling differs along various sections of the coast. For San Diego, McEwen defined the upwelling period as April to September with a maximum during June and July. For Monterey Bay, Skogsberg gave the upwelling period as the middle of February to the beginning of September (ref. 3). Maximum upwelling occurred before the end of July in his investigations. Reid and others suggested that upwelling is strongest when the northerly and northwesterly winds are most marked (ref. 4). This condition occurs in April and May off Baja California, in May and June off southern California, in June and July off northern California, and in August off Oregon. Wyrtki said that upwelling off Baja California occurred throughout the year.

A theoretical consideration for large-scale upwelling was given by Yoshida and Mao. They used their equation for vertical velocity in the surface layers to show that intense upwelling should occur only in the spring in southern California and Baja California waters, because of the positive values in the curl of the wind stress. Also, intense upwelling in the northern areas should occur only during the summer and fall, when the curl of the wind stress has appropriate positive values.

Skogsberg indicated that upwelling was limited normally to the upper 300 meters; but, during years of intense upwelling, the depth could be greater (ref. 3). Sverdrup and Fleming (ref. 2) have indicated this figure to be approximately 200 meters. Roden and others, using statistical data off northern California, concluded that water from depths greater than 100 meters does not ascend frequently to the sea surface.

Sverdrup found evidence of coastal upwelling as far as 100 kilometers from the coast. Yoshida and Mao implied that upwelling of a large horizontal extent could occur as far from the coast as 600 kilometers. Yoshida's theory of coastal upwelling described a narrow strip of upwelling approximately 50 kilometers wide near the coast (ref. 5). The width of the coastal upwelling is controlled by two parameters. The first is the axis of the northerly winds. When the axis is near the shore, the upwelling zone is narrow; when the axis is far from shore, the zone is wide. The second parameter is the latitude; the calculations presented from Yoshida's model showed that the width of the upwelling area decreased with increasing latitude.

Sverdrup and others indicated centers of upwelling along the coast at latitudes 24° N, 35° N, and 41° N. Hidaka suggested that since his velocity components all included the sine of the latitude in the denominator, the intensity should increase with decreasing latitude. Reid and others (ref. 4) noted that upwelling was more intense south of capes and seaward extensions (Cape Mendocino and Point Conception). Pattullo and others reported a similar situation off the coast of Oregon, and Dawson reported this effect off the coast of Baja California. Arthur, using his equation for upwelling velocity, explained this occurrence theoretically. The planetary vorticity term is always negative on the western coast of continents. The relative vorticity is positive north of a point or a cape (opposing the planetary vorticity) and thus contributes to a smaller upwelling velocity; the vorticity term is negative south of a point or a cape and therefore contributes to a higher upwelling velocity. Holly found a correlation between the most persistent areas of coastal upwelling and locations of greatest continental shelf slope (approximately at latitudes 29° N, 31° N, and 33° N) (ref. 6).

During the period from April to September, coastal upwelling is the principal controlling factor of sea surface temperature within 100 kilometers of the western coast of North America; large-scale upwelling is an influential factor in the California Current region farther offshore. Coastal upwelling is smaller in scale and more intense than large-scale upwelling. These two types of upwelling frequently occur at the same time and are separated by a trough of sinking water. The nearshore circulation resulting from coastal upwelling is determined mainly by wind stress; but stratification of the water, bathymetry, and latitude are influential factors. Either alongshore or offshore winds can produce coastal upwelling. A predominantly alongshore flow with a small offshore component produces the most intense upwelling. Intensity also increases, as does width, with decreasing latitude. Large-scale upwelling is produced by the curl of the wind stress. The ascending motion of the water produced by the curl of the wind stress results in a subsurface poleward-moving current. Also, an increase in intensity south of capes and other seaward extensions can be observed and shown theoretically to occur with a current flowing southward on a western coast.

Davidson Current Season

During the period of approximately November to February each year, the Davidson Current, a northward-moving countercurrent, is the dominant inshore transporter of water and suspensates.[1] The Davidson Current is generally deep (below 200 meters) and flows to the northwest along the coast from Baja California to some point beyond Cape Mendocino (refs. 4 and 7); it has been observed as far north as 50° N latitude (ref. 8). It brings warmer, more saline water great distances northward along the coast throughout the year. When the north winds are weak or absent in late fall and early winter, the Davidson Current forms at the surface on the inshore side of the California Current main stream.

Current Measurement

Commencing in the late 1950's, direct measurements of the California Current were made using various

[1] Edmisten, J. R.: California Nearshore Surface Currents: Past Observations and Recent Remote Sensing Information. Univ. of Cal. at Berkeley, 1974. Unpublished research.

measurement techniques. Improved radar and radar reflectors made it possible to track many drogues simultaneously and thus to measure the currents over wider areas with only one ship. Such a technique was employed in March 1958 to gain a detailed picture of the California Current for a 4-day period off Point Sur in the vicinity of Davidson Seamount. The current set was to the southeast at an average velocity of 0.25 m/sec. Rapidly moving streams with maximum velocities of 0.90 m/sec were observed by Jennings and Schwartzlose (ref. 9). Direct measurements of the nearshore surface currents were again made in October 1958 and January 1959 for the same location off Point Sur. Parachute drogues were used to determine current direction and speed. In October, the coastal waters were just beginning to flow northward and the velocities measured using both drogues and geostrophic approximation indicated a degree of irregularity. In January, however, the northwestward-flowing Davidson Current was well established. It was approximately 90 kilometers wide at 36° N latitude, and speeds of 0.10 to 0.25 m/sec were observed. Flow maintained quasi-periodic fluctuations of approximate diurnal and semidiurnal periods. Geomagnetic electrokinetograph (GEK) measurements substantiated fluctuations in flow (ref. 10).

To supplement the direct measurements obtained by drogues and the GEK, drift bottles have been used extensively to study nearshore currents along the coast of California; and, except for remote sensing, few other data show as clearly the existence of the Davidson Countercurrent during the late fall and winter months. The results from drift-bottle studies of inshore currents along the coast of California have been reported by a number of investigators (refs. 4 and 11 to 15). Other related drift-bottle studies have been made (refs. 8, 16, and 17). In late 1954, the Scripps Institution of Oceanography component of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), the Marine Life Research Group, began using drift bottles to study seasonal variations in the inshore portion of the California Current. From 1955 to 1971, a period of 17 years, 148 384 drift bottles were released and approximately 3.4 percent (4995) were recovered (ref. 15). The northernmost return was from Montague Island, Alaska (August 1968); the southernmost return came from an area just north of Acapulco, Mexico (May 1959); and the westernmost return was from the island of Hawaii (September 1969). An interesting feature of the drift bottle results is that few bottles placed more than 75 kilometers offshore have returned to the coast. This result is consistent with the assumption that the surface waters are nearly always moved offshore by the prevailing wind.

Geostrophic Flow Calculations

In the open ocean waters away from regions of effective boundary friction, unaccelerated and frictionless flow is called geostrophic (Earth turned). The only effective forces acting per unit mass are the pressure gradient, the Coriolis effect (to the right in the Northern Hemisphere), and gravity. Currents produced as a result of the slope of isobaric surfaces, which are a function of the density distribution of the water, are called gradient currents. To express these density distributions as currents, some assumptions must be made: that the currents and density distribution are steady; that no effects of friction exist either at the bottom or from wind at the surface; that some depth (perhaps 1000 meters) exists at which there is no motion and to which the density measurements can be referenced; and that above this level, all movement is horizontal and east to west. The geostrophic flow, calculated from temperature, salinity, and depth data, provides a reliable approximation of the actual motion of the water from the time frames exceeding 1 day (ref. 18). However, currents computed from density are not as reliable for nearshore waters because the basic assumption and boundary conditions are not so well fulfilled and because other factors, such as coastline configurations, varying depth, variable winds, upwelling, and oscillations of internal waves, influence the nearshore currents.

DESCRIPTION OF CURRENT SEASONS FROM REMOTELY SENSED IMAGERY

From 1970 to mid-1974, NASA obtained a wealth of imagery of the ocean off California with Landsat, U-2 high-altitude remote-sensing aircraft, and low- and medium-altitude aircraft. These data sources have provided unique views of the coastal currents, from macroscale to microscale and spread over the various oceanic seasons, and have given coastal engineers and oceanographers a tool with which the primary coastal current systems may be traced in detail. High-altitude remote sensors produce extremely comprehensive, clear images of the ocean surface revealing large-scale phenomena and relationships that often cannot be seen from a low altitude (below 5000 meters) or from a surface perspective.

Because coastal water is a complex mixture of solubles, colloids, suspensoids, and biologic substances, visible light is absorbed, scattered, and reflected in the water column in different spectral bands and in varying amounts. These differences create variations in color, brightness, texture, and contrast boundaries on imagery. Oceanic masses are distinguished by these imaged spectral variations. Nearshore current systems are very important in connection with various coastal processes and have a strong influence on the industrial, recreational, and engineering activities in the coastal zone. The principal difficulties in obtaining field observations of nearshore currents arise from the fact that the phenomena of current systems extend to the broad area in and near the surf zone. In the investigation of sediment transport in the littoral zone, not only must the wave characteristics such as height, period, and direction be defined, but also the current field and bathymetry inshore and offshore of the littoral zone must be understood to ensure that models developed to predict sand transport adequately reflect the coastal parameters that exist in the prototype. It is not uncommon for field observers to note that a net sand transport for any particular site will be opposite that predicted by wave characteristics alone because of the dominance of the oceanic current system over the wave transport system. What is needed is the development of models that superimpose wave induced drifts with oceanic current induced drifts. Therefore, a good statistically reliable knowledge of the nearshore oceanic current vectors is basic. Unfortunately, quantitative as well as qualitative data pertaining to coastal currents off the shores of the United States are deficient at present.

As byproducts of attempts to define the nearshore currents that affect littoral transport mechanisms, valuable inputs have been obtained for studies concerning the locating of sewage or thermal outfalls to minimize adverse environmental effects and maximize the use of nutrient or thermal levels in needy oceanic areas. Along the California coast are areas where oceanic current systems tend to move offshore during the oceanic seasons. Therefore, nutrients that would, if introduced in the nearshore zone, cause red tide blooms or other environmentally destructive effects of similar magnitudes could be directed offshore to areas where nutrient levels are low. Therefore, increasing these nutrient levels offshore would increase the biological productivity and lead to the new establishment of new fisheries and other commercial concerns. Also, analyses of oceanic current systems will make possible the determination of areas in which pollutant-rich sediments introduced by rivers move into areas of upwelling and thereby possibly reduce the expected productivity of these areas.

California Coastal Currents

From the discussion contained in the preceding sections of this paper, it should be obvious to the reader that very little is really known about the specifics of the seasonal variations of the California nearshore current systems. However, NASA remote-sensing technology in the hands of oceanographers has provided data suitable for current definition; and, although sufficient imagery has not been acquired and analyzed to withstand the rigorous demands of statistical testing, a suitable quantity of data is available to document, with reasonable confidence, the primary current trends observed during the three California coastal seasons. The imagery used in this study came from that obtained during the Landsat-1 orbits of late 1972 to early 1974, the NASA U-2 aircraft flights of 1972 to 1974, and the NASA Lyndon B. Johnson Space Center (JSC) aircraft flights of 1969 to early 1974. Thousands of individual image frames were analyzed to extract the bits of current vector directions that have been assembled into generalized seasonal current charts in this section, as well as into generalized monthly charts in other publications (ref. 1). It must be emphasized that the surface current systems presented herein are those observed during the period 1969 to early 1974 and primarily during late 1972 to early 1974, and that cyclic meteorological and thermal trends as well as short-term climatological perturbations have not been properly filtered to provide long-term current trends. It is hoped that continued acquisition of satellite and high-altitude aircraft imagery will provide sufficient data that, when correlated with climatological variations, will yield a sample of current analyses that can be used for temporal projections. In addition to outfall and sand transport studies, current projections are seen to be increasingly important in environmental impact studies dealing with offshore oil production as well as the many problems encompassing coastal development.

Figures 1 to 6 are the results obtained from analyses of the three primary coastal current circulation patterns

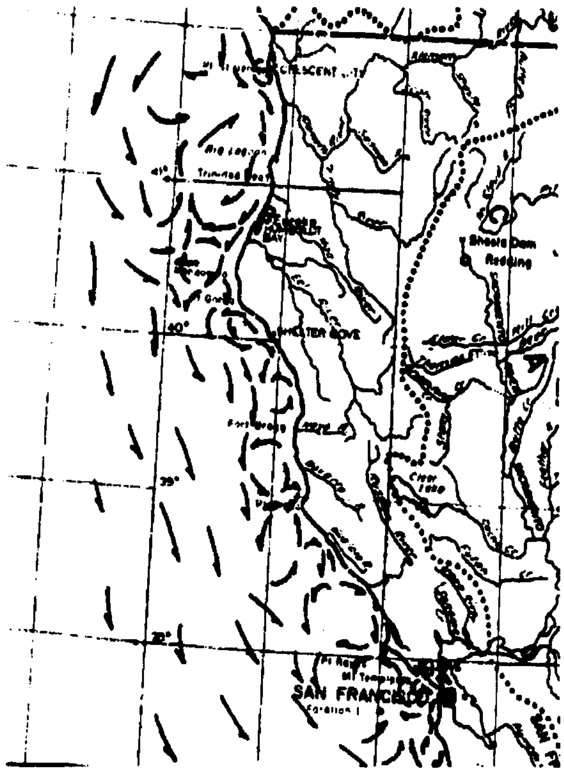

Figure 1. Generalized northern California surface currents for the oceanic season.

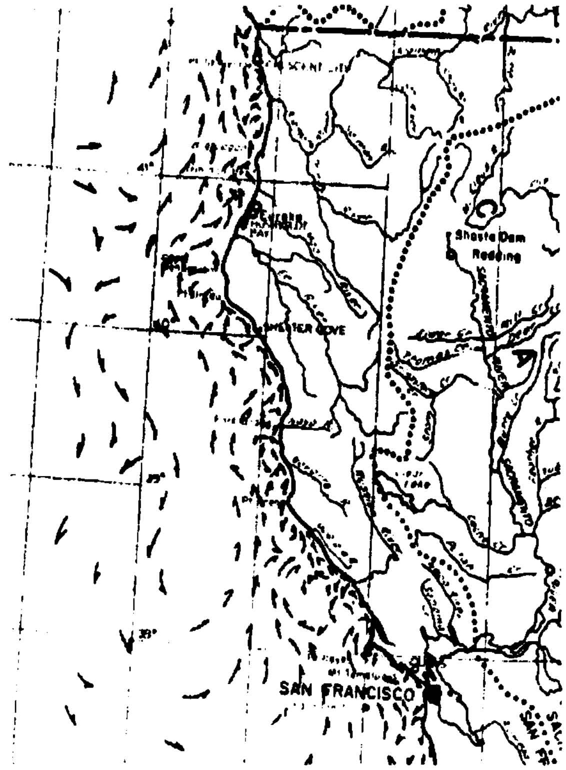

Figure 3. Generalized northern California surface currents for the Davidson season.

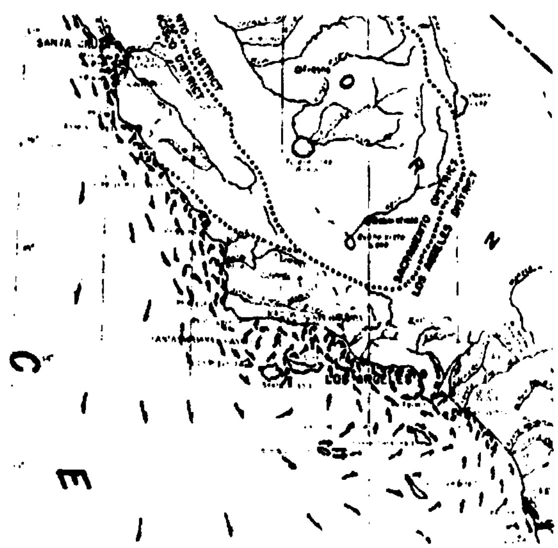

Figure 2. Generalized southern California surface currents for the oceanic season.

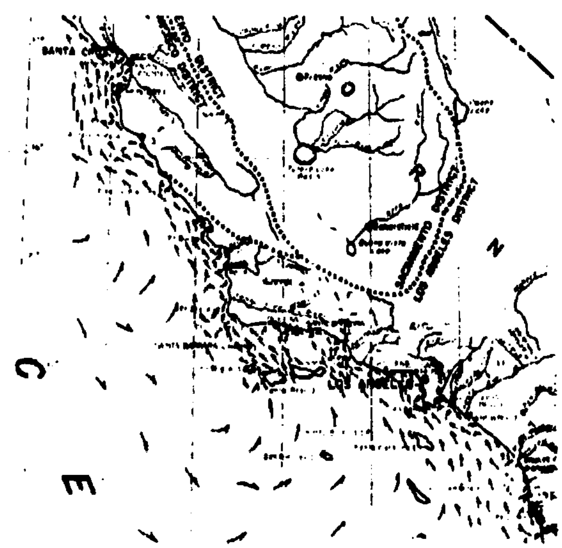

Figure 4. Generalized southern California surface currents for the Davidson season.

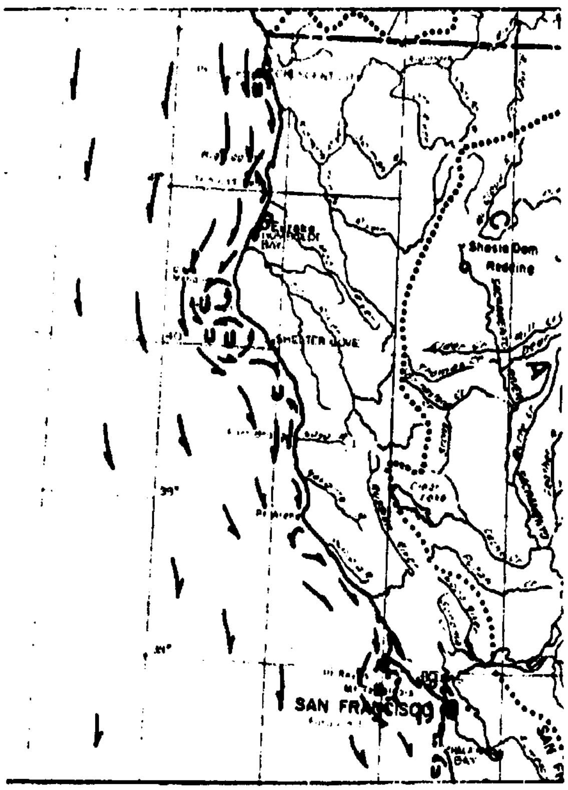

Figure 5. – Generalized northern California surface currents for the upwelling season.

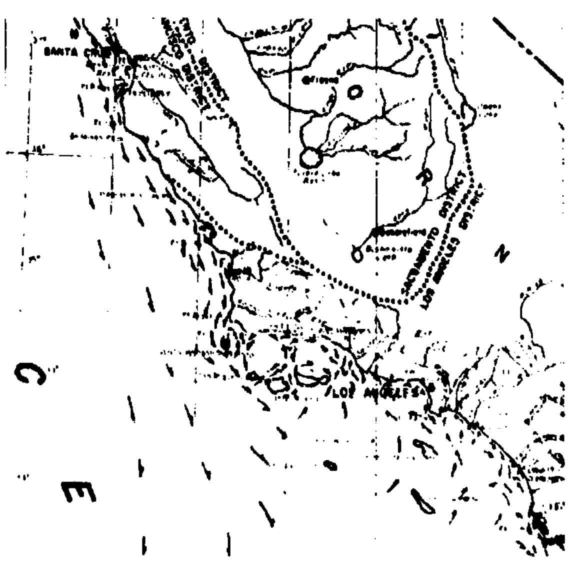

Figure 6. Generalized southern California surface currents for the upwelling season.

off the coast of California. The basic generalized current patterns were found to be in general agreement with the results of oceanographic studies previously discussed. However, never before had the complexity of the relatively stable nearshore circulation been so graphically defined. Future investigations will determine if these generalized current patterns are as stable as assumed now, or if tidal effects as well as short-term meteorological conditions cause perturbations that will frustrate any attempts to quantify generalized monthly current vectors in the nearshore zone out to approximately 30 kilometers.

The techniques used to define current directions, upwellings, and other basic surface parameters ranged from the simple use of photographic transparencies on standard light tables to complex digital processing of computer-compatible tapes from satellites. The machine-processing techniques were useful when it was necessary to contrast and enhance data to emphasize the subtle variances in densities and patterns that were used in describing circulatory systems. Multispectral ratioing and other algebraic functioning allowed for theoretical depth of sediment, lensing, and sediment concentration analyses (ref. 1). Because of the cost of machine processing, the majority of current interpretation was restricted to photographic transparency interpretation using either a light table with stereoscopic viewing or a variable scale projector. With the simpler viewing systems, the interpreter views the coastal images; screens out wind, wave, and bathymetry effects; and organizes the sediment density patterns into a current pattern. To do this effectively, the interpreter must be knowledgeable in the spectral response of the transparency that he is viewing, the magnitudes and the reflective characteristics of the noise and parameters of interest; he must also have a basic knowledge of the area being studied. Wind effects were probably the most difficult form of noise encountered. Complex wind patterns can often be confused with upwellings, internal waves, or island wakes. It is important that the interpreter use all his experience as well as all the spectral channels at his disposal to eliminate confusing noise.

Figures 7 to 9 are examples of the Landsat-1, NASA Ames Research Center (ARC) U-2 aircraft, and JSC aircraft imagery, respectively, used in the coastal current analyses. The U-2 aircraft imagery scales of 1:130 000 were found to be most useful for detection of nearshore structures and overall definition. The JSC supplied imagery scales, between 1:10 000 and 1:40 000, were excellent for littoral zone analysis, and the Landsat-1 scales of 1:1 000 000 were appropriate for studying the macroscopic features and offshore tendencies.

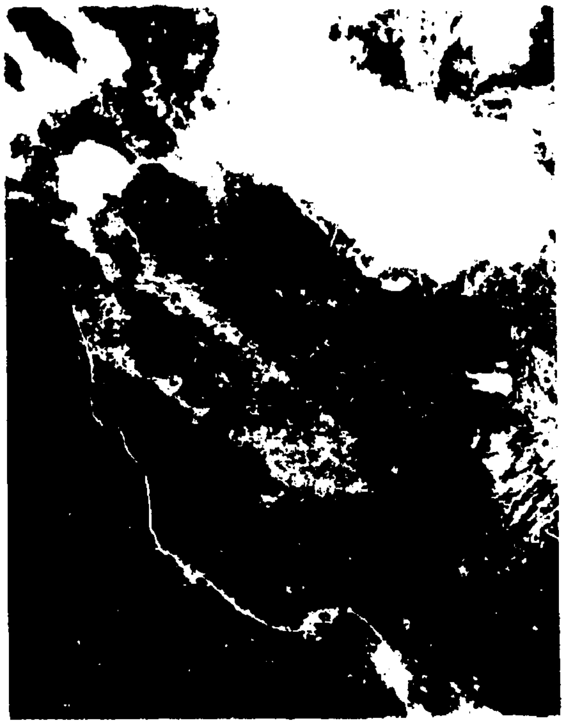

Figure 7.– Landsat-1 image (1183-18175-4), taken January 22, 1974, of the California coast from San Francisco to Monterey.

Oceanic Period

The California Current system dominates the nearshore surface current patterns during the oceanic period from July to November. In the offshore area, this current is the driving force of open ocean waters throughout the year. The surface currents are driven and affected by gravity, friction forces due to pressure gradients, and Coriolis acceleration. Movements of nearshore water overlying the continental shelf, however, are affected to a greater degree by wind, tidal forces, and irregularities in the ocean bottom. The features of particular interest in this study and often visible on high-altitude imagery lie within this continental shelf zone. Before the use of remote-sensing systems, researchers studying local currents often found that shelf effects, combined with seasonal runoff, frequently distorted the nearshore currents sufficiently to make difficult a determination of the regional circulation. Landsat and U-2 imagery graphically illustrate the California Current as well as the nearshore surface currents, when suspended material acts as a detectable tracer. The California Current has a continuous effect offshore even during the Davidson Current and upwelling current periods.

The coastal current effects during the oceanic period are shown in figures 1 and 2. The California Current is the southward component of the clockwise circulation of the North Pacific Ocean. As this current slowly moves southward at speeds generally less than 0.25 m/sec, it becomes warmer under the influence of the Sun and mixing with the warm waters to the west. On the onshore side of the current are found the numerous local disturbances, which are of major interest in this study.

Off Point St. George, a large gyre is normally found offshore from the sandy beaches and then south for a distance as great as 40 kilometers. This feature includes the moving of fine sediment off the critically eroding beach 4 kilometers west of Crescent City. Some of the transported fine material from north of Point St. George is moved back on shore south of Crescent City after bypassing this critically eroding beach.

In the Humboldt Bay area, the sediment being transported is mainly from the Mad and Eel Rivers and has been observed moving southward and offshore to a distance of 100 kilometers from the entrance to Humboldt Bay. To the south and west of Cape Mendocino, an eddy is usually present. This eddy is clearly visible during the oceanic period and appears to be contributing to the critically eroding shoreline 8 kilometers southeast of Cape Mendocino. The erosion is affecting the stability of the highway along this stretch of coast.

Between Cape Mendocino and the San Francisco Bay entrance, a number of sediment gyres move fine material directly offshore. At Point Arena, a linear plume of material moves westward for a distance of approximately 25 kilometers. The first 5 kilometers of this feature appear to be heavily laden with sediment. Farther offshore, settling and mixing of the material causes a gradual decrease in this visible pattern. Movement of this feature offshore into the California Current appears to be permitted by a small clockwise gyre located just north of Point Arena. Similar processes are present off Shelter Cove.

At Bolinas Bay, approximately 15 kilometers northwest of the Golden Gate, the predominant direction of littoral drift past the entrance of the lagoon is from east to west. Reinforcement of drift occurs during storms when the wind and the waves are from the southeast and during the Davidson Current period. Because the shoreline adjacent to the Bolinas Lagoon entrance periodically erodes critically, currents and

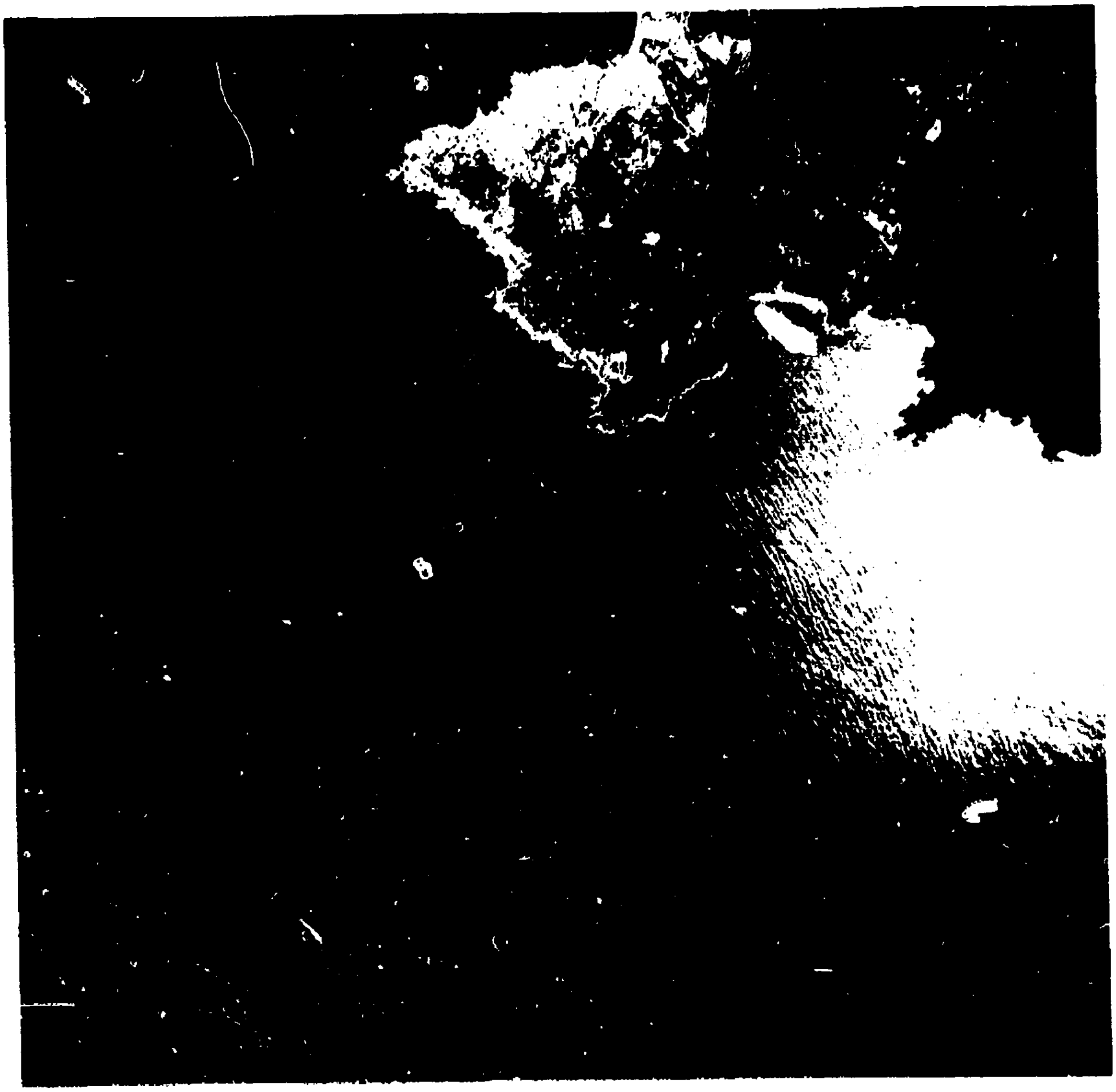

Figure 8. Aircraft image of southerly currents off the Monterey Peninsula taken from an NASA Ames Research Center U-2.

sediment transport studies are essential in this area. A clockwise gyre that is often present off the San Francisco Bay entrance brings sediment from the bay system northward into the Bolinas area. This gyre is part of the overall Gulf of the Farallones current and transport cell.

Some of the most complicated local currents along the California coast occur near the entrance to San Francisco Bay. They result from the effect on coastal currents of high current velocities through the Golden Gate during floodtide and ebbtide, of variations in bottom topography, and of the highly variable wind drift. It should also be noted that rough water conditions, which are often present in the Gulf of the Farallones, have always made detailed survey ship operations extremely difficult.

In Monterey Bay, the offshore area extending to approximately 3 kilometers contains some suspended

Figure 9. NASA medium-altitude aircraft image of Point St. George, California, that shows the California Current moving down from the north (top of the photograph) and a return flow gyre from the east (right). Original photography in filtered color was taken on January 27, 1974, during change from Davidson season to upwelling season.

sediment that forms a crescent-shaped pattern similar to the contour of the bay. Two breaks occur in this pattern, however. The first is 8 kilometers north of Monterey and the second over the Monterey Submarine Canyon off Moss Landing. These breaks appear as areas of clear water in the nearshore suspended sediment pattern. The Monterey Submarine Canyon is the location of numerous upwellings that are indicated by lower temperature lenses, which move to the north and south of the canyon itself. The feature 8 kilometers north of Monterey appears to be a divergence between a small clockwise gyre in the southern end of the bay and a counterclockwise gyre north to the Monterey Canyon.

The coastline between Point Conception and the Mexican border is considered as a single system, which has been described as the Southern California Bight. It is caused by the sharp eastern break of the coast south of Point Conception and the resulting indentation that extends for 575 kilometers to Cabo Colnett on the Baja California coast. The bight modifies the southern flow of the dominating California Current. The hydrodynamic discontinuity forms a return eddy as well as a semi-independent system of water circulation within the bight. This system is called the Southern California Countercurrent and is a combination of converging southern, western, northern, and upwelling waters. What is generally seen during the oceanic period in the bight is a counterclockwise gyre that passes northward through the eight Channel Islands.

In the oceanic period, a small plume of suspended material moves south and southeast around Point Conception and Point Arguello. This plume represents the split between the southward-moving California Current and the material entering the California Countercurrent gyre in the western Santa Barbara Channel. The counterclockwise movement is apparent along the Channel Islands and then coastward to a point between Point Conception and Goleta Point. At the same time, the nearshore sediment transport is toward the east.

Within the Santa Monica Bay, currents and sediment transport are clockwise along the coast to Point Fermin. Very little material rounds the peninsula because of the combination of Santa Monica Submarine Canyon sediment capture and offshore sediment movement.

South of Point Fermin, the nearshore transport is normally southward. South of Long Beach, transport is mixed or northeastward. In the vicinity of Dana Point and Oceanside, current transport is often offshore to approximately 3 kilometers, then southeastward. Although the waters off San Diego contain little suspended sediment, the transport is normally seen to be southward.

Davidson Current Period

The complex movements of the various surface currents that occur during the Davidson Current period are illustrated in figures 3 and 4. Normally, the main influencing current on the coast is the California Current. However, during the period of approximately November to February each year, the Davidson Current, a northward-moving countercurrent, is the dominant inshore transporter of water and suspensates.

The Davidson Current is generally a deep countercurrent below 200 meters that flows northwestward along the coast from Baja California to some point beyond Cape Mendocino. It brings warmer, more saline water greater distances northward along the coast. When the north winds are weak or absent in late fall and early winter, this countercurrent forms at the surface, well on the inshore side of the main stream of the California Current. The evidence for this current is visible on the imagery and supported by temperature contours and current measurements. The temperature contours in the eastern Pacific Ocean bend northward along the coast during the height of the Davidson Current activity; the most dramatic changes occur in February.

In general, figures 3 and 4 of this period illustrate the greatest concentrations of nearshore northerly moving sediments offshore to a distance of 4 to 8 kilometers. At several points, significant volumes of sediment move off the coast and join the southward-flowing California Current.

In the Los Angeles Harbor area, materials from the Los Angeles, San Gabriel, and Santa Ana Rivers move offshore and westward under the influence of the Davidson Current. Inside Los Angeles Harbor, an east-southeastward current is in effect. Outside the Los Angeles breakwater, a slow-moving westward current appears to dominate the nearshore sediment movement. Suspended sediments in Santa Monica Bay ring the bay with a 4- to 8-kilometer-wide border. This band of sediment appears to be escaping the bay area to the west, around Point Dume. This movement agrees with the general Davidson Current pattern. Off Point Conception, the California Countercurrent in the area between the mainland and the Channel Islands appears to pick up and transport suspended particles offshore into a complex pattern region that is influenced by the California Current.

The Monterey Bay surface waters are reported to be exceedingly uniform during the Davidson Current period. The average temperature difference between any pair of stations is slightly less than 0.25° C. No regular pattern of temperature distribution is discernible. The general northern trend of the suspended sediment, however, appears to continue in Monterey Bay; the area from Moss Landing to Santa Cruz contains two clockwise gyres.

In the Gulf of the Farallones, a complex surface current and sediment transport system is present. A large clockwise gyre is present off the Golden Gate Bridge reaching from the San Francisco area northwest to the vicinity of Bolinas. Just north of Point Reyes at the mouth of the Russian River, the distinct northern effect of the Davidson Current is illustrated. The majority of the movement takes place within 5 to 6 kilometers of the coast.

Upwelling Period

During the upwelling period (March to August), winds parallel to the coast move surface waters offshore and allow deeper ocean water to surface. This effect seems to be intensified near submarine canyons and south of capes and points that extend into the current stream. On the current plots, figures 5 and 6, the process of upwelling is illustrated near Crescent City, Cape Mendocino, Point Conception, Half Moon Bay, and Monterey Bay. These colder upwelling waters are often rich in nutrients with the additional result that plankton blooms often accompany this period.

During spring, a gradual warming of surface waters normally occurs along the coast with the exception of the Cape Mendocino area. An extensive offshore upwelling extending from Crescent City to south of San Francisco forms a variation in the general warming trend. Similar features on a more local scale are detectable by studying offshore tonal changes on the imagery.

SITE STUDY OF MONTEREY BAY

A site study was performed to extend knowledge of the surface circulation of Monterey Bay, California. Monterey Bay is an important and growing residential, industrial, agricultural, tourist, and fishing area on the central California coast. To develop the optimum positioning of industrial and municipal facilities, the placement or control of industrial and sewage outfalls, thermal discharge, and harbor pollution must be investigated and backed by reliable data. To achieve this goal, a knowledge of the circulation patterns of the bay is needed.

Description of Monterey Bay

Monterey Bay is a nearly semielliptical embayment on the coastline of central California. It is approximately 35 kilometers long from north to south and has a maximum indentation into the open coast of approximately 18 kilometers.

The bay is an area of wide, flat continental shelf bisected by the deep intrusion of the Monterey Submarine Canyon, the head of which is very near the shore at Moss Landing. Monterey Bay can be considered to be composed of three physiographic units: the northern and southern shallow shelves, and the canyon. The shallow regions are less than 100 meters deep and exceedingly flat, whereas the submarine canyon has very steep sides and reaches depths of more than 1500 meters within the bay. The presence of the canyon allows deep oceanic water access along the center of Monterey Bay.

Skogsberg carried out the first comprehensive oceanographic investigation of the circulation regime in Monterey Bay (ref. 3). He occupied 23 stations located in the bay, taking measurements of temperature, salinity, and other chemical parameters. From his study, he was able to divide a year into three oceanographic seasons. These seasons have been standardized as the upwelling period, the oceanic period, and the Davidson Current period. Bolin, in a study of one station over the Monterey Submarine Canyon for a 5-year period, confirmed Skogsberg's work and refined the definition of these oceanographic seasons.

The upwelling period in Monterey Bay generally begins in mid-February or March and extends to late August or early September. Upwelling reaches a maximum in April or May and begins to decrease in June. The upwelling period is characterized by the ascending of cold subsurface water from depths as great as 150 meters; consequently, the various isotherms become nearer the surface. The surface water temperatures are from 10° to 11° C in much of the bay.

The oceanic period tends to be rather short, usually occurring from September to mid-November. It is characterized by a strong vertical temperature gradient in the upper 100 meters and by the highest sea surface temperatures of the year (greater than 13° C). Both the upwelling and oceanic periods are associated with the southerly flow of the California Current along the coast.

From mid-November to mid-February or March, the northward-flowing Davidson Current is in effect. During this period, the countercurrent flows at the surface near the coast. There are some indications from CalCOFI or from geostrophic computations (ref. 18) and drift-bottle results (ref. 15) that a northerly flow may occur at the surface at other times of the year. During the Davidson Current period, the upper 50 meters tend to be well mixed and to have a weak vertical temperature gradient. Davidson period surface temperatures are usually lower than during the oceanic period, but not as low as those occurring during the upwelling period.

In this paper, the oceanic seasons have been averaged over a number of years. Thus, for an individual year, the time of onset and termination of these seasons may vary by as much as a month or two as a result of changes in the driving forces that cause them.

The prevailing winds in the area tend to correspond with the direction of the oceanic current. During the Davidson period, the prevailing winds are from the south or southwest; during the rest of the year, when the California Current dominates the coastal circulation, north or northwest winds predominate.

It is expected that rotary tidal currents occur in the bay, but they have never been measured in situ. The tides exhibit a diurnal inequality with a mean range from mean high water to mean low water of 1.16 meters and a diurnal range between mean higher high water and mean lower low water of 1.68 meters.

Ocean Currents

Garcia developed a theoretical model of the circulation pattern of Monterey Bay using the shear flows of the ocean currents that occur off the bay as the sole driving mechanism (ref. 19). The open coast circulation varies throughout the year in a manner described by the three oceanic seasons, as discussed previously. Accordingly, the bay circulation was expected to respond seasonally as well.

During the upwelling period and the oceanic period, the offshore current flows southward along the coast. Collectively, these two periods are called the California Current season after the predominant offshore current. During the Davidson Current season, the offshore current flows toward the north.

The southerly California Current was expected to produce a counterclockwise circulation pattern in the bay. Either a single-gyre or a two-gyre pattern appeared probable. Because of the symmetry of the bay, the division between the two gyres was expected to occur in the area of the Monterey Submarine Canyon with a northern gyre flowing in the same direction as the southern gyre. See figure 10 for locations described in text.

The circulation in the bay during the oceanic period was expected to be different from that occurring during the upwelling period even though the offshore current direction was the same. The lack of upwelling during the oceanic period and the associated decrease in intensity of northwest winds along the Pacific coast were important in causing a difference in the bay circulation between the upwelling and oceanic periods.

The northward-flowing Davidson Current was expected to cause the water in the bay to circulate in a clockwise pattern. For this time of the year, either a single-gyre or a two-gyre pattern was expected.

These shear-flow-driven models have been adopted as the most probable general circulation patterns expected to occur seasonally in Monterey Bay. The models were used in interpreting the results of drift-bottle studies and drogue studies and in remote-sensing research.

Drift-Bottle Studies

To examine the variations of Monterey Bay current seasons, Reise conducted bottle drops that were divided into three groups to represent the oceanic seasons (ref. 20). The time limits of the seasons were categorized according to the expected times of the seasons and supported by the results of the CalCOFI drift-bottle study (ref. 15) and a geostrophic current study (ref. 18) for the time of the drift-bottle survey.

Drift-bottle results for the upwelling period indicated a variable current along the northern shore of the Monterey Peninsula. The current turned northward and flowed upcoast from Monterey Harbor. A separate circulation was present in the northern bay. The circulation along the coast was similar to that predicated by Garcia's model if extended to the nearshore regions. The model predicted a counterclockwise gyre or two counterclockwise gyres when a southerly current is flowing offshore as occurs during the upwelling period.

Drift-bottle results from the oceanic period suggested that the current in the southern bay flowed in the same direction as during the upwelling period, but with a weaker circulation. The bottle drift in the southern bay suggested a counterclockwise current pattern along the shore similar to that predicted by Garcia's shear-flow model. The returns from the northern bay were insufficient to indicate whether a separate current gyre existed there. The returns to the north of the bay suggested that the Davidson Current may have been present part of the time.

The drift-bottle results from the Davidson period appeared to fit Garcia's ocean current shear-flow model as a description of the movement of the drift bottles along the coast. The apparent existence of a clockwise current pattern having a southerly current along the coast that turns west and flows along the north shore of the Monterey Peninsula suggested a two-gyre model with one gyre in the northern bay and the other in the southern bay.

During the Davidson period, the surface circulation seemed to be contained within the bay, since few bottles left the bay. Those that escaped were only transported as far as the seaward side of the Monterey Peninsula. Also supporting the view of a relatively closed circulation was the fact that no bottles were found north of the bay even though the predominant direction of the offshore current was northward.

Other Current Studies

Although to compare measurements made using

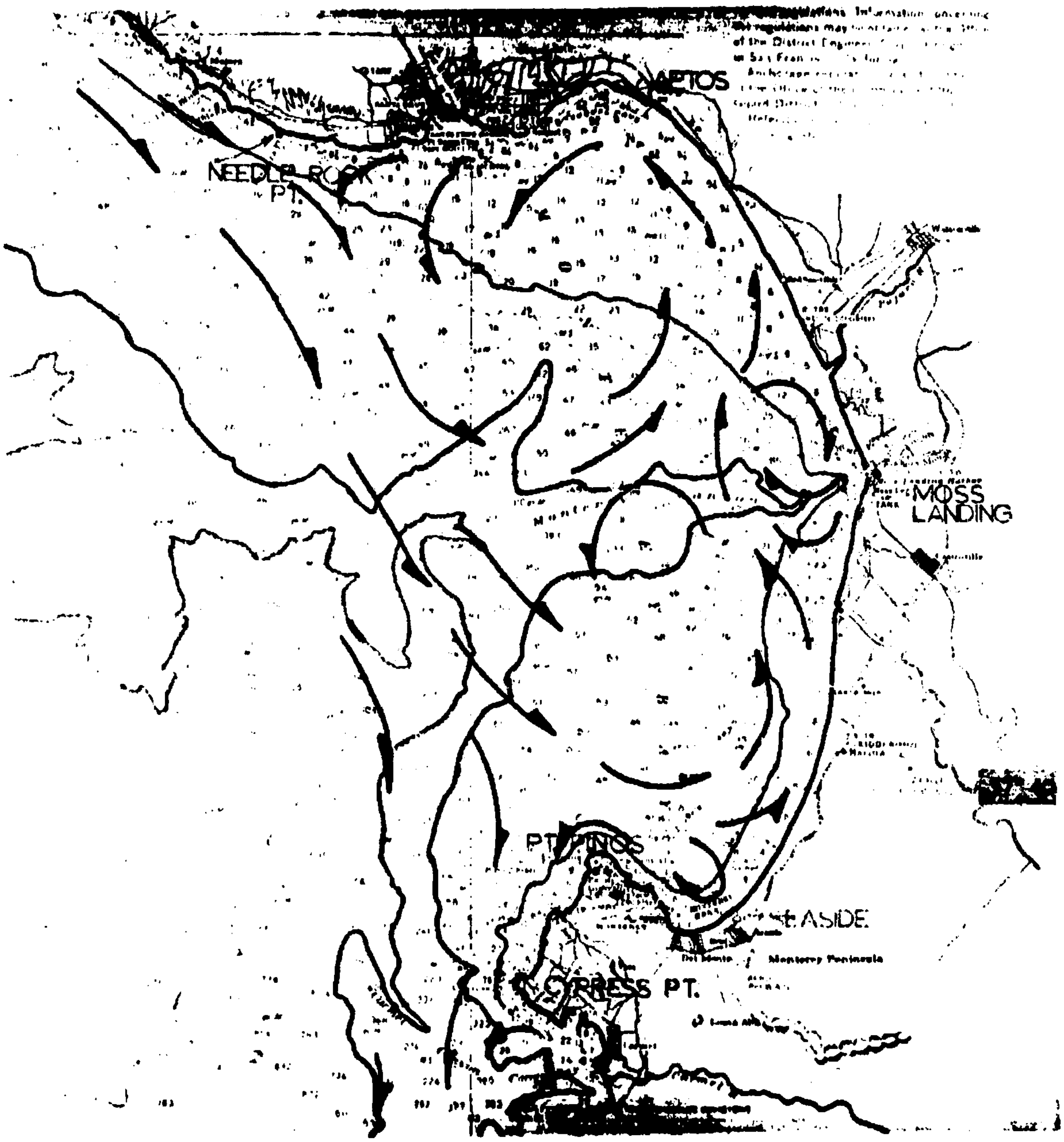

Figure 10. Generalized Monterey Bay oceanic season. Surface currents were observed to be dominated by the driving force of the California Current. Two large counterclockwise gyres were commonly observed to be split by the Monterey Submarine Canyon with a smaller third clockwise pattern directly off Moss Landing Harbor. Drift along the northern side of the Monterey Peninsula varied from eastward to westward, and divergence of currents to the north of Seaside and off the mouth of the Pajaro River was common. Convergent currents near the mouth of the Salinas River, Needle Rock Point, and Cypress Point were also frequently observed.

different methods and done at different times is difficult, several studies of the circulation in or near Monterey Bay are useful for comparison with the results of this study. For example, Stevenson performed a current drogue study in the southern part of Monterey Bay (ref. 21). Stevenson observed the simultaneous movement of drogues at depths of 0.6, 1.2, 2.5, and 4.3 meters for periods not exceeding 6 hours. He conducted two surveys in August and October 1963 and eight more between January and March 1964.

Stevenson found that his drogues moved in directions to the right of the wind for wind directions other than northwest. For moderately strong northwest winds, his drogues moved substantially to the left of the wind direction.

In a period of light winds during the Davidson period, Stevenson's results show the drogue tracks to be much farther to the right of the wind than would be expected for pure wind drift. The extra movement to the right may have been due to the clockwise gyre predicted by the Garcia model for this time of the year. These results are interpreted here as wind drift superimposed on the oceanic component driven by the Davidson Current. It is considered that the diminished wind drift due to weak winds made the oceanic component more prominent than during times of stronger winds. It was concluded in both Stevenson's study and in drift-bottle studies that, except during periods of calm, the dominant driving force of the surface circulation is the wind in the shallow waters of the bay.

Stoddard (ref. 22), in a study to test the feasibility of shore-based radar in tracking current drogues in Monterey Bay, released a total of 41 parachute drogues. The drogues were set at a mean depth of approximately 14 meters and were tracked for periods of 6 to 20 hours and occasionally longer. Most of the drops were in the southern bay, but a few were in the northern bay and some seaward of the bay. The period covered in his study was August to November 1970. Current speeds measured by the drogues were generally between 0.1 and 0.2 m/sec.

Stoddard's results seem to indicate a clockwise pattern in the bay during the Davidson Current period and a counterclockwise gyre during the time of the California Current. The oceanic current prevalent at these times was determined from drogues tracked seaward of a line between Santa Cruz and Point Pinos. He concluded that the oceanic currents were probably the dominant driving force of the bay circulation, with the possibility of tidal forces being important in the shallower regions of the bay. It should be noted that at the depth at which drogues were placed, the wind-driven effect was probably weak except at times of sustained high winds. It may thus be expected that the effects of the ocean currents should dominate the current pattern. Stoddard's results generally agree with the bay circulation model of Garcia and with drift-bottle observations.

Drogue studies were also performed by personnel of the Naval Postgraduate School and from the Association of Monterey Bay Area Governments (AMBAG) from June to August 1972. In two drogue studies in June and July, a clockwise circulation was indicated for the southern bay. This clockwise circulation is opposite to the counterclockwise circulation predicted by Garcia's model for the southerly oceanic current expected for this time of year. Drogues tracked in the northern part of Monterey Bay in early August indicated a counterclockwise circulation cell in the northern bay, with flow out of the bay along the northern coast past Santa Cruz and to the northwest. Drogues tracked in late August in both the northern and southern bay appeared to indicate a counterclockwise gyre for the whole bay with northward flow out of the bay.

In June and July, as stated, the results were contrary to Garcia's model if the direction of the ocean current flowing along the open coast were southerly. The supposition of a southerly ocean current during these months may have been incorrect for 1972, since variability has been shown to exist from year to year by the CalCOFI drift-bottle study (ref. 15). Three of the four AMBAG drogue studies appeared to indicate a two-gyre current pattern, whereas the other defined a single gyre for the whole bay. The average speeds were similar to those obtained from the drift-bottle results. The AMBAG drogues were designed to show the influence of ocean currents, as Stoddard's results did, rather than wind-driven transport.

A regular CalCOFI drift-bottle station was located in the seaward edge of Monterey Bay off Santa Cruz (ref. 15). Some drift-bottle returns from this station suggested a counterclockwise circulation pattern extending from Monterey Bay to Ano Nuevo Point or possibly farther north. The drop of April 1956 appears to illustrate this pattern: 5 to 12 days after being dropped, bottles were found along the coast north of Santa Cruz to approximately 80 kilometers south of San Francisco; 37 to 94 days later, bottles from the same drop were found in southern Monterey Bay. The oceanic current at that time appeared to be directed southward according to the returns from other nearby drop stations.

Lammers (ref. 23) and Moomy (ref. 24) deduced the geostrophic circulation of the bay from the temperature structure of the water. Lammers' results appear to agree with Garcia's proposed bay circulation pattern for October to April, but the two differ from the period of May to September. Moomy's results for geostrophic currents determined from surface sigma-t values appear to agree with the current gyres predicted from Garcia's model during all three oceanic seasons, with results of the drift-bottle study, and with a number of the AMBAG drogues tracked at the same time as Moomy's study.

Because of failure of the assumption for geostrophy, the methods used by Moomy and Lammers may not always be effective. Salinity variations, which were not considered by Lammers, can significantly affect the determination of geostrophic currents. Additionally, Monterey Bay surface currents are weak and may be perturbed by local winds, bottom topography, or tidal forces. Changes in offshore eddies or meanders may also cause these approaches to circulation determination to be misleading.

Wind

The seasonal wind regime on the California coast, including the Monterey Bay area, is reflected in the seasonal offshore current patterns. When considered on a short-term basis, the winds blowing over Monterey Bay are variable in speed and direction in response to the changing synoptic weather conditions and to the local sea-land breeze circulation in the vicinity of the coast. These local winds drive relatively transient currents in the bay. The following is a discussion of these transient systems.

The dominant wind in Monterey Bay, as on most of the California coast, is from the northwest. This wind direction may be attributed largely to the presence of the quasi-permanent subtropical high-pressure cell that is centered off the California coast. In addition, a diurnal pattern of onshore-offshore winds is present along the Monterey coast during most of the year. The stronger afternoon sea-breeze component is characteristically from the northwest, whereas the low windspeeds found at night and in the early morning are usually offshore.

The Ekman wind-drift model predicts that in the absence of a coastal barrier, a water mass will tend to move in a direction 45° to the right of the wind in deep water in the Northern Hemisphere. As the water depth decreases, the angle diminishes until, for shallow depths, the water moves in the direction of the wind. The water depth is actually a relative depth governed by the windspeed; that is, as the windspeed increases, the relative depth becomes smaller (ref. 25).

The angle between the current direction and the net wind direction over intervals has been determined. Careful examination of the data showed that southern Monterey Bay currents moved significantly to the left of the wind (by as much as 80° to 100°) when associated with a northwest wind direction and that current drift for other wind directions was generally approximated by the Ekman model.

It is hypothesized that a northwest wind induces a strengthening of the northward longshore flow in the extreme southern end of the bay.

The components of the bay currents caused by winds and by the offshore currents may act to reinforce or oppose each other. Reinforcement appears to occur frequently in the southern bay for northwest winds during the months when the California Current flows along the outer coast. Winds seem to be the primary cause of transient surface currents in southern Monterey Bay.

In summary, although the effect of the Garcia-type model is evident, the apparent direction of current movement in the bay is determined by the wind direction much of the time.

Waves

For the case of wind waves, it appears from Stokes' third-order theory that the surface transport due to waves is less than a tenth of that produced by wind (ref. 26, p. 324). Accordingly, the mass transport due to wind waves may be considered a part of the wind-driven transport. It is therefore considered that winds alone effectively represent the combined effects of waves and wind in moving the surface water.

Tides

Tides can be an important current-causing force in coastal waters. Tides in Monterey Bay, as for most of the Pacific coast of the United States, are of the semidiurnal mixed type. This pattern of tides leads to a rather complicated pattern of tidal currents. Tidal currents on the open continental shelf in the Northern Hemisphere are rotary, turning clockwise and completing a cycle every 12.4 hours. Because of the inequality of the tide heights and times, the two tidal current cycles per day differ in speeds and in rate of direction change. However, from one day to the next, the diurnal pattern is approximately repeated so that little net tidal transport of water occurs. Tidal currents of this character occur off the entrance of San Francisco Bay.

and it is probable that a similar tidal current pattern exists in Monterey Bay.

No attempt at measuring the tidal currents over the broad shelves of Monterey Bay has been successful, although tidal currents with velocities as high as 0.5 m/sec have been observed in the Monterey Submarine Canyon (ref. 27). Tidal current tables for the Pacific coast describe the tidal currents in the bay as weak and variable. Lazanoff, in an unsuccessful attempt to verify Hansen's hydrodynamic-numerical model for Monterey Bay, concluded from his examination of current data that he could make no direct statement about tidal current velocities and directions, but suggested that the current velocities are probably less than 0.05 m/sec (ref. 28).

From drogue study results, it appears that tidal currents are not important in net long-term movement of the water in Monterey Bay and therefore, because of their rotary nature, have a negligible effect on the average flow.

MONTEREY BAY CURRENTS FROM REMOTELY SENSED DATA

From the preceding sections, it may be observed that the Monterey Bay surface current circulation system is complex, difficult to model, and poorly understood. Remotely sensed imagery of Monterey Bay was used in an attempt to clarify the mixture of models and study results and to present a qualitative picture of the generalized seasonal current systems observed during the period October 1971 to February 1974. Flights over the site on 59 separate occasions produced data sets appropriate for current studies. Of these, 39 were from Landsat-1, 12 from NASA U-2 aircraft, and 8 from either NASA C-130 or P-3 aircraft. Because of film density and spectral selection characteristics of the Landsat-1 sensors, only eight Landsat-1 images could be considered excellent in current-evaluating quality. However, 7 of the 12 U-2 flights produced excellent current presentations as did 6 of the 8 medium-altitude aircraft flights. It was found that a high-resolution color film (filtered to be dominant in the yellow range of the visible spectrum and exposed at least two f-stops more than the normal land exposure) produced the best current images for film products as did the 500- to 600-nanometer channel of the Landsat-1 multispectral scanner.

Imagery selected for analysis represented all three oceanographic seasons with an assortment of wind and wave conditions. Seasonal sets were produced, and, from these sets, three current charts (figs. 10 to 12) were developed to represent the generalized current patterns expected at the peak of each season. The U-2 photographic imagery was found to be best suited to this site study because of its scale characteristics (1:130 000) and resolution.

During the Monterey Bay oceanic season, surface currents were dominated by the driving force of the California Current. Two large counterclockwise gyres were commonly observed to be split by the Monterey Submarine Canyon with a smaller third clockwise pattern directly adjacent to Moss Landing Harbor. Drift along the northern side of the Monterey Peninsula varied from eastward to westward, and divergence of currents to the north of Seaside and off the mouth of the Pajaro River was common. Convergent currents near the mouth of the Salinas River, Needle Rock Point, and Cypress Point were also frequently observed. The oceanic season plot (fig. 10) seems to agree with the primary results of both the drift-bottle study and the drogue studies. Also, it can be seen that the dual-gyre circulation could have been misconstrued to be a simple gyre because of the Moss Landing cell transport link.

All currents observed during the oceanic season seem to be rather weak with wind effects present but transitory. Red tide conditions observed during the oceanic period may have resulted from the poor circulation of the surface waters coupled with the influx of nutrients from sewage outfalls and solar heated surface layers. Circulation was minimal off Seaside during October 1971 when large blooms of red tide were imaged (fig. 13).

The Davidson Current season during winter is represented by figure 11. During this season, Monterey Bay currents are driven by a northward-flowing coastal current that protrudes into the bay. Inshore of this current, three clockwise gyres form; the most massive of these is present off Moss Landing Harbor. Because of the high velocity of both north and south winds expected during winter conditions, Ekman wind-drift phenomena linked with the driving power of the Davidson Current produce clockwise cells in the inner, eastern portion of the bay. The Monterey Submarine Canyon plays an important part in the development of the Davidson season circulation by channeling a high volume of water deep into the bay. A high correlation exists between current plots and bathymetry.

The upwelling season (fig. 12) is of importance in the bay because as the southward-flowing California Current is established in spring and summer and the north and northwest winds freshen, upwelling of cold and nutrient-rich water occurs over the submarine canyon

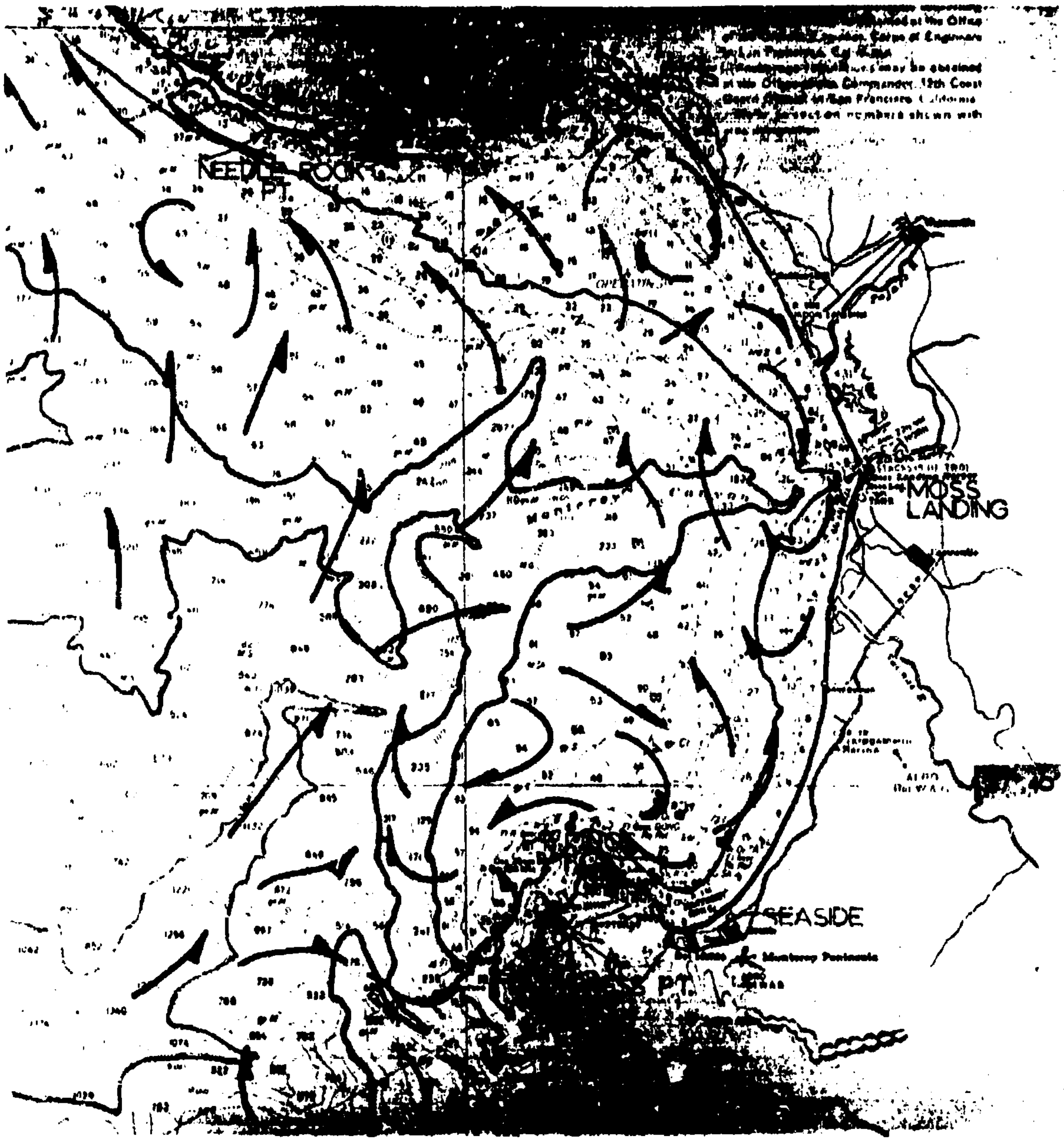

Figure 11. Generalized Davidson current season. This season finds Monterey Bay currents being driven by a northward-flowing coastal current that protrudes into the bay. Inshore of this current, three clockwise gyres are formed: the most massive is off Moss Landing Harbor. Because of the high velocity of both north and south winds expected during winter conditions, the Ekman wind-drift phenomena linked with the driving power of the Davidson Current produce clockwise cells in the inner, eastern portion of the bay. The Monterey Submarine Canyon plays an important part in the development of the Davidson season circulation by channeling a high volume of water into the bay.

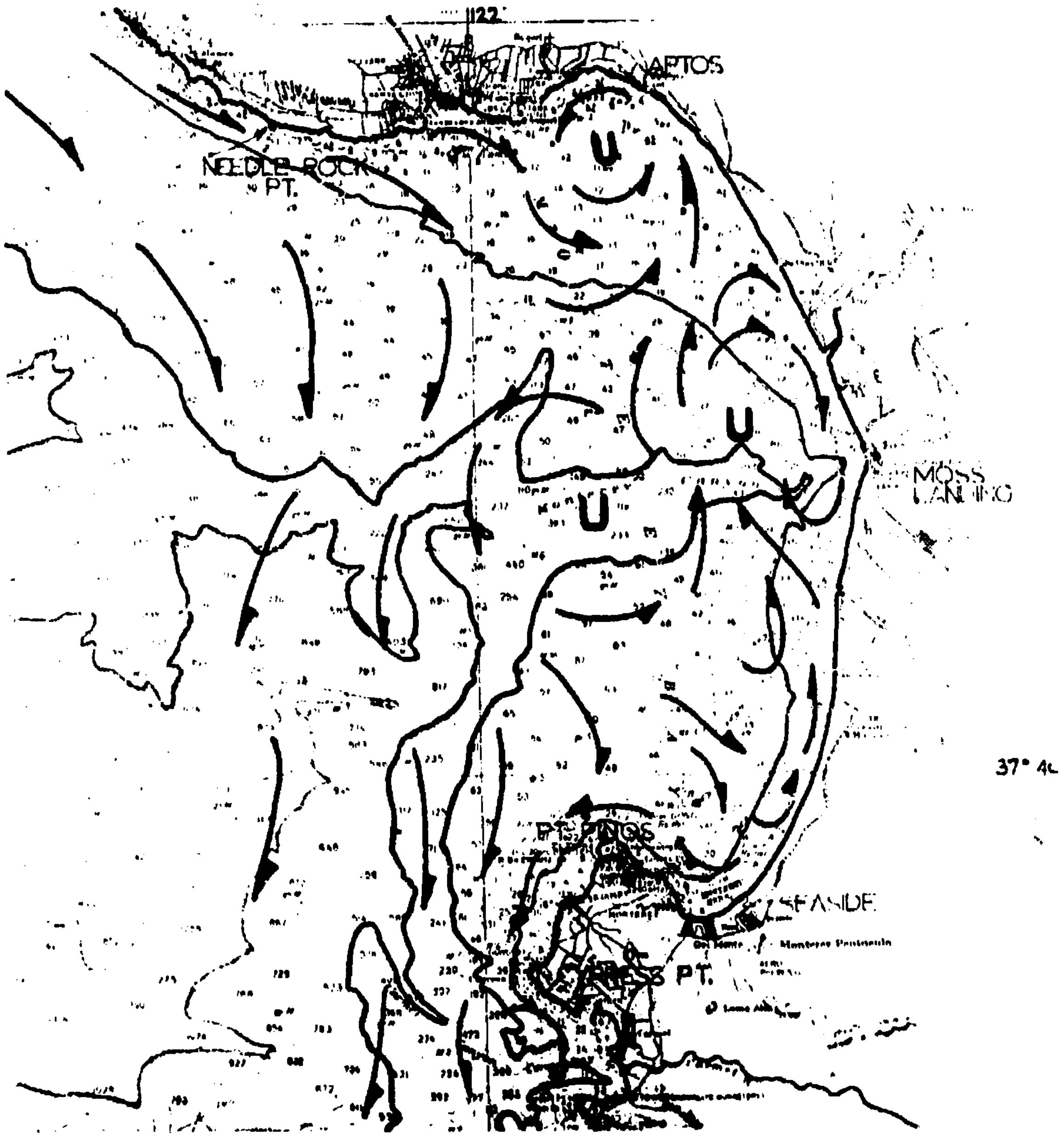

Figure 12. Generalized upwelling current season. This season is of importance in the bay because as the southward-flowing California Current establishes itself in spring, and the north and northwest winds freshen, the upwellings of cold and nutrient-rich water occur over the submarine canyon and adjacent to Aptos. The three upwelling areas (U), shown on the current plot have been observed from space as well as by medium- and high-altitude aircraft and surface measurements. The principal current trends are the formation of three gyres similar to those of the oceanic period, but located more to the north and moving at a higher velocity.

Figure 13.– Southern Monterey Bay and Monterey Harbor area photographed on October 4, 197., from an altitude of 10 000 feet. Original photography was filtered in color and defined currents, sediments, and *Gonioulax polyhedra* (red tide) bloom.

and near Aptos. In the aircraft imagery, the upwelling waters appear darker than the normal surface waters and wavelike rings are common. The three upwelling areas presented on the upwelling season current plot have been observed from space as well as by medium- and high-altitude aircraft and surface measurements. The principal current trends are the formation of three gyres similar to those of the oceanic period, but located to the north and moving at a higher velocity. Sediment patterns early in the upwelling season are shown in figure 14.

CONCLUSIONS

The nearshore surface currents along the coast of California have been seriously studied by numerous investigators for the last 50 years. Early investigators could only obtain localized current data, and spatial and temporal characteristics were inferred by assembling mosaics of local observations. Within the last few years, aircraft and satellite remote sensors have obtained the synoptic "big picture" with respect to nearshore surface currents along the coast of California. Recently evolved techniques applied to the expanding data bank of imagery afford greater definition of sea surface dynamics. Concurrently, surface observations have assumed a new importance as they are required to provide sea truth for the observed sea surface phenomena.

In this study, we have demonstrated the capability of different sensor systems for use in defining the oceanic and nearshore surface currents. At this time, we do not know that what we have observed can be stated to be absolutely correct in its generalized content. However, we do feel that the observations and analyses performed for the California nearshore current seasons make up as good an evaluation of the nearshore currents as found anywhere. We recommend the use of the remote-sensing tool, especially the U-2 imagery, for any nearshore study in which large spatial reaches are to be observed. The questions raised as to the absolute velocities and

Figure 14. Moss Landing area photographed from an ARC U-2 aircraft on April 4, 1974. Upper sediments are from the Pajaro River. Darker center sediments are from Moss Landing Harbor, and lower sediments are from the Salinas River.

directions of coastal currents will only be answered after much more surface data are taken and compared with additional aircraft and satellite imagery.

ACKNOWLEDGMENTS

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C-5. South Louisiana Remote-Sensing Environmental Information System

J. Paul Gordon,[a] Robert H. Schroeder,[a] and Robert H. Cartmill[b]

The New Orleans District of the U.S. Army Corps of Engineers encompasses approximately 60 percent of the State of Louisiana and small portions of the States of Texas, Arkansas, and Mississippi (fig. 1). The southern third of the district may be described as one of the most unique areas in the world with reference to the diversity of water resource interests. I am a water resource planner in this district.

The single most important contributor to the landscape of southern Louisiana is the Mississippi River, which drains approximately 1 250 000 square statute miles or approximately 41 percent of the surface area of the continental United States. In the southern half of Louisiana, the flow of the Mississippi is accommodated by its main channel and by a distributary known as the Atchafalaya River.

Once, 5000 to 6000 years ago, the course of the Mississippi was located near the course of the present Atchafalaya. Over the last few thousand years, however, the course of the river drifted gradually eastward to its present location and left the ancient delta to the whims of alluvial subsidence and the lapping waters of the Gulf of Mexico. As a result of these processes, the delta gradually degenerated to a swamp. The present Atchafalaya River was probably formed in the 15th or 16th century by a Mississippi River crevasse during a great flood. In the 1850's, a logjam was removed from the Atchafalaya in the vicinity of its confluence with the Red River to accommodate navigation; then, the Atchafalaya began a steady increase in flow. During the next 100 years, flow from the Mississippi to the Atchafalaya increased. In 1950, it became apparent that if the process was not checked, the entire flow of the Mississippi would be captured by the Atchafalaya by 1990.

Figure 2 shows the lower Mississippi River flood control plan. Today, flow into the Atchafalaya River is regulated at the old river diversion channel to the proportions that existed in the late 1940's. In conjunction with the Morganza Floodway and the Bonnet Carré Spillway, the control structure serves to regulate floods and thus to protect the cities of Baton Rouge and New Orleans and the industrial-petrochemical complex that has developed in the corridor between the two cities.

Figure 1.– Boundaries of the New Orleans District of the U.S. Army Corps of Engineers.

Under authority first granted by Congress in 1967, we are currently studying the unique situations that have occurred since the growth of the Atchafalaya into a major distributary of the Mississippi. In addition to being the most important flood control outlet on the lower Mississippi, the basin of the Atchafalaya presents one of the rarest environmental habitats remaining in the

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[a]U.S. Army Corps of Engineers, New Orleans, Louisiana.

[b]NASA Earth Resources Laboratory, Bay St. Louis, Mississippi.

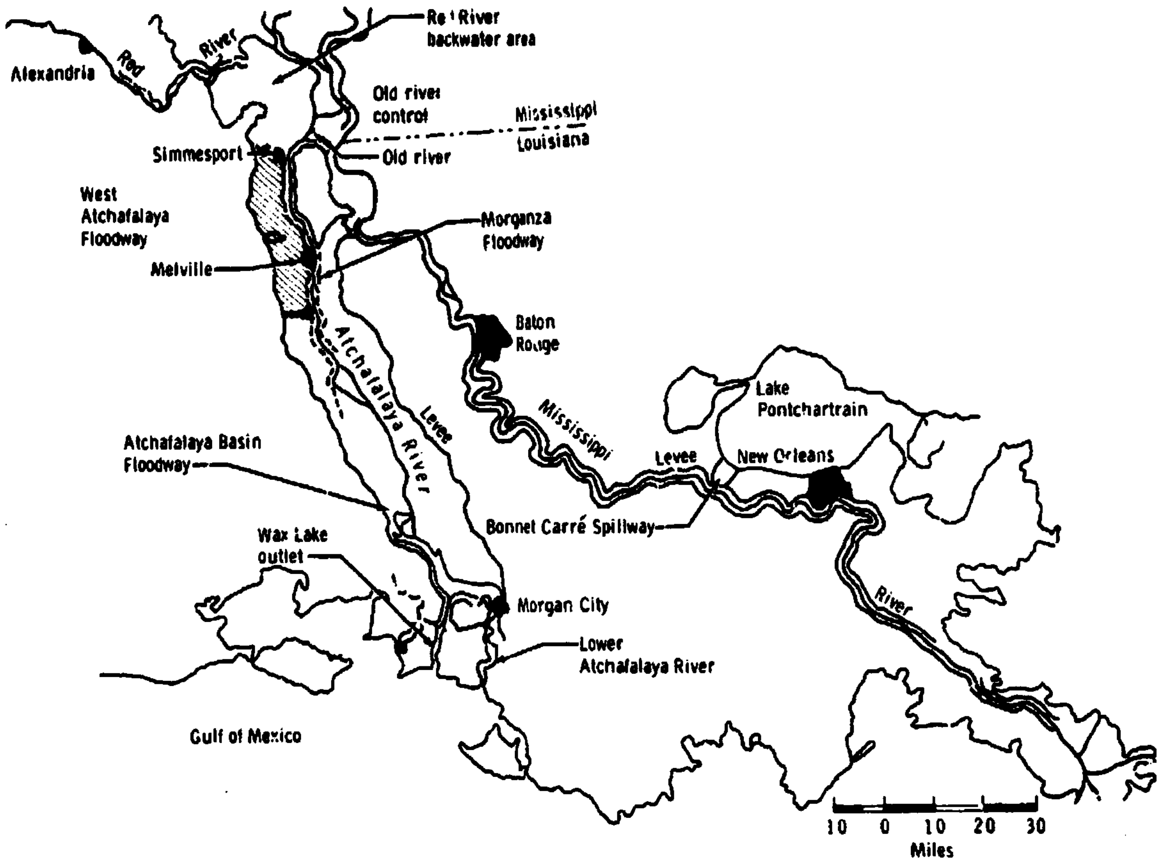

Figure 2. Lower Mississippi River flood control plan.

world today. It comprises the largest remaining natural freshwater swamp in the United States and supports an unsurpassed fishery, in addition to its value as a recreation resource.

A major flood control plan superimposed on a delicate ecosystem such as the Atchafalaya Basin presents problems that were previously unencountered. A plan has been developed to divert approximately 50 percent of the Mississippi River flow down the Atchafalaya River. When instituted, the plan should prevent "silting out" of the Atchafalaya and thereby maintain the basin in its present state for as long as possible. We are currently cooperating with the environmental community in developing modifications to this plan that include components for improving environmental quality to ensure that the final plan best serves the overall public interest.

In an effort to develop the best plan and to include environmental concerns in all facets of the planning process, the New Orleans District contracted with the Engineer Agency for Resources Inventories to prepare a comprehensive data-base document. The atlas they prepared is a compilation of all existing data on the Atchafalaya Basin and includes data on physiographical, biological, and cultural elements in most of southern Louisiana with particular emphasis on the Atchafalaya Basin. It also contains some 20 individual maps illustrating these various characteristics. Figure 3 shows a typical map from the atlas. The atlas has proved to be an invaluable tool and has been well received by local, state, and Federal planning agencies as well as by private citizens' groups and environmental interests. In fact, the first printing of the atlas was depleted within about 3 weeks, and we are now into a second printing.

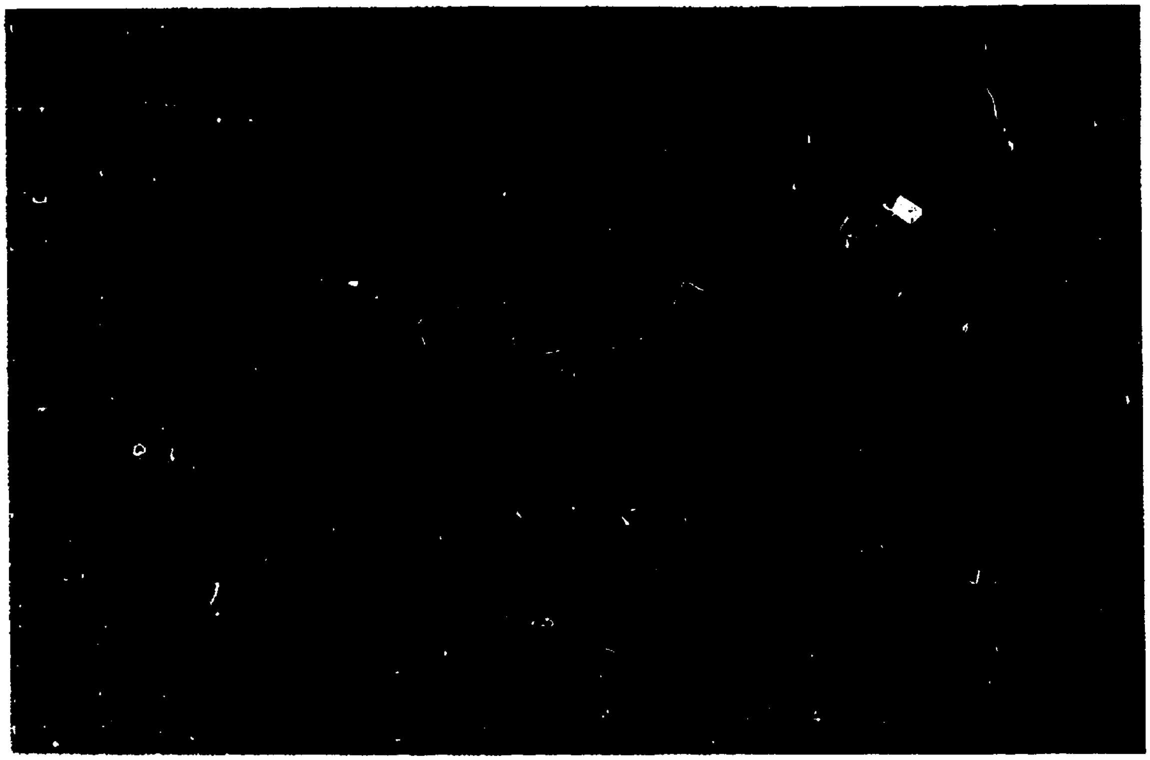

Figure 3. - A typical map of southern Louisiana from the Engineering Agency for Resources Inventories atlas. Vegetation types are shown.

Although the atlas has been a valuable aid in the planning process, we recognize that it has one major fault: many of the data sources used were several years old. The base map, for instance, is nearly 20 years old and does not reflect recent dynamic geological changes, such as erosion by wave action along the Louisiana coast and active delta building in the lower part of the basin. Therefore, the topography itself could be in error. Cultural and natural features are no more recent than the data sources used. The atlas will obviously require periodic updating to remain a useful tool. Consequently, in exploring new ways to keep this document current, the New Orleans District has been working closely with the NASA Earth Resources Laboratory in an effort to determine whether satellite-gathered remotely sensed data would be effective. Dr. Robert Cartmill of the National Space Technology Laboratories at Bay St. Louis, Mississippi, has worked closely with us on this project. The following brief synopsis of the remote-sensing techniques used to update portions of the atlas is presented by Dr. Cartmill.

The basic environmental atlas that was prepared by the Washington Corps of Engineers Topographic Office contains 20 different map categories. The Corps brought us the atlas and asked if we could help update any portion of it. Of those 20 map categories, we determined that three of them could be updated by remote sensing. The three columns to the right in table I show these three categories and the breakdowns of each. We concluded that if we could, by remote sensing, classify all the surface material, as in the column to the extreme left, we could then reproduce any one of the three maps. Basically, we started off in a three-phase program. The first phase was do the easiest thing first, so, we tried to get the seven basic categories before attempting a twelve-class classification. The seven are listed in the Arabic numerals of table I.

How do you do this type of thing? We went to our Landsat files and found what coverage we had of this area. Because it rains so much in Louisiana, we had a real problem finding cloud-free passes. Figure 4 shows the project area and the Landsat frames that are required to

TABLE I.— COMPARISON OF CATEGORIES FOR REMOTE CLASSIFICATION

Remote-sensing categories	Generalized land use	Ecological zones	Vegetation
1. Agricultural	1. Agricultural	1. Cleared land	1. Crops and pasture
2. Urban/builtup	2. Urban/builtup	2. Cleared land	2. Other
3. Forest	3. Forest land	3. Woodland	3. Forest
a. Deciduous		a. Bottomland	a. Deciduous
b. Evergreen		b. Upland	b. Evergreen
c. Mixed			c. Mixed deciduous
4. Forested wetland	4. Forest land	4. Bottomland	
5. Nonforested wetland		5. Marshland	5. Nonforested wetlands
a. Saline		a. Saline	a. Saline
b. Brackish		b. Brackish	b. Brackish
c. Intermediate		c. Intermediate	c. Intermediate
d. Fresh		d. Fresh	d. Fresh
6. Water	6. Water	6. Water	6. Water
7. Barren	7. Barren	7. Cleared land (?)	7. Other

cover it. As it turned out, no 3-consecutive-day, cloud-free passes were available to us that covered the 24 000 square miles of the project area. So the two outside passes shown were in October, the upper two frames of the middle passes were in August, and the bottom one was in November; thus we were faced with trying to classify this area frame by frame, taking each day or each seasonal pass we had, picking training samples, and pushing the images through standard pattern recognition programs to produce a map. Figure 5 shows not only the entire map, glued together, but also the output of our first data processing step. This first step was to make a simulated color photomap for each one of the Landsat frames; each map was made to a scale of 1:125 000. We used these maps to identify what we needed to have in the way of training samples by color interpretation; if we had six shades of water, for example, then we picked training samples to cover those six shades of water. We were fortunate in having some WB-57 photographic coverage of the area which was used to positively identify the training samples. The training sample data were analyzed, grouped into the required classes, and put through the pattern recognition program. Figure 6 shows the ouput of this program. The result is a seven-class classification of this entire area; it has been geographically rectified. We have each mounted on a quadrangle sheet to match the Corps of Engineers' original atlas.

A new technique implemented by our laboratory is the ability to very quickly classify large amounts of data covering a large area. We use a table look-up program that was developed in Houston and implemented at our laboratory in Mississippi. Its use has reduced the classification time over the conventional LARSYS II program by a factor of about 18; thus the actual computer time going from the map in figure 5 to the map in figure 6 is now really quite insignificant. Paul Gordon will now briefly evaluate the quality of this product and its usefulness.

We of the New Orleans District are quite pleased with the results that have come about from the first phase of this experiment. Not being the project engineer on the Atchafalaya Basin project, I could only give you a cursory overview, really. But I have several of my own projects that involve salinity changes in the marsh and the second phase of this project will be extremely interesting to me. We may be able to develop a system whereby we can monitor task-by-task what is going on in the marsh and this is the major component of several studies that I am working on right now. We are pleased, and we feel that this will be a highly valuable source of

Figure 4. Project area and Landsat coverage.

data for updating our current atlases. We feel that in the future for the entire Corps setup, a system such as this may be very desirable for updating such maps as other districts might have besides our own.

DISCUSSION

SCHWERTZ: I am Eddie Schwertz with the Louisiana State Planning Office. You said, I believe, it was 24 000 square statute miles; if that's not correct, please correct me. What was the overall cost of producing this seven-category general land use map?

CARTMILL: The area is 24 330 square statute miles. I will give you a suitable hedge on the cost, because we don't have all our numbers in. As I say, we put this map together only last Friday, and I have not received my bill from the photographic laboratory, et cetera. I will say this about the cost, if we make every contingency for outside cost with the exception of the depreciation of the $250 million dollars that went into Landsat, this thing was certainly done at a cost of less than a penny per acre. I feel very safe in saying that is the upper limit and right now if I were in private business I could do it for 2 cents an acre and really make money. I'm that confident of the system.

SCHWERTZ: You mentioned the months of the pass. Was this 1974?

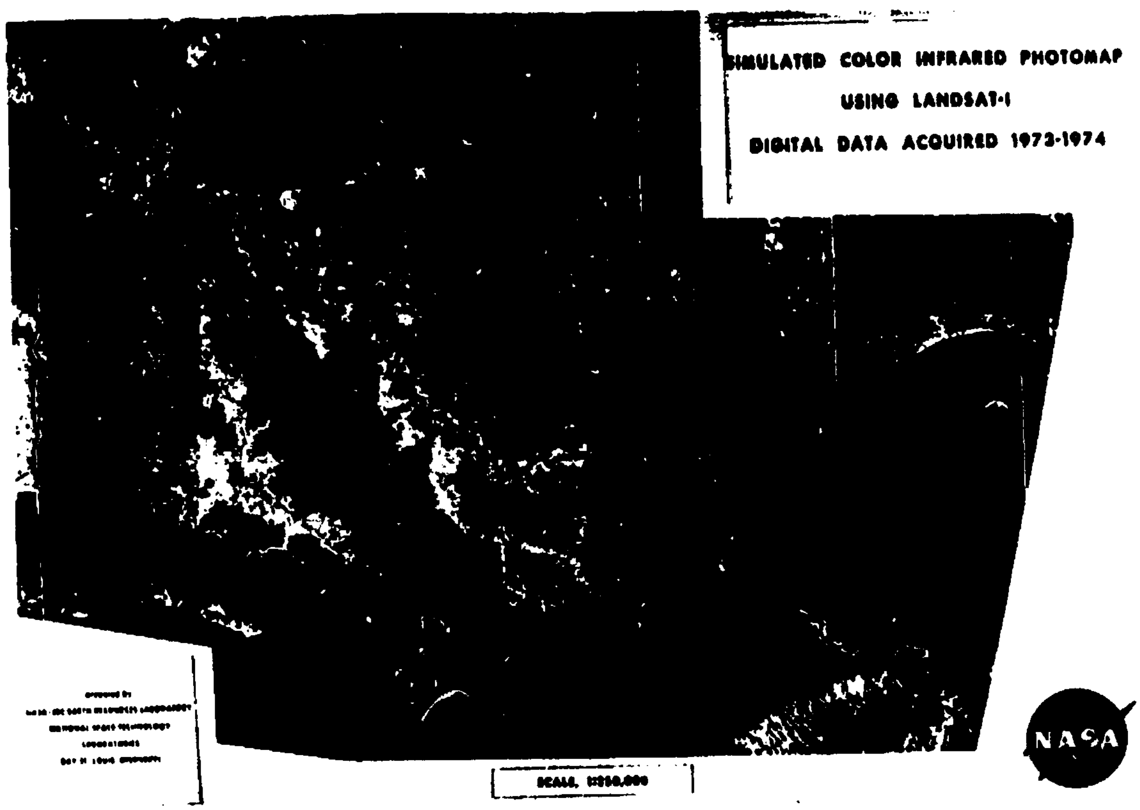

Figure 5. Simulated color-infrared photomap of the project area.

CARTMILL: The October passes were in 1974; the August pass was in 1973.

GRATH: My name is John Grath and I am from Louisiana State University. Did you, over that span of time, take into account in your classifications the change in solar intensity and reflectivity of the classes?

CARTMILL: No, the technique we use avoids that. The technique developed by Purdue requires training samples on each individual frame of Landsat data. These samples are good only for that particular frame of data. This avoids the problem of making these kinds of corrections; each classification is an empirical solution to that particular data set.

GRATH: You classified large areas. Did you go back to those areas to see if the classifications were valid?

CARTMILL: We are in the process of doing that. We have these maps marked with a little tick mark at every 10 000-meter universal transverse Mercator (UTM) grid intersection. We have photointerpreted each one of these locations using the aerial photography that we have and we are comparing the classification at the tick marks with the photointerpreted classification. This work is only 13 percent complete.

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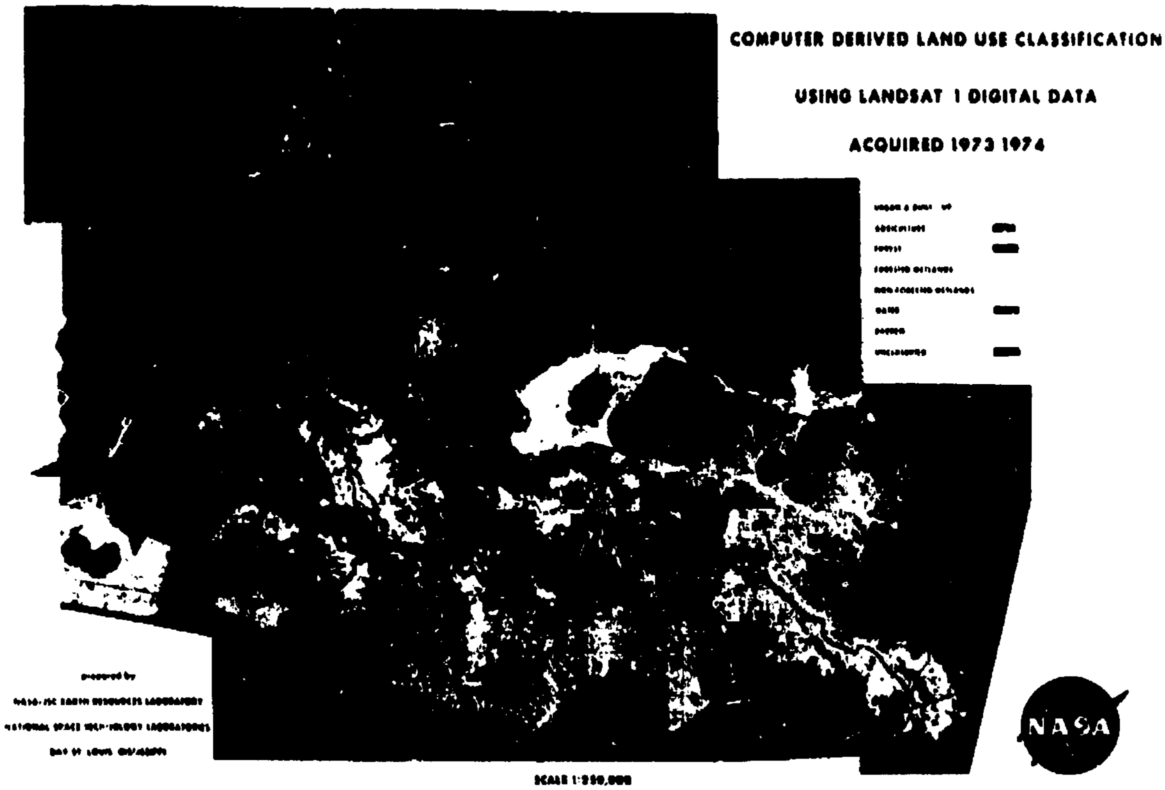

Figure 6. Computer-derived land use classification of the project area.

C-6. Remote Measurement of Shoreline Changes in Coastal Alabama*

C. Daniel Sapp[a]

INTRODUCTION

The increased attention focused on the coastal zones of various states has created a greater demand for factual information. The seaward boundaries, the inland boundaries, the high- and low-water marks, and the lengths of estuaries are being measured. These measurements are done by a myriad of techniques, and yield results of differing reliability. Clearly, more objective techniques and more uniformity in measurement are necessary.

TRADITIONAL TECHNIQUES FOR MEASURING THE COASTAL ZONE

The task of measuring shoreline lengths is not as simple as it may seem. Traditional methods of measuring distances on maps with an opisometer (or map wheel) (fig. 1) appear to be straightforward but may be done in various ways, all legitimate, and all yielding inconsistent results. The failure is perhaps more a fault of the operator than of the instrument, but may be a combination of both.

Measurements of area (fig. 2) likewise are subject to variation because different techniques are used, mechanical corrections are not properly made, or addition and subtraction exercises are faulty. The failure is perhaps most often attributed to the operator, rather than to the sensitivity of the instrument (in this case a planimeter), but the whole system of making the measurements may be faulty.

An illustration of inconsistent results obtained through traditional techniques of measurement is in table I. All of these agencies are familiar, reliable, and dependable, so the inconsistency is probably not caused by a lack of ability, but instead by the use of different criteria for measurement. For example, how far up are the estuaries followed with a map wheel when measuring the shoreline? The tidal limits? By a salinity definition? At what scale is the measurement done? Should maps or photographs be used? What is the level of generalization? Standardization of procedures is sorely needed.

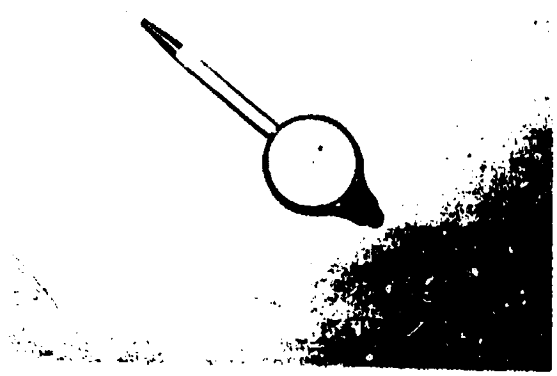

Figure 1. Opisometer, a tool for measuring distance on a map.

Table I shows that people from five governmental agencies measured the shoreline of Alabama: the Army Corps of Engineers; the National Oceanic and Atmospheric Administration (NOAA); NASA Lyndon B. Johnson Space Center (JSC) Earth Resources Laboratory; and two state agencies, the Alabama Department of Conservation and the Geological Survey

*Approved for publication by the State geologist.

[a]Geological Survey of Alabama, University, Alabama.

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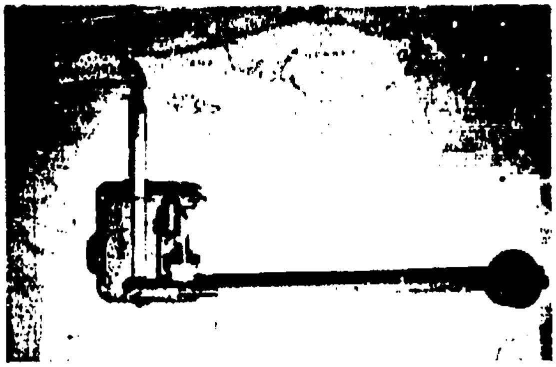


Figure 2.-- Planimeter, a tool for measuring area on a map.

of Alabama. Totals vary by more than two to one. The NASA measurement does not include the entire Alabama shoreline since it does not cover the Perdido Bay area and Gulf coast adjacent to Florida.

The Geological Survey of Alabama embraces the NASA measurement, although this work is not yet complete for the entire Alabama shoreline. A partial measurement of 878.5 kilometers (546.0 statute miles) has been completed for the segment from the Mississippi line to the longitude of Foley (87° 42' W) in Baldwin County. Measurement of the remainder of the shoreline is being done by Kenneth Faller at JSC as part of the project just completed for the Alabama Development Office and the Alabama Coastal Area Board. This project was funded by NOAA, with matching funds by the Geological Survey of Alabama.

One obvious advantage of using the Landsat computer-compatible tapes for measuring the shoreline is that this method bypasses the generalization inherent to a map -- the necessary omissions created by the cartographer in the name of clarity. The tape data discriminate the indentations and other intricate detail of upper estuaries and thereby provide a less generalized measurement of the shoreline. Figure 3 illustrates the detail achieved.

SELECTED CHARACTERISTICS OF THE ALABAMA SHORELINE

The shoreline is indeed intricate, as the high-altitude aerial color-infrared photograph in figure 4 reveals. Such detail is elusive to the cartographer compiling medium-scale maps, and, to some extent, large-scale maps. Figure 5 is a medium-scale map of the image area.

The situation is critical because accurate shoreline lengths and other measurements of coastal zone characteristics, such as area of wetland, are needed for regional planning, allocation of Federal and State funding to coastal counties for various projects, and for statistical purposes. Therefore, uniformly administered measurements are a necessity.

There is another reason for desiring consistently applied measurements of shoreline parameters. This reason lies in the dynamic nature of the coastal zone. The geomorphic processes of erosion and sedimentation continually modify shoreline configuration, and these modifications are accentuated by periodic catastrophes such as hurricanes and attendant flooding. Fifty-six percent of Alabama's shoreline is being eroded, and this erosion is critical in some developed areas. Moreover,

TABLE I.-- ALABAMA SHORELINE LENGTH MEASUREMENTS

Agency	Total length	
	Km	Stat. mi.
U.S. Army Corps of Engineers	491.2	305.3
NASA Lyndon B. Johnson Space Center	878.5[a]	546[a]
National Oceanic and Atmospheric Administration	976.7	607
Alabama Department of Conservation	577.5	358.9
Geological Survey of Alabama	811.3	504.2

[a]Partial measurement only, representative of normal river discharge conditions.

Figure 3.– Line printer map of Alabama shoreline.

man almost rivals nature in his ability to modify the coastal zone, although nature usually prevails in the long run. Alabama's coastal zone is shown in figure 6. As the map illustrates, Mobile Bay narrows northward until it terminates at the Mobile River Delta. The western shore and the eastern shore fringe the bay proper.

A Landsat-1 composite (fig. 7) shows the complete shoreline of Alabama and bordering Florida and Mississippi. The lower bay is being continually modified by natural forces as well as by man's activity. Dauphin Island illustrates the changes taking place. In 1950, this island was sparsely inhabited, as figure 8 shows. By 1960, development was already well underway. New dredge and fill areas have appeared on the lee (northern) side of the island. Figure 9 shows that the filling of the marshes is continuing. The Gulf side of the island is being eroded by the longshore drift. In places, this erosion measures over 60 meters (200 feet) since 1941.

The western tip of Dauphin Island is prograding westward toward Mississippi (fig. 10). This end is uninhabited at present. It has moved 1.5 kilometers (0.9 statute mile) since 1941. Petit Bois Island, another barrier island, was astride the Alabama-Mississippi boundary in 1941 but is now completely within Mississippi. Figure 11 is a high-altitude aerial view of the two islands. Petit Bois Island is located to the left, the Dauphin Island spit to the right, and Petit Bois Pass divides them.

Dauphin Island was breached twice by hurricanes during the 20th century and a number of times during the 19th century (fig. 12). Hurricane Camille affected the coast of Alabama in August 1969. The washover fans on the spit are evident on an aerial photograph (fig. 13) taken immediately after the storm passed over.

In contrast to Dauphin Island, Mississippi Sound is generally in equilibrium. This condition does not apply to the western side of Mobile Bay, however, where residents have been demanding that the Corps of

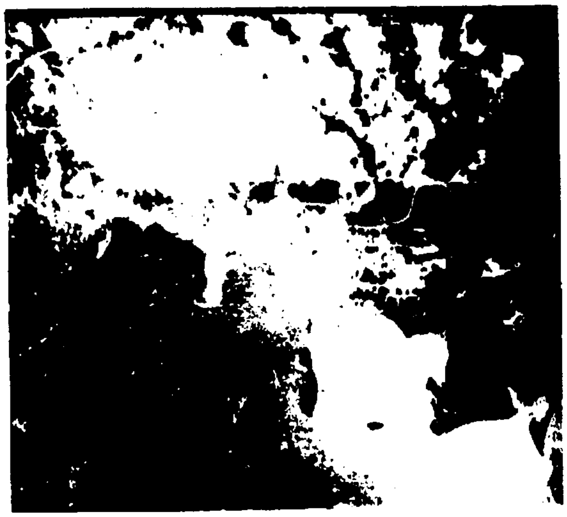


Figure 4.– High-altitude, color-infrared view of southern Mobile County and Mississippi Sound, Alabama.

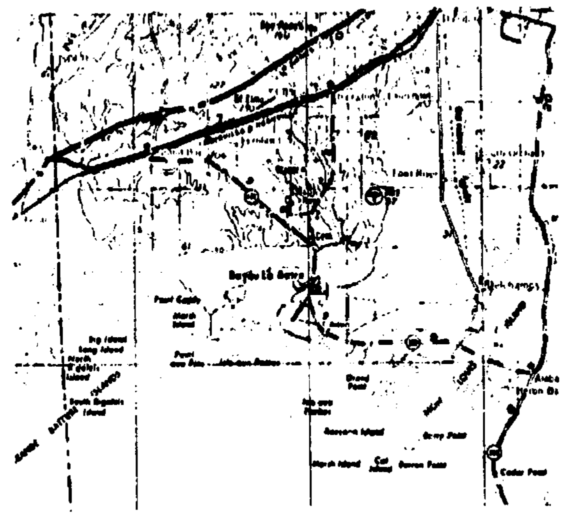


Figure 5.– Medium-scale (1:250 000 on original) map of southern Mobile County and Mississippi Sound, Alabama.

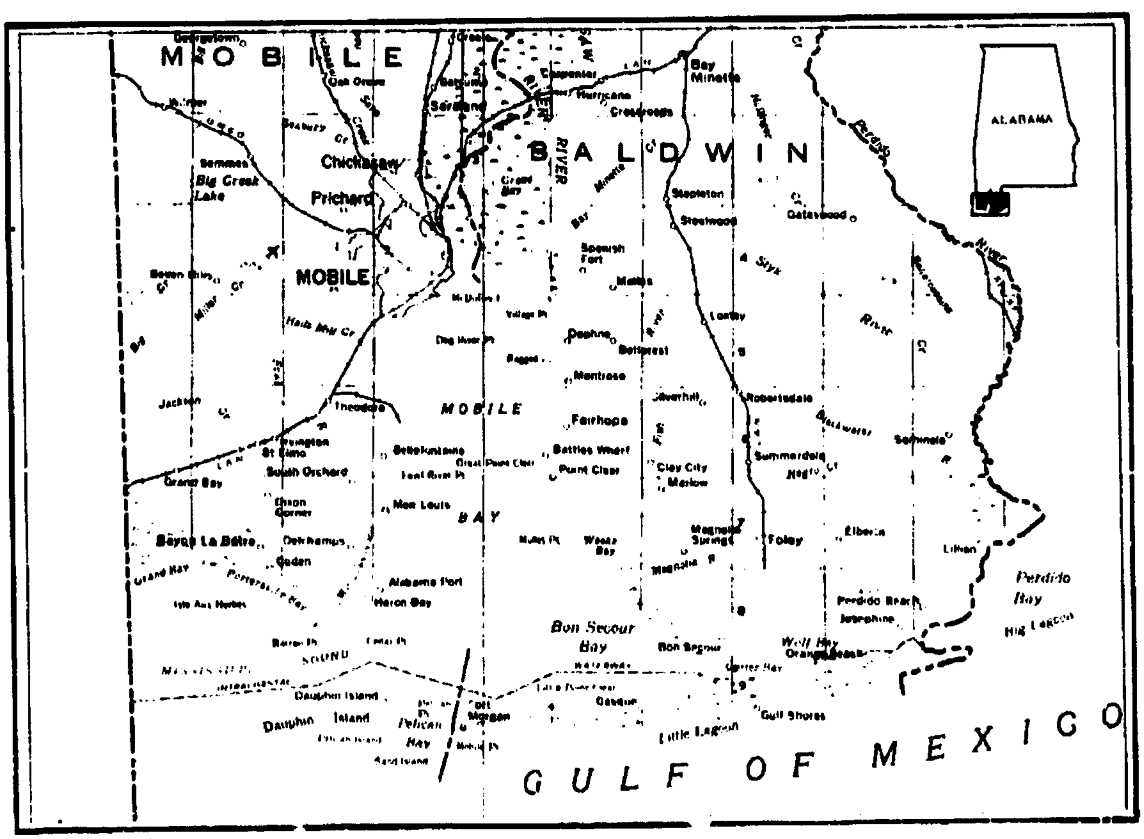


Figure 6. Map of Alabama coastal zone a[illegible] adjacent uplands.

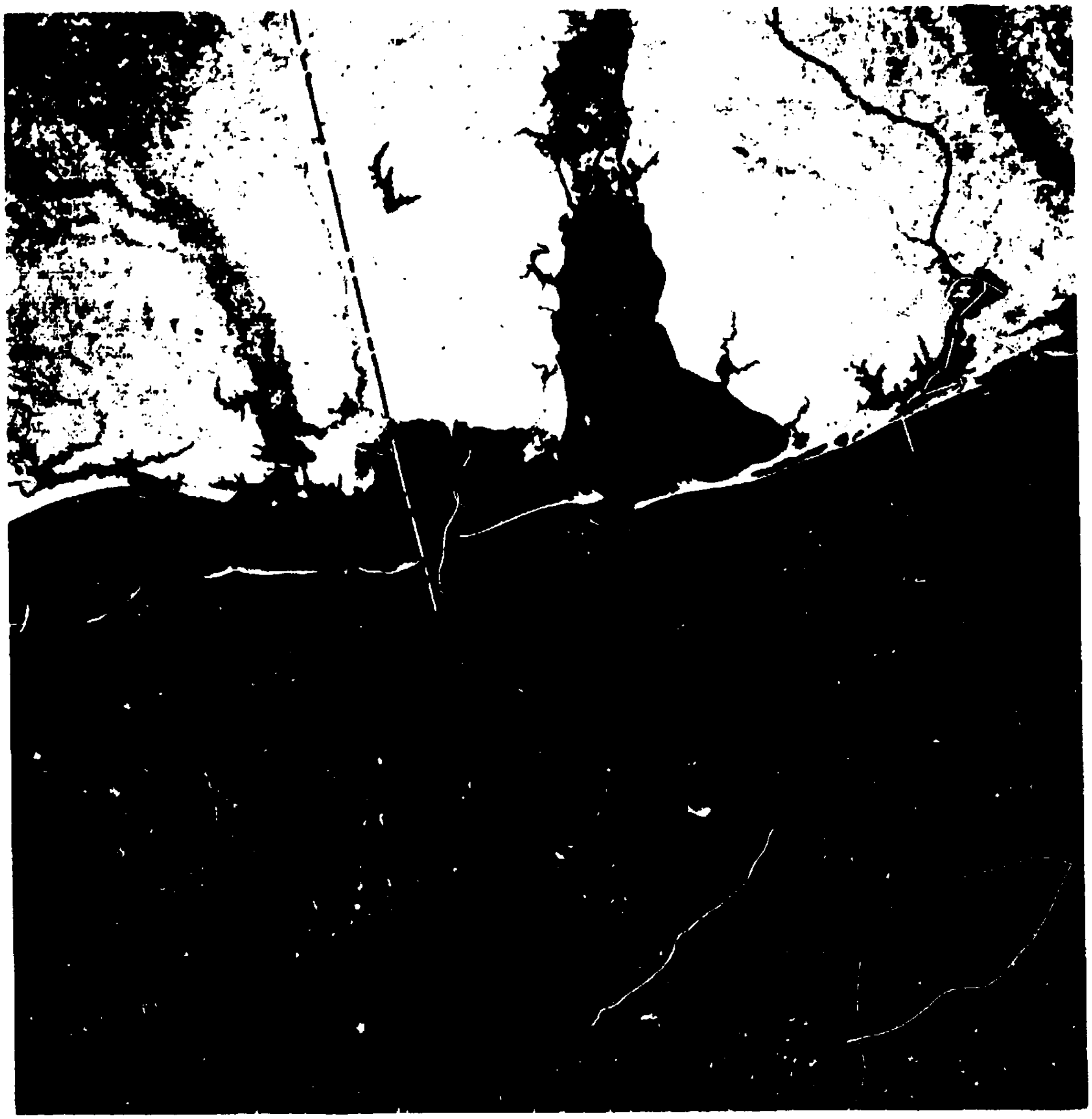
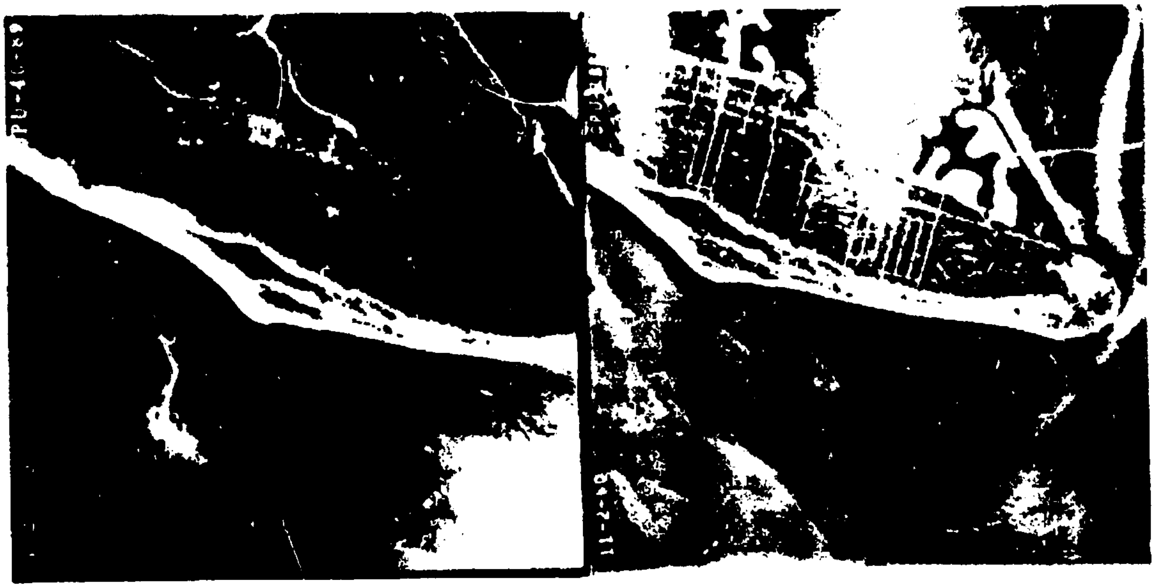


Figure 7. Landsat-1 composite of Alabama coastal zone.

Engineers protect them from the southbound current that erodes their property. Figure 14 illustrates the erosion occurring along this shoreline. Figure 15 shows a variety of protective measures taken along some segments of this shoreline.

The eastern shore of Mobile Bay has some erosion problems, but they are not as pronounced as those of the western shore. Perdido Pass, bordering Florida, must be dredged practically every year to keep it open.



(a) 1950. (b) 1960.

Figure 8.– Eastern Dauphin Island, showing the amount of development over a decade.

Figure 9.– Eastern Dauphin Island in 1975; view looking north.

Figure 10.– Western tip of Dauphin Island; oblique view looking north.

Figure 11.– High-altitude view of Petit Bois Island and western tip of Dauphin Island.

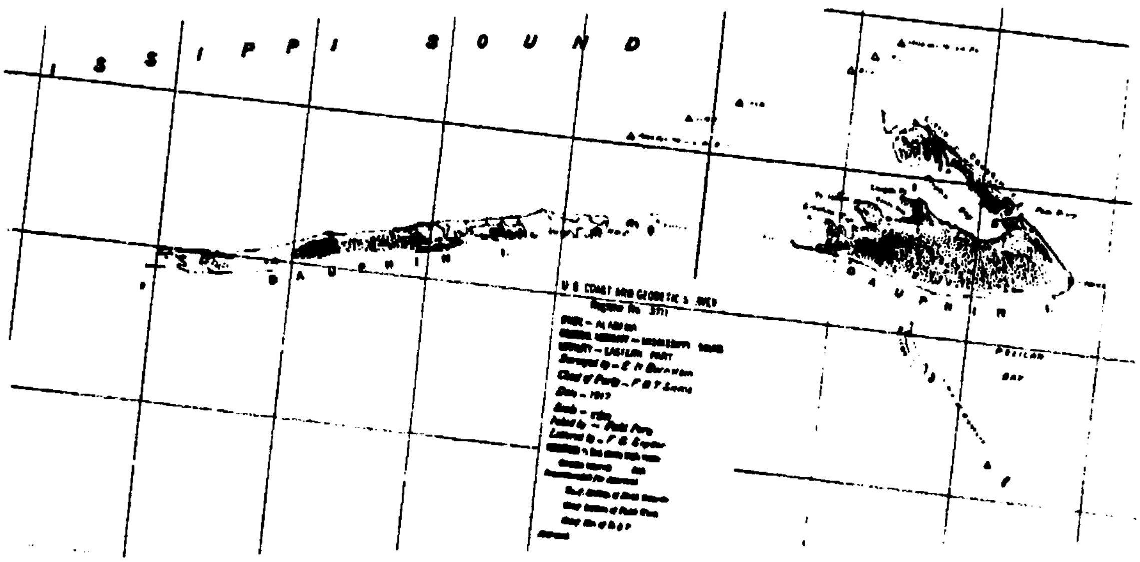


Figure 12. Dauphin Island in 1917.

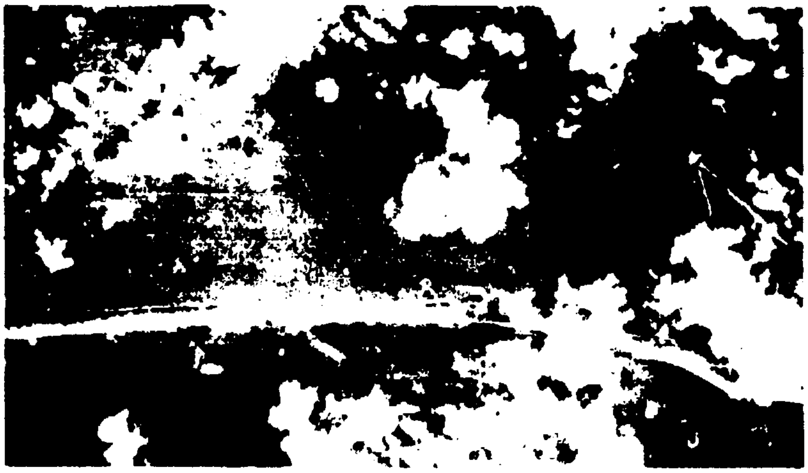


Figure 13.– NASA high-altitude aerial view of Dauphin Island showing Hurricane Camille damage.

Figure 14. Eroded section along the western shore of Mobile Bay.

Figure 15. Protected section along western shore of Mobile Bay.

SUMMARY

Objective, systematic measurements of coastal zone characteristics are now a necessity, and the best way to measure is through use of techniques that bypass the map in favor of remotely sensed data, whether in digital or imagery form. The dynamic nature of the coastal zone lends special importance to such measurements.

ACKNOWLEDGMENTS

The computer measurement work discussed in this paper was done by Kenneth Faller, NASA Lyndon B. Johnson Space Center, Bay St. Louis, Mississippi, for the Geological Survey of Alabama.

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C-7. Remote-Sensing Applications as Utilized in Florida's Coastal Zone Management Program

David R. Worley[a]

INTRODUCTION

The Florida Coastal Coordinating Council was established by the Florida Legislature in 1970 (Florida Statutes 370.0211) to carry out the following primary charges.

(1) "... develop a comprehensive state plan for the protection, development, and zoning of the coastal zone, making maximum use of any Federal funding for this purpose.

(2) "... conduct, direct, encourage, coordinate, and organize a continuous program of research into problems relating to the coastal zone.

(3) "... review upon request, all plans and activities pertinent to the coastal zone and to provide coordination in these activities among the various levels of government and areas of the state.

(4) "... provide a clearing service for coastal zone matters by collecting, processing, and disseminating pertinent information relating thereto."

Mindful of these legislative charges, the staff of the Florida Coastal Coordinating Council recognized the necessity for a planning/management methodology that would illustrate the need for a flexible coastal management plan and would provide a basis for a multiple range of data input.

ESTABLISHING ZONES

The first task of the coastal council was to define the state's coastal zone and then develop a planning/management process for that area. Lengthy research revealed that the most practical method for defining the coastal zone is to use physical features in combination with boundaries of areas for which socioeconomic data are readily available. On this basis, the coastal council decided to use physical characteristics selected on the basis of terrestrial areas influencing the adjacent waters in combination with boundaries of selected census enumeration districts. Physical characteristics involve defining an area by such factors as drainage basins (fig. 1), coastal swamps and marshes (figs. 2 and 3), selected freshwater swamps and marshes (fig. 4), and flood zones. Defined in this way, Florida's coastal zone has an inland boundary varying from 2 to 25 statute miles from the coastline (fig. 5), with the seaward boundary being the limit of Florida's territorial sea.

Within this coastal zone, the council staff has proposed a state zoning system for land and water areas which recognizes three basic categories of management areas.

(1) Preservation (no further development)
(2) Conservation (limited development permitted)
(3) Development (suitable for most intensive development)

Figure 1. Drainage basin.

Preservation areas would protect ecologic units of sensitive flora and fauna as well as areas of dunes, marshes, and swamps. Conservation areas would include

[a]Florida Coastal Coordinating Council, Tallahassee, Florida.

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Figure 2. Coastal swamp of red mangrove.

Figure 4. Freshwater marsh.

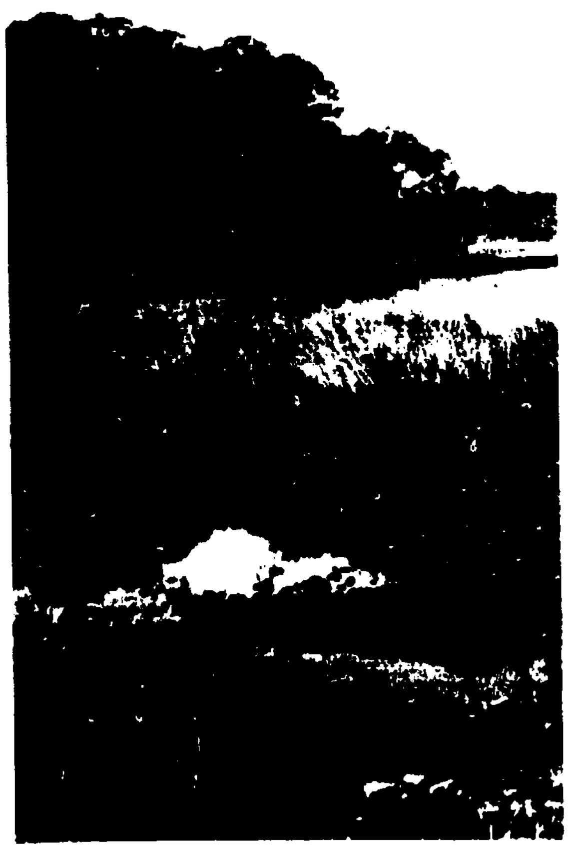

Figure 3. Coastal marsh.

those lands with soils and topography suitable (or suitable with some minor corrections) for intensive development.

Areas throughout the coastal zone have been designated one of these three zoning categories by the coastal council after consideration of the following eight factors.

(1) Soils suitability of the area
(2) Ecological significance of the area and its tolerance to alteration
(3) Susceptibility of the area to flooding, both from runoff and hurricane-driven tides
(4) Historical and archeological significance of the area
(5) Unique features that may warrant protection
(6) Water quality standards in existing state regulations
(7) Present land cover and/or use
(8) Geological factors to the extent possible with existing information

Twenty-nine subcategories constitute the coastal phenomena within the three zoning categories (table I). Many subcategories are considered representative of coastal phenomena essential to Florida's coastal environment, such as: freshwater marshes and swamps, saltwater marshes and swamps, marine grass beds, beach and dune systems, and buffer zones such as woodland-upland areas adjacent to the wetland-marine systems. The proper management of such coastal phenomena has become critical in Florida as pressure on these coastal resources has continued to grow with increased population, wealth, mobility, and leisure time.

To date, only the photographic remote sensors have been used in support of the coastal council's planning/management methodology. To illustrate how

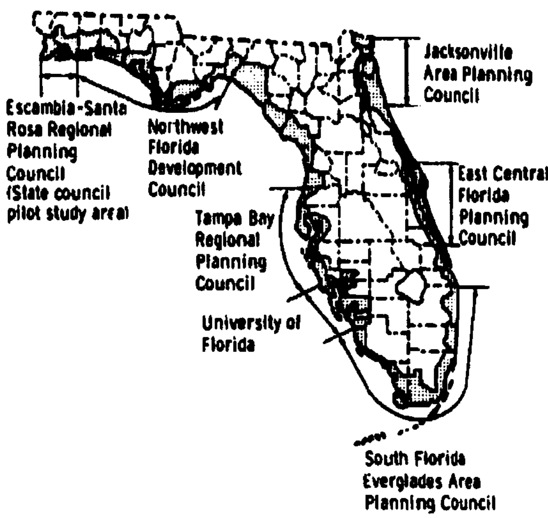

Figure 5.- Florida coastal zone showing areas of regional planning responsibility.

these sensors have been utilized, the following products are described reflecting their use on the broad application format to and including specific application as needed for data support requirements.

The Florida Coastal Zone Management Atlas

The Florida Coastal Zone Management Atlas was received from the printer in December 1972 and widely distributed during 1973 and 1974. To date, more than 600 full atlases and more than 1500 county sets have been sent to governmental officials at all levels, planning groups, developers and real estate interests, consultants, environmentalists, and private citizens. Panchromatic imagery with a range of dates from 1965 through 1971 and a photographic scale of 1:24 000 was the primary data source used for the inventory requirements, with supplemental data and ground truth verification used when necessary. Standard photointerpretation procedures and cartographic application for map compilation were used in preparing the council methodology base maps. Thirty-eight county sets (four maps each, illustrating preservation, conservation, development, composite) were prepared in house (figs. 6 to 9) at a map scale of 1:63 360, which in turn were photographically reduced to 1:126 720, resulting in a final printed map format size of 22 by 26 inches for distribution.

The basic purpose of this atlas was and continues to be a means to provide decisionmakers and concerned citizens with an overview of the components that make up the coastal environment of Florida. At the same time,

TABLE I. ZONING SUBCATEGORIES

Preservation	Conservation	Development
Class I waters Class II waters Marine grass beds Selected coastal marshes Selected coastal mangroves Selected freshwater swamps and marshes Gulf and Atlantic beaches and dunes Selected estuarine beaches Designated wilderness areas Historical and archeological sites Other unique environmental features Portions of hurricane flood zone	Class III waters Aquatic preserves Aquaculture leases Spoil islands Scenic vistas Forestry and game management areas Wildlife refuges Parks and recreation areas River flood plains Marginal lands Portions of hurricane flood zone	Class IV waters Class V waters Presently developed areas Nonconflict Conflict Undeveloped lands suitable for intensive development Undeveloped lands suitable for intensive development with corrections Portions of hurricane flood zone

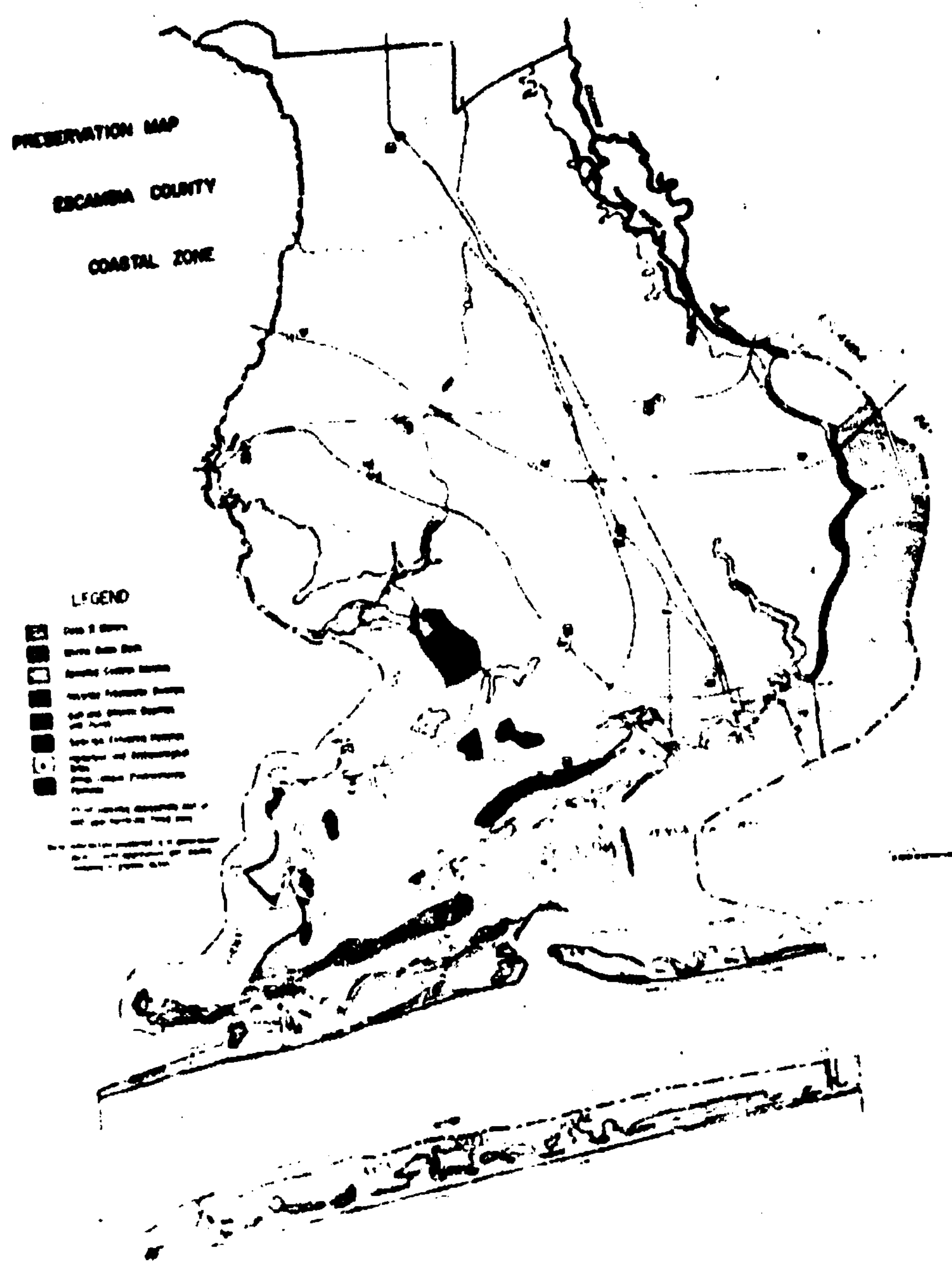

Figure 6. Preservation map of Escambia County coastal zone.

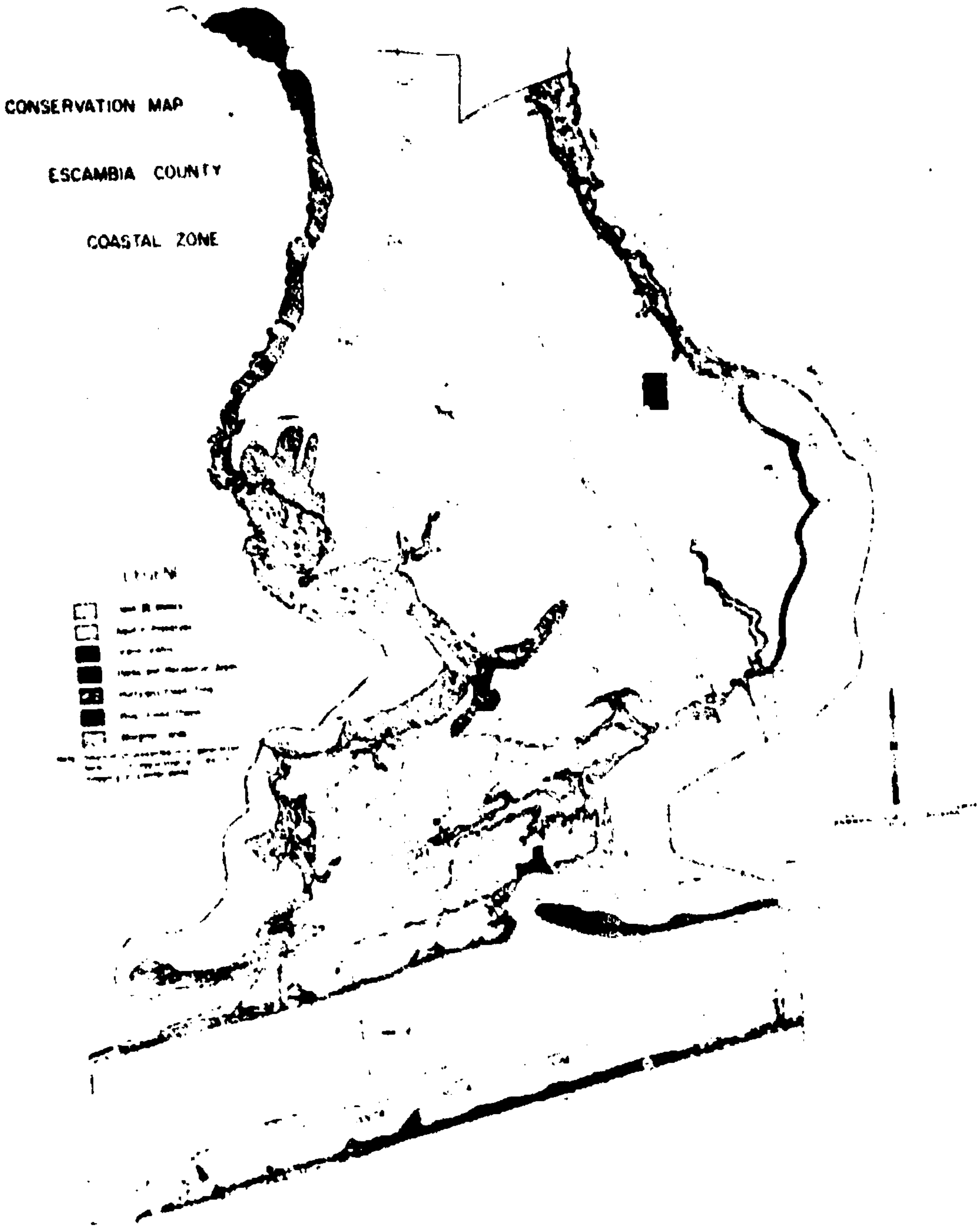

Figure 7. Conservation map of Escambia County coastal zone.

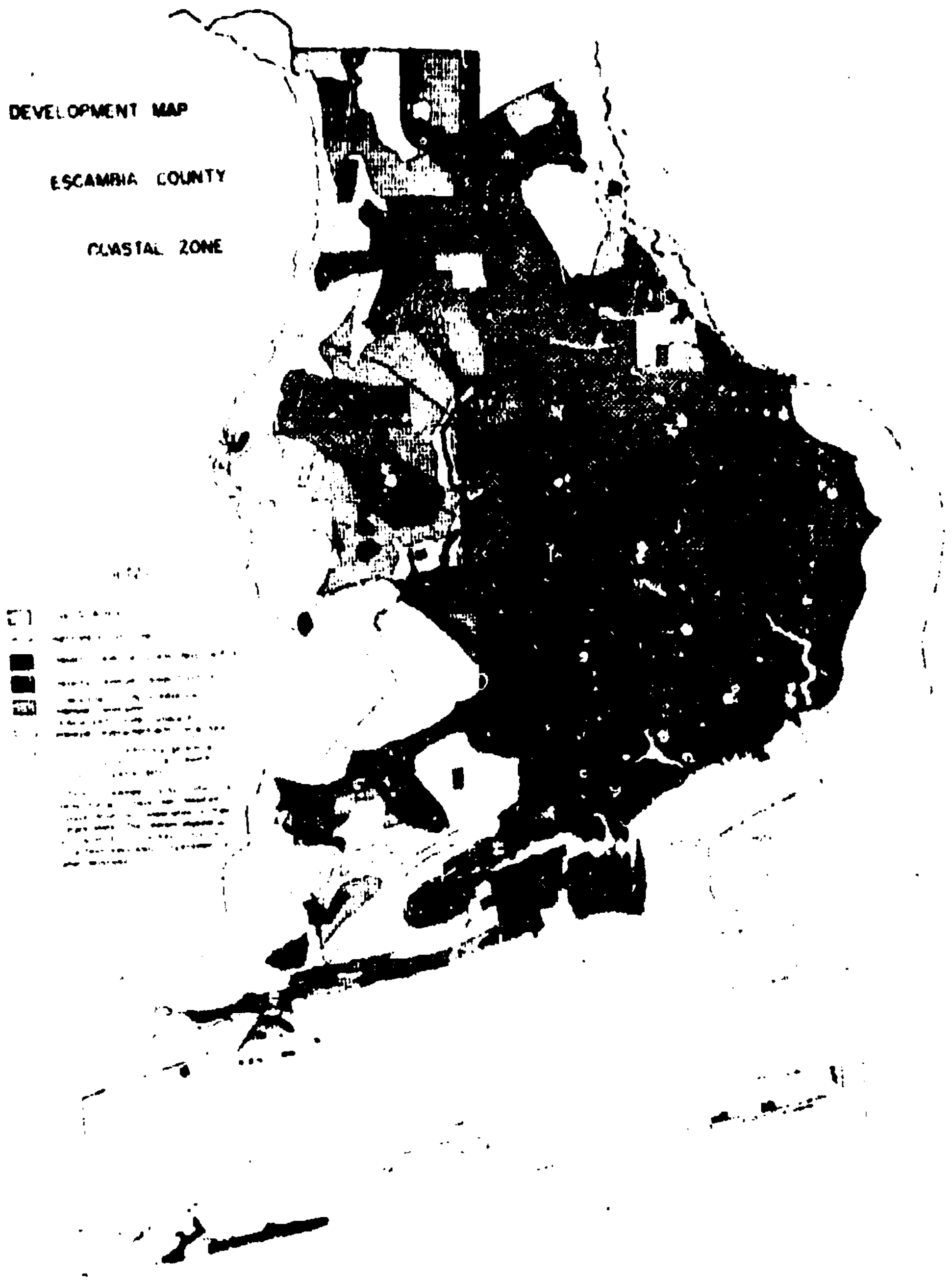

Figure 8. Development map of Escambia County coastal zone.

Figure 9. Composite zoning map of Escambia County coastal zone.

this council would have a means by which the planning/management approach could be disseminated and evaluated by potential users. As a reflection of the council's methodology, the atlas delineates those areas already developed by our rapidly expanding coastal population but at the same time indicates those areas physically suited to accommodate further development where such activity will have a minimum detrimental effect on the environment. Following the proposed methodology format, the atlas contains an inventory of coastal phenomena still relatively undisturbed (preservation subcategories), and recommends that essential, indicated segments of these be "preserved" in order to ensure the maintenance of living marine resources, the esthetic qualities of the coast and the physical integrity of the shorelands. Additionally, a buffer or "caution zone" between development and the preservation areas is designated for "conservation" where limited development with controls can occur, but whenever possible such conservation lands would be considered as a land bank for future generations.

Response to the atlas has been widely favorable, and the planning approach used has been accepted and is being implemented by planners throughout the state in private and public capacities.

Florida Keys Coastal Zone Management Study

In April 1973, council members approved the development of a Florida Keys coastal zone management plan. Because of the many unique features and problems involved in planning for the Keys, and because of the development pressures in the region, it was considered excellent for the development of a pilot management plan. Beginning in May, the full council staff began work on the Keys study. The study format consisted of the following major sections.

(1) Biographical analysis
(2) Socioeconomic analysis
(3) Environmental quality analysis
(4) Planning analysis
(5) Summary and conclusions

This study was completed and published in July 1974 and was widely distributed to local, regional, State, and Federal agencies. This study represented a major extension of the coastal council's methodology as had previously been developed for the Coastal Zone Atlas of 1972, particularly in terms of remote sensing and mapping requirements. While the 1972 atlas was essentially a Level II (U.S. Geological Survey land use classification system) data analysis, the Keys study required a Level III analysis. Two primary base maps were required: (1) a land cover or vegetation map of upland and adjacent marine vegetation was required for a Level III analysis, and (2) a land use inventory mapping effort with a minimum Level II analysis would need to be generated. The categories for the Keys atlas are listed in table 11.

In a joint funding and mapping effort between the council and the State Department of Transportation, Topographic Office, color-infrared imagery was obtained (photographic scale: 1:24 000) for stereographic analysis and the primary base map preparation. Thematic maps then generated from the completed primary base maps included the four standard council methodology maps (preservation, conservation, development, and composite), as well as a land availability map. All were basic to the biophysical analysis section. Land use maps and support services maps were generated for the socioeconomic analysis section. The remainder of the analysis sections were then developed from these data sections. Work maps were prepared in house with a map scale of 1:24 000. The maps were then photographically reduced and printed at a map scale of 1:48 000. The format size was the same as the previous Coastal Zone Atlas, 22 by 26 inches.

PRESENT REMOTE-SENSING APPLICATION

The coastal council and the regional planning councils which include coastal counties are now working jointly on a Level II analysis of the 1972 atlas following the format developed by the coastal council for the Florida Keys management study. The coastal council is doing this biophysical analysis in house using color-infrared imagery (photographic scale: 1:40 000) which the state purchased in 1973. Panchromatic imagery (photographic scale: 1:24 000) for 1974 and into 1975 is available as a supplementary data source for a majority of the coastal counties. Ground truth checks are being made in addition to the use of supplemental data.

The state regional planning councils are using 1:24 000 photoquads, supplemental imagery, and other data sources, as well as ground truth checks to provide data for the social-economic analysis phase for input into the jointly prepared coastal zone management plan. Land use, land ownership, and primary and secondary support services are some of the data currently being generated in part through the use of remote-sensing imagery.

Map preparation for all in-house work by the

TABLE II. FLORIDA KEYS ZONING SUBCATEGORIES

Preservation	Conservation	Development
Marine grass beds Patch reef coral Undifferentiated reef coral (living and nonliving reef proper and forereef rubble) Red mangrove Black/white mangrove Mixed mangrove Scrub/young mangrove Pioneering mangrove Stressed mangrove Historical and archeological sites Other unique environmental features (selected hammock stands, endangered species habitats, etc.)	Class III waters Spoil islands Wildlife refuges Parks and recreation areas Marginal I lands Pine lands Marginal II lands Tropical hammock Degraded hammock Hammock succession zone Marginal III lands[a] Buttonwood transition zone	Presently developed lands Altered lands Could be developed if floodproofed, sewered, and if support services were available Planned unit development techniques with adequate greenspace and attendant vegetation ordinances recommended

[a]Marginal III lands are considered more environmentally sensitive than marginal I and marginal II lands.

regional councils and the coastal council will have data delimited at map scales of 1:24 000. The regional coastal zone management atlases will be printed at this scale or photographically reduced as much as 50 percent depending upon complexity of data representation. Atlas formats will again be 22 by 26 inches.

Another important ongoing remote-sensing application is the use of color water-penetration imagery (photographic scale: 1:24 000) to provide a synoptic overview of the coral reef tract off the Florida Keys. This mapping effort is a preliminary step to a coordinated Federal, State, regional, and local effort for long-term study of the reef tract in an attempt to obtain some answers as to what is affecting the health of the coral: Is degradation occurring naturally or being caused by human activities in and adjacent to the reefs? Or is it a combination?

REMOTE-SENSING REQUIREMENTS FOR THE FUTURE

Implicit in the Florida Coastal Council planning/management methodology, whether a Level II or Level III analysis is used, are the requirements for continuous data updating and a rapid means of data dissemination. Systems for acquisition and dissemination of remote-sensing information are less than adequate, or nonexistent, at the state/regional/local governmental levels, particularly for the data presently in demand, as well as for known future requirements. The problems facing remote-sensing users who seek information are many and varied, given their respective data requirements, data display and/or dissemination format, in-house expertise, access to necessary funding, et cetera.

In Florida, governmental agencies are awakening to the fact that these varied problems exist and that expansion of a centralized capability for remote-sensing activity is necessary if various program requirements are to be met. The focus of the interest is presently with the State of Florida Department of Transportation and its Topographical Office. In the last 2 years, by working through inner-local agreements, data derived from a variety of remote sensors, including photographic, thermal and side-looking airborne radar, have demonstrated the need for remote-sensing application. Gradually, a multiple remote-sensing program will be in demand as greater numbers of present and potential users learn what segment of remote-sensing technology can benefit their own program's data requirements.

DISCUSSION

QUERY: One of the first items in your list of planning considerations included the sensitivity to modification. Remote sensing can give you present status and it can also give you case history for results of modification. How do you project, though, when you consider modification? Particularly to projects like the Cross-Florida Canal or Beckman highway in the swamp?

WORLEY: You are talking primarily about dredge and fill and channelization in Florida. Unfortunately, predicting is a problem in Florida because we lack the background data base to really say, "You shouldn't be doing this." There are reams of studies as to why a project should or should not be done. But these are short-term studies. Right now the council has resolutions from the cabinet and the governor for canal research, so we're trying to get these answers. A good example is the Florida Keys reef tract. You have probably read and heard quite a bit about how they are dying and so on and so forth. Well, it all depends on who you talk to, what vested interests are involved, et cetera. There has not been a long-term study in the Keys. Most of the studies have been over a 2-year period at most. A consensus of the agencies involved and of the scientific interests both private and public is that a minimum of 6 years will be required to get the answers needed in the coral reef tract, for example.

TILTON: A multitude of agencies are involved in these studies. And it seems to be quite appropriate for a state to have one agency to either coordinate or to combine the efforts of all of these rather than letting the Corps of Engineers and private agencies, highway department, and so forth each do its own, and quite often come up with biased answers. One somewhat independent agency could coordinate the efforts of the results. Does Florida have a plan to institute this, say, in the planning commission?

WORLEY: Right now, we are the coordinating agency. At least for the next month. We were composed of four departments in Florida. Two were environmental agencies. They have just been abolished. Hopefully we will continue to be the coordinating agency. We were doing exactly what you say should be done. We've been trying to promote interagency coordination for 3 years.

BAKER: I am Simon Baker, University of North Carolina Sea Grant. I'm wondering what status in law your map has. Is it mandatory that the conservation, preservation, development areas be recognized legally, or how does that work?

WORLEY: Answer to your first question: No, it is not mandatory. The coastal zone management program is voluntary at the state level and at present the mapping methodology is a suggested planning methodology. Nine out of 38 coastal counties have adopted entirely or in part the coastal council planning/management concept.

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C-8. Environmental Assessment of Resource Development in the Alaskan Coastal Zone Based on Landsat Imagery

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INTRODUCTION

The development of additional domestic sources of energy is a prime objective of the United States in the mid-1970's. At the present time the development of energy sources in Alaska means primarily petroleum exploration and production. The Cook Inlet field has been producing for a decade, and the major oil and gas field near Prudhoe Bay is being prepared for production in 1977. Geological data strongly indicate that other vast petroleum and gas potential exists offshore along the northern, western, and southern coasts of Alaska. An assessment of these potential new reserves and the development of known deposits require new knowledge of their environmental setting to serve the sometimes conflicting objectives of carefully exploiting resources while preserving most of the environmental values.

Remotely sensed data play an important role in Alaskan efforts to ease the nation's energy shortage. Data from both aircraft and satellites are heavily used by organizations engaged in activities related to both resource development and environmental conservation; however, the vast expanses involved tend to emphasize the benefits of satellite data. The University of Alaska, in cooperation with State and Federal agencies, has applied existing remote-sensing techniques to many aspects of resource development in the state. Results of three representative projects are presented.

SEA-SURFACE CIRCULATION AND SEDIMENT TRANSPORT IN ALASKAN COASTAL WATERS[1]

The Alaskan coastal environment provides a particularly feasible situation for the application of remote-sensing techniques to the study of sediment transport and deposition. The very large quantities of suspended sediment discharged into Alaskan coastal waters are clearly visible on Landsat images which facilitate tracing the sources and movement of the surface suspended sediments and assist studies of the dynamic relationship between sediment input, transport, and deposition. Such studies are important not only in terms of the marine geology and physical oceanography of the region, but particularly so at this time because a knowledge of the transport path of surface suspended sediments is applicable to the prediction of the movement of oilspills in areas which are currently subject to intensive petroleum exploration and development.

Cook Inlet

Figure 1 is a mosaic of two Landsat images of Cook Inlet acquired on September 24, 1973. Even in the red spectral region (MSS band 6), the suspended sediment load ranging from 20 to 1000 mg/liter is clearly seen. The use of images acquired at shorter wavelengths (MSS bands 4 and 5) permits the suspended sediments to be visible at concentrations of 1 mg/liter or even less when atmospheric haze is totally absent.

In order to quantify the relative variations in the suspended sediment load observed by Landsat, the gray shades present in Landsat negative transparencies were density-sliced and color-coded so that boundaries between ranges of gray shades (representing different ranges of suspended load concentration) can be positively differentiated. This was accomplished using an analog image analyzer consisting of a light table, Vidicon

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[1]Much of this section has been summarized from research reported at the Institute of Marine Science, University of Alaska (refs. 1 and 2).

Figure 1. Mosaic of two Landsat images of Cook Inlet, Alaska, acquired on September 24, 1973. The pattern of suspended sediments in the inlet is clearly visible even in this multispectral band 6 image.

camera, control equipment, and a color television receiver. After a negative transparency of the Landsat image is placed on the light table, the camera transmits the image to the control equipment where the image is density-sliced and color-coded into as many as eight different colors. The color-coded image is then displayed on the color television screen.

The range of gray shades coded as any particular color and the total range of gray shades contained in the entire color spectrum of the display are all continuously variable such that the normally small range of gray shades found in coastal waters can be density sliced into the full code of colors, each color representing a different range of reflectance value or suspended load concentration. The color-coded image displayed on the television screen was photographed using high-speed 35-millimeter direct-positive color film (fig. 2). The 35-millimeter color slides thus obtained were then projected, using a photographic enlarger, onto base maps of the Alaskan coast. The projection of the color slide was alined such that the color image and the base map coastlines conformed, and the color boundaries were traced onto the base map to produce the relative suspended load concentrations as shown in the black and white drafted map illustrated in figure 3.

The analyzer control settings used in density-slicing the various images are, for the most part, arbitrary. The base level and the bandwidth of the total color-code spectrum were normally adjusted such that the entire range of gray shades contained in the coastal waters of the specific image being analyzed equaled the range of the color spectrum displayed by the analyzer. Individual color bandwidths were normally kept equal to each other (linear slicing); however, for some images the relative bandwidths were varied to bring out specific details, such as eddies. In one instance, an acetate transparency showing the suspended load distribution for a scene for which near-synchronous sea-truth data had been obtained was overlaid on the analyzer TV screen. After the TV screen image was enlarged and oriented to conform with the overlay, the image was density-sliced to conform with the suspended load contours of the sea-truth data. This procedure gives good results where at least a limited amount of sea-truth data is available.

A series of Landsat images acquired over Cook Inlet during 1972 and 1973 were density-sliced in the manner described. The resulting maps of relative suspended sediment concentration on different dates were then used to develop the net sea-surface circulation model of Cook Inlet illustrated in figure 4.

The major water movement in Cook Inlet is a to-and-fro pulsation in the lengthwise direction of the inlet caused by the flood and ebb of the tide. However, Coriolis force, basin morphology, and probably winds modify the pulsations to produce a net circulation pattern within the inlet. The major sediment sources are the Susitna River and Knik Arm at the head of the inlet.

Tidal movement and Coriolis force produce a net counterclockwise circulation in lower Cook Inlet such that clear seawater intrudes up the east side of the lower inlet, carried in by the westward-flowing Alaska current, and turbid, relatively fresh water is carried out of the inlet along its western shore. As a result of the configuration of the forelands region, the intrusion of clear seawater is apparently deflected to the west side of the upper inlet to form a net clockwise gyre in the region bounded by the east, west, and north forelands. However, this deviation from the normally expected counterclockwise circulation may be a temporary result

Figure 2. Color-coded, density-sliced image of the Cook Inlet sedimentation pattern illustrated in figure 1. The color bar at the left shows the color code, blue to brown, for increasing concentration of suspended sediments.

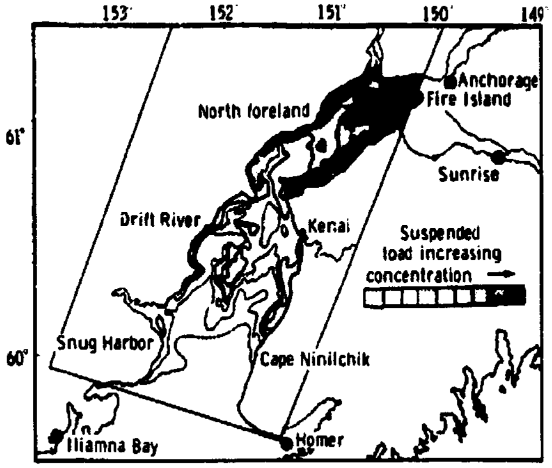

Figure 3.- Schematic diagram of relative suspended sediment concentration in Cook Inlet, drawn from the density-sliced image illustrated in figure 2.

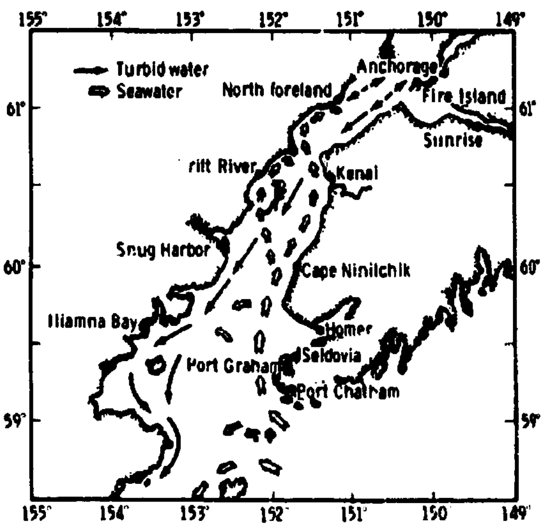

Figure 4. Surface water circulation in Cook Inlet when the tidal stage is near low at Anchorage and high at Seldovia. This model is based on interpretation of sedimentation patterns observed on several Landsat images such as those illustrated in figures 1 to 3.

of the prevailing southerly summer winds (no winter Landsat images are available), in addition to possible variations in circulation caused by the tidal amplitude. (Coincidentally, most cloud-free Landsat images of Cook Inlet were obtained near floodtide at the mouth of the inlet.) Available evidence indicates a highly complex and variable circulation system throughout the region north of Kalgin Island, with extreme mixing of outflowing turbid water and intruding clear seawater. Ship navigation in this area is notoriously difficult.

Tidal current velocities are sufficient to prevent deposition of muds in the central Cook Inlet basin. Substantial deposition of the fine sediments occurs in southwestern Kamishak Bay (south of Iliamna Bay); however, a considerable amount of the Cook Inlet suspended load is carried out of the inlet and into Shelikof Strait (left bottom corner of fig. 4).

The analyses of sea-surface circulation and sediment transport performed for Cook Inlet were repeated for most of the Alaskan coast from Yakutat in the southeast to Barrow at the northernmost point. No attempt was made to study southeast Alaska, and too few cloud-free and ice-free Landsat images existed for the coast east of Barrow to allow a meaningful analysis of that region. The results of these analyses are summarized in figure 5, which shows, in a highly simplified form, the major pathways of suspended sediment transport in the Alaskan coastal and shelf environment. This model, developed by Burbank (ref. 1), is based on Landsat imagery, limited field data on sea temperature, salinity, suspended load, and bottom sediment distributions and on various previous reports, particularly for the Bering and Chukchi Seas.

Gulf of Alaska

Glacially derived sediments introduced into the coastal waters are transported predominantly westward in the Alaska Current. Part of the nearshore suspended load is typically deflected into the various embayments lining the coast. The amount of offshore transport is variable, but in some areas it reaches significant proportions.

In the northeastern Gulf of Alaska, between Kayak Island and Yakutat Bay, the major sources of suspended sediment are Dry Bay, Yakutat Bay, Malaspina Glacier, Icy Bay (Guyot Glacier), and the Bering Glacier. In the Dry Bay region, offshore shunting of the near-bottom suspended load by Alsek Canyon, coupled with a minimal sediment input from farther east, has left relict glacial sediments exposed on the shelf between Alsek Canyon and Yakutat Sea Valley. Yakutat Sea Valley also provides an effective offshore shunt for the near-bottom suspended load derived from Yakutat Bay and the coast immediately to the east, leaving some relict glacial

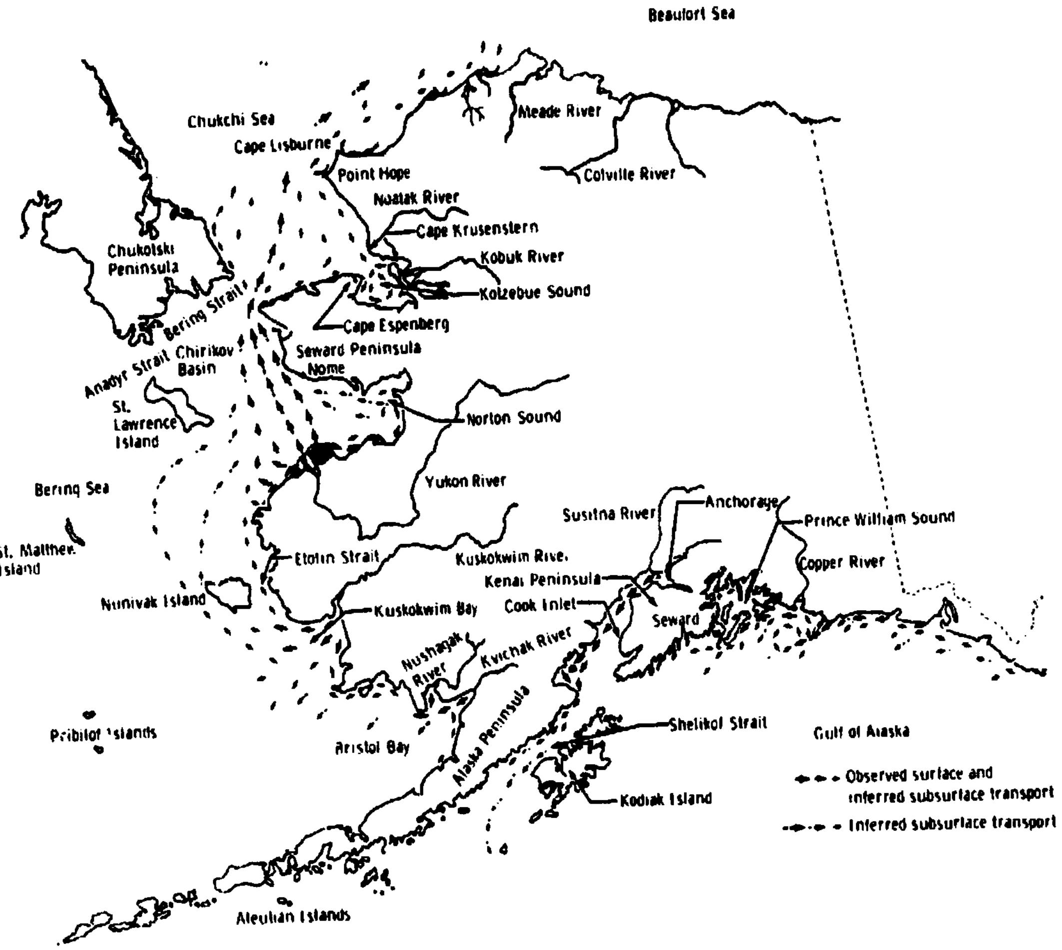

Figure 5. Major pathways of suspended sediment transport in Alaskan coastal waters as interpreted from Landsat imagery, from field data on suspended load, temperature, salinity, and bottom sediment distribution, as well as from published reports.

sediments exposed on the shelf immediately west of Yakutat Sea Valley, however, the considerably increased suspended sediment input from the coastal glaciers west of Yakutat Bay produces a cumulative increase (in a westward direction) in total sediment transport and spreads a progressively wider (in a westward direction of transport) blanket of modern mud over the shelf.

Although some offshore transport of suspended sediments occurs along the entire coast, it is particularly significant where the westward-moving suspended load encounters Kayak Island; the suspended load has been observed to be deflected offshore over 60 kilometers (toward the southwest) in this region. This offshore deflection of fine sediments has greatly enhanced the deposition of mud on the outer shelf southwest of Kayak Island.

A large, apparently permanent clockwise gyre consistently encircles Kayak Island, and sediments are transported north up the west side of Kayak Island to rejoin the nearshore suspended load transport system.

The Copper River discharge greatly increases the coastal suspended sediment load in the north-central Gulf of Alaska. The westward-moving Copper River plume, upon confronting Hinchinbrook Island, splits into several components. A minor amount of the suspended load enters Prince William Sound through channels northeast of Hinchinbrook Island, while a major proportion of the suspended load enters Prince

William Sound through Hinchinbrook Entrance, intruding north almost to the Columbia Glacier, and providing the major source for the fine sediments deposited within Prince William Sound.

The remainder of the Copper River plume is carried southwestward along the southeast coast of Montague Island, beyond which the sediments rapidly disperse and settle. As a result, there is an increasing frequency of exposure of relict and palimpsest glacial sediments westward and southwestward of Montague Island.

Aleutian Shelf

Cook Inlet suspended sediments enter Shelikof Strait as a well-defined nearshore plume flowing southwestward along the northern shore of the strait. With passage through the strait, the plume diffuses across the strait until, near the southwest entrance to the strait, the plume normally has diffused across the entire strait. Bulges in the plume are often observed along the southeastern boundary of the plume, apparently due to transient reversals of the net southwestward movement of the plume during floodtides. With farther southwestward movement, beyond the southwest entrance to the strait, the plume rapidly disperses and settles from surface suspension.

Bottom sediments within Shelikof Strait reflect the cumulative settling and deposition of the fine sediments as they pass through the strait. Beyond the southwest entrance to the strait, the near-bottom suspended sediments are shunted offshore by the sea valley extending from Shelikof Strait to the shelf edge.

The surface temperature and salinity distributions indicate Cook Inlet waters, and therefore probably some suspended sediments, are carried several hundred kilometers westward of Shelikof Strait along the Alaska Peninsula coast; however, there is no evidence of deposition of fine bottom sediments in this region. The shelf seaward of Kodiak Island likewise appears to have little or no input of suspended sediments: the shelf is covered predominantly by relict or palimpsest glacial sediments, with mud filling only the deeper depressions.

Bering Sea

Suspended sediment transport in the Bering Sea is in a general northward direction. In the Bristol Bay region, the Kvichak and Nushagak Rivers supply most of the suspended load. Offshore transport is minimal and, coupled with the high energy of the Bristol Bay environment, the bottom sediments within Bristol Bay have evolved into a well-graded (predominantly sand) shelf in near equilibrium with the energy of the environment.

Transport of the Bristol Bay suspended load is confined mostly to the nearshore zone until the Kuskokwim Bay region is reached. Some of the nearshore transport is deflected north up the eastern coast of Kuskokwim Bay, although entry is slight. The combined Bristol Bay-Kuskokwim Bay suspended loads are normally transported towards the northeast; however, during winter and early spring some Kuskokwim Bay suspended sediments are carried southwest into Bristol Bay. The northwestward-moving suspended load, upon confronting Nunivak Island, bifurcates, part passing north through Etolin Strait to join the Yukon River plume, and part passing west of Nunivak Island to be dispersed offshore into the region south of St. Lawrence Island. Although some of the Kuskokwim suspended load is deposited south of St. Lawrence Island, a significant proportion is redirected to the northeast, producing relatively high subsurface suspended load concentrations in the region between St. Lawrence Island and the Yukon Delta.

The Yukon River discharge, comprising 90 percent of the total (river) suspended sediment input to the eastern Bering Sea, is the predominant influence in the northeastern Bering Sea and Norton Sound. Most of the Yukon River suspended load is observed moving north and northwest towards the Bering Strait. However, a significant amount of the Yukon River suspended load has been observed moving over 100 kilometers directly south in the nearshore zone, while experiencing considerable offshore dispersion towards St. Lawrence Island.

A second important offshoot of the major northwestward-moving plume moves into Norton Sound along its southern and southeastern shore, forming an incomplete counterclockwise gyre within Norton Sound. Most of these sediments are deposited in southern and southeastern Norton Sound; however, some of these sediments are transported out of Norton Sound in subsurface waters in central and northern Norton Sound. Most of the Yukon River suspended load is transported into the Chukchi Sea in near-bottom suspension near the eastern coast of the northeastern Bering Sea and the Bering Strait.

The observed suspended load transport and the bottom sediment distribution correlate well in the northeastern Bering Sea. The major pathways of suspended load transport are generally underlain by relatively high concentrations of silt in the bottom sediments.

Chukchi Sea

The Yukon River provides the major input of suspended sediments to the Chukchi Sea. After passage north through the Bering Strait, the mainstream of Yukon River sediments is carried directly north into the northeastern Chukchi Sea, primarily as a near-bottom turbid layer. Some Yukon River sediments, however, move eastward into the southeastern Chukchi Sea; a minor amount of these sediments enters Kotzebue Sound around Cape Espenberg, while some Noatak River sediments are discharged from Kotzebue Sound around Cape Krusenstern and join the general northward transport in the southeastern Chukchi Sea.

An additional small percentage of Yukon River sediments, after passing through the Bering Strait, are carried northwestward up the Chukotsk Peninsula coast. Upon confronting the southeastward-moving coastal current, these suspended sediments are transported directly offshore in a northeastward direction (initially) and are reincorporated in the general northward transport of Yukon River sediments.

Coastal suspended sediments between Points Hope and Barrow are primarily locally derived from coastal runoff and erosion; however, the input of suspended sediments into this region appears relatively small. The coastal current, which flows generally northeastward, produces clockwise-moving eddies within the coastal indentations. In the vicinity of Barrow, where the northwestward-flowing Chukchi Sea coastal current meets the westward drift of the Arctic Ocean, considerable offshore transport of suspended sediments occurs.

Circulation within Kotzebue Sound is a general counterclockwise gyre. Most of the Noatak River suspended load is transported directly south into central Kotzebue Sound, whereas smaller amounts are carried east into Hotham Inlet and west into the southeastern Chukchi Sea. The bottom sediment distribution conforms well with the surface suspended load distribution within Kotzebue Sound, showing markedly greater concentrations of fine sediments underlying the higher surface suspended load concentrations. The counterclockwise gyre in southern Kotzebue Sound allows deposition of very fine suspended sediments. Most Kobuk River sediments are deposited within Hotham Inlet.

Conclusion

Landsat imagery has proved quite valuable for the study of sea-surface circulation and suspended sediment transport in Alaskan coastal waters. The synoptic overview of large areas provided by Landsat has added a new dimension to the study of dynamic processes and, although remote sensing cannot supplant the need for basic sea-truth data, the combination of limited sea-truth data and comprehensive remote-sensing data can provide far more information than either method alone.

Landsat imagery can be especially beneficial in planning oceanographic research and environmental surveys. Through the delineation of water mass boundaries and regions having particularly dynamic and variable circulation regimes, both of which are readily apparent in the Landsat imagery of most Alaskan coastal regions, it is possible to design sea-truth sampling grids, which can obtain considerably more information for the available ship time and funding. Because of the generally close correlation between the surface suspended sediments and the bottom sediment distribution, Landsat imagery can also be beneficial in the advance planning of bottom sediment and benthos investigations.

The tentative circulation and sediment transport models described in this study will, it is hoped, provide background information to better direct future research in the Alaskan coastal and shelf environment. Future work in remote sensing should be directed toward the acquisition of more comprehensive satellite and simultaneous sea-truth data for various tidal phases and seasons, and toward the development of more quantitative and standardized data analysis techniques. With these two major improvements over the current situation, the present investigation strongly suggests that the use of satellite imagery can contribute significantly to the cost-effective preparation of a comprehensive atlas of sea-surface circulation and sediment transport in the Alaskan coastal zone.

MORPHOLOGY OF SHOREFAST ICE ALONG THE ALASKAN COAST OF THE BEAUFORT SEA

Geologic studies suggest a potential of very large petroleum deposits under an offshore area of arctic Alaska between Prudhoe Bay and the Colville River Delta. The State of Alaska is planning a lease sale of these near-shore submerged lands in the near future, and the Federal Government will be preparing an impact assessment for the possibility of a similar lease sale farther offshore. The oil industry has expressed a great interest in bidding for leases of these offshore areas, but recognizes that the seasonal presence of sea-ice presents unusual problems for petroleum exploration and development. Certainly, in shallow areas, it will be possible to build and maintain artificial islands in suitable locations on which structures and drilling rigs can be built. However, the question will eventually arise as to whether structures can be safely erected in the deeper waters within the zone of shorefast ice. Furthermore, the existence of large masses of grounded ice along the borders of the shorefast ice indicates that underwater cables, pipelines, and other structures must be buried sufficiently deep in the ocean floor to avoid being disrupted by moving ice ridges or piles. The amount of bottom plowing caused by grounded ice is determined by the manner in which the grounded ice pile is created and there are indications that this effect is more pronounced in some places than in others. It is clear that a detailed study of the morphology and dynamics of sea ice must be made before governmental and industrial activities can proceed in this area. The study reported in this section is an initial step in this direction.

General Behavior of Shorefast Ice

During the arctic winter, a relatively stable sheet of ice develops along the northern Alaska coastline, extending distances ranging up to several kilometers seaward. The general characteristics of this shorefast ice have been reported (refs. 3 to 5) as follows.

1. Around midwinter, the ice along the shoreline is no longer subject to breaking free and leaving open water except under the most unusual circumstances.

2. This shorefast ice sheet may contain many pressure ridges. Its seaward edge is defined by the most seaward grounded pressure ridge.

3. Bottom sediments appearing in the piled ice are generally taken to be evidence that a pressure ridge is grounded.

4. The most seaward grounded pressure ridge is characteristically near the 18-meter depth contour.

5. From time to time, a floating sheet of ice can be attached to the shorefast sheet and extend many kilometers farther seaward.

6. The grounded pressure ridge system endures into summer, sometimes as late as mid-July.

Ultimately, offshore engineering in northern Alaska will have to consider the behavioral characteristics and physical properties of this yearly recurring ice sheet. The recent acquisition of Landsat imagery is making possible surveillance of shorefast ice leading to a descriptive morphology.

Reimnitz and Barnes (ref. 4) generalized that the seaward edge of shorefast ice along the north Alaskan coastline follows the 18-meter contour. While the results of this study largely confirm this, pronounced deviations of the boundary of shorefast ice from the 18-meter contour are also apparent. At one location, shorefast ice appears to extend beyond the 18-meter contour, and at another its boundary may be well inside the 18-meter contour. The overall sea bottom configuration is similar in both cases.

Interpretation of Spring 1973 Landsat Data

The relationship between the orbital frequency of Landsat and the areal extent of the acquired images is such that because of the convergence of meridians at the Earth's poles, given points in the Beaufort Sea region are imaged up to 4 days in succession. This overlapping of images, coupled with the fortuitous occurrence of much clear weather in the spring of 1973, made data from that period extremely valuable.

Both figures 6 and 7 were prepared by visual photointerpretation of data collected from many successive Landsat images of the Harrison Bay region between early March and July 1973. In order to illustrate adequately the major sequential ice features during this period and their relationship to one another, the information has been drawn on two separate maps of the same area.

Figure 6 shows the most prominent newly formed leads imaged during a series of Landsat passes in early March. This figure also shows a rather pronounced unfrozen shear line imaged at that time and, near the shore, the location of the 18-meter contour and the seaward limits of extensive hummock fields. Figure 7 shows the same features as figure 6 and also successive locations of shear lines during April through July, as well as the locations of systems of cracks which developed during this time. The interpreted limit of grounded shorefast ice is shown as a series of dots wherever it is different from the shear line of July 2. The 18-meter depth contour is indicated for comparison with the boundary of shorefast ice.

In early March 1973, when the earliest 1973 data were acquired, there was an extensive shelf of ice

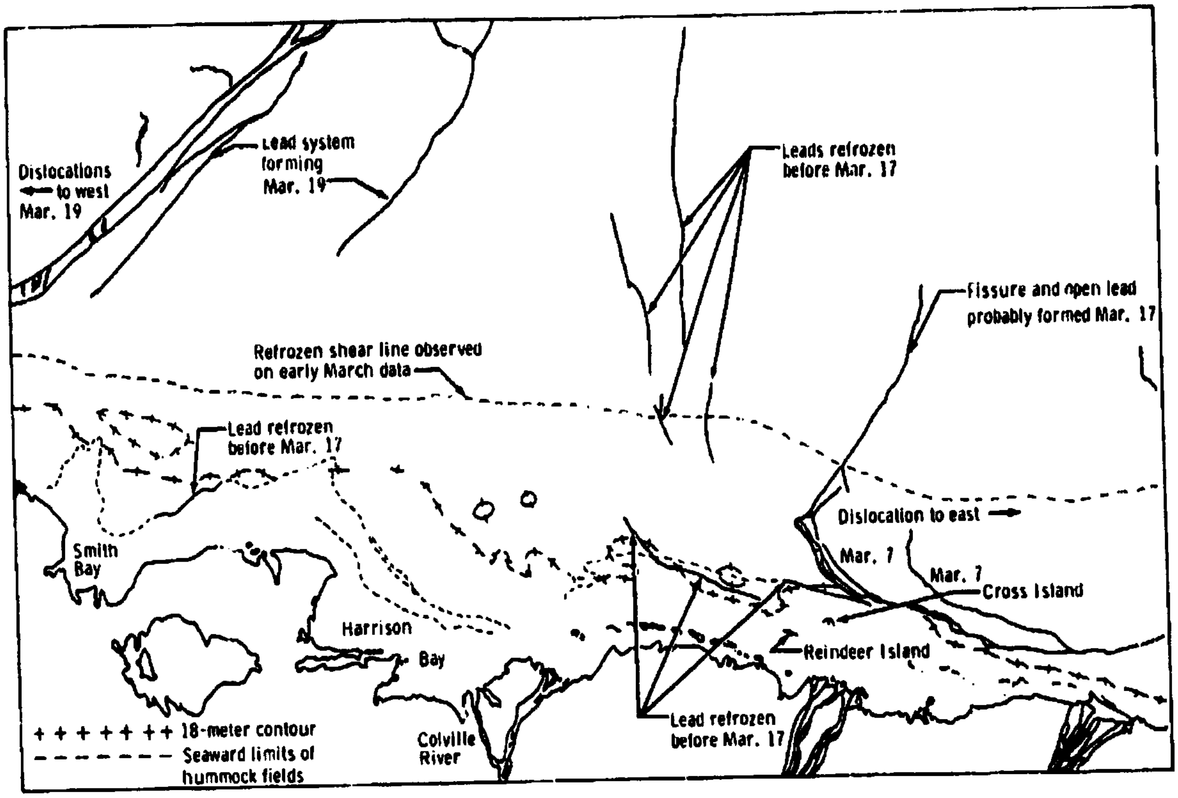

Figure 6.—Sea-ice conditions near Harrison Bay, Alaska, observed on March 1973 Landsat images.

attached to the seaward side of the shorefast ice off Harrison Bay. At that time, part of the large fissure at the right of center in figure 6 was new, while another part of it and the north-south cracks in the center of this figure were somewhat older. Based on Barter Island wind data, we place the date of the new part of this crack at March 7 when 3-hour average winds of 12.1 m/sec from 280° were measured. The older cracks probably date to February 10 or earlier. (February 10 was the last date on which winds on the order of 11 m/sec were recorded at Barter Island.)

Landsat images of March 19 and 20 illustrate the growth of the lead system shown on the left side of figure 6. On March 21, the ice fractured along a path which followed the refrozen shear line running across the map to a point north of the western side of Harrison Bay and then turned seaward roughly along a line parallel to the lead shown for March 19. Even after this event, a considerable expanse of attached ice remained off Harrison Bay.

Early April data show the extent of the attached ice shelf even further reduced, with the shear line running parallel to the older refrozen shear line mentioned earlier.

Late May data show shearing motions with average velocities of 0.5 km/hr along a line parallel to the coast and tangent to what was later identified as a seaward bulge in the boundary of shorefast ice off Harrison Bay. The series of small cracks shown along the 18-meter contour to the east of Harrison Bay and just west of Cross Island were new at this time. They are related to stress within the area defined by this shear zone, indicating some structural failure before shearing took place at a more seaward location. Note that a refrozen lead was identified in this area on the mid-March data. These failures were probably located seaward of well-grounded ice.

Later, data for early July show an even more diminished zone of stationary ice, including little attached ice. Note that there is a portion of the stationary ice at this date seaward of the May 27 shear line. The reason for this appears to be a large block of

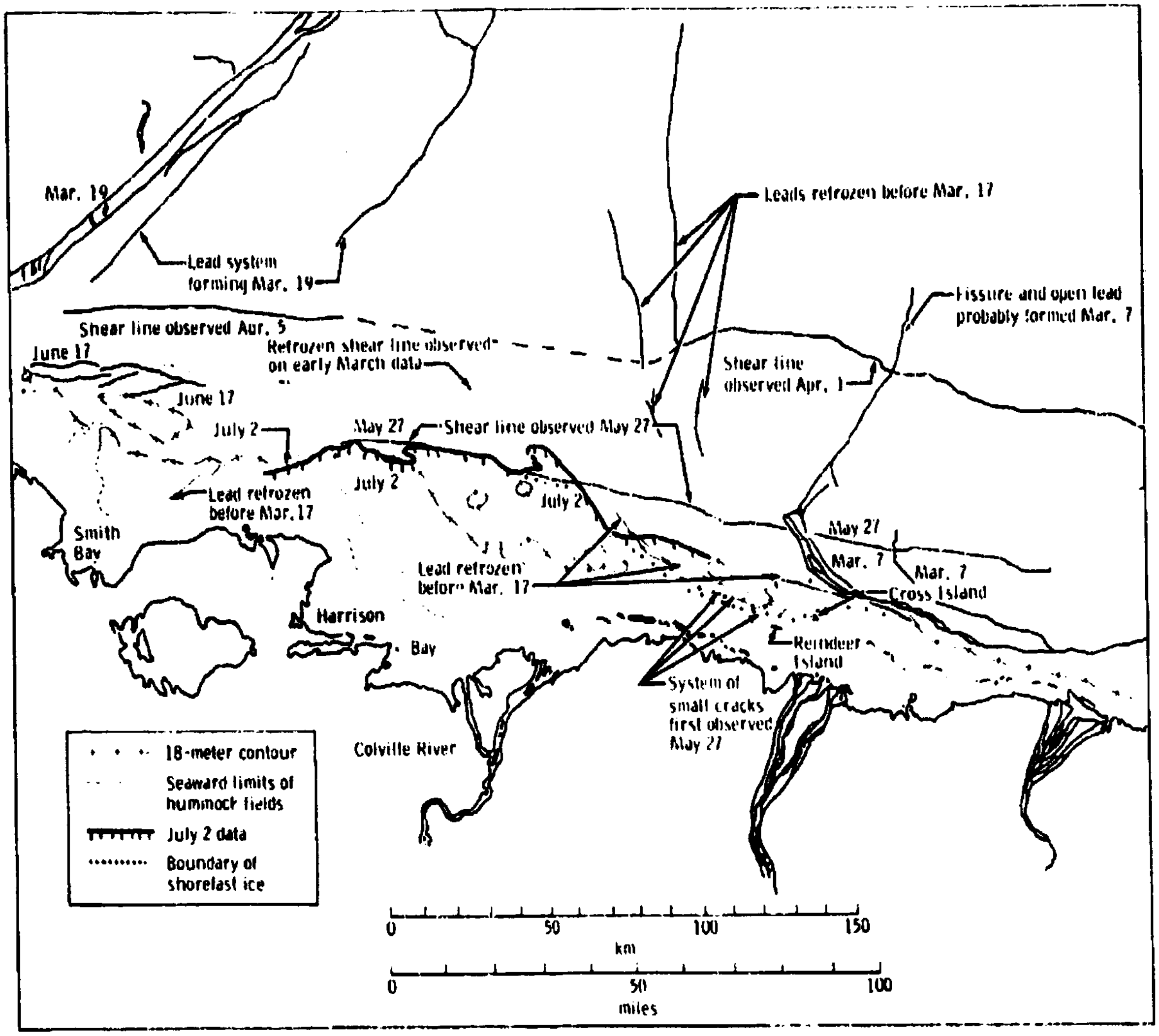

Figure 7. Development of sea-ice conditions near Harrison Bay, Alaska, during spring 1973 as interpreted from sequential Landsat images acquired from March to July 1973.

ice grounded in water 31 meters deep at the tip of the extension of stationary ice. An examination of the June 14 Landsat image shows no sign of this feature. At that time shearing was taking place along the probable boundary of shorefast ice (the dotted line).

The boundary of shorefast ice shown here extends seaward in a bulge off Harrison Bay. Burns and Harbo (ref. 6) indicate a similar bulge based on mid-June data. At the vicinity of this bulge, the 18-meter contour indents toward shore. The depths along the western part of the bulge are very close to 18 meters, while those along the eastern edge are up to 27 meters.

The departures of the boundary of grounded sea ice from the 18-meter depth contour could possibly result from a coastline-averaging process. However, just to the east near Cross Island, the boundary of shorefast ice appears to follow the 18-meter contour much more closely.

Figure 8 shows the central portion of the shorefast bulge in outer Harrison Bay. Although somewhat broken up by this date, July 3, a substantial portion of the ring of grounded ice remains. At the top of the figure, the

Figure 8. Enlarged portion of Landsat image (1345-21342) showing central part of the shorefast ice bulge in Harrison Bay on July 3, 1973.

ring consists largely of a slender curved band of ice. This feature has been observed by aircraft during spring 1973 and 1974, and appears to consist of hummocked ice. The relative stability of the ring of shorefast ice has posed a problem for some time. It is generally presumed that the boundary of shorefast ice is formed mainly by grounded shear and pressure ridges. This ring of ice appears to be quite stable, demanding some explanation beyond ordinary grounded pressure ridges. The large expanse of hummocked ice may be the explanation.

Although the morphology and dynamics of shorefast ice are complex and dependent on sporadic meteorological and oceanic conditions, the results of this remote-sensing analysis reveals that the major morphological features are consistent from one year to the next and coincide with previous reports. This recurrent tendency of sea-ice morphology should help in the planning of petroleum activities and structures in an area of Alaska which presents unusual problems for the oil industry.

Floeberg in the Arctic Ocean

Another related area of sea-ice study where satellite remote sensing has proved beneficial is the location of observation platforms in the Arctic Ocean. Some of these are the relatively rare ice islands (massive tabular icebergs) and ice floes (multiyear ice), but they slowly move, carried by the Arctic Ocean circulation. For some applications, stable fixed platforms are preferred. For the past 2 years, Landsat images have revealed what appears to be a grounded floeberg located at 72° N, 162° W (a strategic location approximately 160 kilometers northwest of Barrow, Alaska). A floeberg is a large piece of multiyear ice, usually consisting of old pressure ridges. This feature is grounded on a seamount in water approximately 30 meters deep. Figure 9 shows a portion of a Landsat image, obtained May 1, 1973, in which the feature has dimensions approximately 5 by 16 kilometers and appears to be acquiring new ice as the Arctic ice pack is driven around it. Figure 10 shows the same feature nearly a year later, March 21, 1974. Here the floeberg is nearly as wide as the previous year but only about half as long. These data would seem to indicate that the floeberg is relatively stable. We recently acquired Landsat image 1406-22131 obtained September 2, 1973, containing the coordinates of the floeberg. At first, we thought that some mistake had been made because the usually obvious feature did not appear to be within the scene. Finally, using the coordinates on the image, we located the floeberg. At that time, its size was approximately 1 by 2 kilometers.

The September 1973 Landsat image has greatly changed our perspective of that feature. Apparently, very little, if any, of the feature is a true floeberg; most of it is a recurring hummock field perhaps initiated by a grounded ice feature but reduced in size by disintegration during summer. Nevertheless, there are many interesting aspects of this ice feature. One of these relates to shorefast ice discussed earlier. How similar is this feature to the fields of hummocked ice comprising the ring of shorefast ice in Harrison Bay? Perhaps this type of structure is more stable than grounded pressure ridges.

The feature at 72° N, 162° W offers an opportunity to study many aspects of ice dynamics and is, at this time, the object of possibly two surface expeditions next year, if it is still there.

MAPPING OF ECOSYSTEMS ALONG THE ALASKAN COASTAL ZONE

Petroleum exploration and development offshore and onshore has a profound effect upon the adjacent land and its people. This relationship is currently exemplified in Alaska by the sometimes conflicting activities of extractive industries and the small socioeconomic structure of native villages in the sparsely inhabited areas faced with imminent development of massive scale. The challenge of these fast-paced events for governing bodies is to become capable of managing and controlling the development in a constructive and timely manner, so that divergent interests can accommodate reasonably well those values which best serve the indigenous people, the state, the nation, the land and sea environment, and the total resources of the region impacted by the development.

One method which is actively considered to meet this challenge is to establish a system of land classification in the coastal regions based upon the natural ecosystems which dominate an area. Specific species of vegetation or types of wildlife habitat which seem to prevail in a given area need not necessarily receive priority in planning; however, at the minimum, there is a basic need to have detailed knowledge of what is present before one can sort through priorities and determine what should be permitted to alter or replace the naturally occurring ecosystems. On a regionwide basis, some sites are more suited to development than others. These need to be identified and agreed upon in any land use regulating system. There are other areas which are particularly

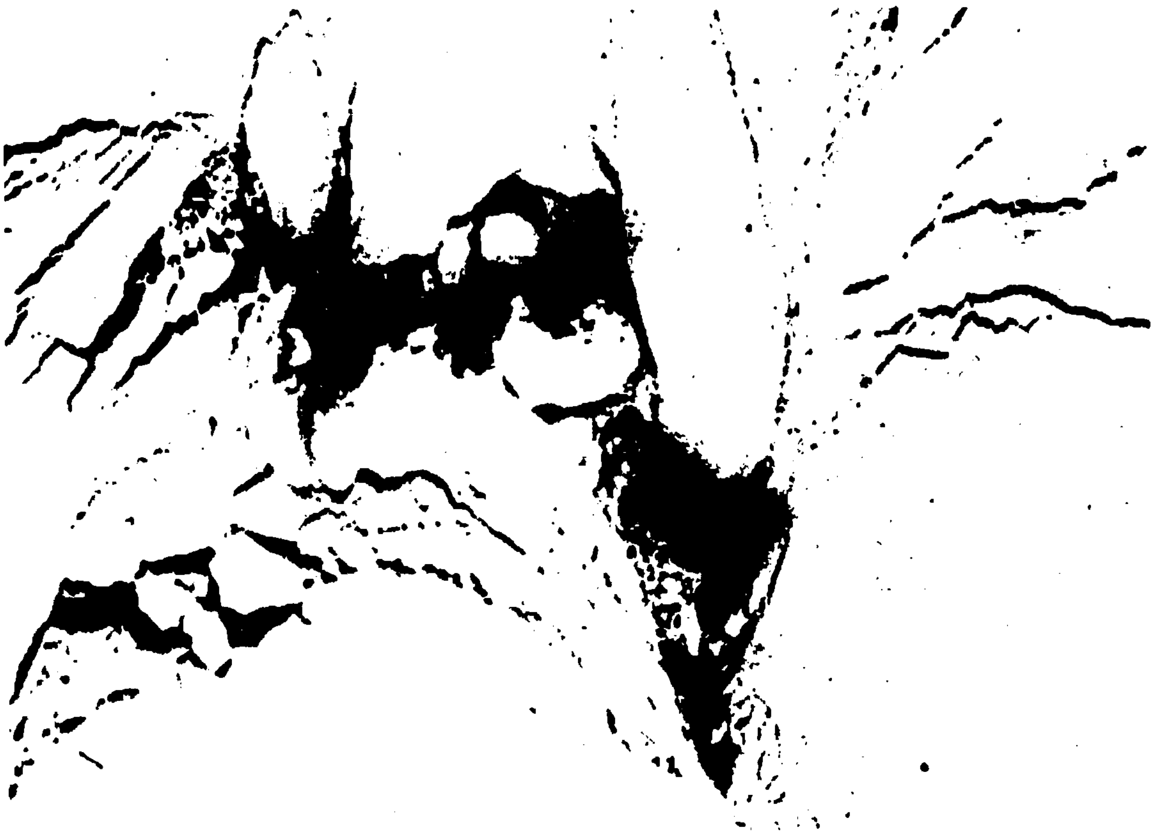

Figure 9. A floeberg (grounded multiyear ice) approximately 160 kilometers northwest of Barrow and first noticed on a Landsat image acquired May 1, 1973 (1282-22261). The floeberg is at the right center of the illustration and has dimensions of 5 by 16 kilometers.

deserving of protection under current and anticipated values, and these critical areas should be recognized and should receive the appropriate regulation.

With half of Alaska's coastline potentially or actually impacted by petroleum exploration and development, the regulation of coastal zone activities is an enormous endeavor, especially when one contemplates that Alaska has more than half of the total United States coastline. A systematic survey on this scale would stretch over several years and with conventional techniques alone would be incapable of addressing the urgent need of the present era.

General Approach

The University of Alaska, with support from NASA and the Alaska Department of Environmental Conservation, is analyzing Landsat data by computer-aided techniques to map ecosystem units and coastal processes in four representative regions of the Alaskan coastal zone. Included are Prudhoe Bay and Beechey Point on the Arctic coast, which consist chiefly of arctic tundra, thaw lakes, and coastal wetlands; the Seward Peninsula, which has a mix of upland and lowland tundra, barrier islands, and some mountain terrain; Kotzebue Sound, which contains uplands, a major river delta, and lowland tundra; and a portion of the eastern shore of Cook Inlet, which is dominated by wetlands, forests, and glacier-fed rivers. The latter region has been impacted by oil and gas development for the past decade.

These four regions were selected to refine the techniques which can prove most useful in land use

Figure 10.-- The same floeberg as in figure 9, observed almost a year later, on March 21, 1974 (Landsat image 1606-22203), has dimensions of 6 by 8 kilometers.

planning of the coastal zones. Computer-aided analysis was chosen to minimize the time necessary to extend the ecosystem mapping efforts to the entire coastal area of the mainland of Alaska. In view of the lack of ground-truth information and the random-mosaic patterns in wildland areas, we decided not to use the supervised approach, which depends heavily upon the quantity of identified training sites and the uniformity of the information which can describe them.

The unsupervised classification method of computer processing lends itself well to mapping the multitude of units of ground cover that occur naturally in wildlands, provided that the many spectral differences which are inherent in the data can be found to have informational value to resource managers. Care must be exercised to maintain control of the automatic classification algorithms so that meaningful outputs are obtained that can be related reliably to the real world. Indeed, multispectral systems tend to reveal more feature classes than we at present know how to use profitably, although this by no means need be a disadvantage. The key is to be able to economically select those features which have informational value, and to (temporarily) discard or merge those which appear to have unknown or superfluous meaning.

The Unsupervised Classification Technique

The classification technique used to generate Alaskan ecosystem maps is illustrated by the flow diagram of figure 11. The method first defines a number of spectrally distinct categories from an iterative cluster analysis of small samples from the area to be mapped. This is followed by the classification of the entire area by a maximum likelihood program into the number of classes previously defined by the cluster analysis.

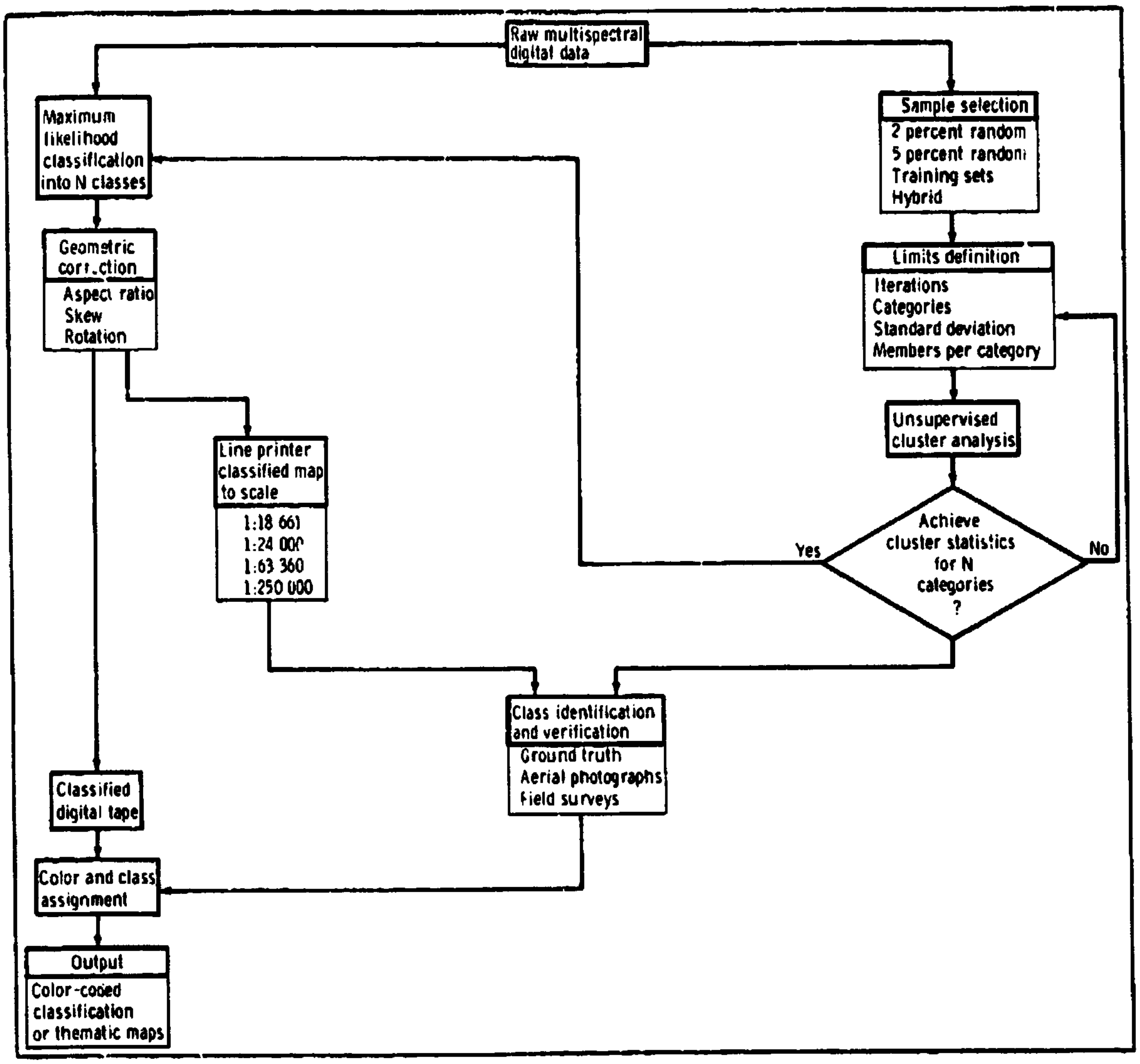

Figure 11.—Flow chart of the unsupervised classification algorithms used for generating ecosystem maps of the Alaskan coastal zone from Landsat digital imagery.

Geometrically corrected output formats can be made at any scale and include both line-printer maps and color-coded classification maps, or a series of colored thematic maps.

While the classification is basically unsupervised, there is adequate provision to ensure that the computer is producing useful results before the output products are generated. A review of the number of classes and their spectral characteristics and statistics can determine whether or not problems are inherent in the definition of the categories during the cluster analysis step. The number of discrete categories, which are generated from varying types of terrain in the area to be mapped, can be regulated by manipulation of the sample selection and limit definition criteria. Once well-behaved statistics have been produced by the cluster analysis on the representative sample of the raw data, the entire data set is economically classified by a maximum likelihood program or other appropriate classification scheme.

The output of the classification program is in digital tape form which can drive a color image recorder after specific colors have been assigned to each class. Typically, there are more discrete categories identified than are desired or useful for a given application; it is necessary to tentatively identify each class as to landform or type of vegetation by correlation with ground truth and the study of the spectral signature of each class. This can be relatively straightforward or quite an extensive effort, depending upon the orderliness of the original data and the amount and type of ground truth available.

In one important operating mode, the unsupervised classification technique can be used as a tool primarily to identify those areas for which detailed ground truth must be acquired. It is not at all necessary to acquire ground truth before performing the classification, and, in fact, one usually obtains the right kinds of ground-truth data of better quality at lower cost once the automatic classification processing has indicated where it is and is not needed.

Once appropriate colors are assigned to each class, the output products are generated in the form of color-coded classification maps or a series of colored thematic maps for those classes of interest. Any or all of the recognizable classes can be used in the final color product, which can be generated at any desired scale. The classified digital tape forms a permanent data record from which different themes and color products may be produced for application to other disciplines.

Results

The unsupervised classification technique has been applied successfully to several areas of Alaska in the coastal zone as well as in the interior. As an example for the coastal zone, it was applied to the Prudhoe Bay and Beechey Point areas on Alaska's North Slope (fig. 12). For the 5000-square-kilometer region mapped near Prudhoe Bay, the unsupervised classification of the land area resulted in 15 ecosystem categories, excluding snow and ice. These categories were identified by correlation with independently available ground truth and are listed in table I. Six categories represent various types of tundra vegetation, four represent bare ground, and five represent water with varying degrees of siltation or depth. In addition to the 15 land categories, the computer analysis recognized 35 spectrally different categories of snow and ice. Six of those represent snow and ice found on some of the lakes in the area, with one apparently associated with anchor ice which forms on the bottom of shallow lakes, remains submerged during spring, and melts more slowly than surface ice. The other snow and ice categories occur offshore and are believed to be relatable to sea-ice morphology and conditions, based on the spatial pattern of their distribution and their spectral signatures which suggest varying degrees of wetness. Unfortunately, the purpose of this project being the mapping of land ecosystems, the ground-truth data on sea-ice and lake-ice conditions during early July 1973 are not available for detailed identification and verification of the snow and ice categories. Nevertheless, the ability of the unsupervised classification technique to differentiate between various types of snow and ice, as well as between varying degrees of water siltation, is promising and of considerable interest to scientists and engineers studying the near-shore and outer continental shelf in preparation for petroleum leasing.

Color-coded classification maps resulting from this analysis are illustrated in figure 13 for the Prudhoe Bay area and in figure 14 for the Beechey Point area. The color code for these maps is listed in table I. In these examples, we selected the color blue for water, brown for bare ground, and red for tundra vegetation with varying shades of each color representing subclasses within the main category. The purpose of this selection was to represent all classes identified by the analysis in such a way that, for certain applications, the colors for the subclasses could be merged mentally into the main class if nessary; for instance, tundra = red. In retrospect, owing to the inaccuracies inherent in photographic color printing, we believe we probably should have selected more contrasting colors for the subclasses.

For the coastal zone management application the first question to be addressed is to define the boundary of the coastal zone. It may extend from one to hundreds of kilometers inland. This first-order application of the computer-processed Landsat data is at a scale of 1:250 000, which is usually adequate for the appraisal of the extent of the coastal zone, based on ecosystem indicators of areas dominated by the influence of the sea, sea storms for example. For this application, the preliminary conclusion reached from an examination of figures 13 and 14 is that, for the most part, the analysis of the Landsat scenes was not carried far enough inland to define the coastal zone boundary. It only appears distinctly at the bottom of figure 14 for the Beechey Point area, where the coastal tundra breaks rather consistently into well-drained tundra with vigorous shrubs, forbs, and grasses.

Figure 12. Landsat image acquired on July 2, 1973 (1344-21283), over Prudhoe Bay (right center) and Beechey Point (left center), Alaska.

Management decisions, of course, must be made upon more detailed knowledge of landforms and ecosystems than the definition of coastal zone boundaries. The same computer outputs as illustrated in figures 13 and 14, when they are reproduced at larger scales, such as 1:63 360 or 1:24 000, can also be used during the second-order application of processed satellite data. At these scales, the extent and variety of surface features and ecosystems classes are accurately mapped in the detail needed for the decisionmaking process of land use management.

TABLE I.– LAND ECOSYSTEM CLASSES FOR TWO AREAS OF THE ALASKAN ARCTIC COAST

Color code	Feature
Water	
Very dark blue	Clear, deep water
Dark blue	Clear, moderately deep water
Deep blue	Clear, moderately shallow water
Light blue	Silty or shallow water
Medium blue	Shallow water with sparse aquatic vegetation
Barren ground	
Black	Wet sand or mud
Dark brown	Wet outwash sand and gravel
Medium brown	Dry outwash sand and gravel, gravel pads, camps, roads, and runways
Very dark red	Mineral soil with very sparse or stressed vegetation; forbs, grass, and dwarf shrubs
Vegetation	
Dark red	Wetlands, frequently drained lake bottoms, with sedges, aquatic grasses, and mosses
Medium red	Wetland bog
Deep red	Wet tundra, with sedges and aquatic moss
Dark orange	Poorly drained tundra marsh, frequently low-centered polygons with sedges and dwarf shrubs
Orange	Moderately drained coastal tundra, frequently high-centered polygons with willows, dwarf shrubs, and lichens.
Medium yellow-orange	Well-drained upland tundra with vigorous shrubs, forbs, and grasses

CONCLUSION

The demonstration projects described in this paper are expected to contribute significantly to two programs related to the nation's search for additional energy sources in Alaska: The environmental assessment of the Alaskan outer continental shelf undertaken by NOAA and Bureau of Land Management (BLM) in preparation for the leasing of offshore tracts with petroleum potential and the formulation of a coastal zone management plan by the State of Alaska. In particular, the demonstration projects have shown that Landsat data can be used effectively for developing models of suspended sediment transport and therefore for preparing contingency plans based on the movement of oilspills in Alaskan coastal waters, for planning navigation routes and offshore drilling structures in coastal areas where sea ice is prevalent, and for assessing the potential physical and biological impact of developmental activities on the coastal zone.

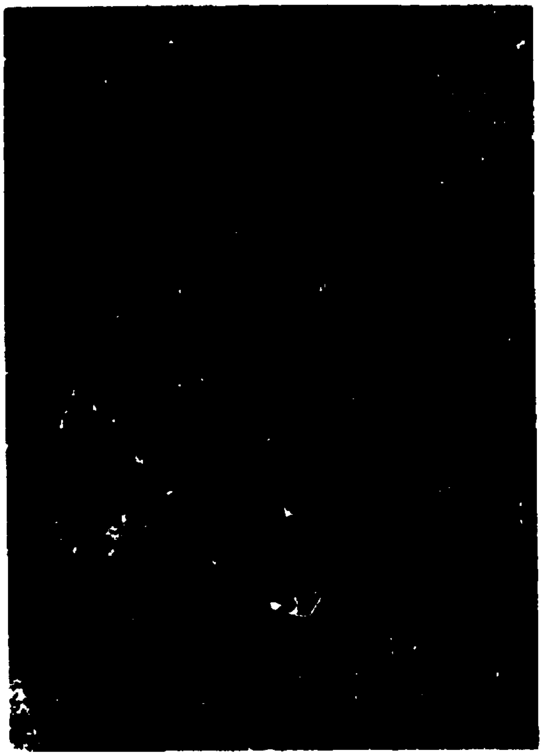

Figure 13.– Color-coded ecosystem map of a 5000-square-kilometer area around Prudhoe Bay, Alaska, based on an unsupervised classification of the Landsat image in figure 12. The color code for the land ecosystem classes is provided in table I.

Figure 14.– Color-coded ecosystem map of the Beechey Point, Alaska, area, based on an unsupervised classification of the Landsat image illustrated in figure 12. The color code is in table I. In comparison with figure 12, the classification has enhanced the barrier island chain, and has separated the sea-ice types in an apparently meaningful way.

ACKNOWLEDGMENTS

The investigations described in this report were supported by grant NGL-02-001-092 from the NASA Office of University Affairs, by contracts NAS5-21833 and NAS5-20939 from the NASA Goddard Space Flight Center, and by the Alaska Department of Environmental Conservation.

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N76-26655

C-9. Coast Guard/NOAA/NASA Great Lakes Project ICEWARN

T. D. Brennan[a] *and R. T. Gedney*[b]

During the winter of 1974-1975, a joint project between the U.S. Coast Guard (USCG) and NASA was conducted to map Great Lakes ice cover on an operational level. The Great Lakes system, often called the fourth seacoast, is bordered by many highly industrialized cities that rely heavily on ships for transportation. For example, over 70 percent of the iron ore processed in the United States is mined in the Masabe Range near western Lake Superior and transported by ship to steel mills, particularly in Chicago and Cleveland. Because of the industrial importance of the Great Lakes, a Federally sponsored winter navigation demonstration program involving 12 Federal agencies, led by the Corps of Engineers and the Coast Guard, has been in existence since 1971. The purpose of the program is to determine the feasibility of and to provide for year-round navigation on the Great Lakes.

Project Icewarn is a joint effort of the U.S. Coast Guard, the National Oceanic and Atmospheric Administration (NOAA), and NASA to establish the operational feasibility of using remote sensing to provide all-weather ice information for Great Lakes winter navigation. To be useful to shippers, the system must be capable of updating ice information daily. This capability is necessary because ice types and distributions are rapidly altered by shifting winds and weather conditions. In order for a ship captain to use the information for navigating around an ice field or through a portion of the ice that his ship is capable of traversing, the information must be accurate as to ice coverage and thickness. Every day that an iron ore ship is delayed or beset in ice, the cost of transporting the cargo increases by approximately $10 000.

The remote-sensing system used in Project Icewarn was developed by NASA and was jointly demonstrated by the Coast Guard, NOAA, and NASA this past winter. Figure 1 shows the various elements associated with Project Icewarn. A Coast Guard C-130 aircraft equipped with a side-looking airborne radar (SLAR) system routinely surveys selected regions of the Great Lakes from an altitude of 11 000 feet. The advantages of the SLAR system are twofold. First, SLAR produces actual radar images of lake ice cover rather than charts drawn by a visual observer. Second, the system has an all-weather capability to gather ice information.

Another advantage is that imagery can be transmitted to the Coast Guard/National Weather Service (NWS) Ice Navigation Center in Cleveland, Ohio, by two possible communication networks: a continuous real-time ultrahigh frequency (UHF) uplink transmission from the SLAR aircraft to the NOAA Geostationary Operational Environmental Satellite (GOES) and a subsequent S-band downlink to the Wallops Island station, which relays information to the Cleveland Ice Navigation Center by dedicated telephone lines; and a near-real-time transmission by an S-band downlink from the SLAR aircraft to a number of shore stations around the Great Lakes, which relay information to the Ice Navigation Center by dedicated telephone lines. The Ice Navigation Center is equipped with an S-band antenna capable of receiving directly transmitted SLAR image dumps. Equipment is also available to record the SLAR image as it is transmitted on both tape and film. At the center, SLAR images along with hand-drawn interpretive ice charts are transmitted by a facsimile scanner over the Great Lakes marine very high frequency (VHF) network to vessels operating in the lakes.

Figure 2 is a schematic of the SLAR system. A beam of pulsed microwave energy briefly illuminates a narrow strip on the ground on both sides of the aircraft for a range of 50 kilometers. The return signals are used to intensity-modulate the trace of a cathode-ray tube, which in turn exposes a moving film. The return signals are also digitized and recorded on magnetic tape for retransmission to the ground. A radar blindspot occurs immediately beneath the aircraft that is approximately

[a]U.S. Coast Guard 9th District, Cleveland, Ohio.

[b]NASA Lewis Research Center, Cleveland, Ohio.

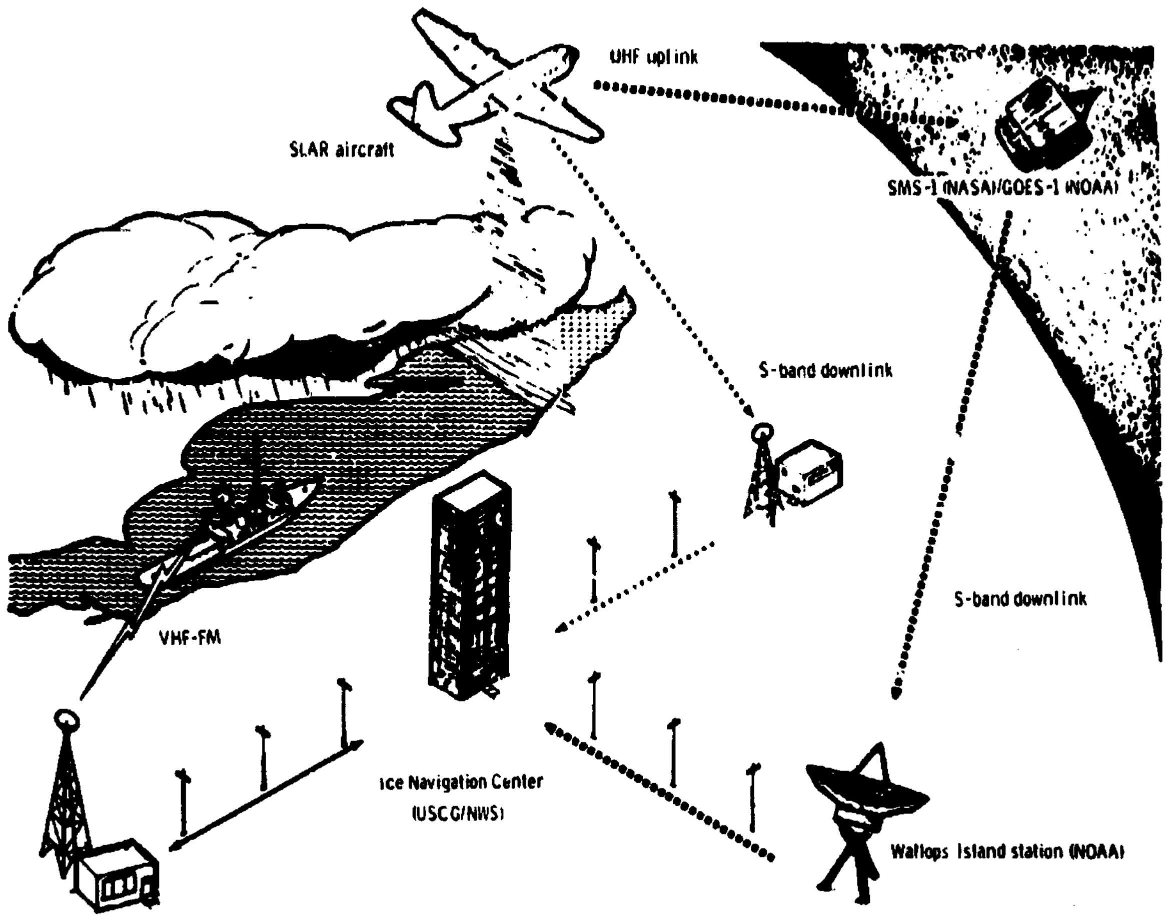

Figure 1. The various elements associated with Project Icewarn.

as wide as twice the altitude of the aircraft. For example, an aircraft flying at 10 000 feet would have a blindspot 20 000 feet wide.

A key element of Project Icewarn is the routine use of an airborne S-band, short-pulse radar to measure actual ice thickness. Profiling the ice directly beneath the aircraft, this radar system is capable of measuring ice thickness to an accuracy of approximately 2 inches from altitudes of 5000 feet or less. Ice thickness is determined by measuring the time difference between the return pulses from the air-ice interface and the ice-water interface. Thickness results from a typical short-pulse radar flight in Lake Superior during March 1974 are shown in figure 3.

For the 1974-1975 winter navigation season, the pulsed radar system was mounted aboard the C-47 aircraft operated by the NASA Lewis Research Center (LeRC). The equipment will be transferred to the C-130 SLAR aircraft for the 1975-1976 season and will be operated at an altitude of 11 000 feet.

Figure 4 shows a view inside the cargo section of the C-130 looking forward. Included in the photograph is the rack system used to house the electronic equipment, including onboard film recorder, digitizing electronics, tape recorders, S-band, and UHF-band radios. The SLAR receiver/transmitter is mounted on a cargo door in the aft section of the aircraft.

The small S-band omnidirection antenna mounted on the underside of the C-130 is only 23 inches above ground (fig. 5). The SLAR antenna could not be mounted here because of the short distance between the belly of the aircraft and the ground. Instead, the 20-foot-long SLAR antenna is mounted on the tail section (fig. 6).

Mounted on top of the C-130 is the UHF antenna used to datalink the SLAR imagery to the NOAA/GOES

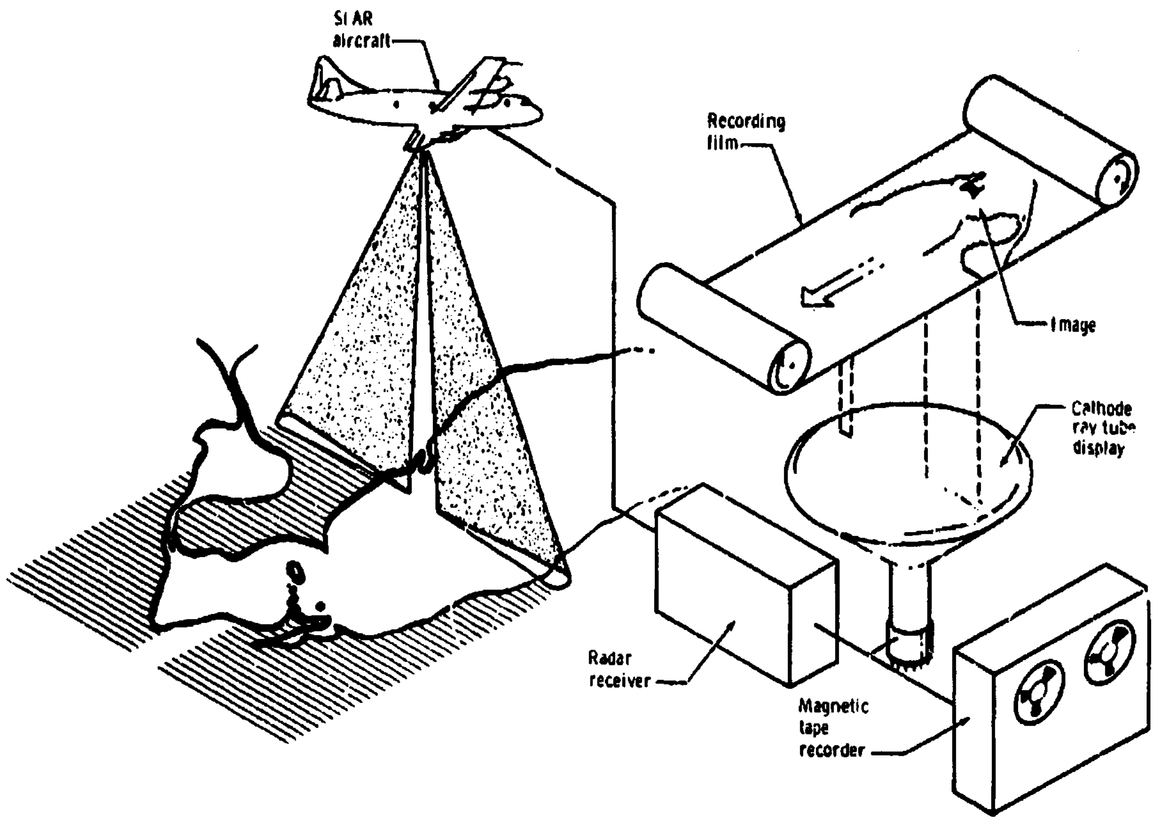

Figure 2. Schematic of the side-looking airborne radar system.

weather satellite. This antenna configuration allows continuous transmission from lift-off to landing. The project was started in August of 1974, and all equipment for the entire system was purchased, designed, and installed by NASA by February 1975. All the equipment in the C-130 was installed by Lockheed under contract to NASA during a 3-month period from October through December of 1974. Flights in the C-130 began in January of 1975.

In figure 6, the SLAR aircraft is shown flying a mission off the Straits of Mackinac, which connect Lake Huron and Lake Michigan. This narrows is clogged with ice throughout the winter and an icebreaker is required to assist ships in moving through the straits. The captain of an icebreaker desired SLAR image blowups of this area to aid him in determining how to cut a track through the ice. North of the straits in Sault Ste. Marie, there was an S-band ground station that could receive the SLAR imagery of the straits in real time. Thus, the captain was able to quickly receive the needed information from Project Icewarn.

Figure 7 shows the geography of the Great Lakes as well as the location of the various elements associated with Project Icewarn. The location and approximate range of the stations making up the Great Lakes marine VHF network are shown. Lake Superior, Straits of Mackinac, upper Lake Michigan, and eastern Lake Huron receive comprehensive radio coverage allowing vessels operating in these areas to aquire ice information immediately as it becomes available. Future stations will extend this radio coverage to all areas of the lakes. S-band data downlink stations were located at Cleveland, Ohio, and Sault Ste. Marie, Michigan.

Figure 8 is an enlargement of part of an SLAR image of the Whitefish area of eastern Lake Superior just above the Soo Locks of the St. Marys River. This image was taken February 27, 1975. The radar blindspot (4 miles wide) is shown running across the top half of the image.

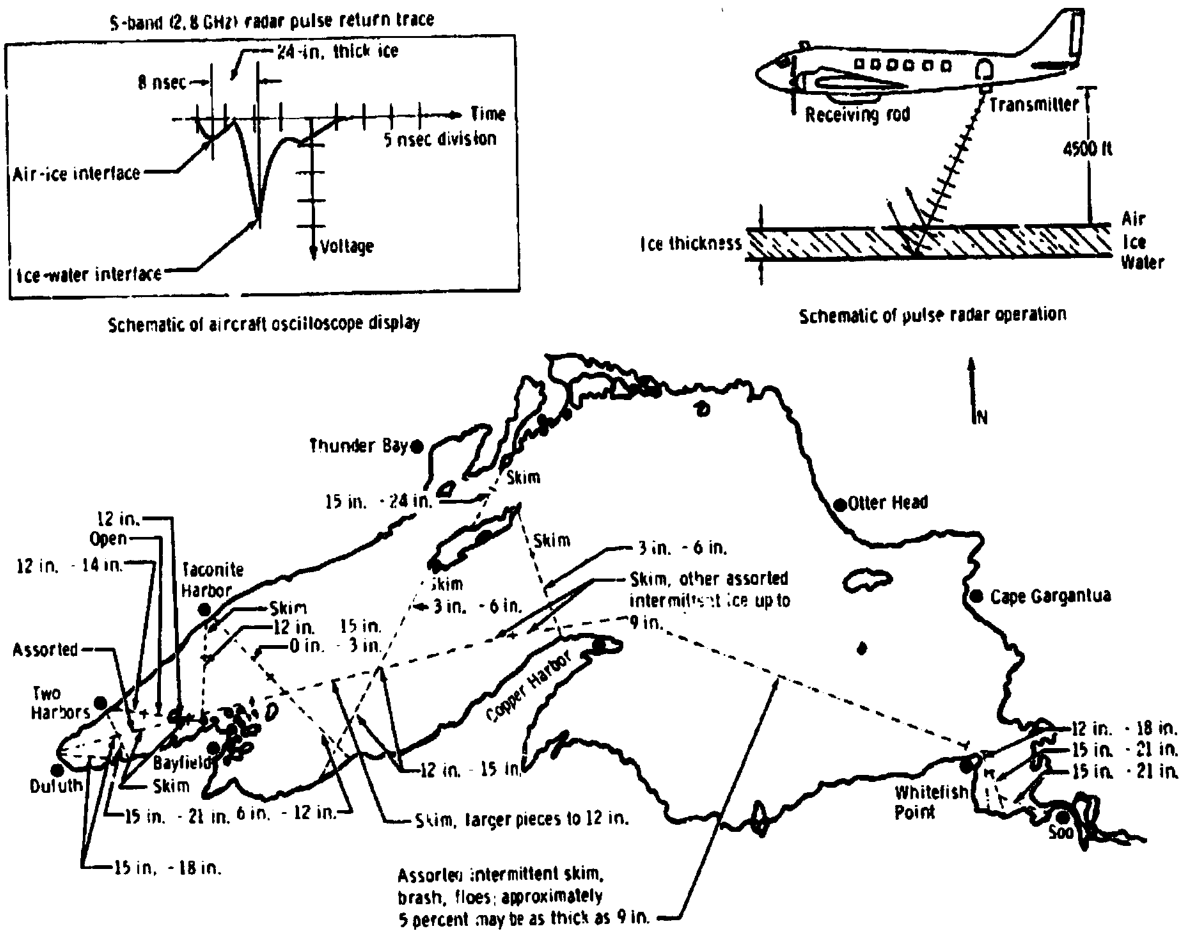

Figure 3. Results of an ice thickness radar flight.

The land features have a characteristic high signal return in this area and are easily identified if one is at all familiar with the geography of this area.

Thick (approximately 16 inches) fast ice encompasses all the eastern bays. In contrast, the western side of the bay below Whitefish Point has only a covering of thin ice. Three vessels can be seen making their way toward Whitefish Point. The wake of the southernmost vessel is easily distinguished in the thin ice. The middle part of the bay is covered with large, thick plates of ice refrozen in a matrix of thin ice and brash ice (broken pieces of ice). The plates having a relatively smooth top surface give very little radar return and appear dark in the image. The brash ice surrounding these large plates has many exposed edges and corners and consequently gives a very high, white return.

Windblown areas of brash ice are piled up along the western edges of this icepack giving a high signal return. Windrowing often occurs along these brashey edges making vessel transit without icebreaker assistance virtually impossible. Only a few small areas of open water can be detected.

A new ship track, the thin line running from right to left with a dogleg in the middle (fig. 8), has just been established after winds the previous day shifted the ice in the bay; the dogleg in this track was to take advantage of the thin-ice area along the western side of this bay. The normal ship track would be right through the middle of this icepack.

Figure 9 portrays the value of SLAR imagery for vessel routing through ice conditions. During the early part of April 1974, the U.S. Steel vessel *Roger Blough* received real-time SLAR imagery. At this time, ice was piled up in the eastern end of Lake Superior along the

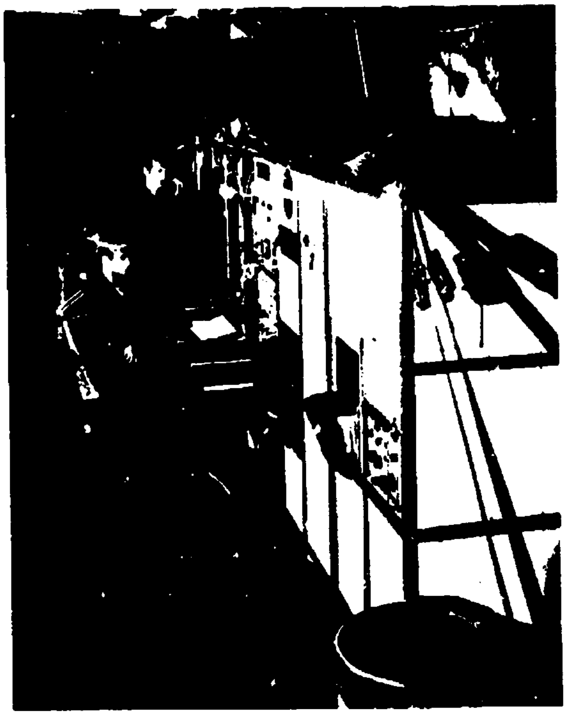

Figure 4.– View inside the cargo section of the C-130. The rack system houses the electronic equipment, which includes onboard film recorder, digitizing electronics, tape recorders, S-band, and UHF-band radios.

Figure 5. The small S-band omnidirectional antenna mounted on the underside of the C-130.

Canadian shore. By april 7, wind forces had compacted this ice cover along the southern shore of the lake, west of Whitefish Point. The *Roger Blough*, upbound on April 7, used this SLAR image to navigate to the north around this icepack. The icebreaker *Southwind* attempting to transit the normal vessel track around Whitefish Point ran into heavy windrowed ice and also had deviated toward the north after being delayed many hours. Three days later, on April 10, a southerly wind had opened this icepack so the best route for the *Blough* to navigate on her downbound trip was a southerly one through a series of large leads and open water along the edge of Whitefish Point.

This combination of an SLAR image (on the bottom) and a hand-drawn interpretive ice chart (on the top) is referred to as an ice information product (fig. 10). The SLAR image/ice chart combination is the type of information supplied to vessel masters over the facsimile network. This figure was from the Straits of Mackinac on February 1, 1975. The Mackinac Bridge, seen in figure 6, is clearly visible in the SLAR image. The ice is generally concentrated in the straits around the bridge between Bois Blanc Island on the east, to Beaver Island on the west, and in the upper reaches of Green Bay.

The hand-drawn ice chart attempts to outline the various areas of ice as to average thickness, relative concentration, and percentage of various sized pieces. As such, it generally "homogenizes" the information available in the SLAR image.

Figure 11 shows an ice information product for the western end of Lake Superior near Duluth, for February 6, 1974. The ice in the Duluth area is solidly packed and over 12 inches thick. Its relatively smoother surface gives little radar return and appears dark on the image. The numerous cracks and ridges in this area give a high radar return and hence appear as white lines. The rest of the lake area is covered with various concentrations of brash ice broken up and moved around by wind forces. An area of open water in the middle of this image will permit the vessels to avoid the ice in this area, eliminating costly delays. Such open water areas will shift with the wind and may be completely closed up the next day. Such dynamic conditions point to the need for real-time information as well as daily updating during periods of rapid wind and weather shifts.

For Project Icewarn, 55 flights were made during the winter of 1974-1975, accumulating totals of 285 flight hours and more than 82 000 miles. Approximately 160 SLAR image/ice charts were made available for broadcast to the users, 28 vessels, including 2 icebreakers. It was the first year that shipping continued

Figure 6.– The SLAR aircraft flying a mission over the Straits of Mackinac. Note the SLAR antenna mounted on the tail section of the C-130.

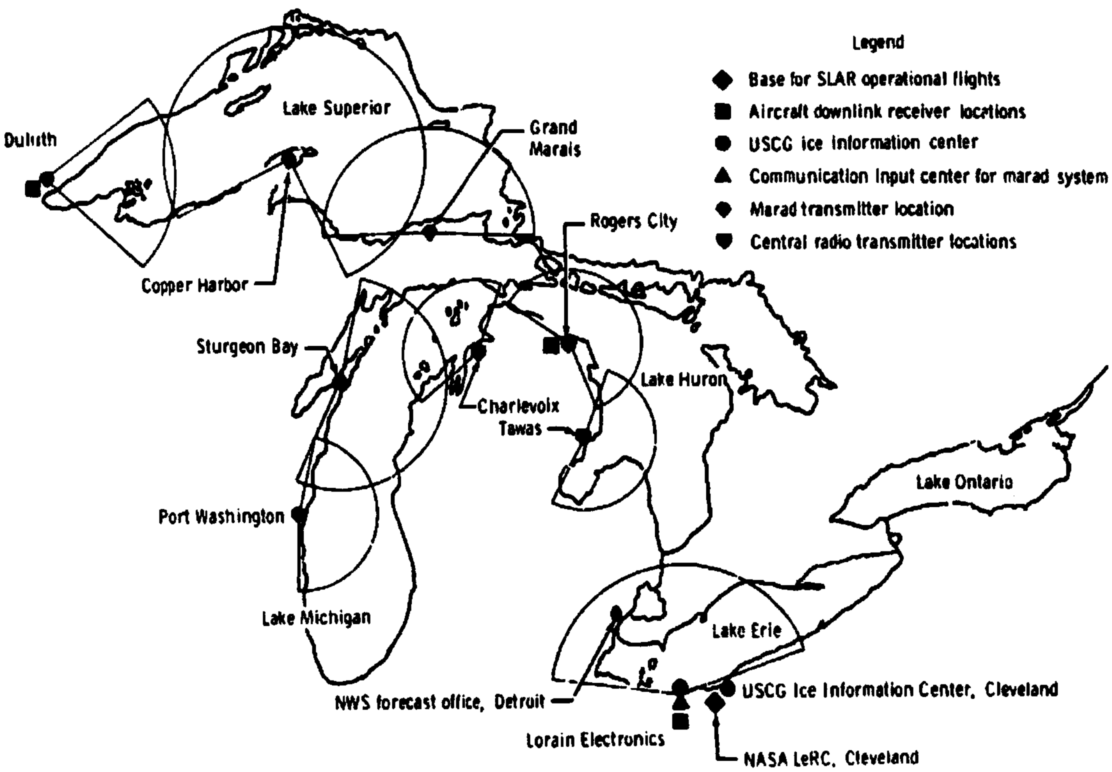

Figure 7. The Great Lakes ice information network, emphasizing the elements associated with Project Icewarn.

through the entire winter on the upper four Great Lakes. Total tonnage movement on the Great Lakes during the 1974-1975 winter season was approximately 20 million tons, almost the same tonnage movement as in the previous 3 years combined. We like to feel that this system inspired increased confidence among vessel masters when transitting ice fields and that it will be an invaluable operational tool for extending the navigation season on the Great Lakes. The system will be demonstrated again in 1975-1976.

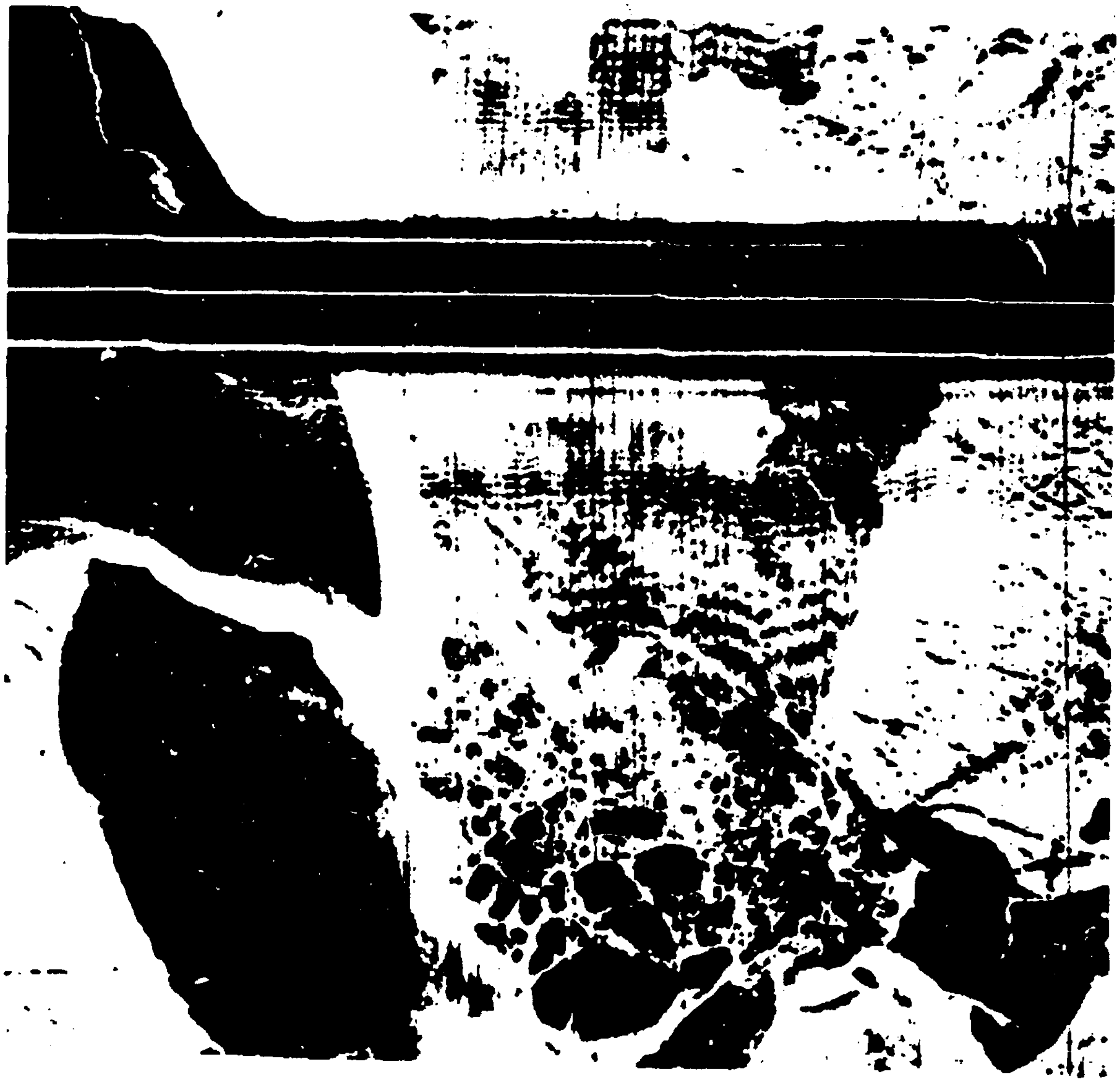

Figure 8. An enlargement of an SLAR image of the Whitefish Bay area of eastern Lake Superior. The radar blindspot (4 miles wide) crosses the top of the image.

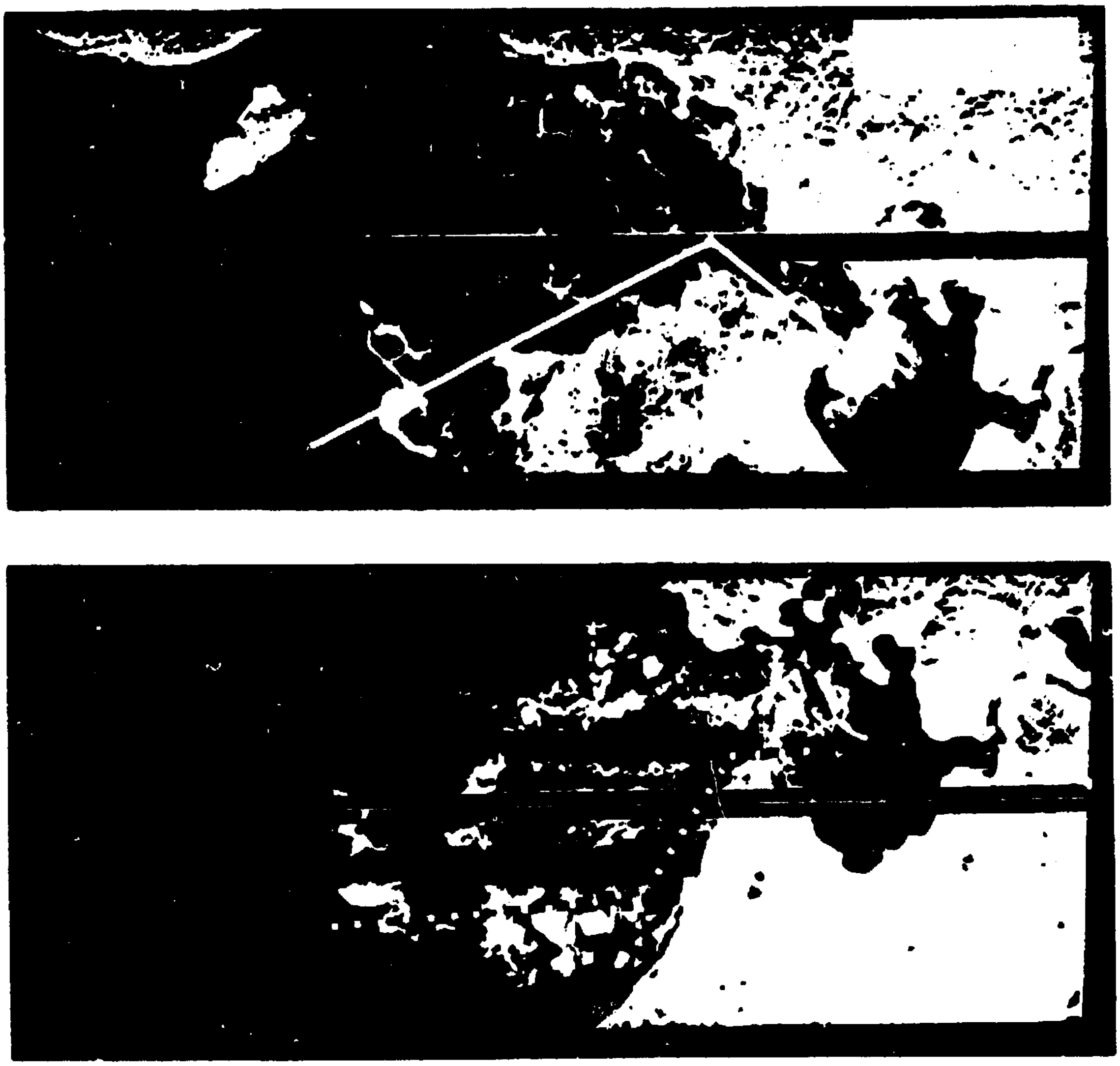

Figure 9. Use of SLAR imagery for vessel routing under Great Lakes ice conditions. The solid line in the top photograph represents the upbound track of the *Roger Blough* on April 7, 1974. The broken line in the bottom photograph represents the downbound vessel track on April 10, 1974.

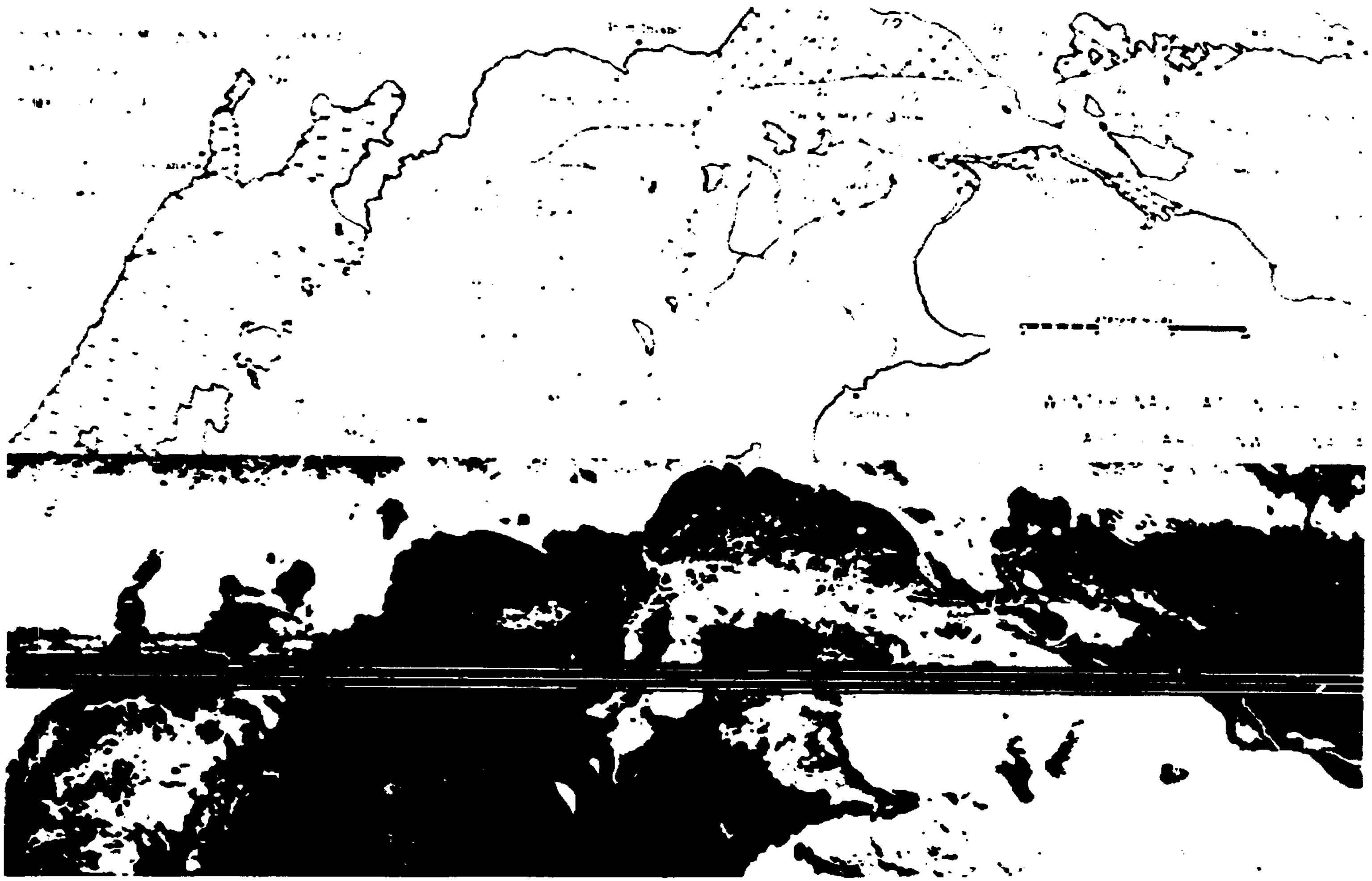

Figure 10. An SLAR image/ice chart of ice information product for the Straits of Mackinac on February 1, 1975. The thin white line is a ship track.

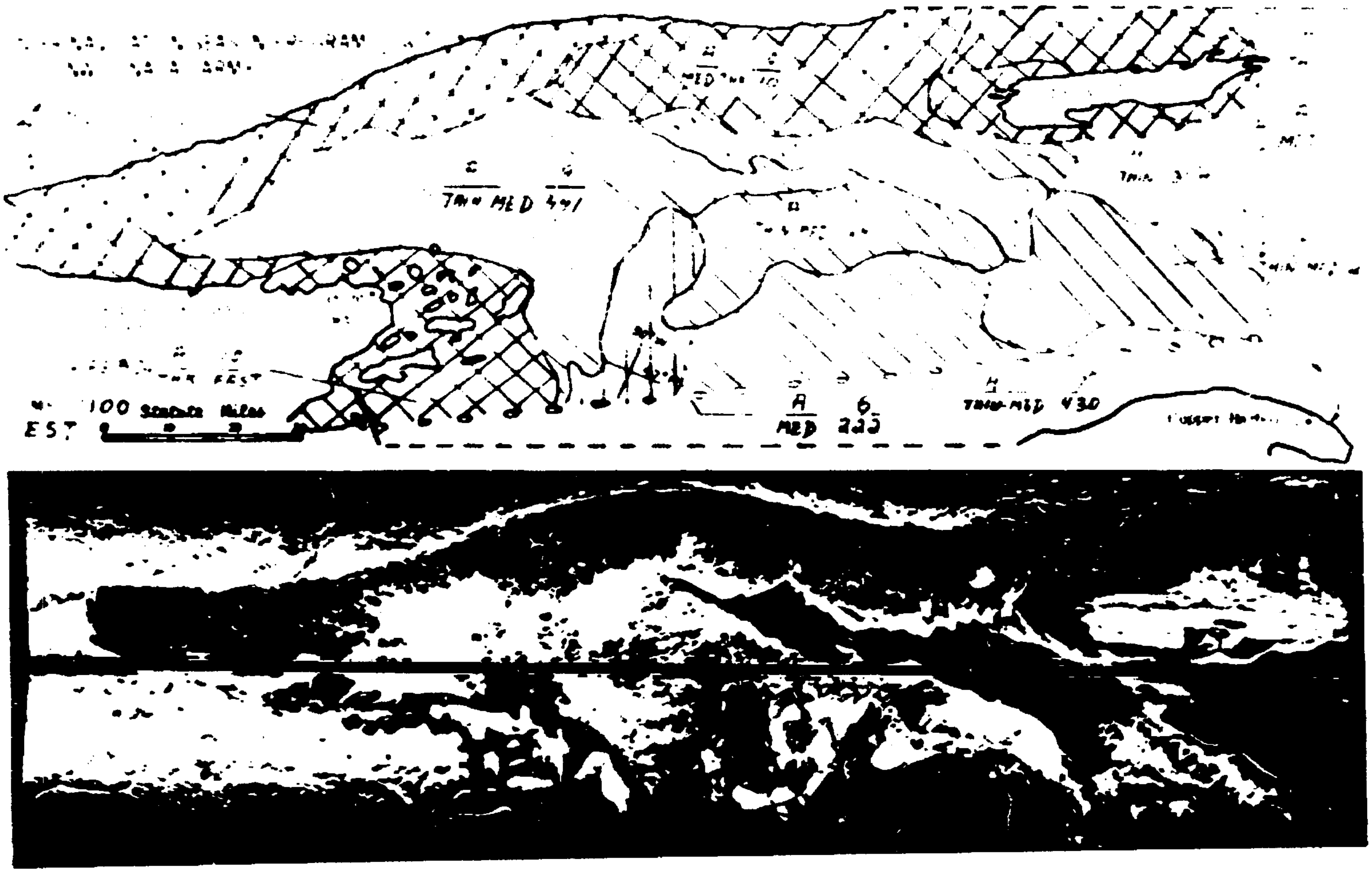

Figure 11 · An SLAR image/ice chart or ice information product for the western end of Lake Superior on February 6, 1974.

N76-26656

C-10. Oilspill Surveillance, Detection, and Evaluation by Remote Sensing

Donald R. Jones[a]

BACKGROUND

Both the 1970 and 1972 amendments to the Federal Water Pollution Control Act, in addressing the problem of spills of oil and hazardous substances, required the appropriate Federal agencies (Environmental Protection Agency (EPA) and Coast Guard) to establish a system of surveillance and notice designed to ensure earliest possible warning of these spills, so that necessary cleanup could be initiated along with the appropriate enforcement action. With the regulation defining a "harmful quantity of oil" as a discharge onto water producing a film or sheen upon, or discoloration of the water or adjoining shoreline, it followed that surveillance, detection, and notice of an oilspill were directly linked to visual or equivalent means of observation.

The initial research and development efforts by EPA and Coast Guard recognized both the large areas of surveillance required (shipping lanes, offshore oil platforms, harbors, inland rivers, and lakes) and the need for surveillance at night and under adverse weather conditions. Also, incidents of very large spills, in excess of 500 000 gallons, were known to affect large water areas and many miles of shoreline, such that effective cleanup response would require immediate aerial surveys to identify where the oil was and the shoreline areas most heavily polluted. Thus, the system of surveillance would require (1) equivalent additional detection methods other than visual, (2) aerial surveillance for large areas in a routine and operational detection mode, (3) immediate aerial mapping of large spills in support of cleanup response, (4) oil thickness determination by aerial remote sensing to determine quantity spilled (unknown in many large spill incidents) and thus identify the heavier oil accumulations for cleanup and assessment of any environmental damage, and (5) fixed-platform automatic sensors to monitor high-risk oilspill sites in harbors and at oil transfer terminals.

The so-called "system of surveillance" was an evolving one, however, initially concentrating on optimum bandwidths for photographic detection of oil slicks and nonvisual methods for detection during nighttime and adverse weather conditions. The EPA/U.S. Coast Guard sponsorship of a number of studies and investigations led rather quickly to a battery of state-of-the-art nonvisual airborne sensors that could detect a variety of petroleum products on water in most environmental conditions. Well known now are the capabilities of active and passive microwave radar, multispectral line scanners in the ultraviolet and thermal-infrared spectral ranges, low-light-level television (multispectral), and ultraviolet-induced fluorescence to successfully discriminate oil on water. Last, but far from least, were the proven capabilities of aerial cameras at high and low altitudes to map large areal extents of big oilspills, although only in daytime, good weather conditions. The latter had been amply demonstrated for the four oilspills, each involving more than a million gallons: Santa Barbara, January 1969; Chevron platform blowout, Gulf of Mexico, April 1970; Shell platform blowout, Gulf of Mexico, December 1970; and tanker collision, San Francisco Bay, January 1971. The NASA provided effective high-altitude coverage of both Gulf of Mexico spills from WB-57 aircraft. Figure 1 illustrates the value of thermal-infrared and aerial photography in mapping oilspills in the Gulf of Mexico.

The remaining elements of the surveillance system have been or are in the process of being completed through a combined EPA/U.S. Coast Guard research and development (R&D) program with continued assistance from NASA and the Naval Research Laboratory. These efforts have merged into operational applications to an extent that an interim system of oilspill surveillance exists and is accomplishing its purpose. This paper will

[a]Environmental Protection Agency, Washington, D.C.

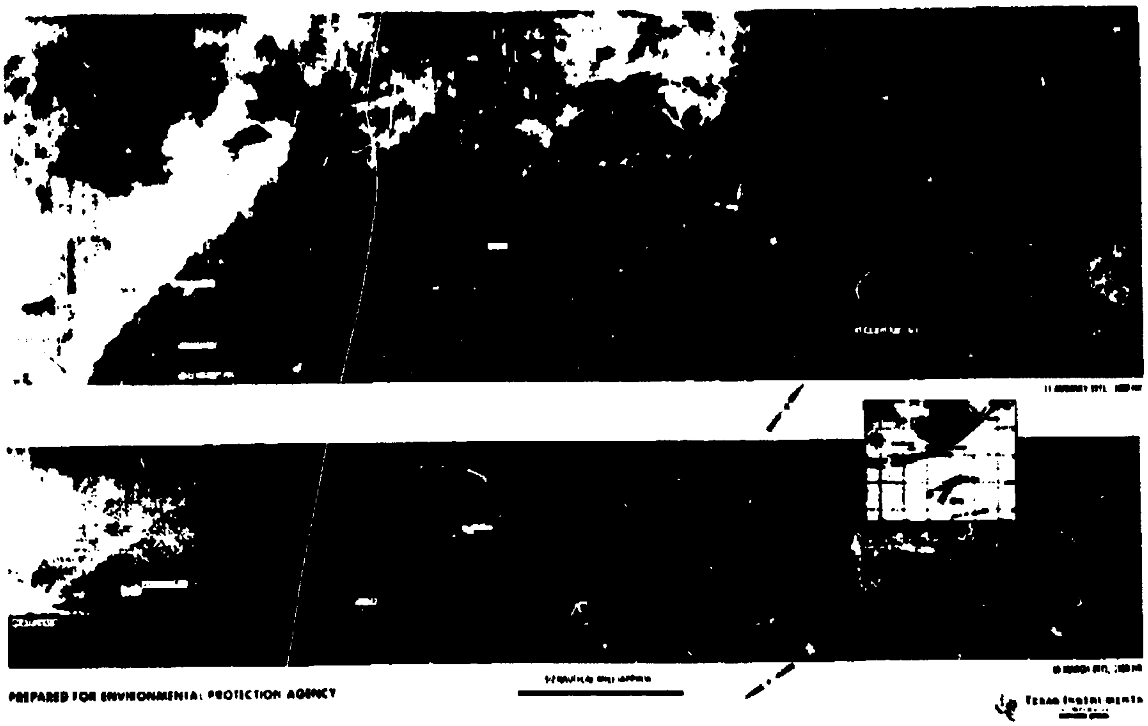

Figure 1. – Infrared imagery tracking the oil slick which resulted from the 1971 Shell Oil platform B fire in the Gulf of Mexico.

briefly describe the oilspill surveillance activities of the EPA and the U.S. Coast Guard and also outline plans to improve and augment the existent surveillance system.

CURRENT STATUS OF OILSPILL SURVEILLANCE

When EPA was formed in December 1970 from elements of a number of other Federal agencies, a fortuitous inheritance from the Department of Health, Education, and Welfare was the Western Environmental Research Laboratory at Las Vegas, Nevada. It is now the National Environmental Research Center (NERC). At this facility were several propeller aircraft, vintage World War II, that were used for air sampling probes in support of underground nuclear weapon tests and monitoring of nuclear powersites.

During the next several years, a remote-sensing facility was established in response to varied and considerable Headquarters and regional requests for water and air pollution surveys, one of the earliest of which was for aerial mapping of large oilspills. Importantly, all the elements and requirements of a remote-sensing system were considered; therefore, a modern photographic laboratory and relevant data processing and reduction facilities were established. Skilled personnel, both Government and contractor, were brought aboard to ensure meaningful analysis, evaluation, and presentation of the data acquired. Although a modest and small operation in comparison to the NASA Earth Resources Aircraft Project, the Las Vegas facility (along with its satellite center, the Environmental Photographic Interpretation Center at Warrenton, Virginia, and contractor data acquisition support) has proved to be a very effective remote-sensing applications unit. The B-26, Mohawk, and C-45 aircraft are used for remote-sensing missions. They carry a variety of infrared cameras, scanners, television equipment, and a spectrometer. A number of successful enforcement actions have taken place, based largely on remotely sensed data, and aerial photographic mapping of oilspills has become an integral and necessary element of effective cleanup operations. Two recent major oilspills (February and March 1975) and the supporting Las Vegas remote-sensing operations served to illustrate this capability that can be brought to bear on a major oilspill anywhere in the United States normally within a matter of 6 to 12 hours. Figures 2 to 4 are examples of aerial photography taken during overflights of a million-plus-gallon spill resulting from a tanker collision, explosion, and fire in the Delaware River. Figures 5 to 7 are products from NERC coverage of a large spill in the Mississippi River near Vicksburg when a barge hit a bridge.

A second and also practical application being carried out by the Las Vegas remote-sensing facility is the aerial surveying of oil production and storage facilities (figs. 8 to 10) in various parts of the country. These surveys are oriented to compliance monitoring to ensure that the facilities are carrying out the requirements of the EPA oil pollution prevention regulation.

The U.S. Coast Guard has established an interim aerial surveillance system using six Grumman HU-16E fixed-wing aircraft equipped with infrared and ultraviolet sensors. This system is utilized primarily in detecting oil discharges from ships sailing in U.S. coastal waters and the Great Lakes. In addition, Coast Guard shore units, harbor patrol craft, and helicopters all have an oil pollution detection mission. This surveillance is primarily for enforcement purposes in both accidental and deliberate discharges.

The Coast Guard assesses the civil penalties for discharges, and prepares the case (for the U.S. Attorney)

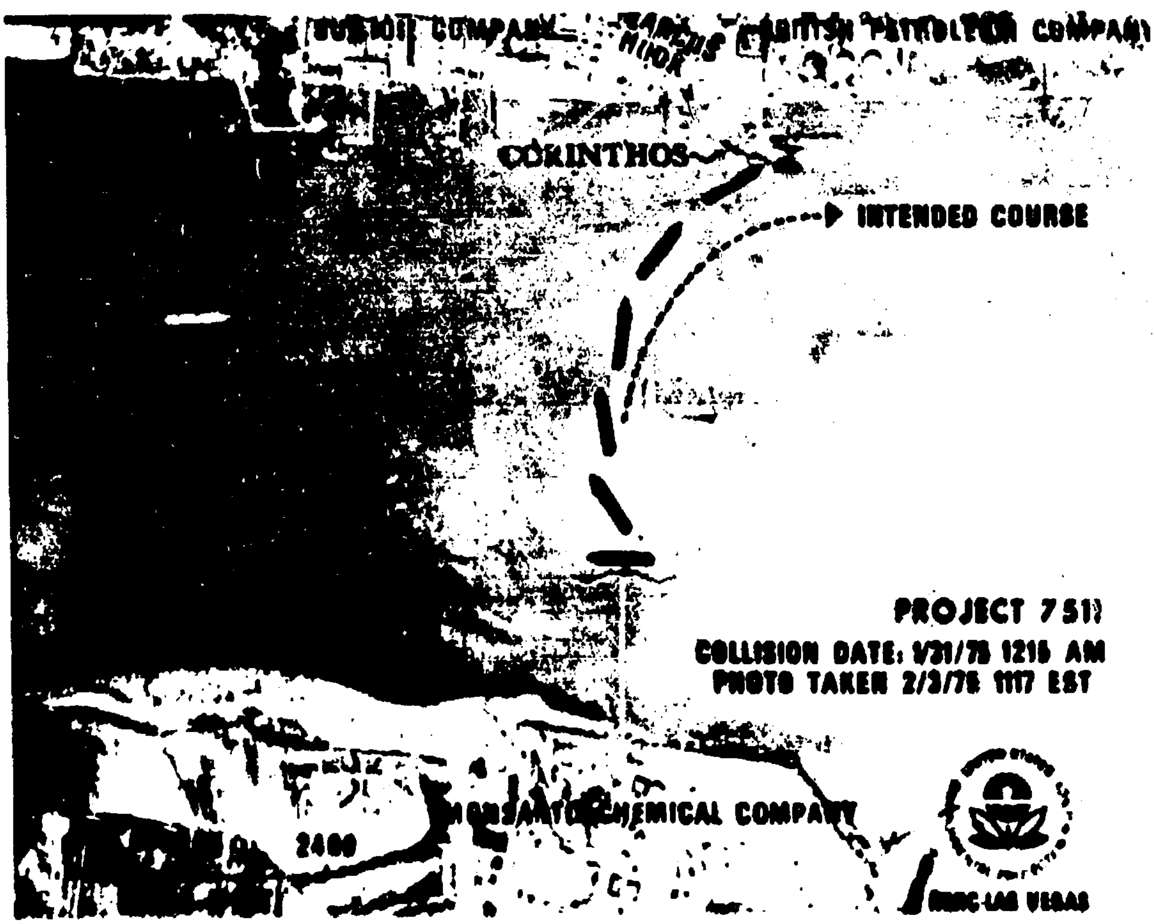

Figure 2. Photograph taken by NERC aircraft 3 days after a tanker collision and oilspill in the Delaware River.

Figure 3.– Same area shown in figure 2 surveyed by NERC 8 days after the spill.

Figure 4. Oblique view of the New Jersey side of the Delaware River, taken on the same day as figure 3, showing the oil along the shore.

for criminal penalty in those instances of failure by the spiller to immediately notify the U.S. Coast Guard. The interim system is not intended for aerial mapping and assessment of large oilspills in support of cleanup operations. The developing Coast Guard aerial surveillance system (to be described in the next section) will have this capability along with a commensurate buildup of data processing and evaluation facilities.

Provisions for surveillance, detection, and evaluation/assessment of oil pollution are being based on both an aerial and fixed-platform (remote sensing and in situ) system. The latter system is applicable to local areas such as harbors, marine transfer terminals, and industrial oil-handling facilities in inland rivers. Both EPA and Coast Guard have supported R&D projects in developing a number of nonvisual, round-the-clock, all-weather sensors with the goal of establishing a monitoring network in high-risk oilspill areas.

An initial active infrared sensor system will soon be installed in New York harbor by the U.S. Coast Guard. The first EPA infrared sensor is now in operation at the Coast Guard Safety Station in the Houston Ship Channel at Galena Park, Texas. Other oil sensors are being evaluated at the Coast Guard R&D Center in Groton, Connecticut, and some of these will ultimately be a part of the local area oilspill detection system. It is important to note here that Federal surveillance and monitoring of oil pollution will always be by random sampling. As oilspills can and do occur anywhere and at any time, it is patently impossible to look for them everywhere simultaneously. The oil pollution laws and regulations require oil-handling operations to display a measure of responsibility in alertness for mandatory reporting, which in turn requires a degree of self-monitoring. The Federal surveillance and monitoring is designed to act as a spill deterrent and to provide reasonable assurance that the laws are being carried out.

FUTURE R&D SURVEILLANCE AND MONITORING PROGRAM

The Coast Guard has undertaken the development of an airborne sensor system to detect, classify, quantify, and map oilspills on the ocean surface. It is called the Airborne Oil Surveillance System (AOSS).

Functions of the AOSS are to (1) detect oil slicks, (2) indicate the magnitude of spills areal extent and approximate thickness, (3) identify and document the source(s) of discharges, (4) assess cleanup operations, and (5) gather data regarding the frequency and magnitude of significant spills. The AOSS was designed to meet the needs of both the law enforcement mission (large search area with infrequent targets) and the

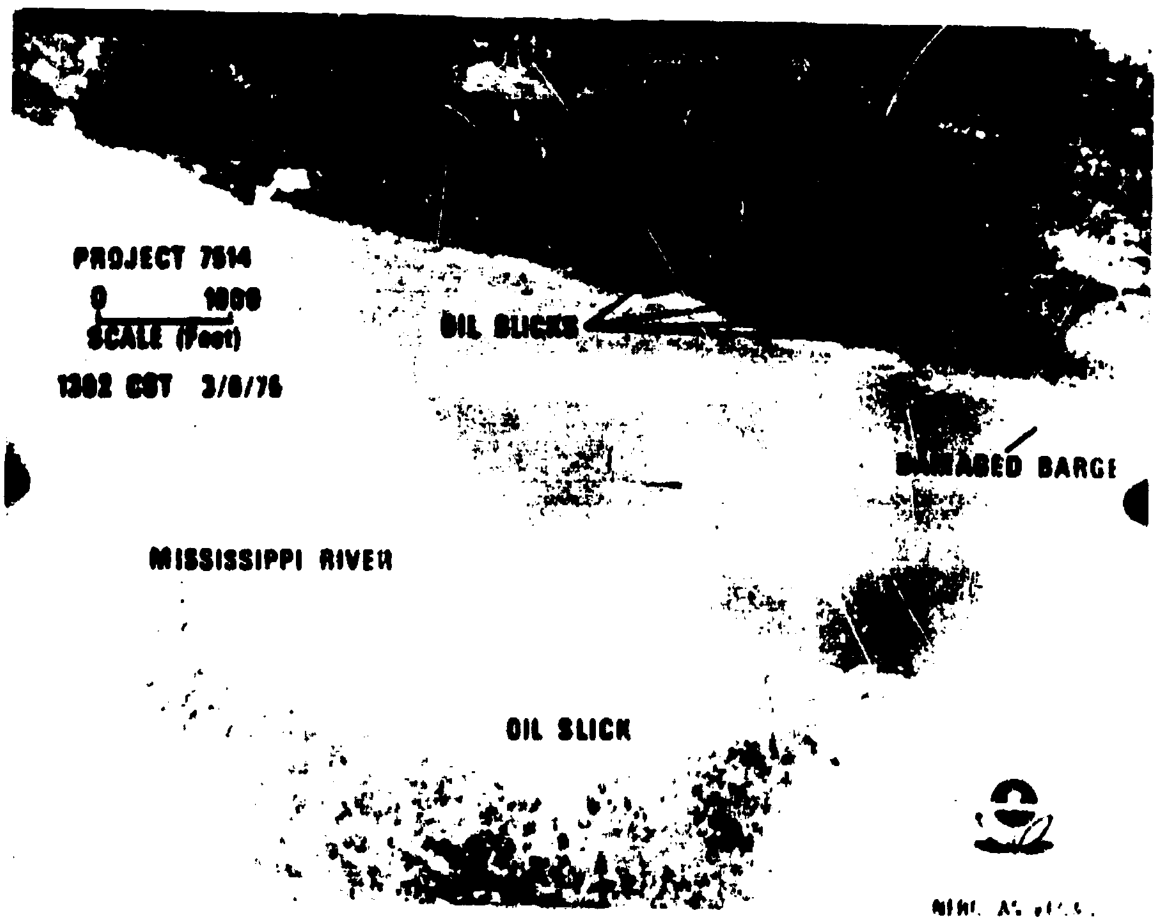

Figure 5. NERC imagery of an oil slick resulting from a barge accident in the Mississippi River. The accident had occurred the day before the photograph was taken.

Figure 6.– Another NERC product of the spill shown in figure 5, taken on the same day.

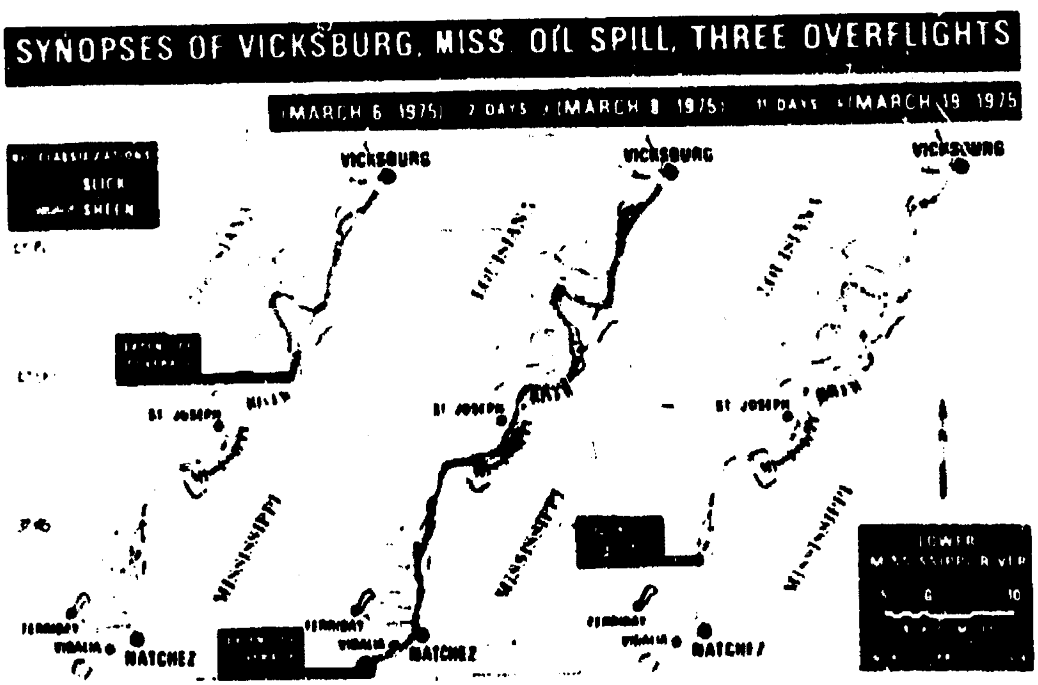

Figure 7. Briefing chart prepared by NERC photointerpreters on the basis of figures 5 and 6, as well as other photographs. This type chart is used to help the on-the-scene coordinator who is responsible for cleanup operations.

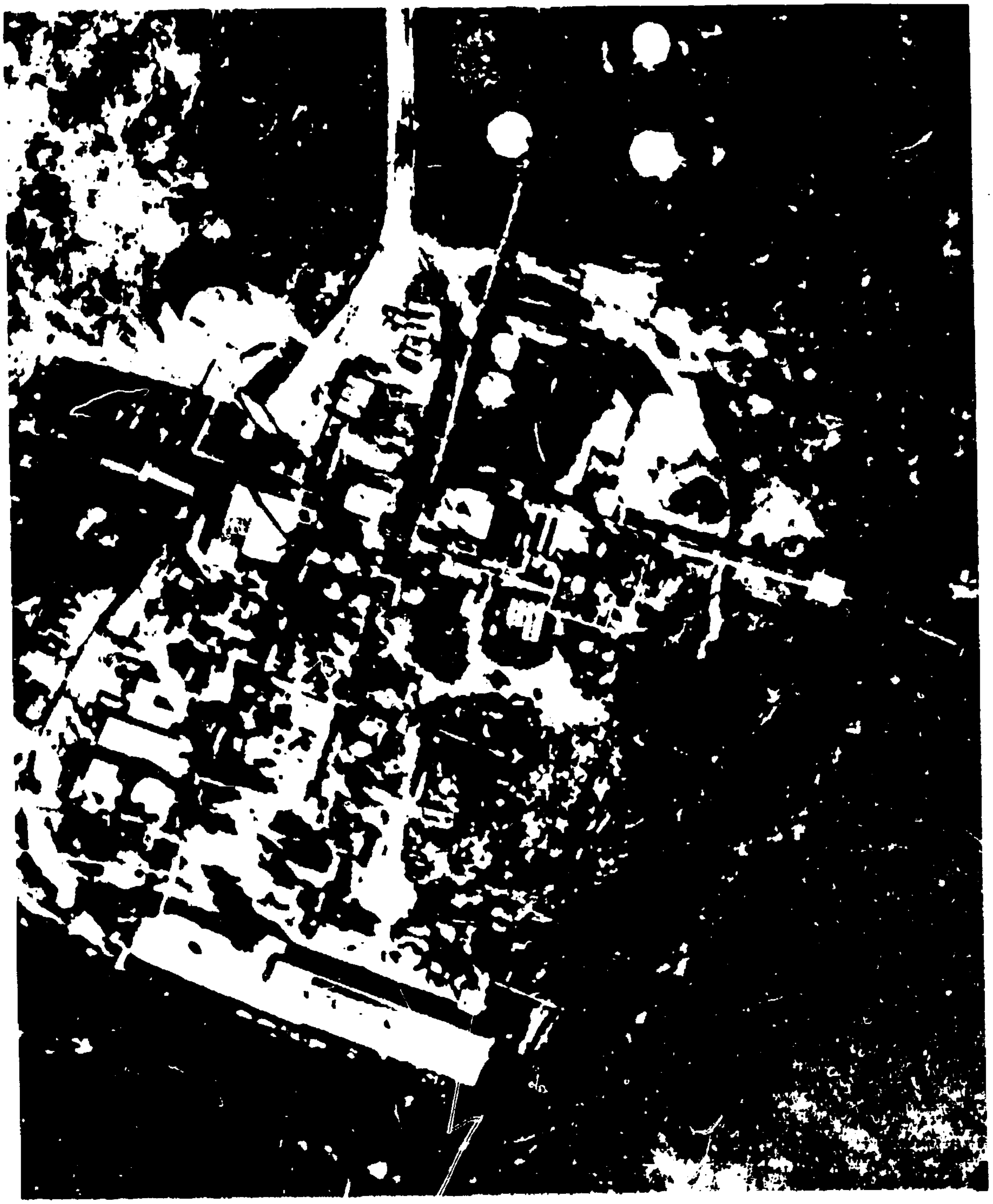

Figure 8. Major petroleum complexes are easy to see in aerial photographs.

Figure 9.– Isolated tanks such as these can also be identified from the air (figure 10).

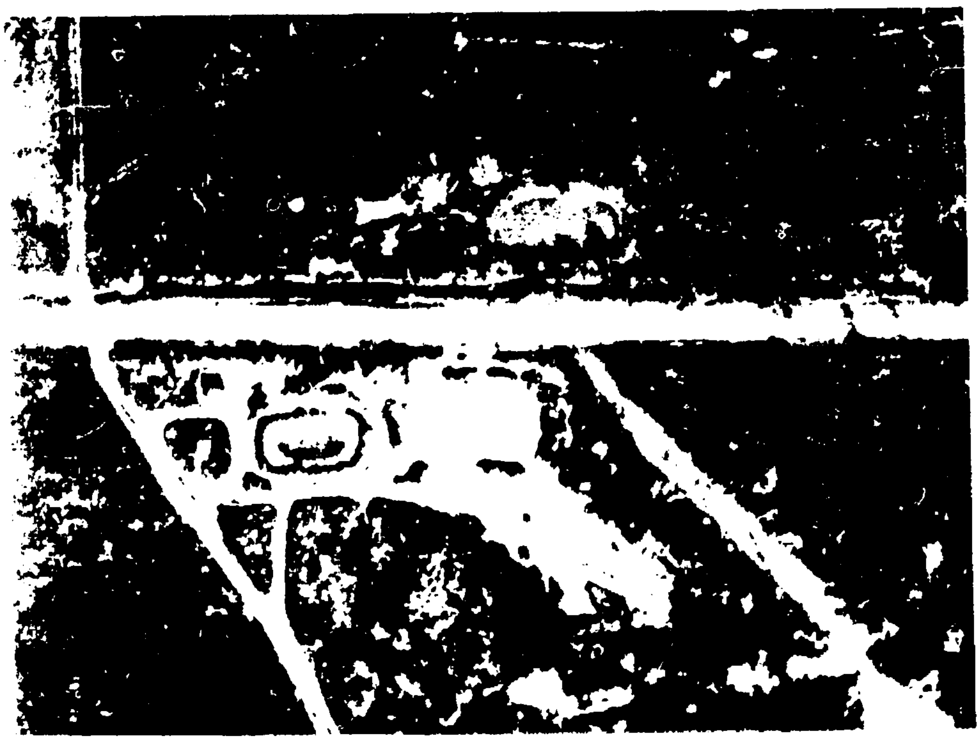

Figure 10. A few tanks are visible in this aerial photograph.

countermeasures mission (oilspill assessment under a wide range of weather, lighting, and ocean surface conditions). Additional requirements placed on the prototype system include (1) effective surveillance of a coastal zone 50 nautical miles wide, (2) long-range (25 nautical miles) detection of ships and long-range detection of oil slicks, and (3) adverse weather operations. In addition to the AOSS, the Coast Guard has sponsored research for an active fluorescence sensor for airborne classification of oilspills, multifrequency passive microwave techniques for oil thickness measurement/quantification of oilspills, and a television system which detects oilspills by displaying the difference of signals of opposite polarization (a NASA Ames Research Center project).

The prototype system was developed by Aerojet Electro Systems Company and consists of (1) an X-band side-looking radar for long-range ship and oil detection and adverse weather oilspill mapping; (2) a 37-gigahertz passive microwave imaging system for adverse weather spill mapping and spill thickness approximation; (3) a multispectral low-light-level television system for high-resolution spill documentation and violator identification; (4) a multichannel line scanner for spill confirmation and discrimination; (5) a position reference system for legal and operational effectiveness; and (6) a real-time processor-display console for maximum operational effectiveness. The system provides for false-target discrimination, automated detection alarming, and a color display to achieve maximum coupling of the sensor information to the equipment operator.

Design of the AOSS was initiated in 1972 and integration was completed in early 1974. The AOSS was installed aboard a Coast Guard HU-16E Albatross in June 1974 and was flight-tested off the southern California coast during a series of shakedown and background data flights from June through August 1974. Background data flights were conducted mostly over the Santa Barbara Channel, where natural seeps and routine shipping activities are commonplace. The AOSS was subsequently based at the Coast Guard Air Station, San Francisco, and it participated in a comprehensive flight test program off the northern California coast during September and October 1974. The test program included AOSS evaluation of (1) a series of controlled static and dynamic spills on an ocean site approximately 100 nautical miles west of Santa Cruz, California, (2) routine tanker discharge operations; (3) surveillance of routine shipping and harbor activities; (4) potential false targets; and (5) selected targets of opportunity. (Details of test results are noted in the Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution, March 25-27, 1975, San Francisco, in an article by A. Maurer and A. T. Edgerton.)

The surveillance system was generally reliable, and the flight test results demonstrated that a practical airborne oil surveillance system is feasible. The tests also show the system to be useful for other Coast Guard missions.

Future implementation envisions sensor package production to be mounted in six to eight jet aircraft with initial surveillance operations scheduled for late 1977. Pollution forecast models have been proposed to develop a large-scale, random surveillance schedule for pollution detection in U.S. coastal waters including Alaska and the Great Lakes. The EPA remote-sensing laboratory at Las Vegas is currently assisting the Coast Guard in developing a plan for data processing and evaluation facilities to effectively handle a "NASA-type" flood of data.

As noted earlier, both EPA and the U.S. Coast Guard, primarily the latter, are sponsoring R&D of both remote and in situ sensors for local areas of high-risk oil discharges. In addition to infrared reflectance sensors, a laser backscatter sensor and an ultraviolet fluorescence sensor are being tested along with a number of in situ sensors. It is anticipated that industry will use some of these sensors when fully proven as they do serve as an early warning device for initiation of immediate reporting, corrective actions, and cleanup response.

SUMMARY

The EPA and the U.S. Coast Guard, in response to the surveillance requirements of Federal law, have established aerial and fixed-platform oilspill detection systems, primarily utilizing remote-sensing means. Augmentation and increasing sophistication of data acquisition is in process with maximum surveillance expected to occur in 1978 and beyond. Recently initiated oilspill prevention programs under EPA and Coast Guard regulations are expected to considerably reduce the current high incidence of oilspills. As this goal of reduction and even elimination in some cause areas is reached, Federal surveillance requirements will commensurately decrease. However, as an integral part of prevention, it is anticipated that industry will increasingly use local area monitoring sensors for early oil discharge detection and alarm. Remote sensing has proven beyond doubt to be an effective means for oilspill detection and assessment.

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STATE AND LOCAL USERS

S-1. Introduction

Charles M. Parrish, III[a]

Here, in one sentence, is what I consider the objective of this session: "To illustrate and compare alternative approaches of remote-sensing applications to state and local resource management problems." The key words are "alternative approaches" and "management problems," which means applications for management problems with alternative approaches.

We have tried to orient this session toward management personnel from state and local government throughout the country. The presentations will deal largely with examples of applications. General approaches will be discussed, but, insofar as possible, presentations will concentrate on illustrative examples that will give you an understanding of what the users are trying to do. And we want to look at their problems as well as their successes. We would like an indication of what they have not yet been able to do, just as much as we would like to know what they can do. We would like to look at applications from the administrative, the political, and the financial, as well as the technological aspects, with the heaviest emphasis on the technological and the financial. We will look at not only what these people are doing but also what they expect to be doing very soon. We expect speakers to address themselves to what they have learned as it might apply to similar jurisdictions elsewhere, to other state and local governments. We know that the satellites and many of the aircraft and other systems are still experimental and are not entirely operational.

We also want to look at the relationship between our state programs and the Federal agencies, meaning NASA, the U.S. Geological Survey (USGS), and whatever else. How does what the Federal people are doing relate to us in state and local governments? How can their systems and their programs be improved or changed to better meet the needs of the state or local decisionmaker?

We would like for this session to be not only constructive but also critical at times. So often we have a tendency to feel that we have to come to one of these sessions and sing the praises of Landsat or other systems. We do want to know what is good about these systems, but also the speakers have been encouraged to provide constructive criticism for change whenever possible. We want to try to identify the specific issues, the consensus on some specific issues, the conclusions, the recommendations, and the general feeling of this group, so that we might take to the general session a feeling about how we think programs should be developed, at the state and local as well as the Federal level, in the coming months and years to better meet the needs of the manager at the state or local level.

Bill Stoney talked about the developing consensus that the multispectral scanner is the way to go (recognizing that the use of color is very important), the tendency toward wanting to look at more detailed resolutions, the need for data on a timely basis for different uses, the need for data on a repetitive basis, and the surprising ability of the user community to adapt to the digital format. Those are all technological things; they all have a bearing on how successful we will be. Maybe these ideas can be used as a point of departure and we will see how they relate to management problems in our states.

[a]Georgia Department of Natural Resources, Atlanta, Georgia.

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S-2. Remote-Sensing Applications in the State of Mississippi

P. T. Bankston[a]

Back in the period of about 1970-71, Earth Resources Laboratory (ERL) personnel, working closely with a variety of state agencies and universities, thoroughly examined the need for data in Mississippi: what kind of data, how often they should be acquired, how often updating would be necessary, and the sort of resolution needed. After this assessment of needs, we concluded that the best format at the starting point would be a series of land use maps. In some parts of the country, including Mississippi, "land use" is not a good term because it is not always understood; I mean a classification or an inventory of what is on the ground.

PREPARING DATA

High-altitude aerial imagery was obtained in a cooperative NASA project. Figure 1 is typical of a frame of that 1:120 000-scale imagery. From this infrared high-altitude photography, by using a simple technique involving photographic enlargement and photointerpretation, classifications were accomplished. Figure 2 is typical of the initial maps that were made showing the resources on the ground. We can color code a map like this (fig. 3) either by hand or by using more elaborate equipment if it is available. Some individuals

Figure 1. Photograph of Biloxi, Mississippi, area taken from 60 000 feet.

[a]Mississippi Office of Science and Technology, Jackson, Mississippi.

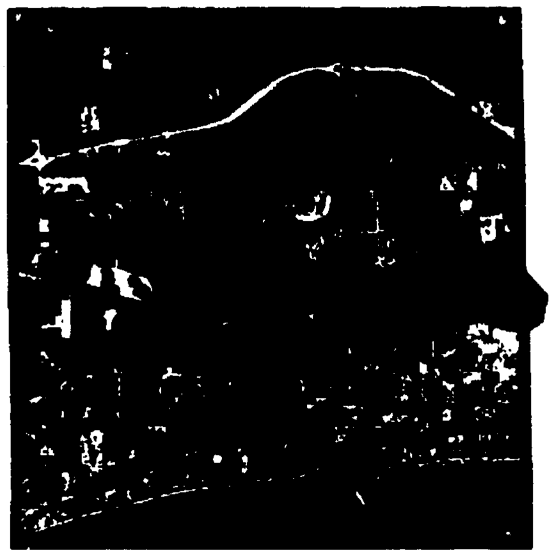

Figure 2.– Initial classification map of Harrison County, Mississippi, developed from aerial imagery.

can comprehend a classification map better if it is in color. The map in figure 4 shows the present status. The darkened areas indicate the parts of the state that have been mapped. We tried the mapping on a demonstration basis with a couple of state agencies on the coast and in the central part of the state around Jackson. The balance of our work has actually been production, under the direction of the state agency called the Research and Development (R&D) Center, which worked very closely with our substate planning districts. A little over half the state has been mapped with the kind of land use maps shown in figure 2.

The initial plan was to manually update these manually produced maps, using Landsat data. Figure 5 is an example of Landsat data classified in the Mississippi Delta. The original was on a scale of 1:208 000. The scale set for the state grid system was 1:24 000 on a township basis. At this scale, the Landsat data become, at least for a map, something that doesn't look quite right. The importance of it, however, is that we have all this information in digital form in the computer and can manipulate it statistically. Instead of manually updating

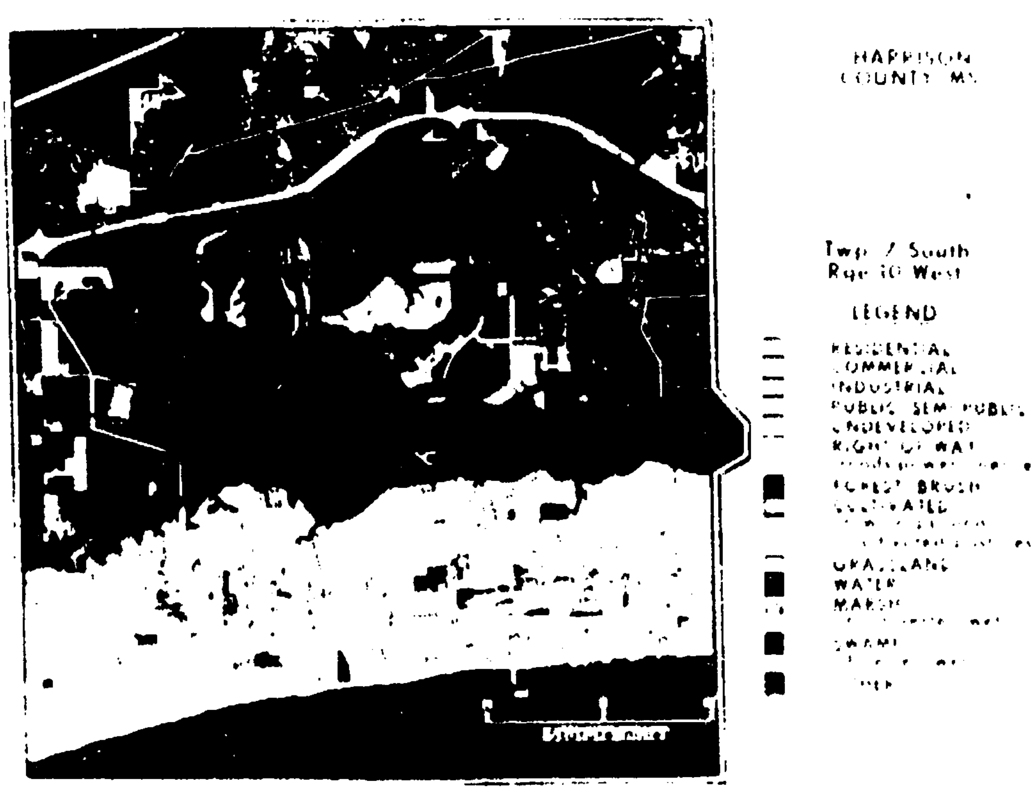

Figure 3.– Color-coded land use map of the same area shown in figure 2.

the maps produced from the aircraft imagery, we have now decided to go directly to a computer-implemented system (fig. 6).

The objective of this inventory system is to test and demonstrate an automated natural resources information and inventory system, based on remotely sensed data, oriented to state and regional use and directed at specific applications. We expect to obtain simplified pattern recognition software, which must be a cross-color system, suitable for a general-purpose digital computer. We expect to be able to use both satellite- and aircraft-acquired data for selected area coverage. The system should be able to accept data from other sources for correlation purposes and should be capable of being implemented in state facilities. Both cost and complexity will be factors in whether or not a system can be used by state agencies. It is terribly important that the system be within the potential technological skills of the people who will be using it. They may not have these skills now, but they must be able to acquire them with appropriate training and must be brought up to speed in both implementing and using this system.

The overall management plan is diagramed in figure 7. The plan is closely coordinated among various agencies of the state, its central computer system, and units of the ERL.

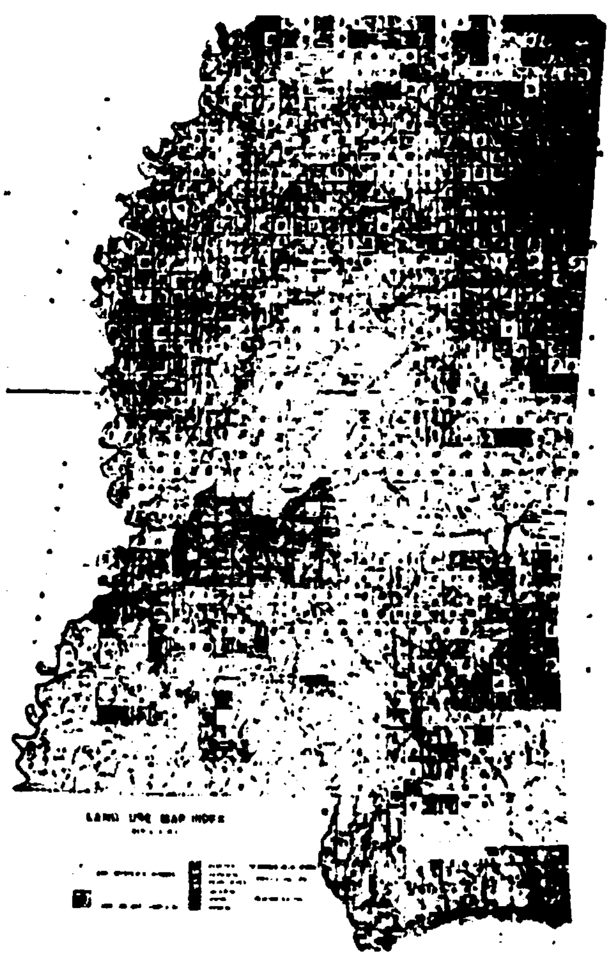

Figure 4. Status of Mississippi mapping project, with light areas yet to be mapped. Hancock County, at the bottom center (the westernmost coastal county), was the area for the initial pilot project.

Figure 5.– Landsat false-color imagery of the Mississippi Delta, taken in 1972.

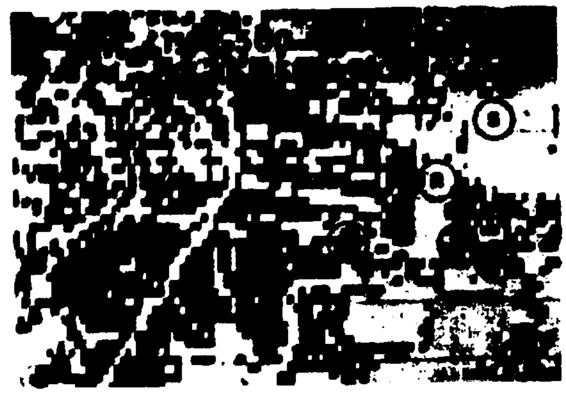

Figure 6.– Example of a computer-implemented land use classification.

DEMONSTRATING THE SYSTEM

The following are some specific areas in which we shall try to demonstrate the utility of this system. Figure 8 shows the location of those projects for which exact locations have been decided.

1. Crop production estimation at the county level will be demonstrated in the alluvial plains agricultural area in Washington County, Mississippi. The Mississippi Cooperative Extension Service/Crop and Livestock Reporting Service is the cooperating agency in this project.

2. A rural development project will be demonstrated in the tricounty area of Calhoun, Yalobusha, and Grenada Counties, a combination of hill country and delta geography that is a pilot area for implementation of the 1972 Rural Development Act. The Extension Service is also cooperating in this demonstration.

3. Coastal zone management will be demonstrated in the three coastal counties of Hancock, Harrison, and Jackson for the purpose of updating land use maps and for providing management with baseline data such as salinity regimes. The Mississippi Marine Resources Council is also working on the project.

4. Urban development planning will be demonstrated in the Jackson standard metropolitan statistical area (Rankin and Hinds Counties) for land use update and change detection, in conjunction with the Central Mississippi Planning and Development District, and in De Soto County (adjacent to Memphis) for development suitability categorization, in conjunction with the North Delta Economic Development District.

5. An aspect of park management, documentation of vegetation types, will be demonstrated in Tishomingo State Park for possible extension to the 14 other state parks. This project also involves the Mississippi Park Commission.

6. In wildlife management, the mapping of whitetail deer habitat and the determining of carrying capacity in one state game management area will be demonstrated in

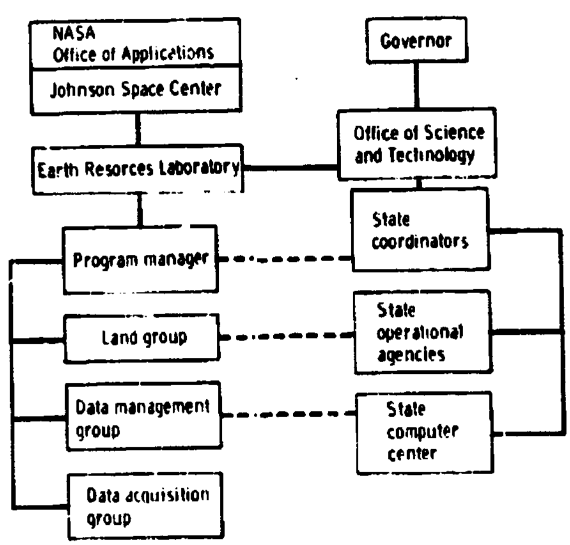

Figure 7.– Management plan for the natural resource information system in Mississippi.

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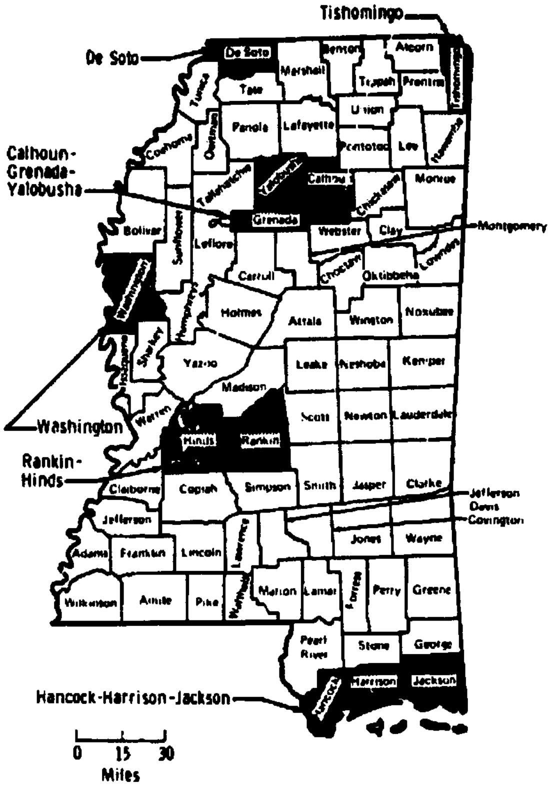

Figure 8. Locations of some of the Mississippi demonstration areas.

cooperation with the Mississippi Game and Fish Commission for possible extension to the 19 other game management areas.

7. Forest management by location of areas in need of reforestation for erosion control will be demonstrated within the Yazoo-Tallahatchie Flood Prevention Project area in cooperation with the Mississippi Forest Commission.

8. Watershed planning will be demonstrated in one basin corresponding to those defined for comprehensive planning under the Small Watershed Act. The Board of Water Commissioners is cooperating on this application.

Certain basic information must be acquired and put into the system before it becomes a useful management tool. Surface features should be identified as agronomic crops, pasture or grassland, orchards, deciduous or coniferous forests, marsh vegetation, open water, catfish farms, or urban areas. Other information needed includes soil types, slope, elevation, aspect, terrain, understory forest vegetation, rainfall, temperature range, population density, ownership (private or public), and accessibility.

Collecting of ground truth is done by personnel from a number of agencies (table I). Figures 9 and 10 are examples of the types of forms used to collect and record data.

EMERGENCY APPLICATION

In April 1975, we had an opportunity to try one application. Mississippi was flooded over some 600 000 acres. It was deeply flooded in the major crop areas of cotton, soybeans, and rice. The crest of the flood was approximately 49 feet (fig. 11). This flood had been forecast in March to exceed the 1973 flood. Because of a very heavy snowfall in the Middle West and because of the holding snowpack, a secondary flood was forecast for May that would exceed the April flood, which exceeded the 1973 flood. Figure 12 shows some of the conditions of the fields in 1973. Because the flood was expected, people started moving expensive harvesting equipment down the road for miles and miles to get it out of that area. People were using bulldozers and

TABLE I.- STATEWIDE GROUND TRUTHING SYSTEM

Category	State coordinating agency	Geographic area	Field personnel
Crops, pasture, orchards	Cooperative Extension Service	Statewide	County agents (82)
Coastal wetlands	Marine Resources Council	Coastal zone	Gulf Research Laboratory (3)
Other natural vegetation	Forestry Commission	Statewide	County foresters (63)
	Game & Fish Commission	20 game management areas	District biologists (8)
	Park Commission	15 state parks	Park superintendents (15)
Urban and builtup	R&D Center/Economic Development District	Urban areas	Economic development districts (10)
Extractive	Geological Survey	Statewide	Jackson office technical staff (2)

GROUND TRUTH DATA FOR CROPS AND PASTURE

TAKEN BY: ______ DATE ______

TRAINING SAMPLE # ______ MAP OR AIR PHOTO INDEX # ______

ESTIMATED FIELD SIZE: ______ ft X ______ ft or ______ ACRES

LOCATION ______
County 1/4 1/4 Section Township Range

GENERAL CONDITION(1) ______

DESCRIPTION (if not crop or pasture) ______

CROP OR PASTURE SPECIES(2) ______ VARIETY (if known) ______

PLANTING TECHNIQUE(3) ______ PLANT HEIGHT (to closest ft) ______

ROW WIDTH ______ PHYSIOLOGICAL STATE(4) ______

ROW DIRECTION ______ VISUAL ASPECT(5) ______

PERCENT GROUND COVER ( ) 0% to 20% ( ) 20% to 40% ( ) 40% to 60% ( ) 60% to 80% ( ) 80 to 100

WEED INFESTATION (species & %, if greater than 20%) ______

DISEASE INFESTATION (kind & %, if greater than 20%) ______

INSECT INFESTATION (kind & %, if greater than 20%) ______

SOIL CONDITION(6) ______

SOIL MOISTURE(7) ______

SOIL TYPE(8) (if available) ______

OTHER COMMENTS (if needed) ______

(1) e.g. crop, pasture, stubble, plowed, fallow.
(2) e.g. soybean, bahia grass, etc.
(3) e.g. row, skip row, drilled, broadcast.
(4) e.g. flowering, heading, mature, etc.
(5) e.g. chlorotic, wilted, etc.
(6) e.g. freshly cultivated, rough, smooth, etc.
(7) e.g. moist, dry, waterlogged, etc.
(8) e.g. series, texture, color, slope, etc.

Figure 9.—Form used by field workers to collect ground truth about agricultural land.

GROUND TRUTH DATA FOR FOREST/BRUSH VEGETATION

TAKEN BY: ______ DATE ______

TRAINING SAMPLE # ______ MAP OR AIR PHOTO INDEX # ______

ESTIMATED FIELD SIZE: ______ ft X ______ ft or ______ ACRES

LOCATION ______
County 1/4 1/4 Section Township Range

KIND OF VEGETATION (check one)
( ) Natural Forest
( ) Forest Plantation
( ) Brush Vegetation

If Natural Forest, indicate:

(1) Major forest type (check one)

( ) Maple-Beech-Birch ( ) Elm-Ash-Cottonwood ( ) Aspen-Birch
( ) Oak-Hickory ( ) Loblolly-Shortleaf ( ) Oak-Pine
( ) Oak-Gum-Cypress ( ) Longleaf-Slash ( ) Mixed Hardwood

(2) Species composition (to nearest 25%) Species %

(3) Average age class of upper canopy trees (check one)

( ) Less than 20 years ( ) 50 to 100 years
( ) 20 to 50 years ( ) over 100 years

(4) Average height class of upper canopy trees (check one)

( ) Less than 20 feet ( ) 50 to 100 feet
( ) 20 to 50 feet ( ) over 100 feet

(5) Slope

( ) 0% to 10% ( ) 30% to 50%
( ) 10% to 30% ( ) 50% or more

(6) Predominant Aspect

( ) North ( ) South ( ) East ( ) West

If Forest Plantation, indicate (1) Species ______ (2) Spacing ______
(3) Row Direction ______ (4) Ave. age: ______ (5) Ave. height: ______

If Brush Vegetation, indicate species composition to nearest 25%.

Species % Species %

Figure 10. Form used by field workers to collect ground truth about forests and brush-covered land.

building mudboxes (fig. 13). trying to protect their houses. Landsat imagery of the flooded area was delivered to the civil defense agency and to the National Guard. which had primary responsibility for damage assessment, within 30 hours after the satellite pass. Don't expect this kind of everyday service out of NASA. It was an emergency situation and they really did everything they could to get us that information so fast. The Corps of Engineers provided additional data 10 days later. The point is that we did have a clear day, we got a good satellite pass, we got the data in the hands of the people that needed it. We are not yet quite sure of how many other ways this sort of data could be used in a similar disaster situation.

FUTURE APPLICATIONS

Now, here is what we expect to get out of the system under development. Figure 14 is a computer-derived land use classification of Landsat data acquired in 1972 of the coastal zone. The imagery produced from the Landsat-acquired data is shown in figure 15. Of course, a ground-truth operation is necessary to input to the computer. We were able to capitalize on some ground-truth operations being conducted at that time in the Pascagoula River area and therefore were able to put together some information very quickly.

The utility of these data does not have to wait until you get consistent. During this immediate past session of our legislature, we had a number of hectic situations. The international economic situation is uncertain. We have a conservative fiscal governing group. The last year of any administration is always difficult. The legislators are required by the constitution to stay within the money that they receive. So their estimates of income are very important as they begin the appropriations

Figure 11. Marking the April 1975 flood crest in Mississippi.

process. Normally, the budget accounting commission makes recommendations that go to both houses and it is very difficult for a person to get any more money than is recommended. We were able to use these remotely sensed data and put together a set of facts in about 3 weeks for a particular state agency. That report enabled the agency to persuade the legislature to authorize the issuance of \$15 million of general obligation bonds for the purchase of approximately 40 000 acres of land to be used as natural wilderness, fishing, and hunting areas. It was a pretty good feat in the face of the situation existing in the legislature and it was only possible because data already existed and because we were able to call on the experts available through ERI and

Figure 12. Fields under water during 1973 Mississippi flood.

elsewhere in interpreting what the data meant. You can do this sort of assessment at any time, once you get your data bases established.

DISCUSSION

SPEAKER: What type of organization works with the state agencies, and what type of training programs do you see in the future?

Figure 13. Barriers against floodwaters.

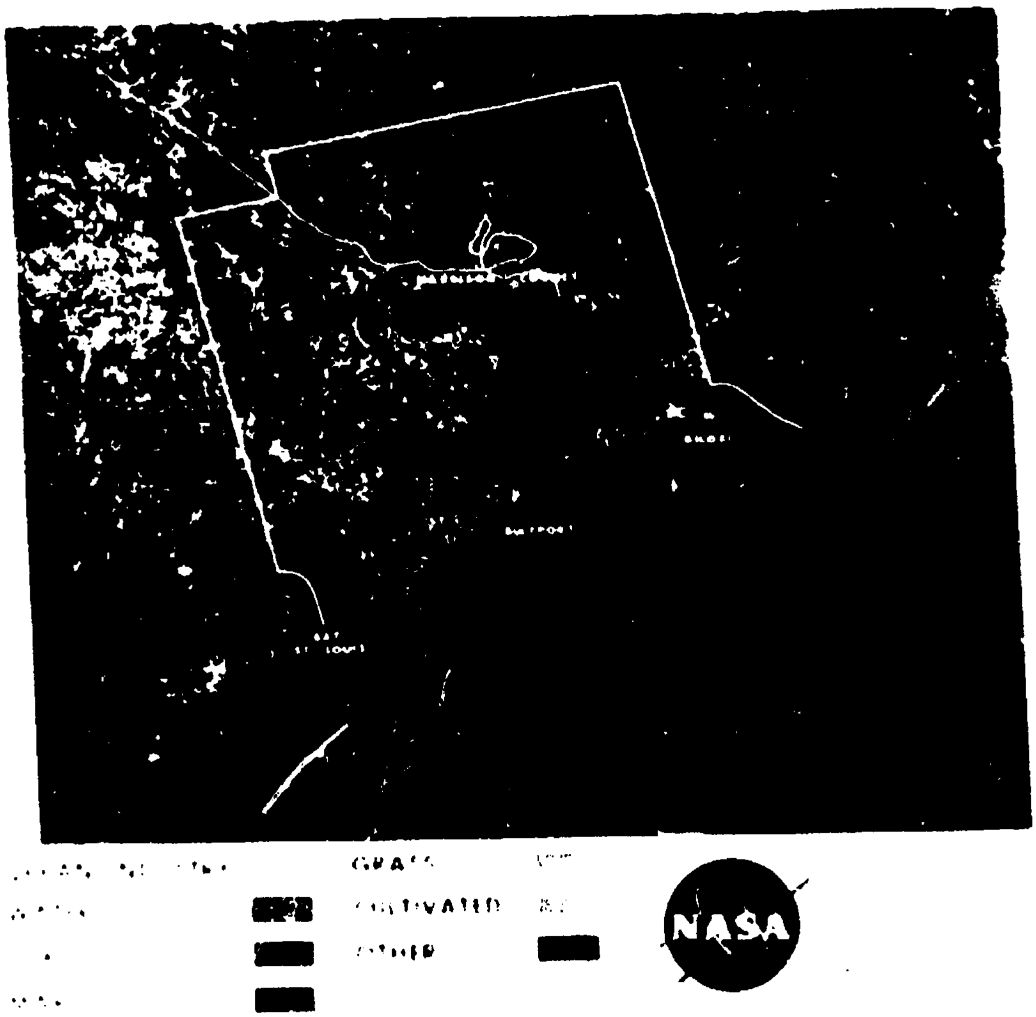

Figure 14. Computer-derived land use classification of Landsat digital data (acquired Aug. 7, 1972).

BANKSTON: I, personally, have a very small organization, about six people. We work with a designated key individual within the appropriate state agency, particularly the Extension Service and their regional and county agents; it depends upon the application. Training is available both from NASA and by working with them. We have a unique situation because of where the ERL is located. The Earth Resources Observation Systems (EROS) Data Center will assist the training too, in, say, photointerpretation. The system being developed is essentially experimental, so we don't know yet what it will be. In field truthing, we send the person out to a test site; we have a test site in each of the 82 counties for each item we are interested in. And the state agencies have been very faithful and diligent in gathering the information necessary.

SPEAKER: You mentioned you have a computer-based inventory system, or did you say you were going to develop a computer-based inventory system using satellite, aircraft, and other sources?

BANKSTON: The Earth Resources Laboratory is developing the basic computer software for pattern recognition. We are translating that software package from ERL's computer system to the state computer system.

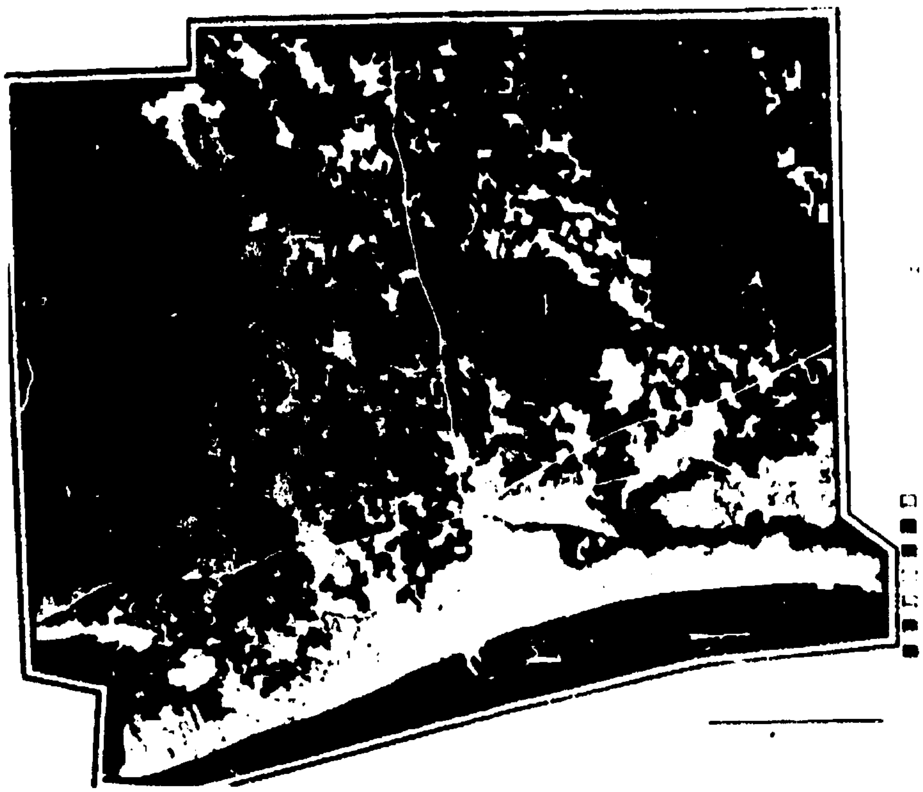

Figure 15. Land use classification through interpretation of imagery from Landsat.

SPEAKER: Is it functional right now or have you used it?

BANKSTON: It is functional in some areas.

SPEAKER: What classification level are you using? I realize that for your 1:24 000 you used a Level III. Are you using a Level I or a modified Level II?

BANKSTON: We use Level I for some things, modified Level II for other uses. Because of this existing data base, we do not need the level of differentiation on the satellite data that we would in the absence of this data base.

SPEAKER: Would you comment on the possible advantages of central, direct reception at Jackson, Mississippi? And have you given any thought to archival requirements, to how long you would like to archive your data and have access?

BANKSTON: Some of this we have not completely thought through. Certain kinds of data have been archived for a number of years, flood data, for example. One of our parameters is to keep the cost low. The best figure I have heard for a direct-reception-type system, antenna, black boxes, and computer, is at least $500 000 and moves on up toward $1 million with display imagery. It is awfully difficult to sell that sort of thing to the state legislature unless you have a host of users. We think we can accomplish the same thing this way, through the normal sequence of the Goddard Space Flight Center, EROS, or whatever, to us.

SPEAKER: Did you say you had satellite information at Level III at a scale of 1:24 000?

BANKSTON: Not satellite information. We have high-altitude color infrared aircraft photography on a scale of 1:120 000 and you can easily enlarge it five times.

SPEAKER: What is your reliability factor in terms of percentage correct classifications?

BANKSTON: This is for Bob Daley, who is director of that division in charge of this whole statewide land use mapping effort.

DALEY: It is for Level I, 97 percent; for Level III, 87 percent, from the high-altitude imagery.

N76-26658

S-3. Information Flow of Land- and Water-Related Data in the State of Wisconsin

Allen H. Miller[a]

Planning in Wisconsin is decentralized with physical planning activities taking place in a number of state agencies, in multicounty regional planning commissions, in county planning and zoning committees, and, of course, at the community level. In addition to the practitioners, there are the research community (the University of Wisconsin, the University of Wisconsin Extension Service, and other colleges and universities in the state) and the state regulatory functions (particularly within the Department of Natural Resources). "We" in the context I am using it is not the State Planning Office where I am employed, but it is all those people within the state who are concerned with the management of land and water resources. As I itemize some specific activities that we are involved with, I will try to point out the coordination involved in those activities. Flow of land- and water-related data requires this kind of interaction if our objective is to apply remote sensing to better decisionmaking. Remote sensing has advanced significantly in the years that I have observed it, about 5 years now. But on the day-to-day activities, the guy on the ground – the county board member or the county zoning administrator – is still faced with the problem of having adequate base maps or current usable photography. As an example of some of our activities, I will follow a flow of data from collection to storage to some examples of its application.

On the collection front, during the past years, we have tried to resolve some of the problems of language. Some 60 professionals from various organizations have worked together on a number of occasions to develop a statewide land use classification system. They represent the local and regional planners, state agencies, and universities. We have gone through at least 12 iterations over a 12-month period to refine a classification system that is acceptable to most users. The acceptance of the system is, I think, primarily because of the investment of the people; they have a part of it; they have done it themselves. The system that we have evolved closely resembles the USGS national land use classification system. However, it has some significant differences. One, we are talking about land use, *not* land cover. We have separated use from cover, from ownership, from zoning, or whatever. Had we utilized the USGS standard classification system, the great State of Wisconsin would have no recreational land use activities. Recreation is probably our second or third major industry. We would have no identifiable forestry land uses. We would have a lot of forests. We would also not identify forested wetlands within the state, and the state is approximately 25 percent covered with wetlands, many of those being forested. The attempt of the land use classification system was to identify "use" not predicated on remote sensing as a sole source, but as one of many sources.

Within the context of collection of information, we are trying to achieve some systematic, uniform aerial photography, general-purpose photography. Our focus is the USGS cooperative program, orthophotos at a scale of 1:24 000. We have done a survey of all county-level planners and managers, as well as regional planning commissions and state agencies, to ascertain how many dollars they have spent on aerial photography and whether or not orthophotos meet their needs. We have found that approximately 85 percent of their needs are met at the scale of 1:24 000. We have a problem in the state which I think most states do. When we consider everyone who is collecting aerial photography, we wonder why the planes aren't bumping into each other. We have communities, counties, regional planning commissions, state agencies, and Federal agencies all flying around trying to get their own thing. Most of their needs are relatively parallel. We found, through a rough estimate of how much they spend, that the cost to cover the entire state on a uniform basis, about every 5 years, is approximately equal to what the local units of government are individually spending on their own imagery. We have communicated with the Soil Conservation Service (SCS) trying to achieve some

[a]State Planning Office, Madison, Wisconsin.

uniformity with its imagery. We will be flying some 19 counties as a part of the coastal zone management program with the same specifications as USGS orthophotos. At the same time, the SCS program will be flying 13 counties at a scale of 1:20 000. There is an obvious advantage to come to some compatible agreement on scales, in which case we would have almost half of the state done in 1 year with imagery usable to a number of people. We have heard a lot from Federal agencies on new scales of imagery and new scales of maps, particularly 1:50 000 and 1:100 000. I don't want to evaluate their need for that particular scale; however, I think the Federal agencies should not presume that states or substate regions need that type of imagery. This effort diverts resources from one program into another without really satisfying the needs of the state.

Going from collection to the storage and availability of data, there are some ongoing efforts at the "inventory of inventories," trying to find out what information is available on an ongoing basis for local decisionmakers. We are looking at all data again, not just remote-sensing data. Within the University of Wisconsin is the Environmental Monitoring and Data Acquisition Group (EMDAG), which runs a remote-sensing data center. It provides information on what is available within the state, and also assists the user in acquiring any imagery needed. Wisconsin took a big step forward last fall, when it established the position of state cartographer. I think we were the first state to do so. The state cartographer is primarily responsible for coordinating map data within the state. He is beginning to provide one source of information on map data. And finally, we are working on a statewide information system. We have been working with the Department of the Interior using the natural resources information system, which is basically a polygon overlay system. We have achieved an understanding of the system and a conversion of some of the languages to make the programs work on our university computers. This is an effort, involving the university (actually two elements within the university), the Department of Natural Resources, and our own office, to establish a hybrid statewide information system to begin the storage of remote-sensing data as well as other types of inventories.

More specific applications of remote-sensing data include a statewide land cover map produced by the university's EMDAG. This land cover map delineates four categories: urban, agriculture, forest, and water.

In addition to land cover, the investigator identified wet-soil patterns and overlaid the two of them. The objective in using Landsat was to provide an inexpensive method to identify land cover that could be repeated on a 2- or 3-year cycle. We used the International Imaging System (I^2S) in an interactive/interpretive capability to derive the land cover map. It is probable that we could repeat this within 3 percent accuracy. It is less probable, I think, to repeat the wet-soil analysis, because the individual doing the interpretation was a soil scientist. The net value of the whole effort provides some context of cover, but, as a vehicle by itself, it has limited utility. When you start combining the cover with other factors, such as public land ownership, you begin to see the relationship between use and cover.

The Department of Natural Resources, together with the University of Wisconsin, has been doing an inventory of lakes. We have some 10 000 lakes in the state. (In deference to Minnesota, we probably have just a bit fewer.) There is the problem of monitoring the trophic state of those lakes. Utilizing the digital data in the infrared band from Landsat imagery, scientists have been able to classify four levels of eutrophication. About 4000 lakes, 20 acres or larger, have been studied. It took 3 months to complete the whole inventory, it was relatively inexpensive and, by comparing it to some ground samples, the scientists have a pretty good feel for what is happening. (See E-12 in technical session presentations, vol. I-A.) Research involving the Department of Natural Resources, the university, and some utility companies has been made on the effect of thermal discharges from power stations. Approximately 100 flights have been made from the Milwaukee area up to the Door Peninsula over the past year. The point of this whole effort is the relationship between those people involved. The utility companies provide the gas for the plane and the dollars to process the data. The Department of Natural Resources provides the DC-3 with the scanner mounted in the plane and provides the pilots. The university provides the research personnel, as well as the hardware to conduct the research. (See W-11 in technical session presentations, vol. I-D.)

Wisconsin also has a great number of wetlands. A consultant is doing an ongoing study of the whole continuum of remote sensing, trying to find some cost-effective method to identify and monitor wetlands. The regulators, people who have to monitor the program, would like imagery at a scale of 1:1200 so they can draw a nice precise line on the ground. Over the entire state, it would cost $10 million or more to acquire that type of imagery on a one-time basis. And while we still have 12 years to go to finish 7.5′ quad sheets, we have 20 years before we finish some basic modern soil surveys. Our geologic base information is projected to be done in something like 3050 at our present rate. So you can see that $10 million to acquire one single bit of information on wetlands is an obvious constraint.

We have had a few more applications of Landsat information. It has been an excellent communication vehicle. One of the regional planning commissions used a Landsat image of Lake Superior to show the sedimentation caused by the red clay soils. The result was a $3.7-million grant to study the problem from the Environmental Protection Agency. We are utilizing historical aerial photography to measure shore erosion rates as part of the coastal zone management program.

There are some potential applications of Landsat information that we are not using. For example, we have had a program for 2 years to identify critical resources within the state. The initial context was that you could take some remote-sensing information and other data (scientific in nature) and identify areas that were critical on a statewide basis. Two problems evolved. One, many of the scientists, particularly vegetation experts, were not comfortable using aerial photography. They had to get on the ground and take their samples as they have done in the past. Secondly, the information was not available statewide. As a result, we have gone to county-level workshops where citizens identify those local areas they deem to be critical. Those people are a valuable source of information. We had a county board member, for example, who has been hunting in this particular county for 50 years. Every time he went out, he took a little log and wrote down climatic conditions, where he went, and what he either caught or shot.

In summary, I want to make five major points. One, the objective of data collection or processing is to make better decisions. I think we need to keep that constantly in the forefront. We want to make decisions, not just collect and process data. Two, remote sensing is just one of many methods of collecting data. It needs to be used in conjunction with others, but it is not a sole source. Three, if you are going to effectively use remote sensing, you must have cooperative efforts between the state agencies and the private community, all the way from the legislature down to zoning administrators. Four, you need some level of balance within the whole system of data flow, from the collection, to the processing, to the utilization of it. And five, apparently most of the members of this audience are state or local in orientation; if that is true I think we are probably talking to the wrong audience. We should probably be talking to the scientists rather than continually talking to ourselves.

DISCUSSION

SPEAKER: We need to understand the political process better to plug in decisionmaking, and we have to develop the applications and the methodologies for using the data. The scientists and technologists have given us a powerful tool and I think we ought to use it. The capability is there; it does not need further developing to be useful. Further development would certainly make it more useful. But we have to interact on the level of policy formulation and decision. In South Dakota, we are trying to do a lot of similar things. We are developing a natural resource information system to hold what we consider the policy-relative portions of our data. But one major difference is that we are doing statewide digital analysis; about 10 percent of the state is done now and I have found it to be fairly useful, but again the problem is getting people to use the data. You can make a really nice pretty colored land use map and it can be accurate and you can give it to the district planner and he says, "Gosh, that's real nice. I'm going to put that right in the comprehensive plan on page 1 for land use." But that is about as far as it gets. And it becomes a pretty picture filed on a shelf somewhere. So I think we have to develop methodologies for applying these data and perhaps this is something done more appropriately on a national scale than a state scale. But a lot of the decisionmakers don't know what questions to ask and would rather continue making decisions in a political vein without really looking at the quantitative information. We need education for these people and we need simple application techniques.

MILLER: The training or education aspect is very important. This particular regional planning commission picked up a Landsat image and used it as part of a proposal to EPA because of an information session done by the University of Wisconsin. The awareness of what is available at a local planning level is really low.

SPEAKER: Another problem involves the question of small-scale data collection being developed at the Federal level in a number of programs, all of which, I'd say, are in borderline competition with each other. States recognize that the data are not usable in the specific programs that we deal with daily.

MILLER: Collection or mapping of information at a scale of 1:50 000 or 1:100 000 may be useful to a particular Federal program. It fills a gap that might exist in the state; but our presumption is that that gap does not need to be filled. A problem is that once you receive land use data generated from any of the Federal programs and you tell your state legislator, "We've got to have some money to acquire land use information on a statewide basis," his response will be, "It's already there." So you are basically stuck with a relatively general classification without the means to go to something more specific if it is needed for particular state- or county-level programs.

JOYCE: I am from the NASA Earth Resources Laboratory. The statistic relative to the survey that was made, I believe, was that 85 percent expressed a preference for a 1:24 000 map. It is not so important what we can do, or what we want, but rather what we can do with the money we have. Did the people in the survey make that choice in view of what it was going to cost them? Did they have cost alternatives at some other scale? And were you talking about the final map base scale, as opposed to the scale of the original imagery or photography?

MILLER: I was talking about the final map scale. Some did respond with some context of cost of other scales; the majority did not, however. They say they are collecting imagery at approximately that scale for their own use. If you went to a statewide systematic program, you could be utilizing state-level dollars to acquire that kind of information. Local communities could then focus on something finer; a scale of 1:6000 or 1:4800, which most of them say they would like to have.

JOYCE: I was involved in a similar study about 8 or 9 years ago in a foreign country, but I think the lesson was the same. On the first go-round, everyone was asked what he preferred in products, in scale, in what he wanted to do with that information. They all wanted everything in as large a scale as they could get it, the most expensive coverage, and wanted to do everything with it. Then we gave them some basic information on relative costs of procuring the different scales, of different types of imagery, of computer time, of digitizing data. We said, "If you were faced with a situation in which you had X dollars, what would you prefer the net result to be?" They all backed off in terms of the scale of the imagery. At that time, of course, spacecraft were not available, but these people wanted the plane to fly as high as possible. They wanted to put the least money into acquisition of the original imagery and to put more money into the working of that data, extracting information, digitizing other data, and comparing them.

MILLER: We asked them only about 1:24 000, 7.5′ quad and orthophotos. We really did not give them a chance to discuss alternatives. The problem is, a lot of people do not know what they really need, what scales they would like to have. They need more explicit information to make decisions. I agree that when it comes down to trading off some dollars to acquire the information they will make the trade.

SPEAKER: You said that you encountered some resistance from some of the scientists, especially those working with vegetation data, to changing from the established ground techniques. In other words, they were not rejecting remotely sensed data per se, but they were simply rejecting using new methods? Is education all that is needed?

MILLER: I think education is the biggest element. A number of people were doing vegetational analyses. Some of the students, research associates, who were working with the program were much more adaptable to the use of aerial photography as a basis for information.

SPEAKER: Does Wisconsin have what could be called a single state remote-sensing technical center that manages, for example, a film library or a film organization that provides photogrammetric services and special training? Would you advise in the state government that such a center would be organized?

MILLER: The closest thing we have now is the EMDAG within the University of Wisconsin at Madison. I think the working relationships between the university and state agencies are quite good; it seems to me an appropriate place.

SPEAKER: Do you think the experimental nature of the work that probably will be done for quite a few years yet would make the university the most logical location?

MILLER: Yes.

SPEAKER: Then, actual day-to-day activities that develop from the research of the university might be dispersed, eventually, in the various departments so the Highway Department is doing preliminary corridor studies or the Department of Natural Resources is being shown how to use Landsat infrared imagery?

MILLER: This is already happening. For example, the lake inventory was a probe out to the Department of Natural Resources to demonstrate some of the utility. The staff members there are now applying Landsat information to their inventories and they are looking at some other applications. It is an educational process. They have become more familiar with the imagery and remote-sensing techniques and now have a good enough feel for it themselves that they can begin looking at their activities and how they can apply it.

SPEAKER: You mentioned that a lot of people are just about crashing their planes into each other flying the same area. Do you have now, or do you have plans for, some kind of coordinated system to record all the types of imagery available as well as plan ahead and assign priorities to what will be flown?

MILLER: We do not now have any type of system that would coordinate these activities. The attempt of the survey was to find out who was doing what. The state cartographer will maintain some kind of monitoring on aerial photographic activities.

SPEAKER: It seems that in your part of the country as opposed to the Southeast, there is a much closer working relationship in terms of ongoing responsibility between the university in general and the state agencies. Our university people tend to stay in system development research and as soon as a program gets to be an ongoing month-after-month sort of thing, it very quickly seems appropriate to move it to our state agency. Organizations develop differently in different areas of the country.

MILLER: That is true. The state cartographer, the state geologist, and a state climatologist are all housed within the university.

CASE: My name is Bob Case, director of state planning for the State of Iowa. Does Wisconsin have any general data collection policy that has been endorsed by the governor or any other general agency policies directing the collection and use of data? I think that the thrust of this conference may be a little too narrow. A lot of the technical questions are not broad enough, are not including data collection for human resource needs. Without a compatible human resource information system plugged into the same geocoding process as our natural resources, we really do not have a system. If we get too far along in making these critical and extremely costly decisions about all the mapping and the data collection and technology without taking into consideration the broader issues, we are wasting a lot of money. We will have to back up and do the work all over again. In Iowa, we are trying without much success to get a single agency or a group of agencies together to be responsible for guiding the decisions or at least for making sure that there is a strong political interface in the decision process on data collection and its use. Since Wisconsin is well along in a lot of these decisions, what is your position on that? And what is the position of your governor about future use?

MILLER: There is no central clearinghouse for data collection. What exists currently is a board of people who decide only on topographic information and geologic information. One of the problems has nothing to do with technology; it is a thing called territoriality, where everybody wants to do his own thing, and it is competitive. There is no central policy. The state planning office, where I work, has just been charged by the governor to coordinate the development of the statewide information system which may provide some of that coordination.

TREXLER: I am Trexler from the Virginia State Water Control Board. You mentioned your lake monitoring program. After you collect your data and classify your lakes, what are you going to do then with the information?

MILLER: The Department of Natural Resources is using that, to my knowledge, as a monitoring system, not a regulatory program.

SPEAKER: Are you in the same position on the thermal sensors?

MILLER: Correct. Jim, can you comment on either of those?

CLAPP: My name is Jim Clapp from the University of Wisconsin. The frame of reference in that study was to come up with a clearly delineated critical resource in a very short period of time. The decision was that they had to use the tried-and-true method because they were going to try to document these things on the ground as a basis for some type of legislative action. They were not prepared to go to the remote-sensing base, with it being uncertain. Following that, they proposed to NASA for further research into this area under the Landsat-2 program. The lake monitoring program, using Landsat as a data base for the trophic classification of the lakes in Wisconsin, is considered a first-cut assessment to attempt to refine those areas where more detail is needed, either from a lower altitude vehicle or on the ground. This program is against the background of the Federal legislation on lake renewal programs. The program on thermal scanning of powerplant effluents into the Great Lakes is conducted in cooperation with the Department of Natural Resources at the university and the power utilities and with some NASA money. That information is being used to attempt to construct what we call a climatological inventory of those plumes under a series of different weather and wind conditions. This inventory will be an input to the hearings on the plume legislation or potential legislation as to whether or not those plants will have to put in cooling towers or can continue to discharge into the lake. It is not the only source of information going into those hearings, but it is a major one.

SPEAKER: Has this been in conjunction with the state permit programs?

CLAPP: In Wisconsin, the certification process goes through a series of public hearings. The first public hearings were held early this spring. And our anticipation is that those hearings will go on for a number of years. The data have been introduced in the hearings as a source of information. In that sense, the thermal data contribute to the certification process.

RADO: Bruce Rado with the Georgia Department of Natural Resources. Does your information system relate at all to some of the earlier I-57 type work?

MILLER: The technique that we used on the I-57 study some years ago had the grid cell as a base storage unit. We are now using a digitized pattern storage. It is much more sophisticated, and much more flexible. The coordination of the whole effort still involves most of the same people who have been working for as long as 5 years, some within the University Department of Landscape Architecture, some within the Cartographic Laboratory, some from our office, and some from the Department of Natural Resources and the Department of Transportation.

BREY: I'm Art Brey with the Office of Planning and Budget of Georgia. Please explain a little further the differences between the land use categories that you have arrived at after your 12 iterations and what technique you use in making these evaluations and determinations.

MILLER: The land use information system follows the Bureau of Public Roads classification and the Standard Industrial Code. The whole process of evolving this system started with what we call the sociological experiment. About 60 people were interested in helping, some professionally, some politically, because they didn't want the state doing it alone. And through reiteration of the system, at least 10 times, we refined the categories to meet the needs of county-level planners as well as state-level functional agencies, such as the Department of Transportation. Everybody was willing to make trade-offs in order to get a system that everybody could work with. The obvious advantage of that kind of a system is that, for example, if county A collects land use information on the same basis as its neighboring counties B, C, and D, officials can look across the county lines and both talk about agriculture. The only classification that we added we call natural areas, where you cannot classify the use of some area; it is in a natural state.

SPEAKER: I wanted to ask a question relative to scale and classification detail. And my experience has been that when you see the 1:24 000- or 1:62 500-scale mapping of the people who want large-scale data, the level of detail is less than that of the second level of the revised Anderson classification system. Do you share this view?

MILLER: I would agree. I do not think you have any more precise classification at a scale of 1:24 000. However, regional planning commissions often want to more precisely locate information.

N76-26659

S-4. Remote-Sensing Applications for Texas

John Wells[a]

If you are going to work in a state, you must understand the political processes; a technologist who does not will fail to get very far. When it comes to a choice between a technological decision and a political decision, you can guess which one is going to dominate. Texas is under an extremely conservative constitution that was developed in the mid-1870's. We have a relatively weak governor's office. Our governor can do three things: (1) He can veto legislation; on the budget, he can veto the entire budget or line items within the budget, so he has a little power there. (2) He can appoint members to boards and commissions with the approval of the State Senate. (3) He can call a special session of the legislature and specify the agenda of that session. That is about the extent of his power. He is also the chief planning officer of the state and he can exercise this power in his work with his executive agencies. We have about 230 active agencies, most of which are single-purpose agencies chartered and funded by the state legislature.

I am sure all of you have already heard how big Texas is, but I want you to understand that we have a very tough time with the sheer size of the state in all of our work. We have 254 counties. Now, just getting together 254 county maps at any scale is a chore. Our topographic mapping is in pretty good shape. The state works with the USGS in a cooperative program to map our state, and this program is going about as fast as it will absorb money. We have 24 councils of government, which are organizations that may include several counties. From time to time these organizations change as counties switch from one council of government to another. Our population is about 11 million and our annual state budget is around $12 billion. However, 70 to 80 percent of this goes to people projects. Our largest single state agency is the Texas Highway Department, which has a budget of about $1 billion. If you round off these figures and say we have a $10 billion budget, 80 percent goes to health and human resource projects, leaving $2 billion. Of that, $1 billion goes for highways. Then we have $1 billion left for all of the other activities of the state. Also, we are pay-as-you-go like Mississippi. So, though Texas is a large state, we have budget problems just like everybody else.

We have 17 agencies in the natural resources area, ranging from universities to the governor's office. We have three water agencies: a water development or planning agency, a water rights agency, and a water quality agency.

The Earth resources/remote-sensing activity of Texas dates to June of 1972. At that time, the management of the Earth Observation Division of the NASA Lyndon B. Johnson Space Center (JSC) told the Governor of Texas that various levels of government in Texas were seeking assistance from JSC for remote-sensing products, cartographic products. Because JSC is convenient, it was easy for the government agencies to request assistance. The NASA did not know how to respond to these requests or what priority to give them. We had a very productive meeting in Austin and our Governor's Division of Planning Coordination was designated as a single-point policy group for coordination of Earth resources activities in the state; this is the function that Joe Harris performs. The Office of Information Services, which I work for, was designated as the technical arm or technical liaison for NASA and the Department of the Interior. Also, NASA appointed Leo Childs as the liaison person to work between NASA and the State of Texas.

One of our first activities was to seek out the decisionmakers in our state agencies and tell them about the capabilities of remote sensing. We spent several months, talked to around 100 individuals in 20 to 25 agencies, to inform them about the remote-sensing products that were available. We did not really emphasize anything that was not in production; we stayed away from some of the more exotic research areas. The orientation sessions were very successful, if only for one thing, which I later found is important. They helped people in agencies build up a vocabulary so that we can talk with those we seek to help. If we cannot communicate with them, it's all over. After the people were better able to converse about remote

[a]Governor's Office of Information Services, Austin, Texas.

sensing, we conducted a data-needs survey. A product of this survey was the identification of the things that we feel are Texas priorities in natural resources. The data-needs survey was updated and is fairly current now.

About that time, I think it was in early 1973, the Congress passed the national Dam Safety Act, under which the U.S. Corps of Engineers had to survey all of the water impoundments in the country of 10 acres or larger and determine whether or not the dam structures were safe. The Corps approached our Water Rights Commission to conduct this survey for them. Texas has a dam licensing activity for water impoundments of a certain size, so structures have to be licensed, and the commission was in the process of seeking out these water impoundments. A combination of digital, photographic, and traditional methods was used to accomplish this inventory. One of the benefits of this project was to locate water impoundments in the state and determine the magnitude of the licensing job to enable the Water Rights Commission to establish a plan to get the job done and to ask the legislature for the necessary money. I think they determined that at the rate that they were working, using traditional methods, they never would have gotten the job done. There were more impoundments being built than they had the capacity to license at that time.

In March of 1973, the Remote Sensing Task Force was established under our Interagency Council of Natural Resources and the Environment. In about 9 months, the Remote Sensing Task Force produced a remote-sensing plan to which all state agencies contributed. A little more than a year ago, we also started a remote-sensing training program in cooperation with Purdue University. Also, we determined that Texas was eligible for a Landsat follow-on proposal. The people on the Remote Sensing Task Force produced a proposal that was accepted and funded by NASA. It is beginning now.

Uses we have found for remotely sensed data include most important land use, meaning a survey of what is located on the ground now, not what its potential is. We had the water impoundments survey. And recently we conducted a wildlife habitat survey. The data can help in coastal zone management. Our long-term uses remain to be seen. They will probably be in the coastal zone or in the entire state. We determined the top state priority was water. We are very concerned about water, probably because our next most important state priority is agriculture. Without water, you don't grow any agricultural products. Then third is energy.

DISCUSSION

WINIKKA: Have you had any programs in the early stages now working with the universities in Texas?

WELLS: Most definitely. We work with the University of Texas, and with Texas A. & M. Our remote-sensing training program would not have been successful had it not been for the people from the University of Texas. And, we hope to have LARSYS from Purdue installed on the computer at Texas A. & M.

RYAN: I am Pat Ryan, director of State Planning in Louisiana. Do you have any programs to relate other types of data to your remote-sensing information, such as educational data, revenue data, transportation data, and soft sciences?

WELLS: The bridge between these other data sources has not been built. In the natural resources area, we have identified that which we call socioeconomic to cover all of the data sources.

RYAN: What type of appreciation have you developed on the part of elected officials for this type of service?

WELLS: Some elected officials within the state are very keenly aware of natural resources problems and have come to us. Elected officials from the metropolitan areas of Harris County on the Gulf Coast and from El Paso have sought us out for advice and information. We have not had a great deal of contact with people from other areas of the state.

SPEAKER: You don't call your land use information program "land use," do you?

SPEAKER: Absolutely not.

GOESLING: I am Paul Goesling, chief of Development Planning for the State of Ohio. Do you see any benefits in having your remote-sensing program in the hands of political-type people, in the political process?

WELLS: I'm not sure I know how to retrieve it from those hands. My general philosophy is that the political process should direct the activities of the people that are serving the state. And if this is political influence driving the technologist, that is the way it should be. The service of the state should follow the direction of the concerned people of the state. And I anticipate that to be demonstrated through the political process.

SPEAKER: Are you using LARSYS in state computers now?

WELLS: No. Texas A. & M. is going through the process of computer hardware acquisition, an IBM 370/168, which is compatible with LARSYS, and that acquisition is not complete. The batch version of LARSYS is installed at the Texas Water Development Board. It is operating in batch mode. But the teleprocessing capability is not. Also, the Texas Parks and Wildlife Department is planning to install the system. We do not have a centralized computing facility. Instead, each agency provides its own computer power or buys time from another agency.

CHILDS: If you were going to go back several years and start over, what would you do differently?

WELLS: The technological problems are simple compared with acquisition of money and communicating with those people that you need to communicate with. So, if we went back and did it all over again, I think I would start working first with the acquisition of money, concurrently with improving our communications capability with the people with whom we are working.

WERMUND: I am Jerry Wermund with the Texas Bureau of Economic Geology. When we have produced viable products of use, we have gotten political backing and/or money. One reason the Texas Highway Department has a reasonably good budget is that it has been a leader for a long time in the area of photogrammetrics, which I also think of as remote sensing. So, while I agree that we have not moved terribly fast perhaps in developing an overall state inventory system, we have made some considerable advances and when we show a viable product, I think we do get reasonably good backing.

WELLS: I certainly did not intend to give the impression that we have not produced anything. We have. Jerry has done some very good work, and Tommy Howell in the Highway Department has one of the best photogrammetry shops that I have ever seen. We have also done a lot of work in computerizing our natural resources information system. We have a lot of work to do, but we have a useful tool already and we produce some useful remote-sensing products.

BANKSTON: A point has been raised about ticing in socioeconomic types of data to these natural resource systems. Provisions can be made for that in the type of system I was describing. It is unrealistic to think in terms of one massive system that will take care of everything, but there must be ways to tie things together. In our state, for example, we have an extremely high incidence, particularly among blacks, of sickle-cell anemia that seems to be concentrated in the delta area. Some long-term research done by the medical community might relate this health problem to a natural condition. We also have a higher than normal incidence of hypertension. We must stop and work closely with a variety of health-care service agencies to develop information systems, and we are making sure they are all compatible.

N76-26660

S-5. Remote Sensing in Arizona

Carl C. Winikka[a] and Robert E. Adams[b]

There are certain common trends and some differences among the states represented here. I think in Arizona we have some special differences, while we have many items in common with other states. Our state is very receptive to remote sensing, with clear weather and not much rain. It is highly visible, although the U.S. Geological Survey has said that not all of it is very photogenic. Some of those deserts do not show up too well and the details are not too visible either. In Arizona, we have quite a bit of land that is just open, what you would call wasteland. It is natural and there has been very little development. Elsewhere, the pressure on development land throughout the state is increasing. These activities are not necessarily bad in themselves, but decisions must be made affecting this land and how it is to be handled.

Arizona does have a fairly large area, about 114 000 square miles. About 16 percent of this land is privately owned; 44 percent, Federal; 27 percent, Indian reservation; and 13 percent, state-owned. Some of our 14 counties have less than 5 percent of private land (fig. 1). Some are mostly Indian reservations, and figure 2 illustrates how these are distributed. National forests occupy about 16 percent of the state. In addition, 17 percent of the state is controlled by the Bureau of Land Management. If we take all of these ownerships and put them on one map (fig. 3), we see checkerboards within checkerboards. If you have the red squares, you sure want to know what the men in the black squares are doing.

One problem here is really coordination. But a more far-reaching problem is the fact that much of the information that people have been talking about here does not yet exist in Arizona. The public land survey has not been completed. A substantial part of the state has never been surveyed for townships. Approximately 30 percent has no topographic mapping at either the 15′ or the 7.5′ scale. Soil surveys are nonexistent in much of the state. So, of course, we lack the more detailed information that we might derive from these maps.

In 1972, we held a series of meetings with NASA, several other Federal agencies, and state agencies to discuss how we could approach the problem. The outcome of that was what we call the Arizona land use experiment. We were considering how we could take advantage of new technology, either existing or coming up in the future, to cover Arizona in a fairly uniform system. Under the land use experiment, NASA provided high-altitude imagery of the state. Each U-2 aircraft had five cameras onboard: a mapping camera, three 70-millimeter multispectral cameras, and one color 70-millimeter camera. The color was for preparation of orthophotoquad maps and also for interpretation. Figure 4 is an example of the color imagery we acquired. We have found that the users are often accustomed to large-scale work. The high-altitude, small-scale imagery is really effective in bridging the gap between space imagery and what the user has been accustomed to.

As a result of this program, we will have an image base of the state prepared by USGS from the Landsat imagery. We are looking to this base as one means of communication among many agencies.

Some obvious flood areas are visible in figure 4. As a result of seeing this from high altitudes, the local government stopped some planned developments in that area. A recent report by the Office of Economic Planning and Development covers remote subdivisions. Figure 5 illustrates the use of this base with schematic overprinting.

Orthophotoquads prepared from the U-2 photography are at the 7.5′ quadrangle scale. Figure 6 is an example.

Much of the land in Arizona is open country, but activity on that land often depends on natural vegetation. So, with the vegetation people, we have produced a vegetation map of the state (fig. 7), a booklet, and a natural vegetation classification system. We have made this compatible with the U.S. Department of the Interior (USDI) classification. The category of natural vegetation includes 160 acres of tundra on the

[a] Arizona Resources Information System, Phoenix, Arizona.

[b] Arizona Department of Transportation, Phoenix, Arizona.

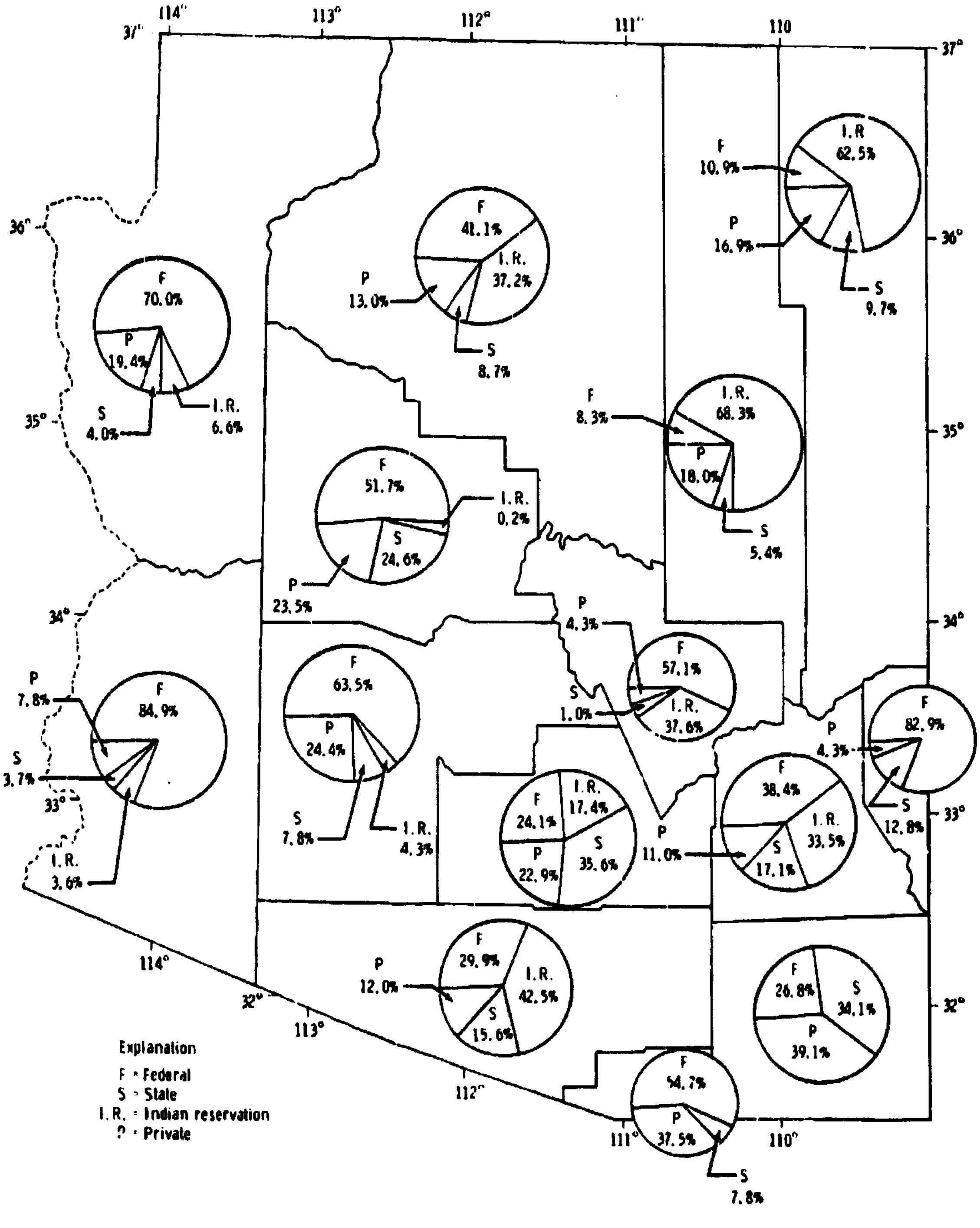

Figure 1. Distribution of land ownership in each Arizona county.

peaks, the near-tropical reeds found in the Yuma area, and all the woodlands, rangelands, and so forth in between.

We were unable to complete orthophotoquads in some areas. In the Grand Canyon section of the state, because of the rough terrain, we had to settle for enlarged aerials. We were able to use Landsat imagery by projecting the photographs on an I^2S viewer and photographing the screen (fig. 8). This is strictly a photographic process, not done from tape. Figure 9 is an enlargement of the central portion of figure 8. The obvious tear-shaped clearing is, I believe, about 3 miles long.

Breaks in vegetation on the ground, such as that illustrated in figure 10, also show up quite clearly on the Landsat photographs. The clearing in figures 8 and 9 is an example.

In the urban development around Phoenix, we are losing a great extent of our agricultural land and we consider this a problem. Some people say, "This is just the way things are going." The local government is not really able to do much about it. The state legislature this year had what I think was a very good land use bill, addressing problems of changing land use; however, it did not pass.

To illustrate the information that can be obtained about urban and suburban areas, figure 11 is a low-altitude view of Sun City. Figure 12 shows the same circular development from a U-2 at 65 000 feet. Figure 13 was taken from Skylab; the development has changed again. This is a way of keeping track of development strictly by photography or physical imagery.

We also are concerned with developments in the desert. New construction does show up quite light in aerial and satellite imagery as you raise dust in a desert area. It is highly visible.

Arizona does have open-pit mining (figs. 14 and 15); this state produces more than 50 percent of the nation's copper. In some instances, these pits are considered objectionable, and a balance is required between economic development and the effect on the esthetics of an area. These two figures illustrate the transition we can make from ground to high-altitude information.

Arizona also has a fair amount of agricultural land. Figure 16 shows how agricultural areas appear in red on color-infrared imagery. Figure 17 is of a flood control dam with some agricultural area around it, and figure 18 is a closeup of the agricultural activity. We are going to be working with the U.S. Department of Agriculture to consider this type of imagery for determining which agricultural land has been active.

One way to make a quick graphic transfer of information is by a Zoom Transferscope (fig. 19). Such information as school district boundaries can easily be overlaid on an orthophotoquad. The Soil Conservation Service and the U.S. Forest Service are both using the 1:24 000 orthophoto base for some of their work. Various kinds of information are being recorded on this accurate base and we believe the base is suitable for eventual input into computer systems.

During the past year, we have just been getting the system together. I expect we will go through a reassessment and regrouping as we put some of these things into operation. If we want to predict the future, we can just glance back and see where we were 5 years ago in remote sensing. Most states have taken tremendous steps in the past 5 years, and at least that much progress can be expected in the next 5 years.

I see a need for at least one center where emergency-type information from space can be assessed and put into the hands of the user almost immediately. The technology is here and I think it should be available in an emergency situation, such as a flood. I am sure people from any state would be willing to go to such a center to get the information and get it to the decisionmakers.

Another problem as we look ahead is changing to the metric system. An adjustment of the grids will be needed in North American data. My primary advice now would be to stay flexible in order to adapt to new systems as they come.

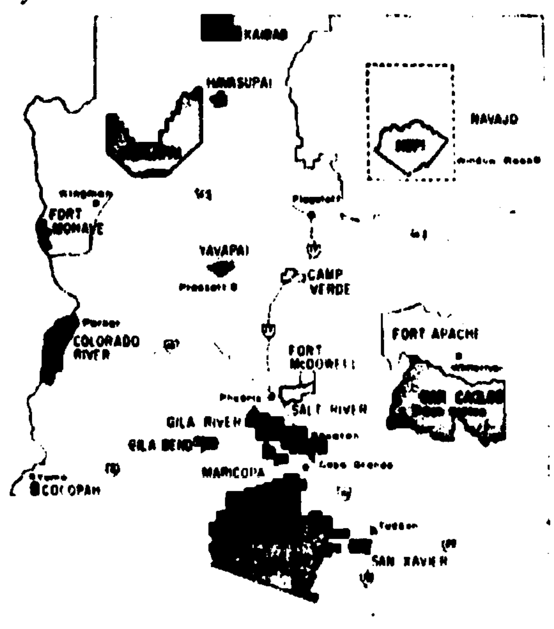

Figure 2. Location of Indian reservations in Arizona.

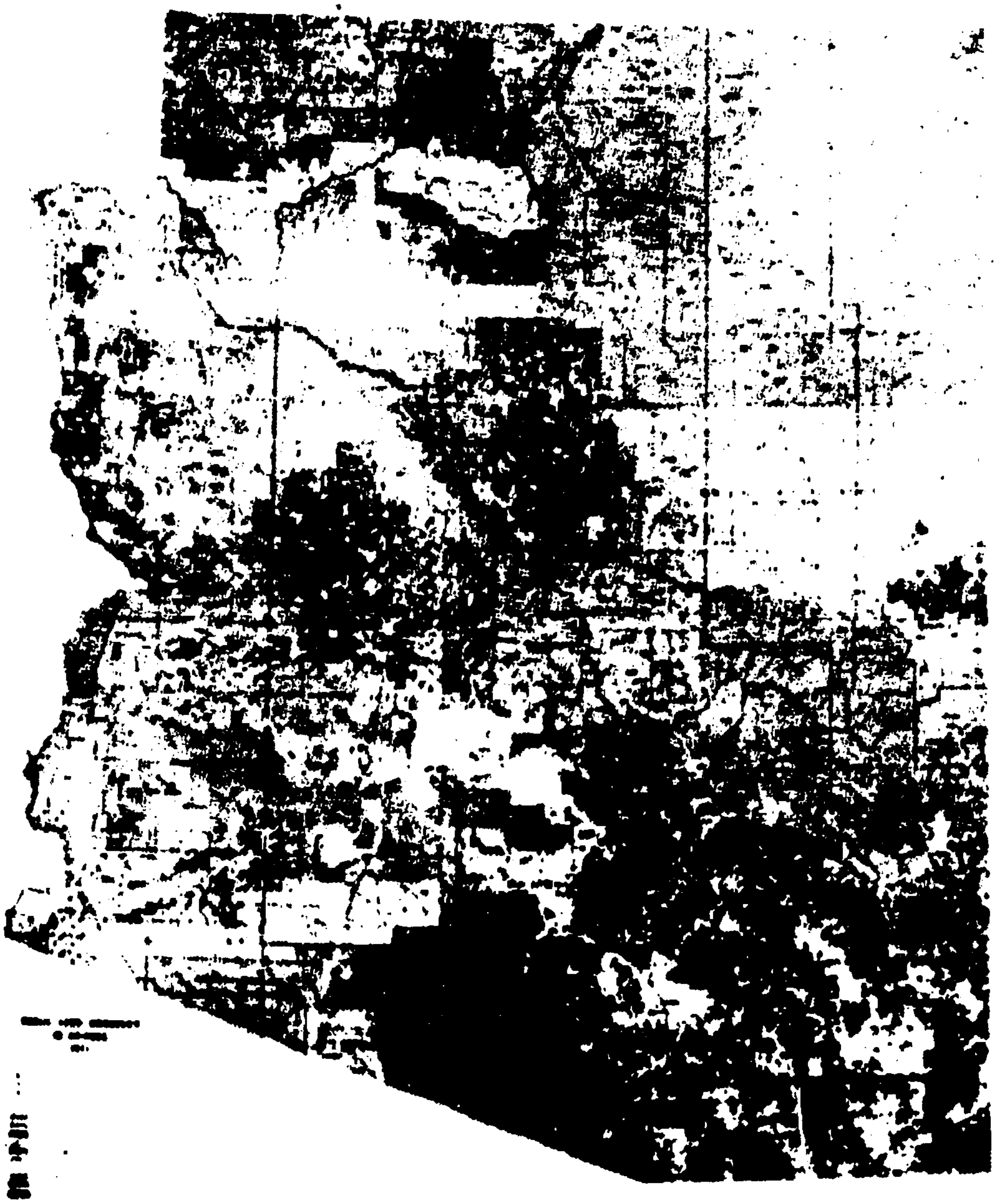

Figure 3. Detailed map showing all types of public land ownership within Arizona.

Figure 4. Floodprone areas are visible in this photograph taken from an aircraft at 65 000 feet.

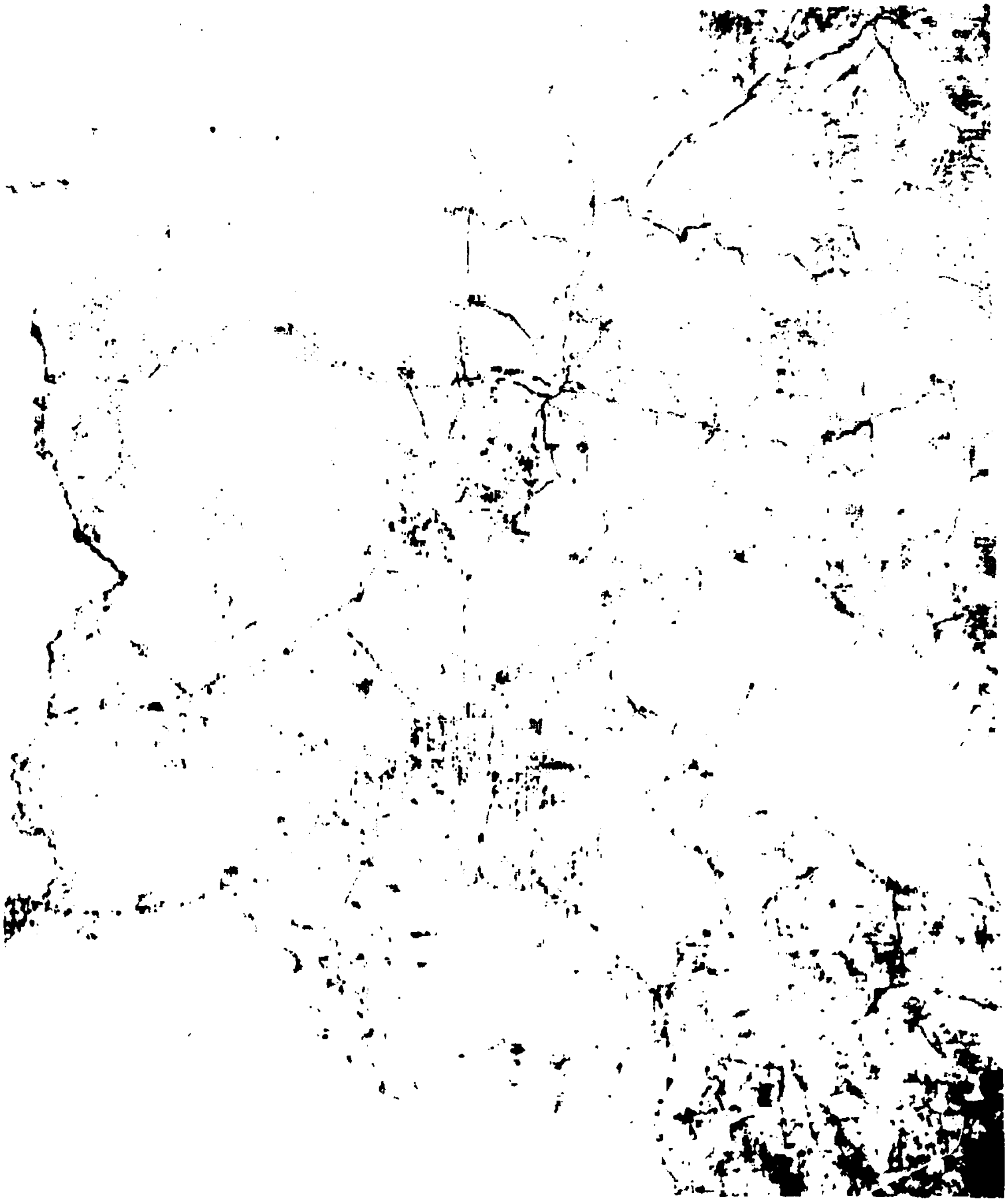

Figure 5. Map shows locations and concentrations of remote Arizona subdivisions. Each dot represents a section of land in which a planned subdivision has been recorded, but not necessarily built.

Figure 6. Example of a standard 7.5' orthophotoquad.

Figure 7. Vegetation map of Arizona.

Figure 8.—Photograph of a Landsat false-color image of the Grand Canyon area on an I^2S viewer.

Figure 9.—Enlarged section of figure 8, showing how much detail can be seen.

Figure 10. View of a break in forest vegetation. This sort of feature is easily visible on satellite imagery.

Figure 11. Low-altitude view of Sun City, Arizona. At the time this was taken, developers were completing about 11 houses every day.

Figure 12.- High-altitude photograph of Sun City taken from a U-2 at 65 000 feet. The same circular pattern seen in figure 11 is visible here.

Figure 13. Skylab view of Sun City area taken more recently than figure 12. The circular pattern seen in figures 11 and 12 is still visible from this higher altitude.

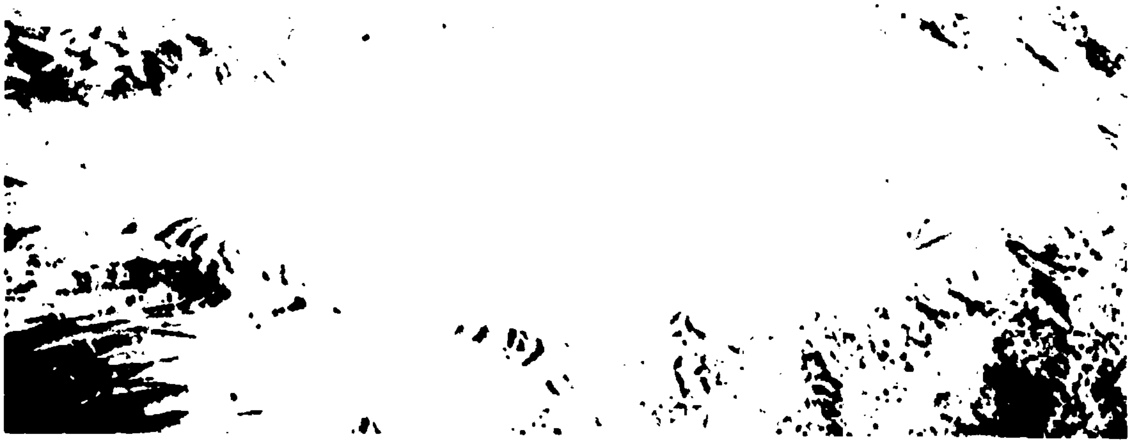

Figure 14.– Open-pit copper mining seen from a low-altitude airplane.

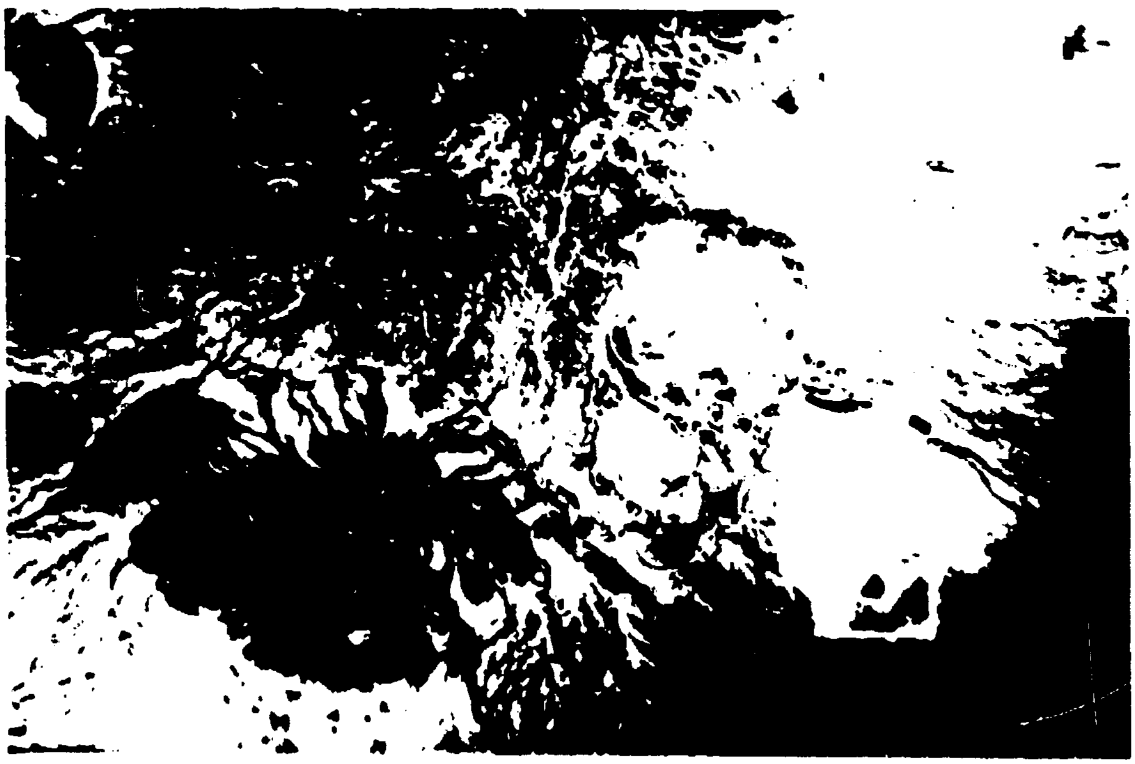

Figure 15. Open-pit copper mining seen from a high altitude.

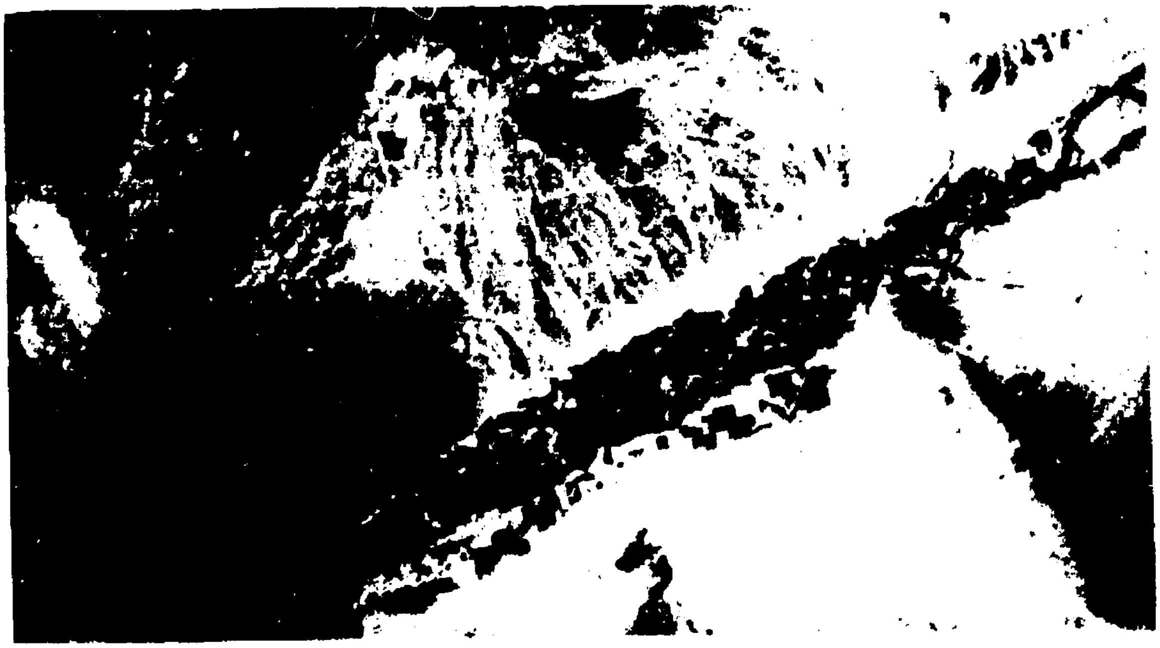

Figure 16. Agricultural areas stand out in red on this color-infrared imagery.

Figure 17. A color-infrared view of a flood control dam and nearby agricultural areas.

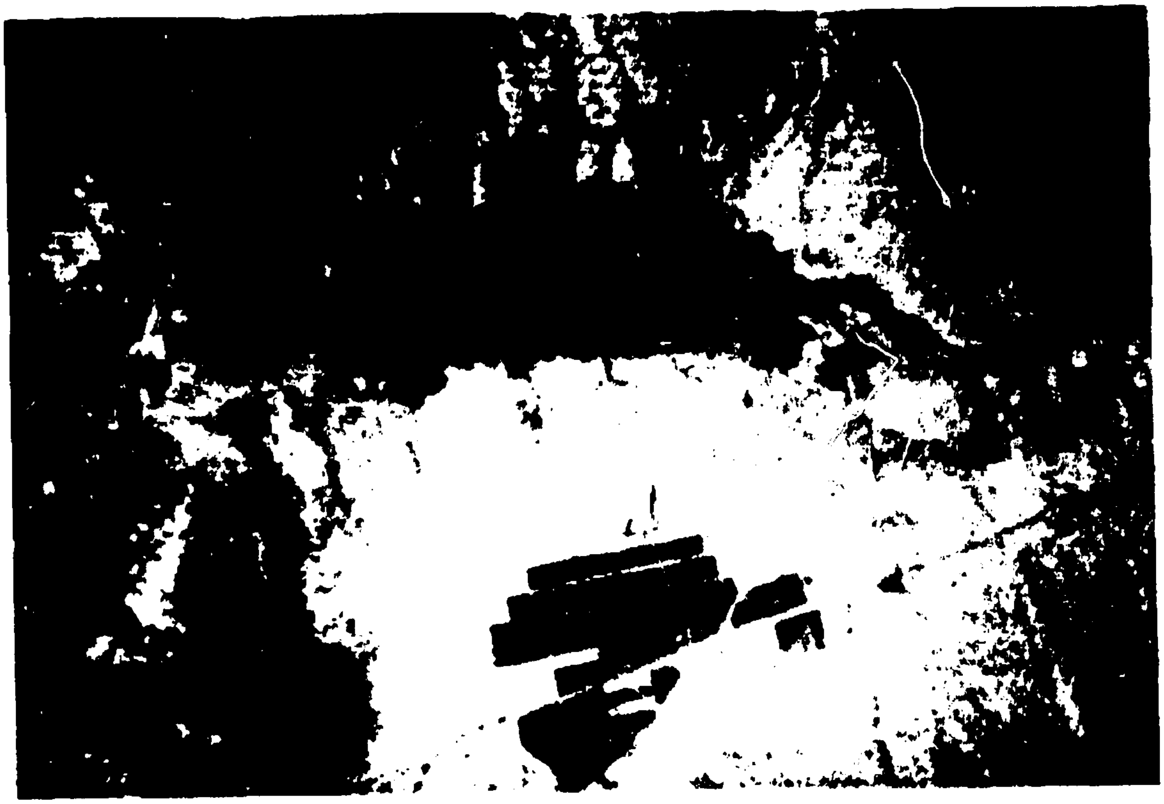

Figure 18. An enlargement of the agricultural area and reservoir seen in figure 17.

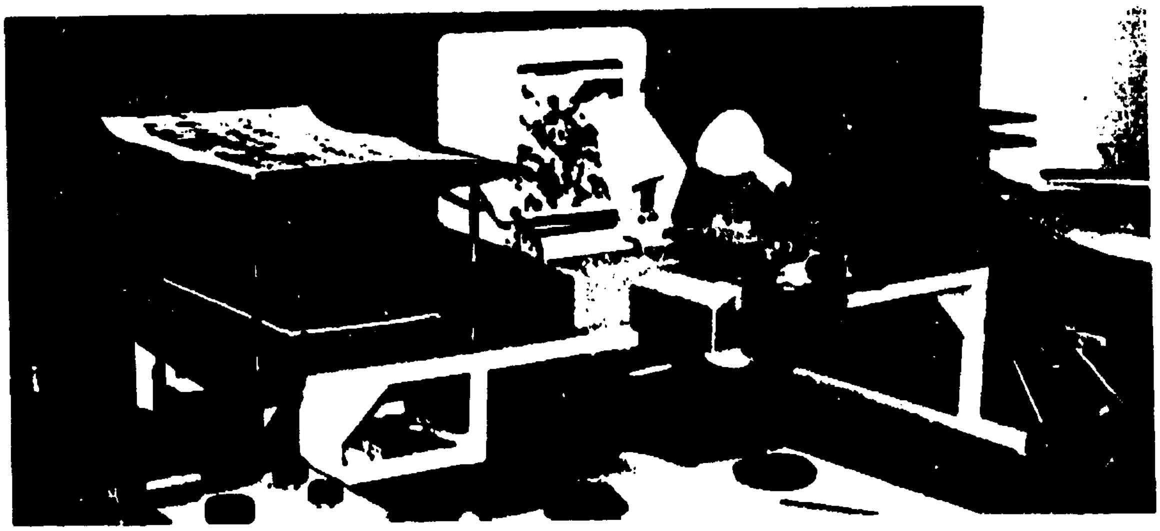

Figure 19. A photograph on a Zoom Transferscope, used for quick graphic transfer of information.

DISCUSSION

LEONE: Frank Leone from Ohio Natural Resources. I am familiar with the Arizona trade-off model, which, I understand, evaluates environmental, economic, and demographic conditions and is used as a decision tool. How, if at all, are the remote-sensing data used in the Arizona trade-off model? Are these data at a resolution compatible with other parameters?

WINIKKA: There is no feed into that system at this time. It was operated for evaluation by the Office of Economic Planning and Development, using a cell size of 60 square miles. We have not crossed the gap on how we would input, but I am sure this will be considered for the future.

WILSON: Jerry Wilson, Federal/State Land Use Planning Commission for Alaska. How does the public get access to your data? If a citizens' group wants to look at an area, how can they?

WINIKKA: We have an open office as far as the public is concerned. Unless we would have to schedule people, they can drop in any time. We have miners stopping in and people from cities and counties come to see an area in which they are interested. They can look at the data in any one of several ways. We have the orthophotoquads completed of the state, we have NASA imagery, and we have viewing equipment. If they want copies of the orthophotoquads, they are available in several formats. Citizens can get them photographically or, for some areas now, in blackline or blueline copies.

WILSON: What are you doing about training? Is your imagery coming into your universities? Is it coming into local community colleges?

WINIKKA: We have fairly close contact with both Arizona State University and the University of Arizona. The University of Arizona has an Office of Arid Lands that is getting a copy of the Landsat imagery on a regular basis. Only two or three junior colleges are actively interested in this area. We are not sending anything to them but people from junior colleges have been in the office working on studies or picking up material.

HUNT: Bill Hunt from Montana; I am a representative of the Department of Intergovernmental Relations. In Montana, we have one of the problems you do: some of our land is fragile and perhaps should not be developed. Have you been able to use this imagery to convince the legislature of the problem? Have you been effective? Have legislators shown any interest?

WINIKKA: We have not had a formal opportunity within the Office of Economic Planning and Development to show any of this material. However, many legislators are familiar with it. We had some fairly strong support in the legislature; however, it just was not sufficient. We are ready to begin a project to detail the land that is being taken by remote subdivisions. In some instances, developers scratch out some roads and sell lots to people throughout the country. No further work is ever done on the subdivision. We will be using this very graphic means of illustrating the problem.

MOODY: Steve Moody from Missouri. A person from NASA told me he considers the states to be the prime users; I disagree with that. Our state is the generator and our primary users will be regional planning commissions, counties, and cities. Did you actually involve these people when you developed the systems? If so, how did you do it?

WINIKKA: The proposed legislation on land use had a strong emphasis on local control. Any land use bill that eventually passes in Arizona will include strong local control. More specifically, our material is definitely being used by counties. For example, one county is using it to evaluate census boundaries. Several counties are inventorying their county roads for the first time. The scale of 1:24 000 is not terribly suitable for cities and, for that reason, the cities are not active in using it.

SPEAKER: Did you ask the cities and counties what they needed?

WINIKKA: Not directly. There was no information existing and the counties had often been working at smaller scales than ours. So our information was readily accepted. The counties find this scale acceptable for most of their work.

SPEAKER: It seems to me it is going to take a lot longer time to go back and influence the user to use what is available than it would to bring him in before you begin. I realize this method will result in a longer time to set up the system originally, but when it is done it will be most usable.

WINIKKA: Our approach was primarily from the state agency standpoint and we did have a dozen or more state agencies involved and very supportive of the work and the scale.

SPEAKER: This system is still in an evolutionary stage. The counties were involved early in the evolutionary stages and have been very supportive in the development of this system. They did have strong input in the initial design of what we were trying to do.

N76-26661

S-6. Alaska's Needs in Remote Sensing

John L. Hall[a]

Future shock has hit Alaska: the Trans-Alaska Pipeline; the proposed Trans-Continental Gas Line; 44 million acres of new private land; 80 million acres of new national forests, parks, and wildlife refuges; 104 million acres of land to go into state ownership; relocation of our capital city from Juneau to somewhere west of the 141st parallel; a horrendous offshore oil development proposed by the Federal Government; and bulging urban sprawl. The last frontier ended in 1975.

The new private native corporations, the expanding state agencies, and the Federal agencies are all in need of the most modern and best services in all phases of remote sensing. To emphasize this point and the problems we face in Alaska, I would like to quote from the letter dated November 6, 1974, from Robert C. Simmons, Jr., chairman of the National Research Council, to Dr. James Fletcher of NASA. The subject was the tentative recommendations of the Space Applications Board (SAB). I'll quote out of context: "Another group of panel recommendations is under study. These recommendations, while they deal with problems the SAB considers valid, suggest solutions that the board wishes to consider further before reaching conclusions." I think we are working on those.

The recommendations relate to the following problems. There is an important transitional stage between research and development and the implementations of operational applications systems. In this transitional phase, the technological capabilities of the system have been demonstrated but the user community has not yet had sufficient opportunity to try the system and decide if it should replace or supplement older methods. Some authorities consider that the National Aeronautics and Space Act of 1958 authorizes NASA to work in a transitional phase; others do not. Under the circumstances, NASA has refrained from carrying demonstrations beyond technical feasibility. As a result, potential users have not had adequate opportunity to evaluate new services. They exist at present. No existing insititutional mechanism permits a large body of potential users (which the board sees as existing in state and local governments, in the business communities, and in educational institutions) to express their needs and have a voice in matters leading to the definition of new systems. Today, it is the providers of space systems who devise what they believe are useful requirements and proceed to build experimental systems. They then find themselves in a position of trying to sell this technology to prospective users. We have all seen this during the last 3 years. This process needs to be reversed. The board perceives a need for some organizational mechanism designed to ensure user participation in defining the system. I think that is one of the problems we are facing here.

These recommendations came from the strong recommendations of the SAB Panel on Land Use Planning, on which I served. The panel made the following recommendations related to factors which it concluded were inhibiting exploration of the potential use of satellite-derived information in land use planning. The panel recommended that studies be made to resolve issues in the user community concerning grid size, accuracy, and map projections. It called for the capability to provide users with information products, to process to varying degrees, and to verify the accuracy of the products. It recommended that joint Federal/State remote-sensing centers be established regionally to provide locally oriented research, development, operational, and extension services to users. It recommended, that, in view of the pressing requirements for planning land uses in Alaska and the unique opportunities that exist there, a prototype remote-sensing center be established there immediately. It recommended that NASA be authorized by Congress to provide operational and extension educational services to both public and private users regarding data extraction and utilization. It recommended that users participate in the planning process by providing information requirements.

The panel informally guesstimated that nonfederal agencies will spend approximately $250 million per year in the next decade collecting information that

[a]Joint Federal State Land Use Planning Commission for Alaska, Juneau, Alaska.

satellite-based remote-sensing systems could supply at a 30-percent-lower cost.

We have a start in Alaska, but it is not enough, not when we are faced with settling the state, the land pattern of the state, and social and economic cultural issues in a very short 5-year period. No conference or symposium is good unless it produces some action. As a suggestion, I would urge that you think about these recommendations. Congress has bills before it that would authorize and direct NASA to be in the operational and extension field. Although these bills might not give all the right answers, they are a start in the legislative process. I urge you, the local and state users and those involved in the Federal Government, to support this type of legislation. And if you think you can do a better job, draft your own ideas on legislation and contact your congressman. The joint Federal/State remote-sensing centers were recommended because we felt it necessary to get the information out to the users and consumers. These centers could be patterned after the forest and range experiment stations scattered throughout the nation that are operated by the Forest Service of the U.S. Department of Agriculture. I know some of you are thinking, "Hey, we need one in our state!" The governors, commissioners, legislators, mayors, corporate presidents and boards, planners, and managers need the information now. This is so true in Alaska. I think most of you would say the technology is probably 25 years ahead of the application in the field. And, as users, we just can't wait for the present government institutions to respond. Therefore, the administration, the Office of Management and Budget, NASA, and the Departments of the Interior and of Housing and Urban Development (HUD) must accept their responsibilities and provide their latest and best remote-sensing information to the planners and decisionmakers at the state and local level in both the private and public sector.

In the analysis of Alaska, the 44 million acres of private land is only 11 percent of the state, but the native corporations (native in Alaska refers to Eskimo, Indian, and Aleut) will control roughly one-third to 40 percent of the state's resources, subsurface and surface. Now, a big question we face is: what type of easements should be reserved on their land by the Federal and State Governments before it goes into private ownership? This is a very controversial problem and, of course, one that remote-sensing data really can help in resolving. We need high-altitude photography. We could have it from NASA and the military. All we need is about 60 000 flight line miles. We already have an excellent statewide inventory from old remote-sensing data, photography taken by the military in the 1940's and early 1950's and a series of resource maps on a scale of 1:250 000 for the entire state. We divided the state into quad-quads based on USGS 1:250 000 quads; there are 46 for the state. We have a set of 20 to 25 resource overlay maps for each quad-quad. We have divided the state into six planning regions and we are preparing a series of regional atlases. These were a result of interagency cooperation between the state and the Federal Government: HUD, USDI, and the Division of Planning, Development, and Research in the governor's office. The commission has published a statewide inventory based on the 6 planning regions and the 18 subregions. One thing our inventory shows is how little we know about the state. Sometimes, as the nation focuses on its needs for oil and gas, wilderness, national parks, and wildlife refuges in Alaska, we get a little bit bitter when we see the amount of money that our nation has put into other parts of the world. Now Alaska's needs are great and we face important decisions and we're short of data.

To summarize, the two important points I have tried to bring out are, one, the need for NASA to get into the operational, educational, or extension field. This requires an act of Congress. And two, the idea of remote-sensing centers. The Forest Service experiment stations have worked and remote-sensing centers could work. Low-altitude, high-altitude, and satellite data really need to be centralized in one spot.

DISCUSSION

HITCHCOCK: Just a comment about the centralized remote-sensing centers. The Tennessee Valley Authority has had some experience with different extension-type work. We have seven states in the Tennessee Valley, three forest experiment stations, and three NASA organizations we are dealing with (Bay St. Louis in Mississippi, Kennedy serving Georgia, and Huntsville serving Alabama and Tennessee). Remote-sensing centers would be good provided they don't force the states to conform to each other so that they would have to use one very inflexible data source. If the centers try to make the data flexible enough to fit each state's individual system, there will be a benefit. If the centers try to convince states to use any specific system, they will fail; they just have to be careful.

SCHUMANN: I, too, would like to talk about joint State/Fe tal centers. We considered this seriously in Arizona. I have several questions. What is the current status of the proposed one for Alaska? Would you visualize the scope of these activities as simply data analysis and applications or would we get into data collection as well?

HALL: Right now, it is still in the planning stage. In answer to your second question, it would be data collection and, to a point, analysis. This part has to be worked out yet.

SCHUMANN: I think we would see across the country that these centers would be unique to the state or to the area. Each one has different problems. How do you visualize funding of these State/Federal co-op programs, or how would they work?

HALL: It would be very desirable to go back to the bills in Congress on NASA to get them in as lead items. It would be best if shares of the Department of the Interior, HUD, and others could come right off the top. How much should the state kick in? Our present commission is funded 50-50. My own feeling would be that the Federal Government might have to kick in 60 to 70 percent. I would emphasize that every state and region is different. In the legislation, you must have a fixed figure and it definitely should be a firm, strong financial commitment by the state.

MYLES: I am Ron Myles, State of Oregon, and I feel a kinship to Alaska to some extent. We are the 10th largest state. We have 75 percent of our population living in one valley, but we have vast unexplored land to develop and, fortunately, not under the pressure that Alaska is to develop it tomorrow. I have a concern about user definition of need and getting a body to implement those needs defined by the users. I see in the discussion thus far the various states and their needs being just another version of what went on in Wisconsin and Texas. If we are hoping to get Federal involvement and implementation, we had better get together on what those user applications and needs are going to be. By the time you pull all of the various user applications together for 50 states, you have something that nobody, including the Federal Government, is going to want to tackle. I just hope that states such as Alaska do not go the way Oregon, for example, has been over the past years, trying to develop everything on an insular basis. Many of the applications and many of the means of implementation have been developed. Somehow we must pull it all together. Otherwise, these special uses are just going to overpower everybody, including the Federal Government.

HALL: You must assign priorities so that you are not doing 12 similar projects. I know this has happened in many other organizations.

HEDRICK: My name is Wally Hedrick; I am responsible for the remote-sensing project with Pacific Northwest Regional Commission, for the States of Idaho, Washington, and Oregon. I was surprised at the estimate of $250 million per year to gather information by the private sector, nonfederal. That probably is even a low estimate. Do you have any ideas on how to involve the private sector, the large natural resource agencies, the forest product agencies, in some kind of remote-sensing program?

HALL: In Alaska, our private sector is now 12 regional corporations who will own these subsurface rights to the 40 million acres and then about 204 village corporations who will control surface rights on the 44 million acres. We may have a unique situation there. My experience in dealing with large companies is that sometimes they have their own programs, but here again there is an opportunity for coordination. A lot of private low-level and high-level photography has been done in Alaska and, of course, the public sector cannot get hold of it. It would be nice if we could, but you have to get into reciprocal agreements; that is, what do you have that they want? The opportunity for private industry to take a very active part in these centers has to be considered, as well as the opportunity for the research arm, mainly located in the universities.

BOOTY: We visited Bay St. Louis a year ago and were definitely impressed with the facilities. We would like to see those types of facilities around the United States but I don't know if I would care to have Federal agencies doing all the work. I think state personnel ought to be doing the work as much as possible with guidance from the Federal agencies.

HALL: If I indicated to you that they would be staffed by Federal people, no. We have found it was desirable to have 50-50 state and Federal people. If you don't have the state personnel, you may have to hire the individuals as employees of the center. But I think to make them successful you must have the state and also the local users, the boroughs and counties, as a part of it. You would have to draw upon all sectors.

SPEAKER: I fear that if the information was just generally given to the states, it would just sit on the shelves like many other plans do.

HALL: That's a very good point and one that I think would have to be followed up because it's so true. We found this in our inventory. In fact, we were accused of being too much on the Federal side just because few state people were available.

SPEAKER: In the matter of data acquisition by aircraft, I'm talking about the high-altitude aircraft that are research only with NASA. The USGS does not have the hardware. Private enterprise can do some of it, but if a state wants it, it pays 100 percent state dollars. Do you see the possibility of either NASA or USGS expanding cooperative programs to get into some sort of arrangement where if a state wants to be flown, the Federal Government puts up part of the money and the state puts up part and we all use the data?

SPEAKER: The orthophoto is now considered a standard mapping product by the USGS and is available on a cooperative basis.

SPEAKER: At what scale?

SPEAKER: We have just launched into a program to develop 20 000 orthophotoquads nationwide to be done with contract Lear jets at 41 000 feet.

SPEAKER: The nonpoint program of the Department of Agriculture might also be considered. That type of imagery is going to be needed for any nonpoint sources and it will be one of the problem areas in the future. The SCS has said that there are 500 to 600 more pollutants from nonpoint sources than from point sources. This is controversial, too, because it is land use.

PARRISH: Right. We passed a law in Georgia requiring every county or city government to come up with a sedimentation erosion ordinance in 2 years. And for local people to do that work, they will need the kind of data we can't provide to them right now.

SPEAKER: The Department of Agriculture is also looking at the resource conservation needs inventories and may use remote sensing the next time around instead of the 2-percent sample.

N76-26662

S-7. User Requirements for Project-Oriented Remote Sensing

H. C. Hitchcock,[a] F. P. Baxter,[a] and T. L. Cox[b]

INTRODUCTION

Foresters and land managers of the Tennessee Valley Authority (TVA) have long regarded remote-sensing technology as a valuable resource tool. The Division of Forestry, Fisheries, and Wildlife Development uses remotely sensed data in the analysis and appraisal of the regional timber industry and the forest resource situation. One of the earliest applications of remote sensing in this program area was during the period 1937 to 1940; TVA foresters, aided by 1:24 000 planimetric sheets and aerial photographs, produced a valleywide forest-type map (ref. 1).

In the 1950's, a continuous valleywide forest inventory system, relying heavily on aerial photography, was initiated. Photointerpretation provided sampling expansion factors based on forest area estimates. Additionally, the photography aided fieldmen in plot location activities. Today, aerial photographs are used to update forest area estimates and to monitor land use changes related to the valley's forest resource situation.

Remote sensing has been used in programs related to wildlife habitat evaluation, strip-mine reclamation, and general land use mapping. All the applications involved photointerpretation, with field verification as a single data source for solving natural resource problems. However, this type of approach often proves to be a great disadvantage. Natural-resource-related phenomena are the result of complex interactions involving many factors. Such relationships make it imperative that land managers take an interdisciplinary approach to problems and utilize the full potential of all available tools.

Recently, the forestry division has been developing modern analysis techniques using digital data that greatly enhance land analysis and decisionmaking capabilities. The benefit acquired from the use of these techniques stems from the ability to combine data from many sources to focus on a set of interrelated problems. Remote sensing is only one of the tools that a land manager possesses, and its value is increased greatly in an interdisciplinary approach to land management decisionmaking.

This paper focuses on two major areas: (1) the role of remote sensing as an effective data source in present and future land analysis systems used by TVA and (2) problems associated with using remote sensing as a partial data source and requirements for alleviating these problems.

ANALYSIS PRINCIPLES

The land analysis systems in the division have been described[1] as having the following four major objectives related to program needs.

1. To provide inputs to planning and environmental impact assessment processes through analysis of current, accurate, and rapidly retrievable spatial information about natural systems and factors that potentially affect them

2. To analyze characteristics of the forest and wildland resource so that its value and benefit can be maximized through accurate recommendations and predictions

3. To provide the capability of rapid, site-specific analysis of spatial land-related data using simple and flexible computer systems of moderate cost

4. To provide a structure for the decision process that evaluates spatial and temporal distributions of land treatments

Details of various land analysis systems will not be given. However, three elements common to all land analysis systems are pertinent to this discussion.

First, the systems employ an interdisciplinary task

[a]Tennessee Valley Authority, Norris, Tennessee.

[b]Remote Sensing Institute, Brookings, South Dakota.

[1]Baxter, F. P.; Cox, T. L.; and Gregory, R. P.: Land Analysis Systems. Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Technical Note B-9 (in press).

approach with individuals from several disciplines working and interacting for a common goal. The task approach is necessary because it emphasizes a final product as a goal and enables the group to view the project systematically. In such an atmosphere, remote-sensing technology retains its proper role as an analysis tool rather than an analysis system.

Secondly, the analyses are "computer assisted." Those processes more economically done by hand are not computerized: but the computer is used where it is obviously more efficient, such as in the analysis of regional data sets or when overlaying a large number of data sets simultaneously.

Finally, the existence of a spatial hierarchy is recognized, the level of analysis detail depending on feasibility constraints of data collection, computer capacity, and processing time.

An important part of the computer-based spatial analysis is the reference system. It is the referencing of data or registration that permits the integration of different data sources in the analysis process. The systems used by the forestry division primarily employ geodetic cells for data storage and analysis. Rectangular or square cells are difficult to use where universal transverse Mercator (UTM) zone boundaries occur, such as in the Tennessee Valley. Geodetic cells change with latitude, but the change in area can be calculated by the computer. The cell hierarchy (figure 1) consists of cell sizes ranging from 3.75" (1.09 hectares) to 30" (69.2 hectares).

APPLICATIONS AND PROBLEMS

Aerial Photography

In developing intensive forest management plans, two types of analysis are needed to develop site- and time-specific land management activities, especially as related to timber.

First, there must be an inventory of present forest conditions to identify areas with high potential for management. Secondly, there must be an analysis to identify areas where physical or social constraints dictate modified or low-intensity management. For example, an area with high timber productivity may be eliminated from certain harvesting practices because of slope and inaccessibility. Another example may be a ban on certain regeneration methods in an area near a high-use recreation area.

Cox and Weber (ref. 2) demonstrated the feasibility of using medium-scale infrared imagery for interpreting forest resource variables such as stand size, stand volume, and stand types for regional analysis of a

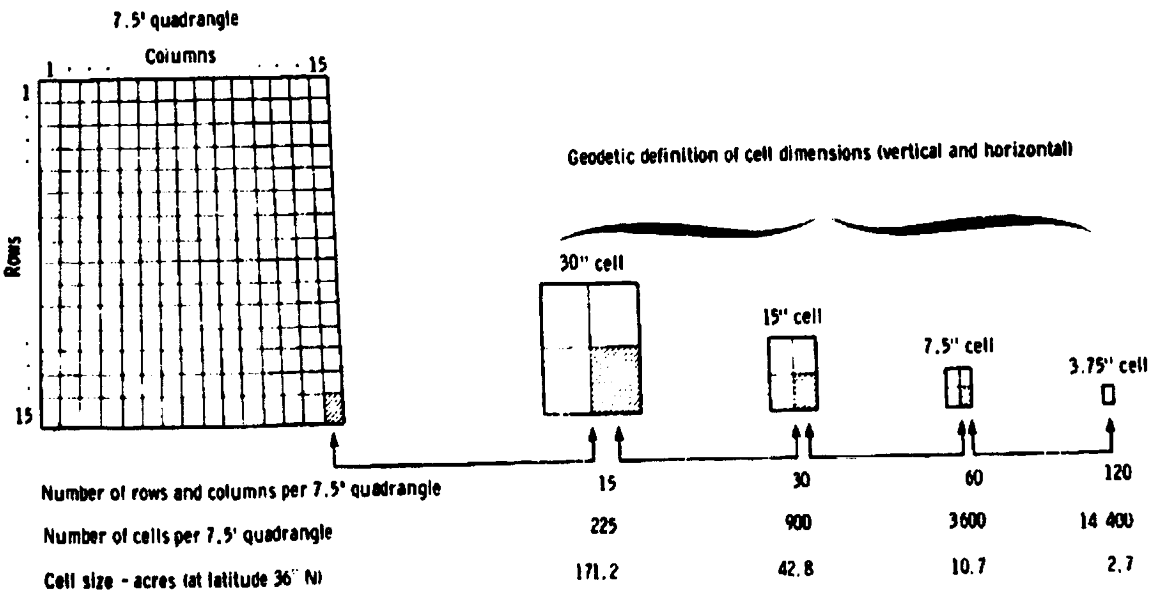

Figure 1. Geodetic cell hierarchy of the land analysis systems used by the TVA Division of Forestry, Fisheries, and Wildlife Development. Illustrated is the subdivision of a 7.5' quadrangle to geodetically register data for spatial analysis.

dispersed resource base. They made direct interpretations of each variable from 1:24 000 color-infrared transparencies. Each variable was plotted on a 7.5′ topographic quadrangle map and then hand digitized and coded into 3.75″ cells for registration.

After registration, the data were overlaid in the computer with physical variables digitized from other sources, such as soils data from SCS soil maps and topographic data from quadrangle maps. Overlaying the basic data in this form made possible the identification of timber capability classes or areas that, because of their physical characteristics, had or could have high timber productivity.

Not all areas capable of high timber productivity are suitable for intensive management. Thus, a second analysis was needed to identify those areas where constraints (such as excessive slope, shown in fig. 2, or conflicting land uses) existed. Following the analysis, the study areas were then grouped into homogeneous units for management purposes.

In this instance, photointerpretation was used to inventory forest resources and aided in the identification of land capabilities. Further analysis of the data with other variables permitted the rapid identification of management problems and potential conflicts, thereby facilitating the management decisionmaking process.

When using photointerpretation techniques as partial input for development of intensive forest management plans, certain problems arise. Aerial photography is typically flown on a project basis for individual geographic areas. Therefore, no central files exist by state and government agencies, existing data provide incomplete coverage of a study area, and if data are available for a wide geographic area, they are in varying scales and film types and were taken on different dates.

If the majority of user agencies within a region would

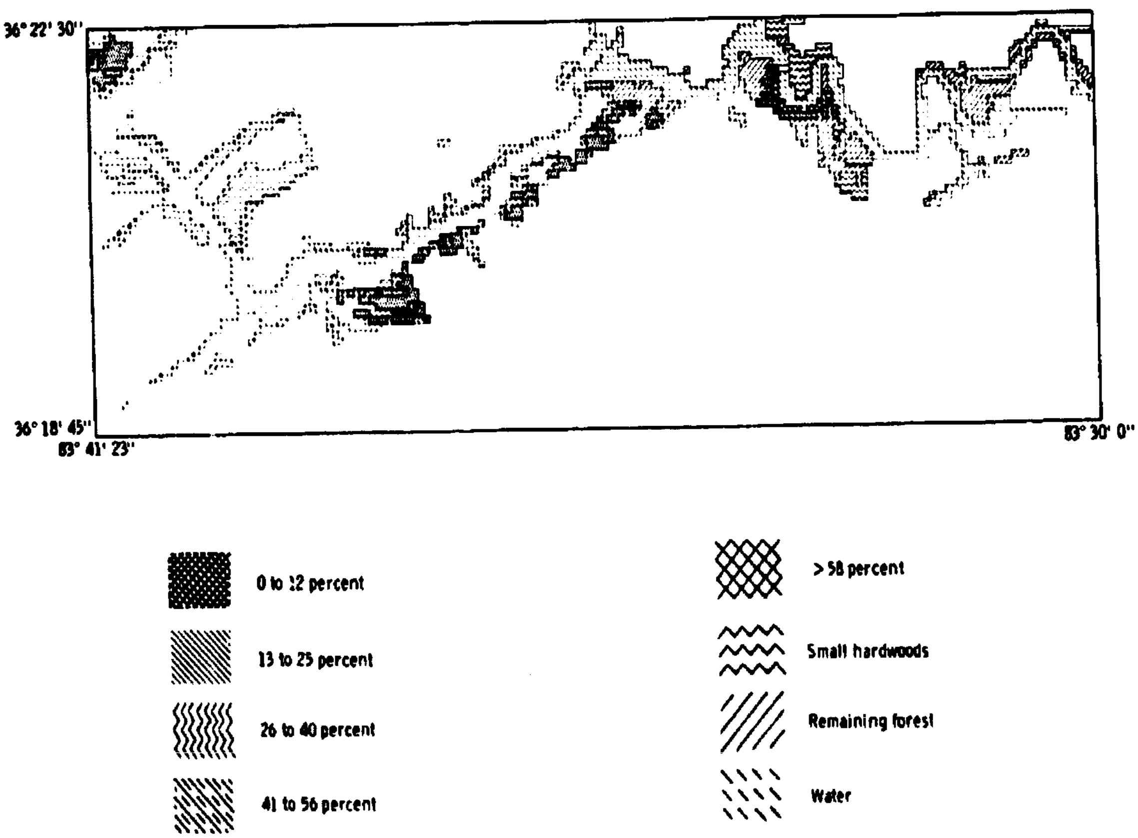

Figure 2. Use of overlay analysis to delineate timber management classes for TVA lands at Norris Reservoir, Tennessee. Timber volume was interpreted from aerial photography and slope classes (percent of slope) were derived from basic soils data.

enter into a joint task approach (establishing mission criteria and using the data), users could enjoy major benefits, such as: (1) a decrease in the cost of each project, (2) an identification of duplications in effort and of those areas having incomplete coverage, and (3) an increase in the relative accessibility of all coverage if one agency were used to perform acquisition activities.

Multispectral Scanners

Many problems associated with the project-oriented uses of aerial photography do not exist with multispectral scanners. With the launch of Landsat-1, resource managers have been able to get repetitive coverage of large areas within a reasonable time frame. Because of the unique qualities characteristic of scanner systems, however, new problems are replacing the old ones.

Scanners that are mounted on satellite platforms characteristically provide extensive coverage at loss of detail. Even though this principle is generally understood, many users expect the data to provide all of the answers.

It is very costly, time consuming, and it is often unproductive to attempt to make Level II or III land use classifications from satellite scanners. In fact, no effort should be made at all to classify land use based upon the sole criterion of electromagnetic reflectance values.

The rationale behind this type of philosophy is quite simple and also very similar to the previous example of land capability versus land suitability. Land use classifications are based upon social and economic factors as well as physical factors. In some cases, the nonphysical factors affect the physical and actually bring about resulting changes in spectral signatures. For example, does a large patch of asphalt belong to an airport, an interstate highway, a school, or an industry?

Several factors (including shape, size, topographic position, tone, pattern, shadow, and texture) must be evaluated in identifying features on aerial photographs. The absence of any of these factors reduces considerably the power of the photointerpreter to identify features. Analogous to this is identifying or classifying land use employing multispectral scanner data. The ability to correctly identify land use is dependent on many factors, primarily the interrelationship of land cover, topography (slope, elevation, etc.), soils (drainage, parent material, etc.), and ownership characteristics.

The forestry division is attempting to use this type of land use mapping in several project areas. Soils and land cover are being successfully overlaid to enable inferences about land use or resource characterization[2] (fig. 3) to be made. Work is continuing on acquisition of topographic and ownership data.

Land cover can be efficiently classified for large areas at reasonable cost by using Landsat multispectral scanner data. The digital form of the data lends itself to rapid processing by computerized land analysis systems. The problem in using digital data is in registering the data to the geodetic reference system used by the division; success has been achieved with regression models using third-order polynomials.

A drawback in using regression models is the increased number of data points needed as the size of the area increases. The solution to this problem is proper data registration at the time of collection. Several alternative methods exist, but proper registration of multispectral scanner tapes greatly increases their utility. Registration to the geodetic coordinate system, which is universal and easily transposable into other coordinate frames including state plane and UTM, would also increase utility.

Land cover information derived from Landsat multispectral data can be overlaid in a reference system with soils data to make inferences about a number of land uses. A computer-based approach has been developed to accept and interpret soil survey mapping unit data and provide a variety of spatial soil information in the form of single-factor maps. Each soil mapping unit is coded and a legend is provided describing basic soils data for each unit. Basic interpretations of soils data include such items as permeability, slope, or depth to bedrock. In this process, the basic mapping unit is digitized only once and then all subsequent interpretations and overlays can be made by simply manipulating the original data.

The major benefit from storing basic resource data, such as land cover and soils, in the manner described is flexibility. A land use interpretation map can be used only within the constraints of the interpretations; i.e., a land use map is based on preset definitions. The methodology previously described is more flexible in that definitions can be easily changed to fit program needs without having to acquire new data.

[2] Hitchcock, H. C.; Cox, F. L.; Baxter, F. P.; and Smart, C. W.: Resource Characterization Through Soils and Land Cover. Photogrammetric Eng. (to be published).

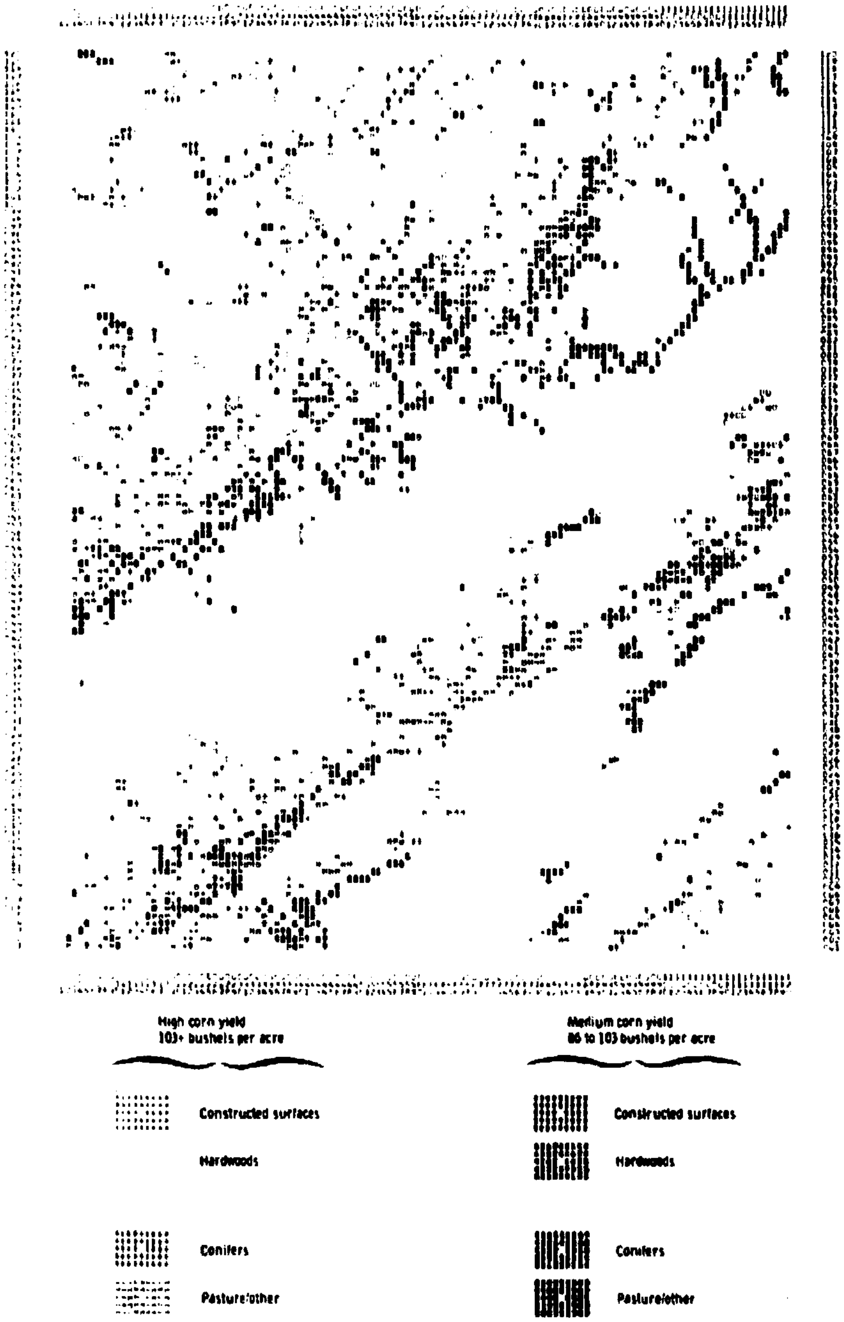

Figure 3. Corn-yield potential, derived from detailed soil map data, was overlaid with land cover data acquired from Landsat-1, enabling the identification of highly productive land and its present cover. The information was prepared by the Division of Forestry, Fisheries, and Wildlife Development in March 1975 of the Fountain City, Tennessee, area.

SUMMARY

Remote sensing provides a valuable source of data in land analysis activities; however, such data must be analyzed in conjunction with all other data. The TVA Division of Forestry, Fisheries, and Wildlife Development accomplishes this by registration of the remotely sensed data to geodetic coordinates, thus providing capabilities for overlay analysis.

Two problems arise when using remotely sensed data in land analysis. For aerial photography of a large area, differences in scale, dates, and film types have to be reconciled. These problems could be eliminated with a regional task force of user agencies for data acquisition and dissemination.

The second problem is registration. Aerial photography can be hand registered, but multispectral scanner data must be machine registered, often at considerable cost to the user. This problem could be solved by proper registration of the data at the time of acquisition.

If remote sensing is to become a universally applied tool in land management and planning systems, a major conceptual change in the attitude of the remote-sensing community is needed. Remotely sensed data must have the inherent flexibility to fit a number of analysis systems, each one designed for a unique purpose. We can no longer expect analysis systems to be designed around one rigid and inflexible data s[illegible].

DISCUSSION

TREXLER: I am more familiar with water quality studies with Landsat data but I think you are probably the only person I have heard who has definitely used the data to make very impressive decisions. It seems that everybody is collecting data and arguing about money and everything that is involved. Who has really used it? For instance, how would water quality or Landsat data stand up in court? I am glad to hear that somebody is making decisions based on it. This decision system that you have concerning the whole ecosystem is excellent, also.

HITCHCOCK: You may not really say the whole ecosystem, because we are looking at physical factors. The people sitting around making the judgments input the ecological variables in the form of expert opinion. In the data base itself, we do not have such factors as site index or importance values. They come in the form of expert opinion.

SPEAKER: At least everything is being considered as much as is practical. I would like for you to expand on your section 208 application to EPA.

HITCHCOCK: A consulting firm from New Jersey is running one of these section 208 projects in Knoxville. The project includes certain criteria as input into nonpoint pollution sources. Our data base happens to include all the soils information and all the land cover information the consultants want. The only variable that we do not have is bedrock geology. It is just a simple matter of coding these things using the grid we had. Because we have each data point tied into a place on the ground, the consultants can transpose it into the reference frame that they use.

SCHWERTZ: I wanted to address some of the points you made concerning the stacking of data. Many people have heard about the land use and data analysis (LUDA) program. It is a computer system. It is the ability to stack data. Louisiana has a complete system of numbers for land use cover. Accompanying this system are four data analysis overlays: water basins, parishes (counties), ownership information, and census subdivisions. We are adding soils; we have recently done flood information. But the point I want to stress is that land use mapping is nothing in itself. It must be registered to some coordinate or geodetic referencing point. Without the ability to stack data, you will continue to have nothing but pretty maps to look at. And therefore, although the LUDA system differs from the TVA system, I think the basis is still the same. It is the stacking of the data, and I think it is a very good approach.

SPEAKER: I would just like to be assured that what is done under this program is in such a reference frame that we can pick up your data base and use it at a cost of just a few dollars. When people are using the same reference frame, they can start acquiring data together, sharing the cost.

ANDERSON: There is a great deal of difference in how variables are mapped. For example, some counties have soil surveys only in minimum mapping units of 640 acres. It seems to me unnecessary to get a land use map down to 1 hectare or 1 acre to compare it with soil survey data at a minimum mapping unit of 640 acres. I do not think enough attention is given in collecting data to what use you intend to make of it. You can go to a lot of cost getting that extra detail and then have other variables with which you want to compare that have not been mapped at near that level of detail. In each case, one needs to be very careful about compromising the level of detail. My second point is about the national land use data set or land cover mapping. One of the arch principles, in my thinking, is that we must provide for flexibility in developing any kind of an approach to land cover mapping. We are doing a standard land use/land cover mapping effort with a minimum mapping unit of 10 acres in certain types of uses and cover and 40 acres in others. For example, the State of Florida, with which we have a 50-50 cost-sharing cooperative agreement, wanted additional categories of data that were not in the USGS standard level categories. On a 100-percent rebate basis, we are putting those data onto a map referenced to the Level II categories. For example, we are breaking out mangrove, which is very important in parts of Florida, and cypress. I would call these Level III type categories. In our cooperative agreement with the State of Georgia, we are doing some mapping of city parks in the Atlanta region, which are not really delineated in remote-sensing data sources.

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2. Cox, T. L.; and Weber, S. G.: Medium Scale Color Infrared Imagery Evaluation as a Data Source for Developing Intensive Management Plans. Paper presented at the Symposium on the Utilization of Remote Sensing Data in Southeastern United States (University of Georgia, Athens, Ga.), Jan. 29-30, 1975.

N76-26663

S-8. Louisiana Comprehensive Planning Information System

Patrick W. Ryan[a] *and Ed Schwertz*[a]

Planners in Louisiana are trying to move from a planning mode into what we call a service mode. We have been in the planning business, the research business, and the library-building business for some time. However, very few elected officials are interested in developing a progressive library system. So, through this information program, we have tried to create a service that people can use in their own planning and research. It is one of the first operational programs in the nation and we believe it is one of the best (table I).

This information program and system has many components. Land use mapping is part of it. This is an experimental effort with the U.S. Geological Survey to develop a statewide computerized land use mapping program at a scale of 1:250 000 that uses polygons to identify land uses in Louisiana, employing the USGS classification system. We have implemented this over the past 18 months. The land use mapping program is the basis for our information system.

Last year, we entered into a contract with the Soil Conservation Service to add SCS soil data to our basic mapping program. These data will be digitized into the computer and completely integrated with the land use data. Also, we are now a census tape processing center, and, to the land and soil data, we are adding the population and housing census data. In addition, we are identifying the various economic data on per capita income and on other economic indicators that can be useful in relating to the overall system. We have added unemployment figures from communities and parishes in the state. We have a section about public assistance. We have added data in the area of development of public facilities, transportation facilities, power facilities, and education facilities. This will be useful for people developing or making decisions within a particular parish. In fact, we find that commerce and industry are among our biggest users. Developers want to know about a parish or county when they move into it.

The key to this system is not the fact that we have different elements in the program but rather the method we are using to actually operate the program called national information processing system (NIPS). This program, which originated with the Defense Department, has the unique capability of actually interrelating and interfacing various forms of data among various categories. We are storing certain types of data, and we are constantly locating other forms.

This information is not being fed unnecessarily into

TABLE I. COMPREHENSIVE PLANNING INFORMATION SYSTEM

Data	System	Uses
Land inventory	Store	Status and change
Soils inventory	Locate	Compare
Census	Access	Create visual displays
Economic	Combine	Retrieve
Employment	Analyze	Evaluate alternatives
Area development	Model	Eliminate duplication
Public assistance	Report	--

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our computer; in fact, we do not have a computer. We have terminal ties into the Louisiana Department of Highways' IBM 370-158 computer and the Office of Information Services' Honeywell, and we will in the coming year add another tie-in to the State Police Univac. Our terminal has the capability of communicating with all three. Actually, we will be storing some information, and we will be able to locate and have access to other types of information and to combine the various sources. For instance, if someone is interested in land use data, soil data, or per capita income, we can manipulate, analyze, and run various statistical analyses on the program, creating various models to experiment with different theories and to generate reports. For example, this information can compare one parish or county with others, compare one region with others, and even compare certain areas.

We have interstate information on the status of change in a particular parish. We are trying to get time series on the information to indicate changes during the past 5 years, 10 years, et cetera, when comparing one parish or one state with others. In the land use program and elsewhere in the system, we have created visual displays, and we are using SYMAPS and various methods of creating computer-generated displays. We can retrieve the information, evaluate various alternatives through the models, and, we hope, eliminate much duplication in building various economic models to create a central system for use by various state agencies in planning. For instance, when the Department of Highways becomes involved in building a bridge or a north-south expressway, an environmental impact statement is often required to determine the effects of such a project. The Department of Highways needs data in such areas as employment and company income. In fact, a state agency must take a comprehensive approach no matter what field or specialty it might be in. If it does not have this information, the public will be at its doorstep.

The State Planning Office is trying to help other agencies that are beginning to seek our assistance in accessing this data. The governor signed Executive Order 27 in February 1973 to create a uniform system of state planning districts in Louisiana. Our office has asked all state agencies and encouraged all Federal agencies to adopt these boundaries, particularly regarding formal planning and data gathering. We had some problems with implementation from the Department of Highways and other management agencies whose planning programs overlapped into different districts or whose projects involved only a portion of a certain planning district. These agencies were concerned about the cost of expanding their planning programs to include whole planning districts. There can be some differentiation regarding the actual field operations of some agencies, but we are anxious to have these agencies develop their planning data and information programs in the context of the uniform districts. Uniformity will make the information more usable for a police juror, a legislator, a governor, a congressman, or anyone else who has to make a decision. These people are not just interested in highways, for example, but rather in how one program complements another. They must make budgeting decisions based on the total scope of state or local government. The State Planning Office is trying to simplify this decisionmaking process.

In the Department of Highways, a major upcoming project is a north-south expressway. This project requires land use data and soils data from various parishes. We are now providing this information. The superport is another major project in Louisiana, and one important concern is the secondary impact of such an energy facility on schools, hospitals, roads, agricultural land, and community development. This information is a prerequisite to Coast Guard approval, and we are providing data assistance in these areas. The coastal zone management program involves the task of delineating the boundaries of the coastal zone. We must begin dealing with Federal/State land, public ownership. We must also determine the extent of community expansion and development in the coastal areas, and our land use program is the major thrust toward this end.

In our present land use system we are not dealing with photographs. The imagery that was developed as part of our program is classified as Defense Department photography. The U.S. Geological Survey has taken this photography, delineated the various land uses, and computerized it. We are using the map that was generated.

As part of the informational program, we are working with regional and local planners across the state to identify the most critical indicators. We have also held various on-the-job training programs to provide instructions on the use of our system. Civil defense and comprehensive planning agencies include this system as an integral part of their program. The 1975 flood afforded a unique opportunity to use the computerized land use mapping and the satellite imagery for operational purposes. Ed Schwertz will tell you about our recent flood mapping.

Pat mentioned the classification system. The USGS classification system (table II), is slightly different from the 1971 version. The only difference is category 6, wetlands. Previously it was classified only as nonforested

TABLE II. - LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Level I	Level II
1. Urban and built-up land	11. Residential 12. Commercial and services 13. Industrial 14. Extractive 15. Transportation, communications, and utilities 16. Institutional 17. Strip and clustered settlement 18. Mixed 19. Open and other
2. Agricultural land	21. Cropland and pasture 22. Orchards, groves, bush fruits, vineyards, horticultural areas 23. Feeding operations 24. Other
3. Rangeland	31. Grass 32. Savannas (palmetto prairies) 33. Chaparral 34. Desert shrub
4. Forest land	41. Deciduous 42. Evergreen (coniferous and other) 43. Mixed
5. Water	51. Streams and waterways 52. Lakes 53. Reservoirs 54. Bays and estuaries 55. Other
6. Wetland	61. Forested 62. Nonforested
7. Barren land	71. Salt flats 72. Beaches 73. Sand other than beaches 74. Bare exposed rock 75. Other

wetlands, but it is now broken down into forested and nonforested wetlands. There was a comment made earlier that the USDI classification system did not permit identification of wetlands categories, specifically, swamp and marsh. However, we do have this capability. The entire state, 50 000 square statute miles, has complete land use mapping using polygon digitizing techniques. Since we had this capability and the land use data, and since we knew that USGS and various others in 1973 had done some flood mapping from satellite imagery, I thought of the possibility, on April 5, 1975, of taking the land use information from the LUDA program and combining it with the Landsat data to provide flood information on land use type acreages by parish and aggregate it to the state total for the purpose of disaster declarations. Therefore, we asked Governor Edwards if he would like to pursue this. He did, and on April 8 he sent a letter to the administrator of NASA, Dr. Fletcher. The NASA agreed to attempt to provide the satellite imagery within 48 hours after the passes over Louisiana. The NASA people were a bit pessimistic about their ability to deliver in that time frame, because it had never been done before. The request from Governor Edwards was the first of its kind for emergency-type information. They decided to give it a try, and they did an excellent job; we got the information in 36 hours.

Once we received the information, we used an electronic digitizing planimeter (fig. 1) to measure acreages for those polygons not completely flooded. Figure 2 is the Landsat image taken April 15 of the Baton Rouge-New Orleans area. It is cloud free. We saw gray areas that were flooded. The imagery was enlarged to a scale of 1:250 000, which is our basic mapping scale of the land use maps. We used visual mapping techniques to delineate flood areas by taking out dark areas. Then we merged our land use maps with the flood maps to obtain acreage tabulations.

The Alexandria area is visible in figure 3, taken April 26. Despite considerable cloudiness, we could see some black areas where extensive flooding was occurring around Avoyelles, Catahoula, and Concordia Parishes. Figure 4 is a land use map of Avoyelles Parish taken from the 1:250 000 Mylar overlays. It shows the various polygons we have mentioned. Figure 5 illustrates the flooded areas in Avoyelles Parish. In figure 6, the dark areas, identical to the flood areas in figure 5, have been

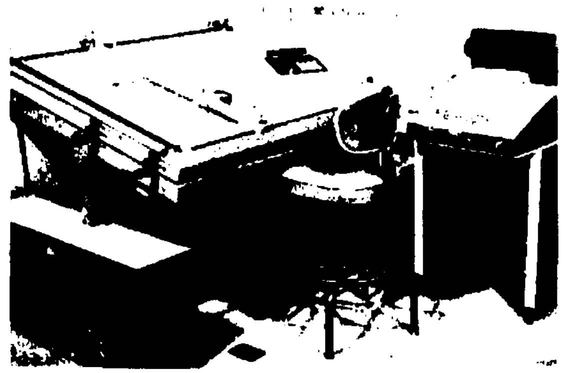

Figure 1. Electronic digitizing planimeter at the EROS Applications Assistance Facility at Bay St. Louis, Mississippi.

merged with the land use map of figure 4. We took the polygons that were flooded and referred to our computer punchcards for data about the number of acres in each polygon. We had some polygons that we could pull automatically, and we created new polygons, using the electronic digitizing planimeter, where they were not complete polygons in the system. In Avoyelles Parish, 35.5 percent of the land was flooded. In Catahoula, 45.8 percent was flooded; and in Concordia, the percentage was 45. Figure 7 is the final product of flood mapping in Concordia Parish.

There was flooding in 27 parishes for a total of 1 118 191 acres. Table III shows the land use categories and the amount flooded. We validated the flood maps with Cooperative Extension Service county agents, who estimated that 1 122 000 acres were flooded. This figure was quite comparable, so the agents were asked to validate the flood maps. Enlargement of the satellite images cost an estimated $200. Eight man-days were required to do the work, and the total cost of the project was $700. The information is being used in our request for major disaster designation. We believe that it will stand up in court. The Federal Disaster Assistance Team wanted to know where the floodwaters had been. The flood maps were used to certify Governor Edwards' disaster request. With this technique, we knew where the floodwaters stood at the time of the crest.

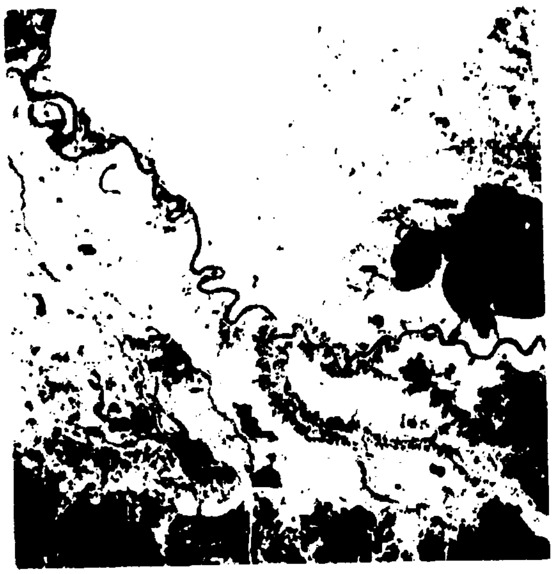

Figure 2. Landsat, band 7, image of flooding in the New Orleans-Baton Rouge area taken April 15, 1975.

Figure 3. Landsat, band 7, image of Louisiana flooding taken more than a week later than figure 2. Despite cloudiness, extensive flooding is visible in Avoyelles, Catahoula, and Concordia Parishes.

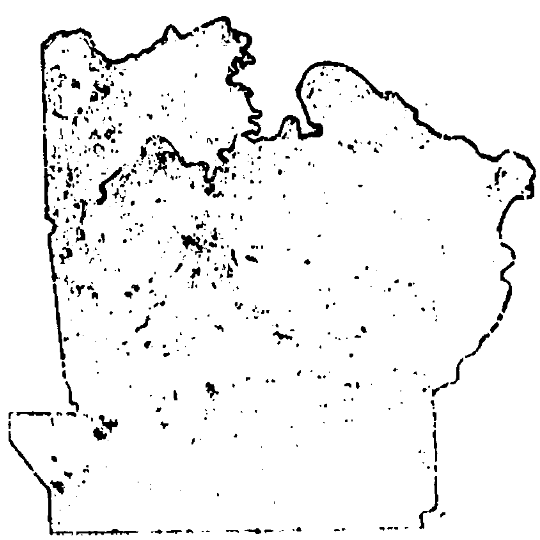

Figure 4. Land use map of Avoyelles Parish is typical of those made for the entire state under the LUDA program. The polygons are clearly visible and the numbers refer to the classification system.

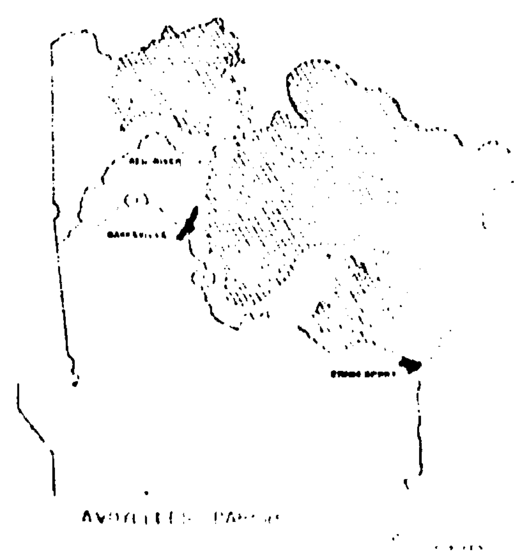

Figure 5. Map of flooded areas in Avoyelles Parish, developed from Landsat imagery.

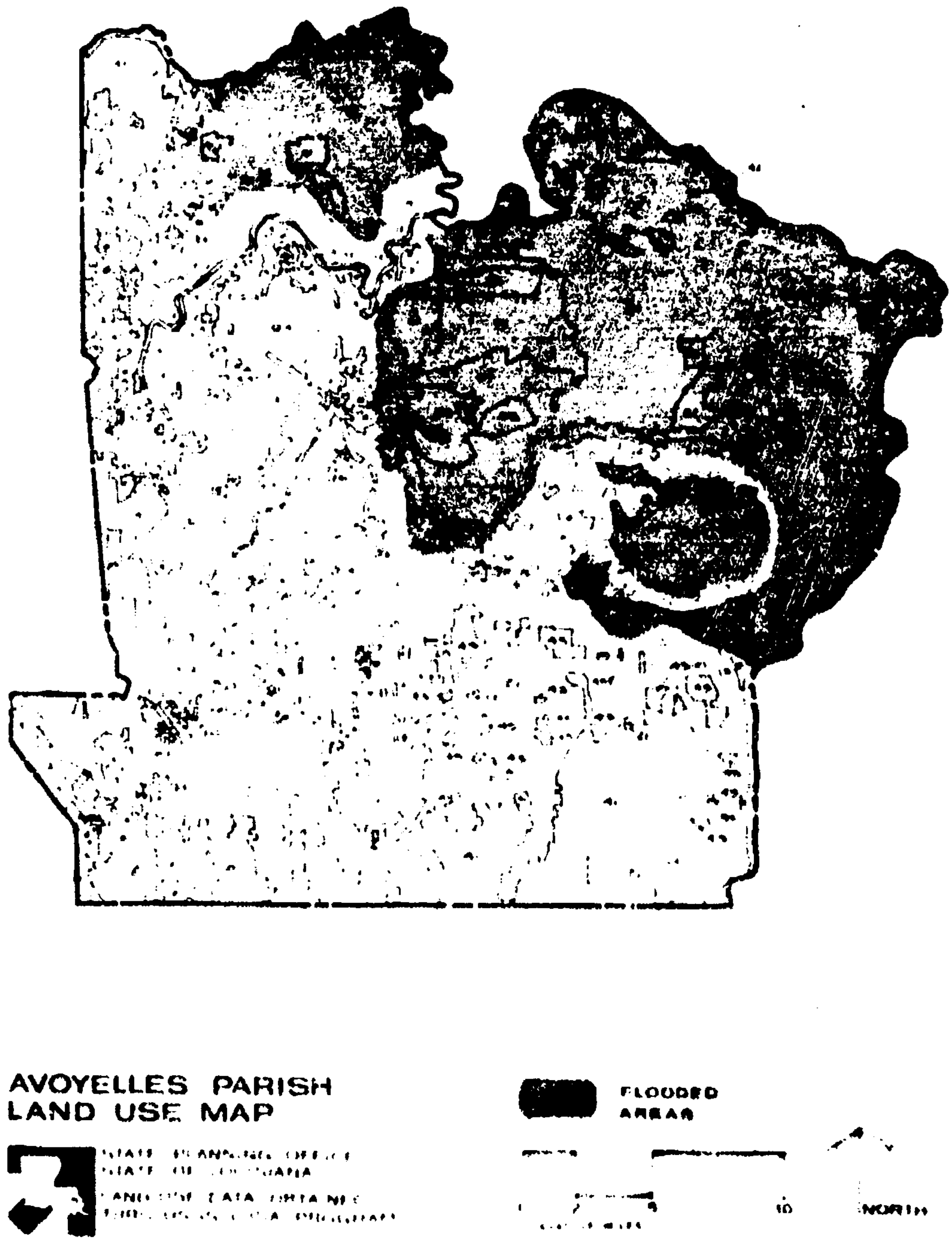

Figure 6. Land use map from figure 4 merged with flood areas outlined in figure 5.

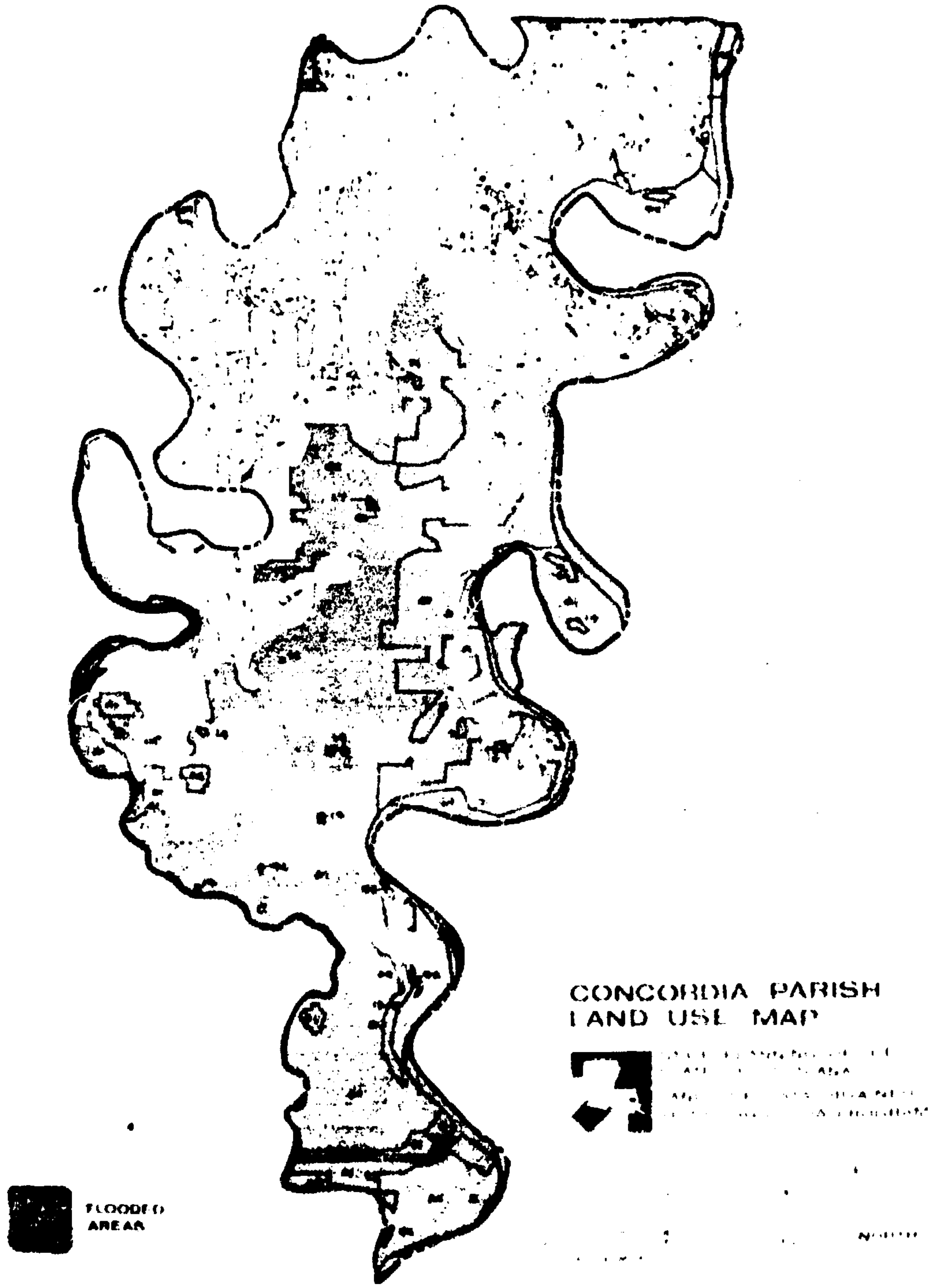

Figure 7. Map of flooded areas in Concordia Parish, developed in the same manner as figure 6.

TABLE III. FLOODED AREAS IDENTIFIED BY LAND USE AND PARISH

Land use categories	Flooded parishes, acres						
	Ascension	Assumption	Avoyelles	Caldwell[a]	Catahoula	Concordia	East Baton Rouge
Urban and built-up land	--	607	136	--	545	1 048	113
Residential	--	62	--	--	--	--	--
Commercial and services (businesses)	--	--	--	--	--	--	9
Industrial	--	--	--	--	85	43	104
Extractive (oil and gas wells, sand and gravel pits)	--	--	136	--	425	902	--
Transportation, communication, and utilities	--	--	--	--	--	17	--
Institutional (schools)	--	33	--	--	--	--	--
Strip and clustered settlement (rural residential)	--	512	--	--	35	86	--
Agricultural land	--	7309	54 026	1 112	115 700	30 235	84
Cropland and pasture	--	7309	54 026	1 112	115 669	30 235	84
Other (farmsteads)	--	--	--	--	31	--	--
Forest land	875	--	8 659	--	8 171	2 899	7433
Deciduous (hardwood)	875	--	8 397	--	247	--	--
Evergreen (coniferous and other)	--	--	262	--	5 593	2 899	5177
Mixed (pine and hardwood)	--	--	--	--	2 331	--	2256
Barren land (nonvegetated)	--	--	--	--	--	693	--
Beaches (sandbars)	--	--	--	--	--	693	--
Other	--	--	--	--	--	--	--
Subtotal of preceding categories	875	7916	62 850	1 112	124 416	34 875	7630
Wetland	--	--	125 940	32 351	93 173	171 691	2261
Forested (swamp)	--	--	119 952	32 351	89 903	170 205	543
Nonforested (marsh)	--	--	5988	--	3 270	1 486	1718
Total area flooded in parish	875	7916	188 790	33 463	217 589	206 566	9891

[a]Cloudy conditions made delineation of flooded areas difficult. In areas completely covered by clouds, no delineations were possible.

TABLE III.- Continued

Land use categories	Flooded parishes, acres						
	East Carroll[a]	East Feliciana	Franklin[a]	Grant	Iberville	LaSalle[a]	Madison[a]
Urban and built-up land	--	--	--	--	--	362	183
Residential	--	--	--	--	--	--	--
Commercial and services (businesses)	--	--	--	--	--	--	--
Industrial	--	--	--	--	--	--	142
Extractive (oil and gas wells, sand and gravel pits)	--	--	--	--	--	362	41
Transportation, communication, and utilities	--	--	--	--	--	--	--
Institutional (schools)	--	--	--	--	--	--	--
Strip and clustered settlement (rural residential)	--	--	--	--	--	--	--
Agricultural land	11 917	--	15 905	--	3611	7 686	7 166
Cropland and pasture	11 917	--	15 081	--	3611	7 686	7 166
Other (farmsteads)	--	--	824	--	--	--	--
Forest land	13 853	2051	436	1210	433	5 213	165
Deciduous (hardwood)	13 853	--	360	1210	340	5 213	165
Evergreen (coniferous and other)	--	--	76	--	93	--	--
Mixed (pine and hardwood)	--	2051	--	--	--	--	--
Barren land (nonvegetated)	--	--	--	--	--	--	--
Beaches (sandbars)	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--
Subtotal of preceding categories	25 770	2051	16 341	1210	4044	13 261	7 514
Wetland	989	--	10 212	3165	191	72 494	26 204
Forested (swamp)	989	--	8 234	3165	191	66 077	26 204
Nonforested (marsh)	--	--	1 978	--	--	6 417	--
Total area flooded in parish	26 759	2051	26 553	4375	4235	85 755	33 718

[a]Cloudy conditions made delineation of flooded areas difficult. In areas completely covered by clouds, no delineations were possible.

TABLE III. -- Continued

Land use categories	Flooded parishes, acres						
	Morehouse[a]	Ouachita[a]	Pointe Coupee	Rapides	Richland[a]	St. James	St. John
Urban and built-up land	--	--	--	--	--	--	--
Residential	--	--	--	--	--	--	--
Commercial and services (businesses)	--	--	--	--	--	--	--
Industrial	--	--	--	--	--	--	--
Extractive (oil and gas wells, sand and gravel pits)	--	--	--	--	--	--	--
Transportation, communication, and utilities	--	--	--	--	--	--	--
Institutional (schools)	--	--	--	--	--	--	--
Strip and clustered settlement (rural residential)	--	--	--	--	--	--	--
Agricultural land	--	1005	6 678	430	6306	431	223
Cropland and pasture	--	1005	6 678	430	6306	431	223
Other (farmsteads)	--	--	--	--	--	--	--
Forest land	22 188	2797	3 190	514	1147	--	--
Deciduous (hardwood)	--	824	--	514	1147	--	--
Evergreen (coniferous and other)	21 590	302	345	--	--	--	--
Mixed (pine and hardwood)	598	1671	2 845	--	--	--	--
Barren land (nonvegetated)	--	--	96	--	--	--	--
Beaches (sandbars)	--	--	96	--	--	--	--
Other	--	--	--	--	--	--	--
Subtotal of preceding categories	22 188	3802	9 964	944	7453	431	223
Wetland	2 215	--	18 796	10 979	1134	--	--
Forested (swamp)	1 622	--	18 796	8 970	1134	--	--
Nonforested (marsh)	593	--	--	2 009	--	--	--
Total area flooded in parish	24 403	3802	28 760	11 923	8587	431	223

[a]Cloudy conditions made delineation of flooded areas difficult. In areas completely covered by clouds, no delineations were possible.

TABLE III.- Concluded

Land use categories	Flooded parishes, acres						
	St. Landry	St. Martin	Tensas[a]	Union	West Baton Rouge	West Feliciana	Total for all parishes
Urban and built-up land	--	--	414	4 157	7	464	8 036
Residential	--	--	40	--	--	--	102
Commercial and services (businesses)	--	--	203	--	--	--	212
Industrial	--	--	25	--	--	367	766
Extractive (oil and gas wells, sand and gravel pits)	--	--	146	4 157	7	92	6 268
Transportation, communication, and utilities	--	--	--	--	--	5	22
Institutional (schools)	--	--	--	--	--	--	33
Strip and clustered settlement (rural residential)	--	--	--	--	--	--	633
Agricultural land	3221	601	9 146	2 110	1 694	13 697	300 293
Cropland and pasture	3221	601	9 146	2 110	1 694	13 697	299 438
Other (farmsteads)	--	--	--	--	--	--	855
Forest land	--	--	842	7 819	8 961	10 166	109 022
Deciduous (hardwood)	--	--	--	4 111	485	--	37 742
Evergreen (coniferous and other)	--	--	226	99	--	--	36 662
Mixed (pine and hardwood)	--	--	616	3 609	8 475	10 166	34 618
Barren land (nonvegetated)	--	--	1 900	--	--	147	2 836
Beaches (sandbars)	--	--	1 900	--	--	--	2 689
Other	--	--	--	--	--	147	147
Subtotal of preceding categories	3221	601	12 302	14 086	10 662	24 474	420 187
Wetland	--	--	80 875	6 522	--	38 812	698 004
Forested (swamp)	--	--	80 717	6 522	--	38 812	674 387
Nonforested (marsh)	--	--	158	--	--	--	23 617
Total area flooded in parish	3221	601	93 177	20 608	10 662	63 286	1 118 191

[a]Cloudy conditions made delineation of flooded areas difficult. In areas completely covered by clouds, no delineations were possible.

DISCUSSION

SIZER: What is the access to the system? Do those people who want to use the system have ready access to it? Do they come through your agency?

RYAN: They come to the State Planning Office and actually request our land use maps. We have told them that the maps alone are of little value. Part of the program is the computer system. The key point to remember in servicing any agency is to know its specific needs. We have to know what the information is to be used for so that pertinent information can be provided. The consultants in our office are very familiar with this program. We have had some problems with consultants doing work for other state agencies. Rather than provide our information to the consultant, we ask the state agency to request that the information be provided to the consultant. This protects the state agency from being charged fees to have information collected when this information is available without charge.

SPEAKER: Do you have any fees at all?

RYAN: Right now, we do not. It is difficult to determine how to provide this information without putting ourselves out of business.

SIZER: We found also in Minnesota that we can identify water or wet areas quite effectively with this. Did you have any aerial photography taken at the same time? In Minnesota, usually, in high flood times, the Corps of Engineers or other Federal agencies that fly will have photography. I was wondering if any had any for comparative purposes.

SCHWERTZ: There were some photographs flown, classified photography by the Department of Defense for the Corps of Engineers. I have not seen that photography, but we did field checking at the same time the satellite was passing overhead so that we could if necessary correlate some of our known flooded areas to the imagery. As it turned out, we did not need the correlation. The areas that we could not definitely say were flooded were not included.

SPEAKER: What did you figure your degree of accuracy was?

SCHWERTZ: We were not able to establish that. However, based on the verification by county agents and the fact that their figures differed by only 3000 acres, I would think that we were considerably accurate.

SPEAKER: Are you a planning coordinator or are you the planning agency? Do you set both parameters for these substate districts?

RYAN: Yes, our office is a technical staff; we are an arm of the governor's office. We get involved in coordination. At least we say we did that, but I never could figure out what coordination actually was, so we have simplified it somewhat. If we can know what goes into these planning efforts, like land use data, soil data, and population projections, then we can establish common denominators and get the professionals to agree on the indicators and standards to be applied. In this manner, everyone would not be going off in different directions.

SPEAKER: But once you agree on the standards of this kind of information, then you will somehow get that data base filled with data like social, economic, or for an environmental impact statement?

RYAN: P. J. Mills or the Department of Highways can do that. We provide the information.

SPEAKER: Do you have econometric models that this somehow feeds back into?

RYAN: We've been looking at those. In fact, the Department of Conservation, Division of Energy and Natural Resources, is working with those now. At this time, we have Dr. Fred Wrighton working on econometric models. We have heavy university involvement in our programs. We have contracts now with four state universities. Ed Schwertz is under one of these contracts. About half of our staff are employees of Louisiana State University working full time at the State Planning Office. Dr. Wrighton works on economic development.

SPEAKER: You mentioned that you collect data by census tract. And I presume that economic data are included.

RYAN: I think there is a great deal of difference between economic data and econometric models. We are adding this information into the computer by census tract, along with information on population, housing, per capita income, and so on. If it is available only at the parish level, we have to stop there.

SPEAKER: The next question also relates to that basic information system. What about welfare information? I presume there are legal constraints on accessing some of those data files.

RYAN: Yes, there are restraints, there are dead ends. Whether it be census information on a business indicator, or revenue data, or welfare data, we can't identify any individual or allow indirect identification, where it is very obvious that the information relates to only one individual, one very small client. We get their programs and our programs together by area.

SPEAKER: If I wanted to build a pipeline, and I came to you and said, "Look, I want to avoid marsh and wetlands. I want to go through urban areas of a certain density level. I want to avoid seismic risks and I do not want to cross rivers over 100 feet in width. Can you provide this type of information for me, optimizing my alternatives?"

RYAN: I would say yes. Ed might have a comment on that. It would take some programing to do that specifically. But, I would say that it could be done. Let me mention that this is something particularly interesting in corridor development, highways, or whatever you might have. If you were interested in a highway, you could digitize a line in a computer and ask for a feedback of all types of information you want in that corridor. It would give you the acreage of these soils or land use acreages. And this is really the key in project planning, whether it is a pipeline or whatever.

SCHWERTZ: You mentioned streams at a maximum of 100 feet; this information is limited by the specifications of the program. We would be able to get the information you wanted only on water bodies that were at least 660 feet in width.

SPEAKER: To what kind of geographic unit do you aggregate your data? By this, I mean your census data, census tract and census block information. On a statewide basis, what unit do you use to retrieve your information?

SCHWERTZ: We have statewide bases. We have state and substate planning districts. We have the river basins delineated by the Water Resource Council. We have the census county subdivisions.

SPEAKER: So, you have a whole series of corresponding tables that point to each one of these. In Los Angeles, we have had problems in polygon overlay, data handling. How did you insert your flood plain data, for example, into these different units? Did you have a base unit to all of them?

SCHWERTZ: We digitized by polygon. However, we do not access by polygon; we access by cells. We put a mathematical grid into the system that merges with the polygon digitized data. At the present time, we are accessing by 1-kilometer cells (247.1 acres). The USGS or LUDA program is developing a variable-grid-size cell program. For example, you can access by 10 acres, 40 acres, or whatever you want. For soils, we will access by 640 acres.

SPEAKER: I think the data holding up in court is going to be the final test on a lot of this information gathering. Certainly in the environmental field. Do you find that you have competition within the state, in providing these services, or have you more or less gotten exclusive jurisdiction in providing this kind of planning information?

RYAN: There certainly is some competition. In Louisiana, energy is the big thing. They will budget \$25 million to do some energy planning. They will hire many consultants to do the work who will scatter out and overlap in their work. We are trying to cut that down. The more people who know this information is available the more will come to us. And it is an educational thing. You have to develop credibility when you are in the planning business. I think that is the key point. As time goes on, state agencies are not going to contract for information with a consultant, because they can get the same information from us at no cost. We would like to see these agencies hire a consultant to do a little thinking, a little analysis, rather than hiring consultants to go out and do so much number business because that's free. But they must know it is there.

FREDEN: Stan Freden, Goddard Space Flight Center. As you acknowledged, we made special effort to get the flood data to you in 36 hours, and I noticed you did the classification on it. How is that classified information used? In other words, what requirements were there and what did you do with the data that required us to get it to you in that type of time scale?

SCHWERTZ: The reason we wanted the information in that kind of time scale is so that we could get the information to the EROS Applications Assistance Facility over at the National Space Technology Laboratories (NSTL) to manipulate the data. In other words, interpret it and then get it into the hands of the county agents for use in their work in the disaster declaration request that we have made. We got the information in the hands of our people at our office where they prepared maps for the various parishes. This was turned over to the Cooperative Extension Service and then the very next day sent to them for use in the field. They verified this and it is now being used for the major disaster declaration. It is very useful. They hope to use it in terms of economic projections, economic impact loss, and so forth.

FREDEN: Why was the 36 hours required? Couldn't that have been done 3 weeks later, just as well?

SCHWERTZ: The Federal disaster team will come down to Louisiana when we have a disaster, and I think this type of information is very useful to them. In the past, it has taken about 4 or 5 months to do this. The governor is involved in making decisions on how significant the losses are for a particular area. What is the value? What's the type of land use? I think that when you have a disaster — if you have over a million acres of land that is flooded — decisionmakers have to address these issues with this type of information early. The quicker they can get it, the more significant it is to them and to the people in the state. If you are trying to impress the President of the United States with a problem, you must hit him with it quick. You can't just say, "Well, I'm going to come on in there about 4 months from now."

SPEAKER: What decisions were made based on that information?

RYAN: I would say the decisions on the significance and the value of flooded agriculture land and the significant value of the residential area involved: How bad is it?

BANKSTON: Let me also respond to that question because I was another cohort in this. We had the same concerns, but a different one as well. At the time the request was made, the River Flood Forecast Center was forecasting that the crest would exceed the 1973 crest. At the same time, we had this big snowpack that was melting. And it looked at that point as if there would be a long, high flood. Our problem in Mississippi, and I suppose they have a similar problem in Arkansas, was drainage, backwater flooding, and the danger of blowouts of the levee system. As it turned out, the snowpack, fortunately, dissipated over the spring period instead of suddenly melting. We were afraid because of the condition of the levees. In addition, we wanted to know what roads were being cut off, et cetera.

RYAN: I might mention one other thing. On the Morganza Floodway and the Bonnet Carré Spillway, the Corps of Engineers was involved in making decisions over a period of a month about whether or not to open them. Any time the floodways are opened, very severe damage to fish and shrimp production and so forth is caused. People all across the country don't realize that Louisiana flushes out 42 percent of the nation's floodwater. Morganza Spillway was built to keep the levee from collapsing.

SPEAKER: How long does it take you to outline flood data after you receive it?

SCHWERTZ: It took us approximately 1 hour per scene. There were 8 scenes or 8 hours of interpretation.

N76-26664

S-9. Remote Sensing in Minnesota: Evaluation of Programs and Current Needs

J. E. Sizer[a]

Remote-sensing materials have actually been used for some time as aids to planners, decisionmakers, resource managers, and the like. However, in many instances, the available material has been quite scattered and somewhat sparse. The Minnesota State Planning Agency works with various state agencies to help coordinate the planning. One of our initial problems was the lack of consistent and accurate data, which are not available in most states. We have a lot of data, but the consistency, the reliability, and the accessibility leave much to be desired. We thought we needed a working system that would encourage people to reorganize the way they kept their data. And, with that in mind, we certainly thought we needed a single source of information, a data element, that we could use to begin establishing a statewide system.

In 1969, we acquired aerial photographs of the entire state. We made interpretations of those photographs, believing that we would then have some information at a known level of consistency to put into the system. We have since begun developing information on geomorphic regions, land ownership, forest cover, soils, geology, and two other items that are changeable: land classification and land capability.

Figure 1 is an example of a blueline that we use to make these interpretations. These bluelines were enlarged from the scale of 1:90 000, at which they were originally flown, to a scale of 1:24 000. In the 4 years that bluelines have been available, approximately 62 000 separate prints have been distributed in state agencies. We charge only for the cost of the paper, about 25 cents per quad. They are rectified to quad size.

We realized there was a need to get users involved early in the project, but we decided we could not work with detailed information about the entire state. Instead, we started working with the northeast area of the state and with one county in that area. We have divided Minnesota into 13 different regions, and we are working a region at a time to input information on ownership, forest cover, soils, geology, and so forth. By using this method, we can work with the regional people, the local units of government, which are going to be the major users of some of this information. The state agencies that are regionalized are also using information at that level.

We noted that there are many data sources and that the cost of acquiring this type of information was fairly high. The aerial photographs that we initially purchased cost \$120 000 for the entire state. If we were to duplicate that now, the price would be more than \$400 000. We thought we needed some way of adding to

Figure 1. Example of a blueline used in Minnesota land classification interpretation.

[a]State Planning Agency, St. Paul, Minnesota.

and updating the system. We investigated Landsat imagery to see what kind of information was available and what we could use. We found that on the aerials, we were able to interpret water; we were able to do the same thing with Landsat imagery. We were able to identify forested areas; we were able to do the same thing with Landsat information. Major roads, plowed fields, vegetative cover, and general land use information could be identified on both the aerial and Landsat imagery. However, when it came to soil types, geomorphic regions, forest types, detailed land use, separating vegetation cover, and topographic updates, we found that we still needed greater detail. We find that we can use these Landsat products to update a good many things, but we cannot use them as broadly as we had hoped that we could.

Figure 2 shows a soils map that was hand drawn with a good deal of labor and effort. We were looking for a more rapid way of producing this information. The soils people will use one kind of coverage and the geologic people may use another, producing maps at various scales and not necessarily covering the area in which the decisionmaker is interested. A firm in Minnesota has a machine called a Dicomed that we thought might be interesting to try. Figure 3 shows the same soils information produced with the Dicomed. The interpretations by the soils people were put into the system, and all we were doing was rapidly printing it out. The data for this map were input by 40-acre cells. We could call out the information by cells to make comparisons between geographic areas. The cost of preparing this map and producing 1000 copies was $171. So, we decided that, at that rate, we could use this particular technique when we needed to furnish information quickly. Figure 4 is an example of geologic regions mapped by the same process.

Figure 5 is an example of the output from our system and reflects land use in Itasca County, one of the counties we are working with to get detailed information. The white spots are developments, primarily cabins around lakes. The tremendous development pressures are apparent, and this is the type of information planners need to know as they consider what action they may have to take. Figure 6 is a hand-produced map showing forest cover in Itasca County, and figure 7 shows the same information produced with a Dicomed. Both are readable, but the Dicomed product is much cheaper and faster to produce.

Public land ownership in Itasca County is shown in the Dicomed product in figure 8. The colored areas are lands owned by local, state, or Federal agencies. As you can see by the pattern, a great deal of land in this county is not privately owned. And even some of the resource people themselves are not aware of the ownership patterns that exist until they see a map like this. We ask them: "How do you manage those forest lands? Do you guys meet every morning and discuss where you are going to be that day?" Understanding the pattern becomes very important in land sales, exchanges, or acquisition. Consistency in management plans among the several agencies that have the responsibilities is important. Minnesota has approximately 13 million acres owned or controlled by a governmental unit at some level.

Figure 9 is an example of a printout taken directly from a tape, showing the kind of features that can be identified from this imagery. This printout operation takes only a few hours.

We find now that we have a good deal of information available, and we are developing new techniques for making it more accessible to more people and for getting people more involved in its use. The present organization involves the State of Minnesota, the planning agency, several resource agencies, the pollution control people, the Department of Natural Resources, and the Highway Department.

In summary, one of the problems we have had is the varying reliability of regular information that is available. We need a reliable data base and we think our resource people need it. We have not received what we consider to be good systems assistance from the Federal Government in this area, and we would like to receive better assistance. We need this assistance to develop a common base, and we think that probably all states would like to have a common base from which to operate.

We thought that the WB-57 aircraft coverage was very good but limited. We asked for more coverage for the State of Minnesota and also coverage for Wisconsin and upper Michigan, so that we could make comparisons between the states. We were unable to get that coverage. Obviously, there is a problem here of who is responsible for paying. I asked for funds to acquire aerial photographs again and the legislature gave me $150 000. I cannot get the aerial photographs for $150 000 unless I can get others to participate in a cooperative program. If several states could get together with the Federal Government, it is possible we could get good photographic coverage with the funds available. We think we have made a good start, but we have a long way to go and we all need to cooperate more in the future.

Figure 2. Section of a soils map prepared by hand.

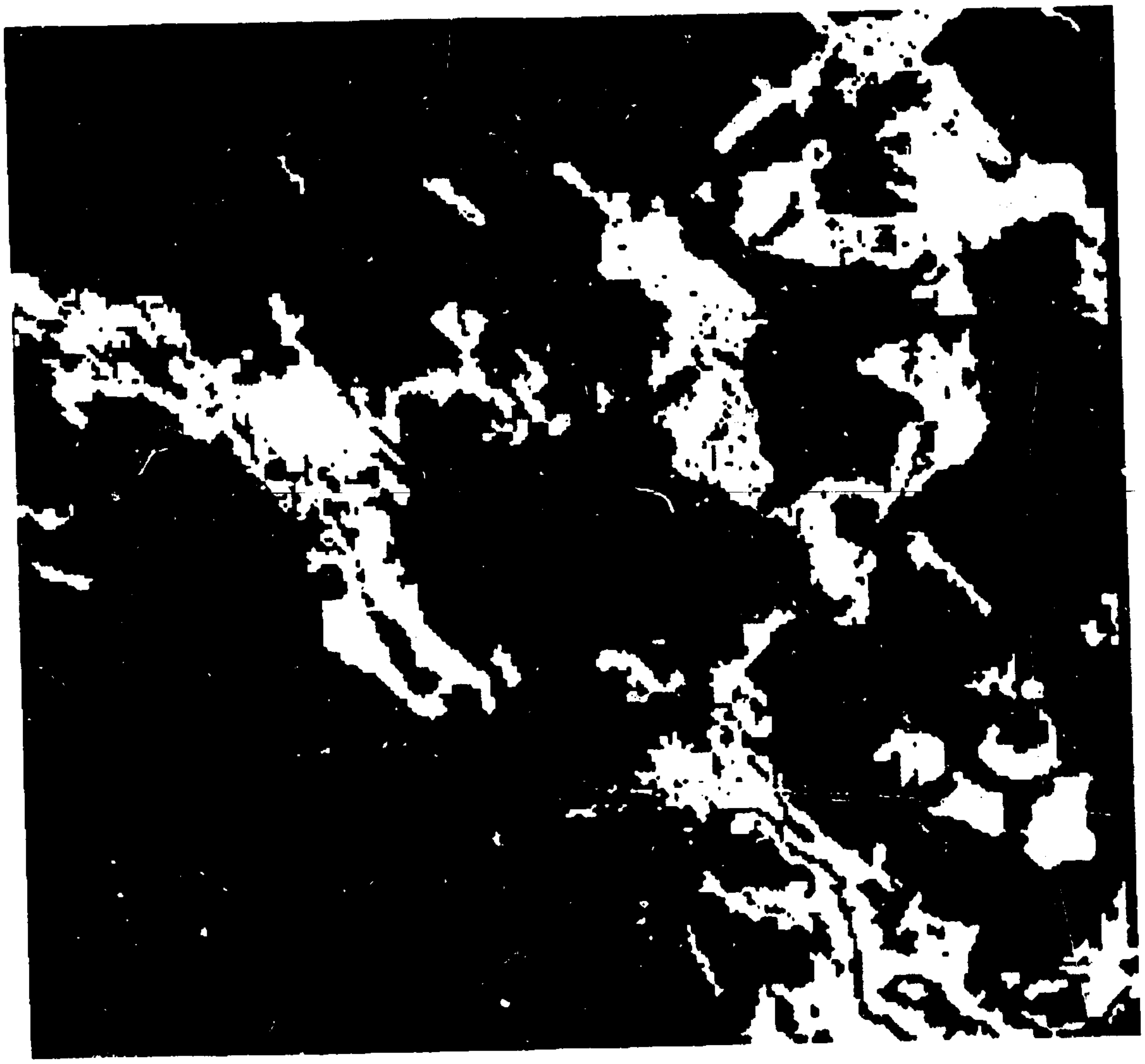

Figure 3.- Same soils information as shown in figure 2, machine-processed, for Itasca County. Loam is orange; sand over sand is yellow; sand over loam is light green.

Figure 4. Machine-processed map of geologic regions in Itasca County.

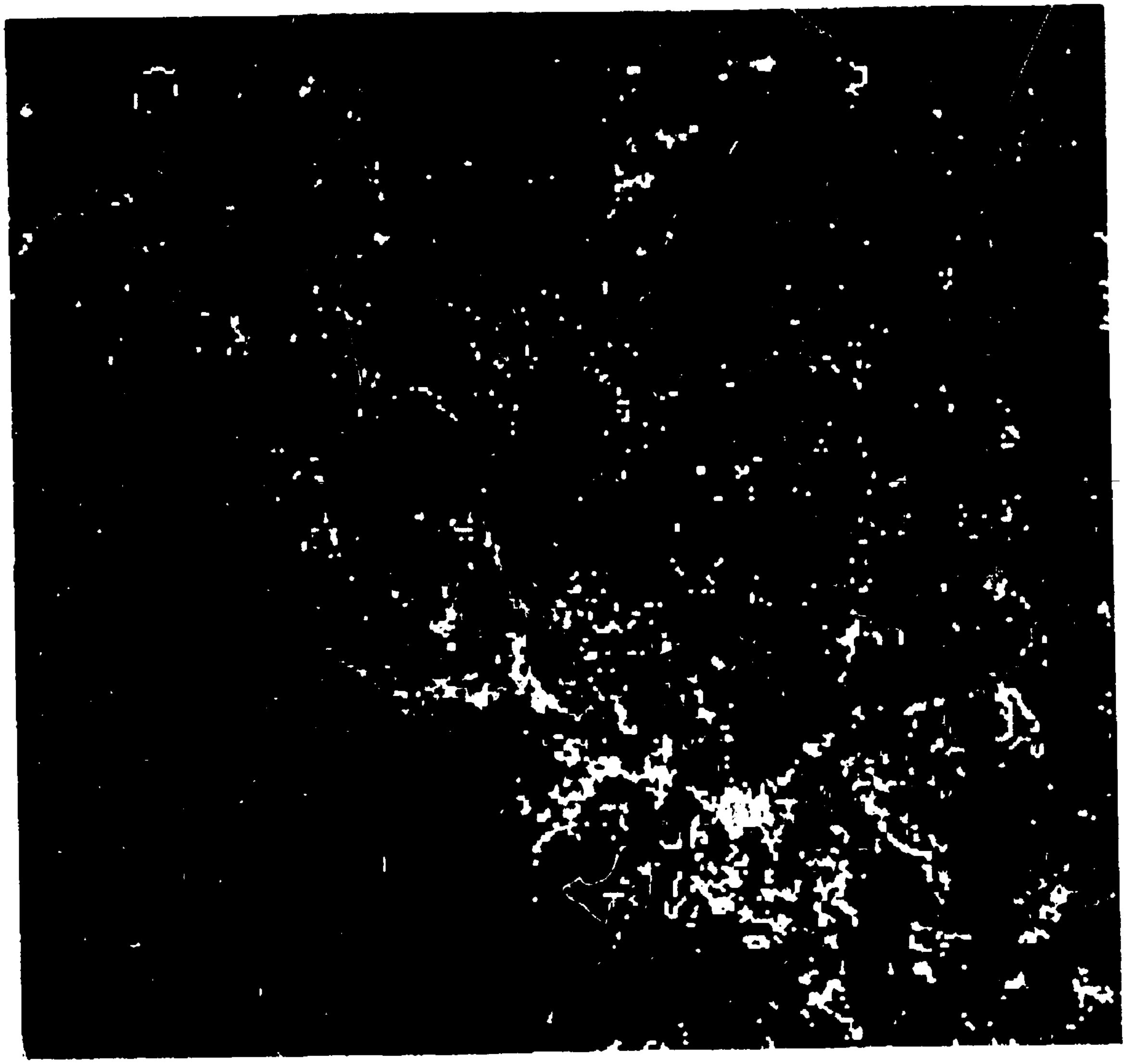

Figure 5. Land use map of Itasca County produced by the Minnesota State Planning Agency.

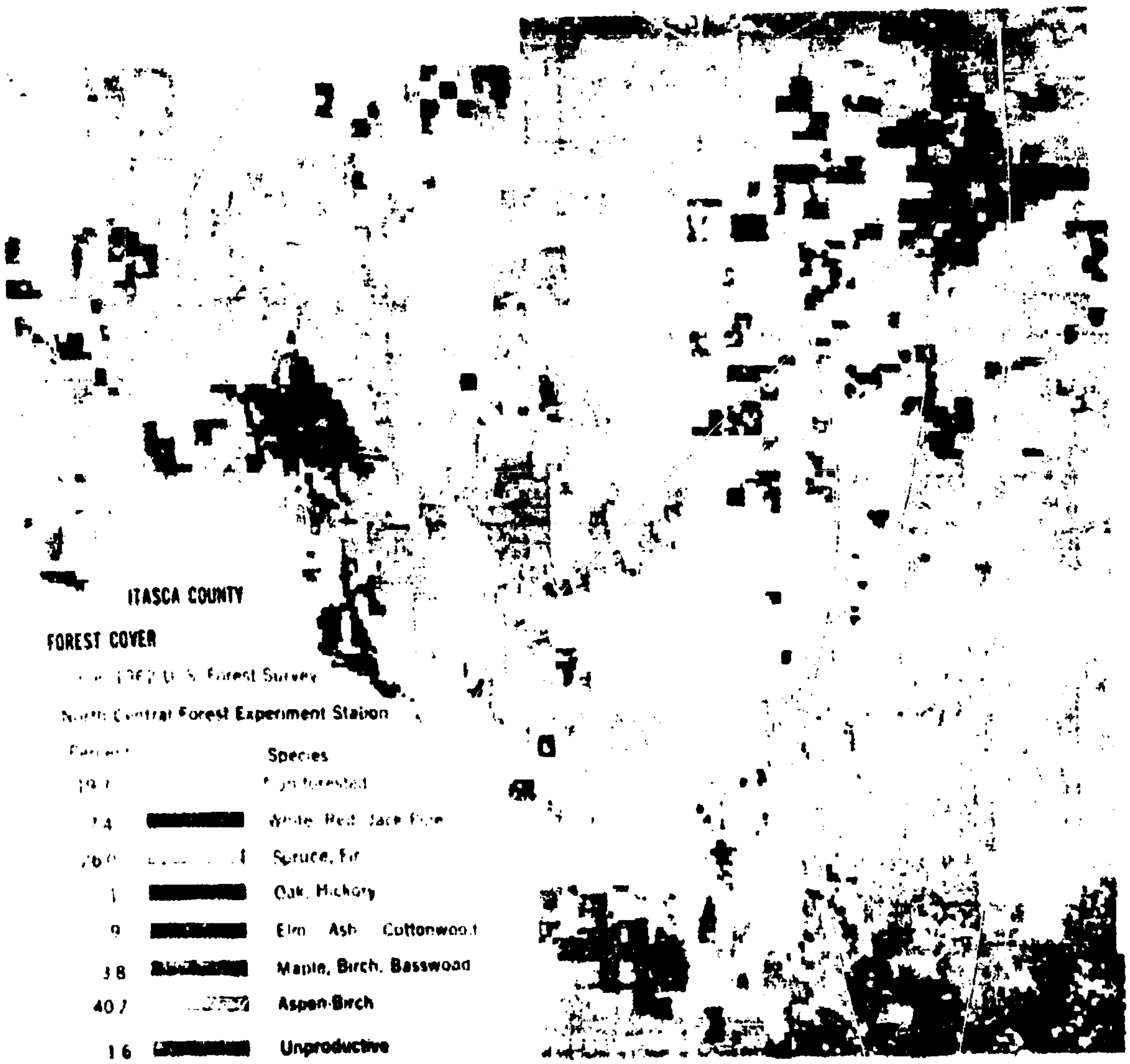

Figure 6. Hand-produced map showing types of forest cover in Itasca County.

Figure 7. Machine-produced map showing the same information for the same area as figure 6.

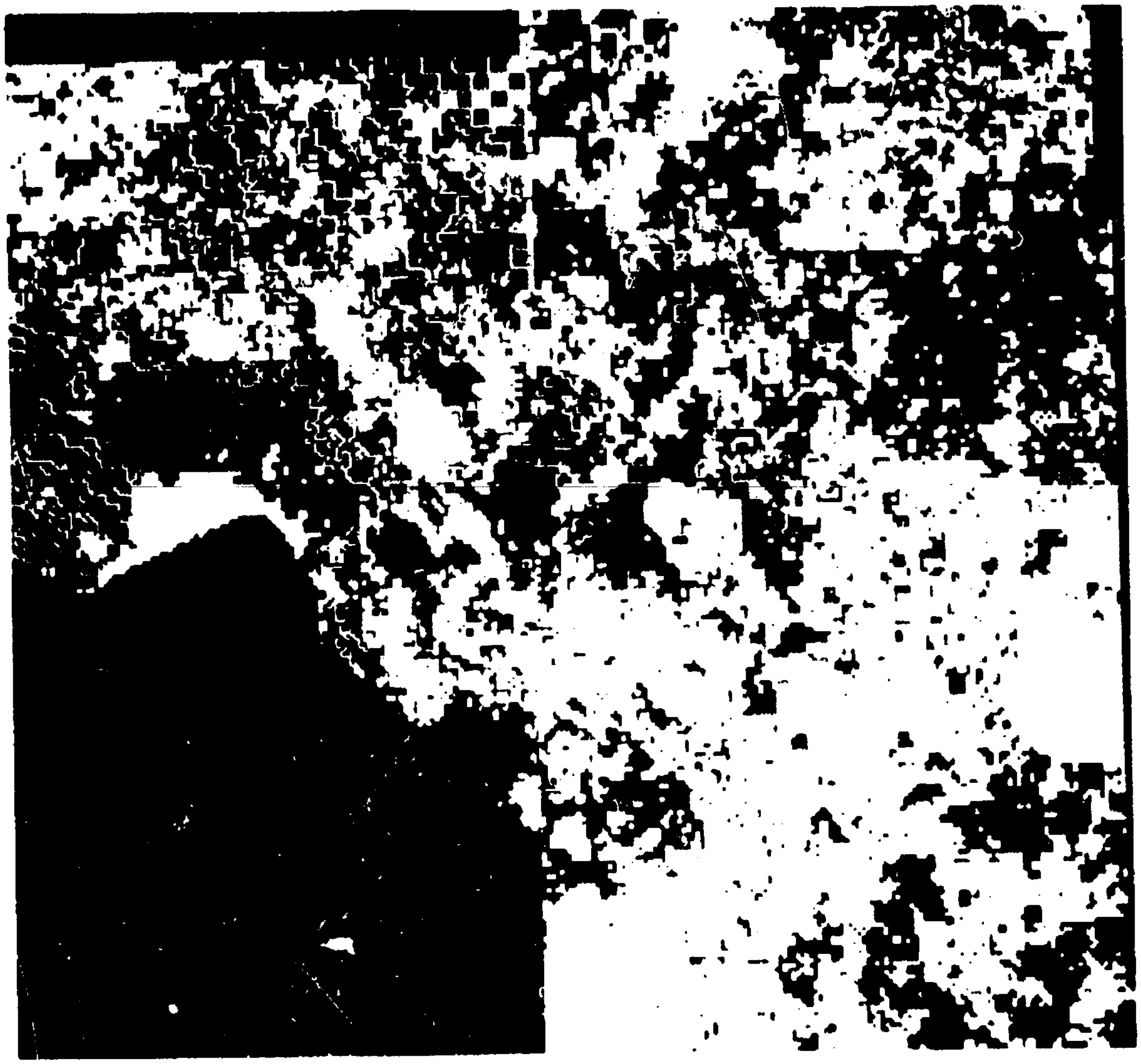

Figure 8. Public land ownership in Itasca County shown on a machine-processed map.

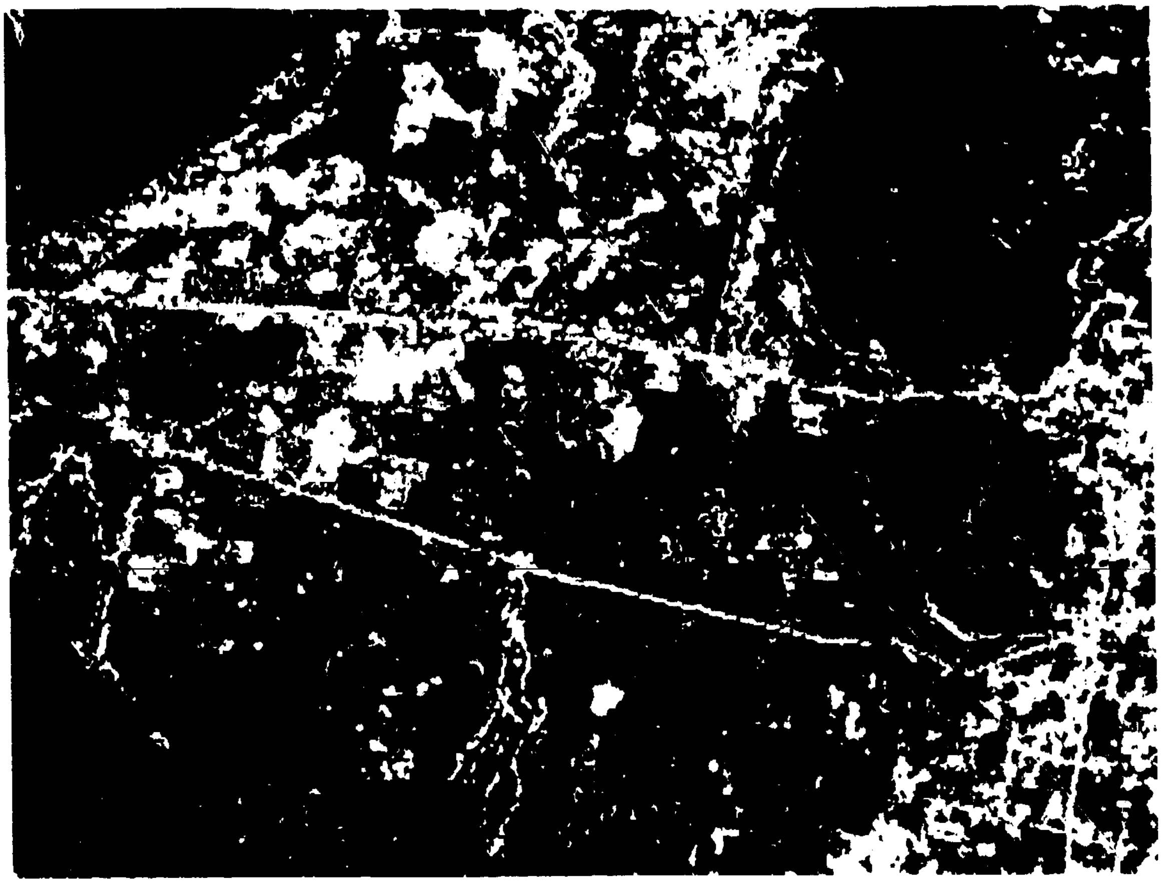

Figure 9. A printout map made directly from a tape. Both lakes and urban areas appear blue. The lines are major highways.

DISCUSSION

HARDY: In New York State, we have never been very successful in putting any great amount of land ownership into a retrieval system. The cost is high and the amount of use is limited because, usually, the agencies and people who own the land already know they own it. It is not really new information.

SIZER: Most of the land in Minnesota is the responsibility of the Department of Natural Resources. The problem is that its staff cannot effectively display the locations of that ownership. So, although they know where it is, they cannot look at it in a way that will help them start making judgments. Until the ownership pattern is known, it is difficult to discuss meaningful management programs. When we get information from Landsat, we cannot apply it to the responsible organization, because we do not know which agency has the responsibility in that particular problem area. We are trying to pull that information together, particularly that involving the public-sector land. In Minnesota, the Department of Administration has a responsibility to maintain an inventory of all state-owned lands. These people scratch their heads and say, "How do we do that?"

SPEAKER: I would guess that probably most planning decisions are made with information that is no more than 80 to 85 percent accurate, if we could measure any accuracy level at all. I see some heads nodding in agreement. Consequently, how far do you think we need to go in terms of accuracy? We cannot afford to go to 100 percent; that is far too expensive. Is 85, 90, 95 percent an adequate rate of accuracy?

SIZER: As a planner, I think this range would be extremely adequate. The real problem is knowing how adequate it is. I don't think it is a matter of 95 percent or 85 percent. It is important that I know which it is so I will know what kind of decisions I can reasonably make with the information. I need to know how reliable it is, how often it was updated, and what the potential is for error. We were putting things at three levels: 2.5 acres, 40 acres, and 10 meters. The information on soils that is at 40 acres, for example, we know is accurate at somewhere between 200 and 600 acres. So, even though it has been input at 40, we know that the level of accuracy is not 40 acres but, rather, 200 acres to a section; it depends on where that soils interpretation was done. In certain areas of the state, we know that soils are pretty consistent; therefore, the 40 acres may be quite accurate. So it is really a matter of knowing the state.

SPEAKER: There are two types of accuracy in resource inventories. One is cartographic accuracy; the other is interpretation accuracy. Have you been able to separate those out of your resource inputs?

SIZER: The cartographic accuracy is going to be limited by the cell size being used. We can print out to about 1 acre. The problem again is the interpretive accuracy of the 1 acre. The other real problem is the geocoding technique. If you are using UTM, or the 40-acre, or longitude and latitude, your accuracy limits are determined to some extent by what you are using. We are trying to develop the capability of moving from the universal transverse Mercator to the Miller cylindrical projection because we want to get the census information into that as well as the physical information that has been collected in another system. Some information is accurate only to the county; for example, population information.

SPEAKER: You are assuming that those 40-acre cells are uniform; but if you accumulate those cells on a statewide basis, how much variation are you getting?

SIZER: We are getting some variation. The problem that plagues us is that, where we have overlaps, we have to sit down and make a decision. We decide where we think the line ought to go and therefore what information should go into the cell. When we place all these things on what should be a grid and they do not fit, we must squeeze them together just a little bit. And, that is when we have to make additional interpretations. An interpretation was made at one time for a given area, and it does not fit. It is simply a matter of trying to correct for errors that were made in the original land survey.

SPEAKER: In that land use inventory, storing the land use for every 40 acres, do you lose information?

SIZER: Yes. For example, if a 40-acre tract has five houses or more, it becomes residential. The rest could be forested, but the decision is made that the ultimate use of five residential units makes it more residential oriented than forest oriented. And so the decision is made to call it residential. That is why you always need clear ledgers, chronicling what you have done and why, so that people can go back and make additional interpretations if they wish.

SPEAKER: We have had some experience trying to relate Dicomed outputs to people who are more accustomed to a map that records points and highways. What is your experience using a computer-generated type of map?

SIZER: We are still wondering how it is going to work. We have not had a chance to put the Dicomed material into the hands of the users. Users can understand and work with the hand-colored maps. They are using the normal maps they get, the soils map or the geologic topographics. When they receive something a little different, it might take a little time, but the color separations are so clean that we hope some of the resource people will soon begin adapting. Whether this is the best hardware to use or whether we should use some other machine, I just don't know. But, it is not too expensive and the time required to produce a map is very small.

STEWART: I have yet to hear anybody explain how to get this information into the hands of the county-level government officials, who are going to be making decisions on where to grant variances in the flood plain, and to the city planners and planning commissions, who are going to be deciding the uses for these 40-acre tracts. I don't have access to any of this information. Can those of us on the local level get it?

SIZER: In Minnesota, we are working with the regions, one at a time, and with the individual counties within that region. So, as we build up the information for their area, local officials are being taught how to access the system. Region 3, the one that we are just finishing, has a terminal now, so people there can access the main information source at the university at St. Paul. They can retrieve information, they can add information, and they can make analyses and call things out. The only way is to actually work with the local planners and decisionmakers. If we tried to do it any other way, it would not work, because they would reject the idea as being too sophisticated for them, although it really isn't so complicated. It takes longer to develop the system this way, but we have a user base when we get through.

SPEAKER: Do you then hold public meetings and get additional information from the county levels?

SIZER: We are actually taking some of the information from the county itself.

N76-26665

S-10. Remote Sensing in the State of Ohio

I. PUBLIC POLICY

Paul Goesling[a]

Today, I have my bureaucratic hat on, and if some of you question that I'm really a bureaucrat, I have a hole in the bottom of my shoe that indicates I'm overworked and underpaid. If it seems strange to have somebody here from the Department of Economic and Community Development and somebody from the Department of Natural Resources making a joint presentation, it's really because we don't trust each other alone.

In Ohio, we have 16 major metropolitan areas while 80 percent of our gross state product is generated by agriculture. We have an Appalachian region covering 28 counties which have been strip mined, outmigrated, and finally resurrected as an example of what bureaucrats can accomplish. We have some of the richest farm area in the country augmented by urban areas that are either in an advanced state of decline or in an extremely healthy state. In Ohio, we have roughly 10 million people and an \$11 billion biennial budget. In short, we have a great deal of work to do, which is why we work together.

The history of involvement by the Department of Economic and Community Development in remote sensing began with a no-cost Skylab contract in which we contributed \$7000 to see what would happen. We did find some interesting results. This was followed by a Landsat investigation, and now we are engaged in a follow-on. The orientation of our department has always been as a user. We have been primarily interested in getting other people who might potentially be consumers involved with remote-sensing applications.

Strictly from the viewpoint of a state agency, a successful remote-sensing program depends most importantly upon the user commitment. In our department, we had to get some personnel who understood the technological aspects of remote sensing. We had to generate some additional funds, either by cutting out programs for which we had low priority or by using whatever funds we had in the appropriation to get some additional support. We have had to invest considerable managerial time to make sure that things fit together as they should. And finally, we have had to maintain a constant orientation toward applications. We have not been provided the luxury of examining the long-range aspects of remotely sensed data, but instead have had to focus upon immediate applications because we generally have an impatient clientele.

Some managerial concerns that we have identified as being extremely crucial to our remote-sensing program in Ohio are as follows.

The program must be interagency. We have no overall coordinating state planning agency and we must work together and must seek each other out. I believe we successfully accomplished this on our own initiative without anybody imposing that upon us. We have certainly addressed ourselves to the intergovernmental aspects. I think intergovernmental applications are reflected in all our work. We certainly have constantly tried to demonstrate a potential return without overstating the progress and capability. We find, when we try to solicit consumers and get them involved, it is very easy to overstate what can be done and what products can be generated for them right now. Later, they walk away disappointed because we were unable to meet their expectations. Finally, we must have a broad network of technical and user contacts and be able to handle constant interaction with the various groups.

I'd like to grind my own ax just a little bit. We have an economic and community development orientation and always have had and always will; that is what we're charged with doing. Most of the present research orientation is toward natural resources: land cover and environmental issues and the identification of natural phenomena. As a department, we bring a somewhat different orientation which emphasizes the urban areas in Ohio, industrial location, growth and development trends in urban areas, state economic policies, public facility investment, and management. This orientation has caused us to look at different types of applications of satellite and conventional remote-sensing data.

[a]Ohio Department of Economic and Community Development, Columbus, Ohio.

We have identified three major potentials into which we are presently putting some research funds and really trying to generate some useful products. We're looking at the expansion of urban areas and the pattern of development, and we hope to get a routine procedure for monitoring urban growth in Ohio. We have developed the software programs and are now collecting some of the input data to a growth allocation model which uses Landsat land use information as the basic component in allocating future growth. It is generally a policy analysis model (explained further in paper L-3, vol. I-C). Finally, we are looking at key facility siting and monitoring and the use of remote-sensing data in this kind of application.

We have a number of problems. We find that we must emphasize the urban in the research and applications. We must continually stand up and be counted as being primarily interested in the urban because we find a tendency to deal with natural resource issues. We also find it very difficult to anticipate in-house costs for making this kind of research operational. For example, we cannot say that in 1977 we will need an exact number of dollars to make something work on a routine basis which has been proven to work in a research framework. Finally, we have had some difficulties in developing systems personnel and techniques to build the applications bridge between what the researcher can do on a one-time analysis and what we need in order to deliver a meaningful service to our clientele. Service delivery requires a great deal of in-house commitment and capability.

We have a number of recommendations. We would like to see NASA consider mechanisms for merging Federal funding sources (such as highway funds or Department of the Interior or Department of Commerce funds, or maybe even some HUD funds) to provide applied research with specific applications in mind. In other words, we are suggesting that we have some up-front money to look at different potential applications of the data, but we're having difficulty finding funds once we hit upon an application which can be made operational. For example, we may be able to use highway funds to make operational some of the work in the land use area. Finally, we would like to think it possible to consider making specific application funds available from NASA. In other words, given a situation in which the research indicates a useful output, funds should be made available for developing the in-house capability to harness the output and for generating the output on a regular basis. It requires a great deal of salesmanship and it requires a great deal of justification to generate the in-house funds.

We have found in Ohio a successful way to make Landsat data operational in an inventory which can be used across the state at a variety of scales and with a variety of levels of classification. We have made an interagency commitment to the routine use of satellite data. Without this kind of commitment and without in-house state capability, the routine use of satellite data will remain difficult if not impossible.

II. SYSTEM DEVELOPMENT

Frank Leone[a]

A system has been developed in Ohio over the last few years which I think will allow us to handle data from remote sensing, or otherwise collected, in a variety of mechanisms for doing land use and land-related problems. We in the Department of Natural Resources have three concerns in terms of our land use planning program. The first of those is the provision of technical assistance to local units of the government. And the second is to develop detailed data for state programs on a site-specific basis. And the third is the development of generalized data for statewide land resources policy development.

The technical assistance program was basically our response to serving 1300 townships, 88 counties, and 15 regional planning districts. We are trying to provide uniform data around which they can base their planning programs.

The data collection for the site-specific program at the state level includes assistance to the legislature on scenic rivers and natural area laws, a coastal zone management grant for Lake Erie, and planning for some 360 000 acres of strip-mined land in the Appalachian regions.

The mechanisms chosen in development during the

[a]Ohio Department of Natural Resources, Columbus, Ohio

last 2 years is something we call the Ohio capability analysis program (OCAP); OCAP has two parts. It is a software package to store, edit, and manipulate map data to a form that we believe is suitable for various users. The format that we have chosen is organized around a 7½' quad, the series of maps out of the USGS. The data can be manipulated into any format besides that; for example, by county, township, or watershed. But the original data are stored at the quad basis. We are not talking strictly about land use and land cover and remote-sensing data. We are also talking about detailed soils classification, surface and bedrock geology, and topographic analysis of surface and ground water. The second part of the OCAP program is a set of analysis functions which evaluate the data base for a prescribed set of land uses, usually dictated by the user that we are trying to serve. For example, if a township wanted to know the impact of a proposed state park, we would provide data at the township level for planning for that contingency. We would provide a county with county-level analysis for the preparation of comprehensive development plans. And we would provide data to multicounty agencies for programs such as the EPA section 208 waste water management program.

You may think that a flexible data manipulation system will allow us to provide the assistance that we are talking about in each of these areas. I think it will probably get me to a point where I can talk a little bit about remote sensing. We rely very heavily on remote-sensing data in the process we use to get data base into the computer and operational, to digitize a hard copy map and get it into a clean data file, to get a map copy with a high-speed printer output of the actual data and a map copy of the analysis function. To date, we have used mostly black-and-white low-altitude photography at scales ranging from 1:4800 to 1:24 000 for site-specific analysis and 1:80 000 for regional analysis. This, of course, requires a great deal of data conversion. We have to manually interpret the data, using equipment such as a Zoom Transferscope to transfer to a uniform base map, digitize, edit, and finally have a clean map file.

The nature of the Landsat data and the reason for proceeding with the inventory for land covering is that the computer classified tape can be easily input directly into the OCAP system, giving us a mechanism for manipulating the data once obtained. This becomes one data variable in a set that ranges somewhere from 10 to 20 data variables, depending on the analysis we are about to perform. I think a really good example of how the system can be used is the work of the Ohio-Kentucky-Indiana Regional Council of Governments (OKI) using Landsat data in the section 208 waste water management program. We think that the process is relevant and should be provided at the state level for all regional planning agencies doing the same kind of work that OKI is now performing. And we hope to be able to provide it to them using the OCAP system.

In summary, we have specific uses in mind for the data. And we think we have a system to put it into once we get those data. And we are satisfied in the mechanism for the use of Landsat data to the limit of the resolution. I think NASA and other Federal agencies must channel their efforts or rechannel their efforts to provide detailed data for various programs states are charged with doing under proposed and existing Federal legislation. Duplication is occurring in small-scale national data collection efforts, and this should probably be examined very closely.

DISCUSSION

QUERY: At the time the system was developed, at the time you got your original go-ahead to participate in this, or at any time during the development of this system, was there ever a cost/benefit analysis done on your part to see if it was really worth being involved in? Or, because you are providing services to users through your own staff, do you feel that is really not an appropriate kind of question at this point of the system development?

SPEAKER: It is an appropriate question, but I think the cost/benefit analysis would be very difficult. We can't amortize an investment at the state agency because of cost savings accrued by local regional agencies through the provision of the data. Take the example of a county analysis completed in Ohio. Lake County was the first county we completed. For the year since it has been completed, we can evaluate the numerous uses that have been made of that data base and that analysis, by public agencies in the county, by the county itself, and by private consultants. I think you begin to amortize the investment quite easily. The cost of getting that system together — not the data collection itself but getting the system, taping the data, putting it into the computer, and providing the analysis — will range about $15 000 per county. The money is well spent.

QUERY: The whole system is aimed at providing better information to make decisions on, and yet it is never challenged itself as to the decisions that are being made in relation to the development of the system. We just assume, and I think perhaps incorrectly, that the political process is not operating or not operating at an optimal level and therefore a system needs to be developed to provide information to expedite the political process. But that system itself and why we should be involved in it doesn't seem to ever be challenged except from one point: either we are in it or we're not. But nowhere do we come up with any kind of cost. And the second question I wanted to ask was about capital investment. What is the relationship between your state capital investment plan and the use of these data? Is there a comprehensive capital investment plan, and what is the input from this?

SPEAKER: We do have a comprehensive capital investment plan which covers 5 years. It is really a wish list. It is not a realistic listing of those projects which are likely to become realities. It is a collection of submissions from agencies invited to make a capital request. That document is virtually discarded and what becomes a reality is an appropriations bill, which in Ohio – much as in many other states – is in some degree a pork barrel and in some degree a reflection of some real priorities. An example of what is being done is with the aid to higher education bill. A somewhat cursory examination of the economic impact of those investments in those counties where they occur is being done. And the state of Ohio Department of Economic and Community Development will assess the increase in jobs resulting from the capital investments. But the land use inventory and the application of remote-sensing data do not play a role in that assessment.

QUERY: How big is your annual budget for this program, for the remote sensing through to the analysis?

SPEAKER: For the upcoming year, we have a grant from NASA of \$180 000. We have a \$112 000 commitment from three state agencies, the Ohio Department of Natural Resources, the Department of Economic and Community Development, and the Ohio Environmental Protection Agency. In addition, we have an approximately \$40 000 Skylab grant, but it is not related to any of this discussion.

QUERY: Can you translate that into the cost per square mile or something?

SPEAKER: I didn't mean to imply that total amount applied to the inventory. It certainly does not. We are talking about a statewide inventory generated from the computer-compatible tapes run through software programs at the Department of Natural Resources and output as maps. That process costs roughly \$171 000 for the entire state. In 1960, my department did a similar inventory manually for the cost of \$191 000, which in 1975 dollars converts to about \$304 000. If that's some type of cost/benefit analysis, I doubt it, but at least it gives you a comparison.

QUERY: Even while the amount of money involved is not that large, still I think it is right to require that a system be challenged on that basis. I think everybody is aware that the new in-vogue activity for state planning agencies and other state agencies is the use of information systems, and they have just proliferated. Every time we turn around in Iowa, we are being asked to take on a new information system and develop it. The money involved is not that great, but it continues to grow. We get involved in them and we're producing information, but to what end? And it seems like in just another year or two, there is always something new which comes along in which we have no master plan ourselves for controlling its adoption.

SPEAKER: I think your point is well taken.

QUERY: I was going to ask a somewhat similar question. You did mention there was no central agency responsibility for the development of the system, that it is now based on the interest of several state agencies in cooperation. Would you feel more comfortable if a single state agency were charged with this responsibility, either legislatively or through governor's directive? That agency could begin focusing on the kind of questions that obviously are going to come up: the validity of the data, what kinds of manipulations will be permitted, how reliable it is, and how often it is going to be updated. Whether it be \$500 or \$5 million, we are interested of course in how we spend the money, but we also want to make sure that we get as much as we expect to get out of it. But no information system is going to answer the question for you. Therefore, someone has to be able to put a limit on what is a reasonable amount of money and a reasonable anticipation.

GOESLING: Let me respond to that by making three points. There is an agency under development by the present governor, a very small one consisting probably of three people, that will have the major responsibility of coordinating interagency programs. Secondly, our governor has the philosophy that if you cut a department's budget to a point where it is really strained to accommodate those programs that it considers very high priority, you will induce interaction. And in this case, it worked. The Department of Natural Resources took a technical look at the situation and said, "This seems to work for us; what do you think?" Our reaction was that it does work for us the same as the Ohio Environmental Protection Agency. And then I took a look at what kind of funding we had and said, "What kind of money do you have?" And we were able to buy into the product proportionally. Another point I think is important to understand in terms of defending what we do, either as a lump investment or as a realistic product that makes sense. That is the responsibility of the person applying that information in a given situation. Any information wrongly applied will certainly yield wrong results, and then it is the responsibility of the individual who applied the information to justify what it did. I think that is the viewpoint the three departments have at this time. Our potential application is different from the Department of Natural Resources applications. And the Ohio Environmental Protection Agency's application is different than the two of ours. And we don't particularly want to defend the Department of Natural Resources staff's application, nor do they want to defend ours. So it is each man for himself.

SPEAKER: The process as it now stands was defined out of user requests. We concentrated on what we thought was a consensus of specific needs in specific areas, so that user applications did not have to be sold when the process or the project was developed. The need was there before we even initiated the development of, say, the software package or the uniform data collection.

QUERY: You mentioned key facility. What does that mean?

SPEAKER: We have no definition. We prefer to choose the route that Wisconsin seems to have chosen, which is basically to enter the local political situation and have those people tell us what they consider the key facility. I know that is essentially begging the question and asking somebody else to give you a definition. But we feel more comfortable with that procedure at this time. What we have done, though, is to develop the methodology for assessing the environmental and economic impacts of the key facility. The theory applied in the particular technique we have developed is no more sophisticated than input and output analysis and survival population projections; it seems to yield the reasonable results when tested against user criteria. I want to emphasize our orientation toward a decision, be it a small housing development or a nuclear powerplant. If you would like to get into the business of trying to determine what that decision means to you as a community, however you define that word, we will try to help you technically and with information and some expertise.

QUERY: Are you trying to take this information to the counties and the communities and help them learn how to use it, or are you just working with the regions?

LEONE: We work with a mixture of agencies. If we have 15 projects in a year, we will deal with a mixture of townships, counties, and regional agencies pretty much evenly divided. The idea of the process is to put together a uniform data base that can be used with any of those applications.

QUERY: You said that you were basically user oriented? Does that mean your classification system is open-ended and expandable? Can it be changed to the users' needs?

SPEAKER: Yes, it is.

SPEAKER: I'd like to react to the comments on cost/benefit analysis. I am not convinced that cost/benefit analysis is a valid technique to be used for evaluating land capability analysis systems, for two reasons. It is hard to measure a lot of things that you can do with it. For example, through a land capability modeling process, you prevent one section of prime agricultural land from being converted to a residential development, and kind of shuffle that residential area off somewhere else. What is the value of one section of prime agricultural land? It has a certain market value per acre, but the long-term value is often hard to assess. And the second reason is that it is very hard to evaluate spinoff effects. You really can't figure those items into a conventional cost/benefit analysis. My personal philosophy is that if you are working with limited resources, you can either talk about doing something or you can do it. Often in a bureaucracy, you can really get carried away with this cost/benefit thing; you have a real nice analysis after a few years, but that's all you have. You don't have any product at hand. I would prefer to go ahead and possibly risk making a mistake and wasting a little money, because the cost/benefit analysis might do the same thing, and get something done with the effort that I would be applying to that analysis.

N76-26666

S-11. The Use of Satellite Data for Regional Planning

A. H. Hessling[a] and Timothy G. Mard[a]

The use of satellite-generated data and maps by state governments has, in just a few years, become widespread and almost commonplace. But local planning agencies, whether county or municipal planning commissions, special-purpose agencies such as conservancy districts, or regional planning agencies, are just beginning to make use of this valuable new source of information. Regional planning agencies, which are often organized as councils of governments, may offer the best opportunity for the expanded use of satellite-generated information. The reasons for this are (1) the relatively large area covered by each regional planning agency, (2) the type of planning activities in which they are involved, and (3) the large number of such agencies. In describing this "new market" for satellite-generated information, it may be useful, as an example, to discuss the experience of the Ohio-Kentucky-Indiana Regional Council of Governments (OKI) in its development of a regional land use inventory from computer processing of Landsat-1 digital tapes and the use of those data in the OKI water quality planning program. Some brief background information about regional planning in general, OKI, and regional water quality planning in particular will help to put things into perspective.

According to the "1974 Regional Council Planning Directory," published by the National Association of Regional Councils, there are more than 600 regional planning agencies throughout the country. These agencies exist in almost every one of the approximately 250 metropolitan areas in the United States. Many, such as OKI, were created in response to the Federal Highway Act of 1962, which required local governments to participate in a regional development and highway planning program in order to qualify for Federal highway assistance. In addition to the urban-oriented regional planning agencies, most states have created multicounty, substate planning districts. In many instances, the metropolitan planning agency is also the substate planning organization for its area.

Each agency has undertaken planning activities in various functional areas. The OKI, for example, has completed an overall development plan, as well as plans for highways, housing, open space, water supply, sewage disposal, and solid waste. Currently, the OKI staff is working on a mass transit plan and a water quality plan as well as updating other plans.

The OKI region, geographically centered on the Cincinnati metropolitan area, encompasses 3100 square statute miles in 10 counties: 5 in Ohio, 3 in Kentucky, and 2 in Indiana. The council of governments was created by agreement of the participating counties under applicable provisions of the three states' statutes. The region has a population of 1 646 811 (1970 census), which is projected to surpass 2 200 000 by the year 2000. There are 128 municipalities, 81 townships, and a large number of special districts within the region. In this context, the need for regional planning becomes obvious, as many of the problems that face local government cross political boundaries. Prime examples of this are transportation, water quality, and air quality.

The OKI is a locally controlled, representative organization whose 100-member board of trustees includes representatives from all areas of the region. The board meets annually to elect a 26-member executive committee, which has the power to adopt plans, resolve major issues, and establish policy. In addition, OKI has been designated by the U.S. Office of Management and Budget as the metropolitan clearinghouse for review of local applications for Federal assistance to ensure that the projects are compatible with the plans adopted by OKI.

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) created several programs to fight water pollution. Under provisions of section 208 of that act, regional planning agencies such as OKI were given the opportunity and funding to undertake regional water quality planning. The OKI was one of the first regional agencies to receive

[a]Ohio-Kentucky-Indiana Regional Council of Governments, Cincinnati, Ohio.

a section 208 grant from the U.S. Environmental Protection Agency (EPA). By mid-1975, 149 agencies either had begun work or had been assured of funding. The EPA-administered program differs from past HUD-financed water and sewer planning in that it deals with all sources of water pollution, not just pollution from municipal sewerage systems. Other sources of water pollution for which planning responsibility is given are industrial discharges and what are termed "nonpoint" sources, which include runoff from agricultural areas, runoff from urban areas, erosion from construction sites, and leachates from septic tanks.

A major task of the section 208 planning program is the prediction of water quality in rivers and lakes resulting from existing and future land uses. This prediction will lead to the formulation of new land use policies that will reflect the need to improve water quality. To achieve this, OKI has developed a model that can predict the flow of sediment, total phosphorus, total nitrogen, and organic wastes into major streams.

An essential input to the model is an accurate map of land use. The OKI needs to know how much acreage of each land use type is within each of 225 drainage areas within the study area. Other variables include slope and soil type.

Each land use type has a special characteristic that is important in calculating the quantity and quality of stormwater runoff. For example, land used for growing crops is often tilled in the spring when rainfall is heaviest. Much of the rainfall is absorbed into the ground, but erosion can be significant under such circumstances, resulting in sedimentation in nearby streams. In a central city area, where virtually all of the ground is covered by pavement and buildings, little or none of the water is absorbed. Instead, it flows rapidly into storm sewers, carrying with it dirt from streets and buildings. The runoff from these two types of land uses is quite different in character.

The relationship of land use planning to water quality planning, then, becomes quite obvious. The inventory of present land use, together with population projections, will serve as a basis for developing a future land use map. With future land use predicted, the water quality model will be run again to determine the impact of future development on water quality. This analysis will lead to an identification of critical areas where alternatives will have to be developed to minimize any deleterious impact on water quality.

Because the section 208 program involves planning agencies in a type of planning with which they have not previously dealt, new data systems must be developed. This is particularly true in regard to land use data. Land use information currently available to planning agencies is generally not adequate for water quality planning purposes. Usually, agricultural, forest, and vacant land has been lumped into one category: miscellaneous. Urban land uses often are not identified in terms usable for water quality planning.

Because most planning regions are fairly large, the traditional land use inventory techniques of manual interpretation of low-altitude aerial photographs and "windshield" surveys are too costly and time consuming; measurement would take a team of five people approximately a year to complete. Faced with this dilemma, OKI found another source of data: Landsat-1 digital tapes. The staff found that the needed land use inventory could be generated through machine processing of Landsat-1 digital tapes at a cost no greater than that of traditional techniques and with a great savings in time. The fact that the data are computerized and could be plugged into other programs was very important in OKI's decision. Subsequently, OKI entered into a contract with the Bendix Aerospace Systems Division for it to process the digital tapes, to provide statistical summaries by drainage area, and to provide a color-composite map for display purposes at a scale of 1:60 000 (fig. 1).

The OKI staff worked with Bendix to determine which land use categories could and should be identified and assisted in selecting ground-truth data. The result was a land use breakdown that includes grassland, active cropland, two densities of woodland, four densities of urban development, and surface water. A map of a small portion of the OKI region, produced at 1:24 000, was used to verify field inspection results. The data did require further manual interpretation; some categories required a further breakdown, whereas others were so similar that they needed to be combined. It was OKI's experience that machine processing of Landsat-1 digital tapes is a viable method for conducting a land use inventory for water quality planning. In the future, OKI intends to determine how the data might be used for other OKI regional planning activities and how the data might be used by local planning agencies in their land use decisionmaking.

Perhaps one reason more regional planning agencies have not used satellite-generated products is that they are reluctant to base the success of their various planning programs on something so new. Others might be more receptive to the use of these data if special funds were available to them for the development of data systems or if the Federal or State Governments would process the tapes and furnish the data to the local users.

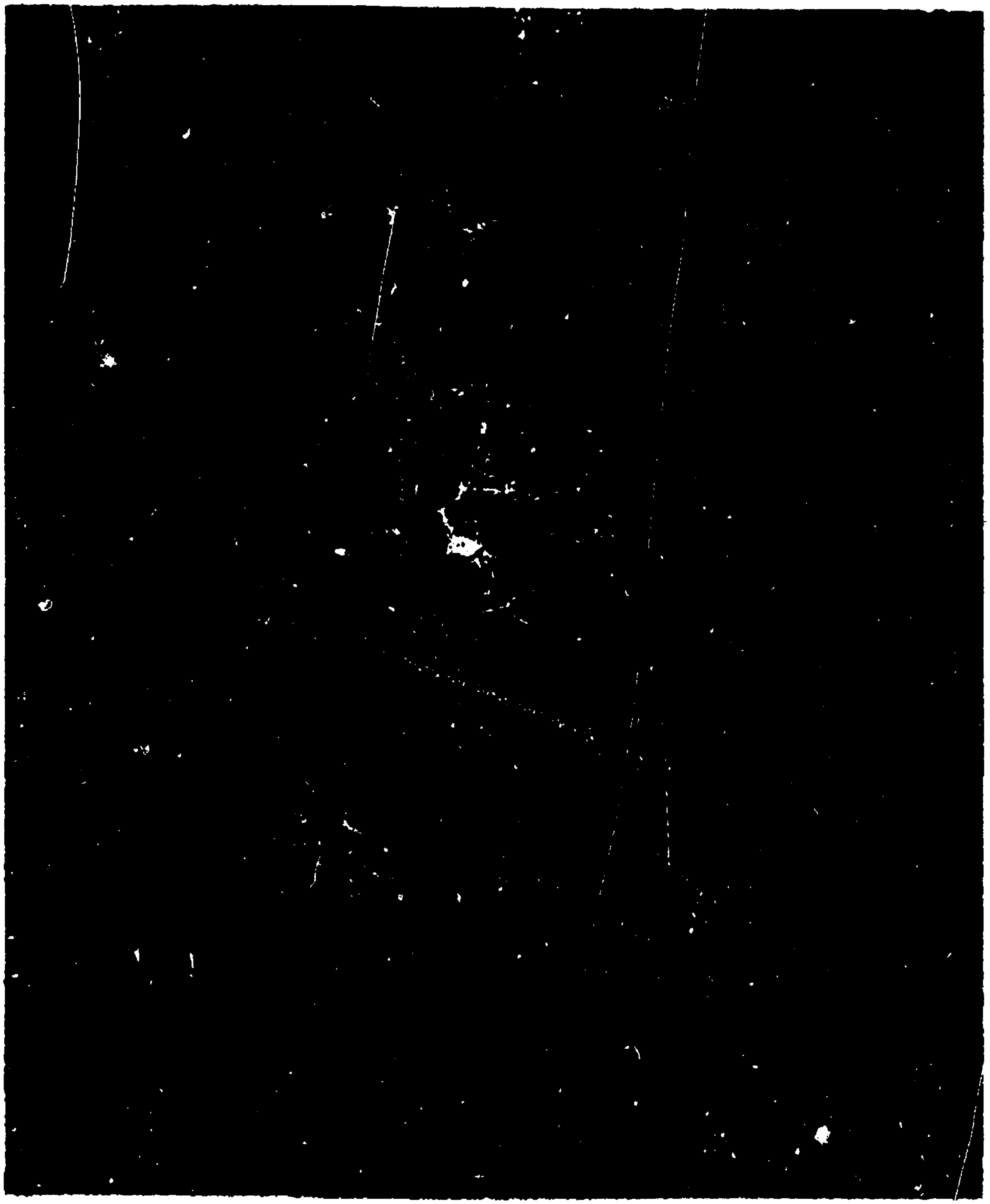

Figure 1. Color composite of land use in the OKI region and surrounding areas generated from Landsat-1 digital tapes. Cincinnati, appearing white, is near the center on the Ohio River. The southern part of the region is more heavily wooded (green), whereas active cropland (red) is more prevalent in the north.

N76-26667

S-12. Policy Implications in Developing a Land Use Management Information System

Albert J. Landini[a]

For the past 15 years, the Los Angeles City Planning Department has systematically sought to develop an integrated land use information system. Our ideal has been the development of a geographically based system using the individual land parcel as the primary record and encompassing all data associated with that parcel.

Lacking sufficient monetary resources for our ideal, we developed single-stage information systems for each level in the critical geographical hierarchy. These systems have not necessarily been computer oriented, and natural resource data were not considered for incorporation.

Because we elected to join with the Jet Propulsion Laboratory (JPL) in the land use management information system (LUMIS) project, we began to critically consider the constraints of scale and resolution as they apply to planning policies. We found that all planning data need not come in at the level of the individual land parcel. We abandoned the grid cell system because it lacked credibility with the planners using the data.

Cities have streets and streets are probably the primary identifier that we all use to describe some area of the city. If I recommend a particular restaurant, I give you a street address; if I tell you how to get there, I tell you in terms of a street network. Therefore, I believe relating data to the street pattern was more critical than was the actual resolution of the data being constructed. That is the reason we went to a polygon system, the master polygon being census blocks, which are 99.9 percent defined by the street pattern.

We looked at the kinds of maps the planners were using. We found, in general, in what situations they would require parcel information, particularly for a neighborhood, community, or citywide plan that was aggregated to a block or to a separate tract. After we made this discovery, we thought that high-altitude imagery, or photography and Landsat imagery, would play a key role in providing us with necessary natural resource data for making a plan for a fairly large city of 470 square statute miles.

However, we found that photographs themselves, no matter what kind of photographs, lack credibility with a planning staff. Largely, I think, it is because planners don't know how to look at photographs. In the city of Los Angeles, which services about 2.8 million people, we can only find one person who claims to be a photointerpreter. In the county planning agency, which services 8 million people, there is only one man who claims to be a photointerpreter. So, when we took these photographs to planners, they did not know how to work with them and they generally rejected them. We then did a little market survey on the availability of photointerpreters in the planning profession. We found that throughout the planning profession, there was a real lack of photointerpreters working as planners, or planners who had photointerpretation skills.

What about using computer tapes directly? I make no pretense of being a computer programer. If I get a 20-statement FORTRAN program to run on the first submittal, I go out and have a special dinner that night. So that puts my programing skills in the perspective of what goes on in my department. I would ask a potential user one question: "Can you process the Landsat material?" Three people all gave me the same answer: "No. It's better for you to go out and seek to get $10 000 and find a consultant to do that." So a specialized industry seems to be growing up using the tapes themselves or using hardware to interpret the tapes. This will not work for cities.

Planners in a large city like Los Angeles need the USGS land use maps for the census cities. Granted, these are relatively gross maps, because someone has prejudged the resolution needed for the problem by saying, "Give it to me at the census tract level." So what do we need? We need land use maps, produced just like USGS maps, at the same price. And we need data tabulations pretty much like the census tabulations for your area that you

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can buy for $20 at any Federal publishing house That gives us the percent of land use per tract, the acres in that land use for each tract, and the number of types of land use for the area under study.

I have a daydream: I would like to be a data gypsy, wandering the countryside, bringing new techniques to small agencies, solving urban problems. If I would ever actualize this fantasy, I'd do it with $1000 of front money for any one city. And what can I do for $1000 in the planning information system today? Compare this to what you can do with $1000 using Landsat. That $1000 will buy SYMAP-HARVARD computergraphic maps (a well-documented and well-established and now fairly well-accepted computer mapping program compatible with a standard computer) for almost any metropolitan area, all of the census data (on tape and in printed publication), and the census maps. And there will be money left over to buy the USGS maps for that area and a copy of the UCLA biomedical statistical package. Now I can put all of these obviously patchwork pieces together and produce a fairly viable information system, a system that probably 80 percent of the cities over 100 000 population do not have now. That is what $1000 can do.

That $1000 cannot be spent comparably to process Landsat imagery. I don't like to just walk away, leaving you with a problem. Let me propose a solution. There are three primary data-providing agencies in the Federal Government right now. Two of the agencies, USGS and the Census Bureau, provide data under their charters on a routine and timely basis to the public. The NASA, I understand, is not allowed by its charter to produce information for users on a continuous basis, but must limit itself to experimental activities. I urge NASA, as strongly as I can in the voice of one planner, to seek to change its charter and become the third in this proposed triad of information providers: the map from USGS, the data for socioeconomic conditions from the Census Bureau, and the natural resources information provided by Landsat from NASA. With that, I think the planning cycle is completed; then, we can begin to seek to improve it.

DISCUSSION

QUERY: You are talking about a very small statistical unit the census tract is on. Do you perceive that this information could be used in zoning decisions and small area planning?

LANDINI: I surveyed our department before coming here. We have two major functions, what we call current planning and advance planning. The current planning function handles day-to-day problems. If you want to put a swimming pool in your backyard, or build a new bedroom on the back of your house, you go to either your commission/hearing process, or to our zoning administration process. Both offices use maps at a scale of 1:1200. So the small-scale data probably account for at least 40 percent of our budget here. Census tract data are for gross planning activities.

QUERY: Do you think that the satellite-generated data would be at all useful in neighborhood planning?

LANDINI: The current land use map for the city of Los Angeles was hand drawn in 1973 by the guesstimation process which involved a 1970 Plymouth Valiant and two guys going out driving a couple of afternoons. And it went sort of like this: "Do you think that block where we saw that gas station was 2 acres or 5 acres?" Yes, I think the processed Landsat data would be of value for a city the size of Los Angeles. Especially because we don't have much vertical development in the southern half of California, I think the data would be of value to any city of 100 000 population or larger in that area.

SPEAKER: You made an interesting comment about processing by the city versus processing by consultants. In our project, although we had the data processed by a consultant, we stipulated in the contract that the tapes became the property of the agency. And we also stipulated that the tapes be produced with a format compatible with the state's OCAP system. Therefore, our computer people could reaggregate the data by some other statistical unit

WRAY: I'm Jim Wray from the U.S. Geological Survey, office of land information and analysis geography program. I appreciate the kind words recognizing some of our efforts to bring together information from remote sensing into demographic users' statistical areas, such as the census tract. I see three dilemmas. One deals with the transferability of the knowledge that is being gained, one concerns the role of the map in the geoinformation system, and one concerns the dependence on parcel level detail. In the transferability dilemma, we can only commend LUMIS for the knowhow it has identified, both from a user point of view and from a technology transfer opportunity. But it also points out the limits in planning groups, the lack of photointerpretation skills. There is a limit on the transferability. The dilemma concerning the role of the map: it is a polygon-oriented system, and it requires maps of various parameters and maps also of this hierarchy of geographical areas. They must have a common base of geographical accuracy. Too often, people talking about information systems assume that, if the maps are available, they are compatible one with the other. This simply is not so. Another part of the dilemma may be that, ultimately, users such as planners do not really want information in a map form. Who says a geoinformation system has to be in map form? The third dilemma is the dependence on parcel level detail. The parcel level is an ownership unit. And, obviously, management decisions affecting how plans get carried out have to be on a management basis. So, somewhere along the line, we have to relate to this aspect of the real world: who owns the land and what is the owner's plan for its use? In my experience, working with metropolitan planning groups, the best information systems involving parcel level detail are incomplete and take 18 to 20 months to get into an information-retrievable form. So the dilemma is the timelag. We need a way to get a handle on what is happening before we get the word on the ownership level of detail. And the final question is, what is the role, if any, for Landsat in a land use management information system for metropolitan areas?

LANDINI: On the transferability, right now on the LUMIS project itself, we are trying to make a transfer of that technology to Tacoma. That will be the answer to the first question on transferability. I don't see any change in the photointerpretation process. I think photointerpretation is going to remain a relatively minor skill in the planning profession, and we will have to look to specialized consultants or specialized agencies to reformat or to do the data transformation from the photgraphs.

WRAY: Or more HUD 701 money so planners can buy consulting and technical services?

LANDINI: I think the trends should be perhaps away from reliance on the Federal funding action in local government. I don't mean specifically in terms of the Los Angeles planning department, but in general. Short-term skills get developed, for which there is no continuing use. I would rather see all of these minigrants lumped together to create something that would be vital in the long term, such as the decennial census or the USGS quad sheet activity. Some people have talked about regional centers; that may be one way. In reference to maps, I trained as a geographer, and my cartographic training was that maps were, in fact, precision instruments. Then I got into the planning profession where, instead of using the 00 rapidograph, I was handed a felt-tip marker and I knew that cartographic standards, somewhere, went by the boards. The map ceases to be an engineering tool and rather becomes a means of conveying data. I call it a fancy statistical chart. We don't model from the map. We don't even make planimetric decisions from planning maps. But a map will sway an audience about a policy a planner is seeking to implement. One of the needs that we definitely have is for data tabulations, as well as for mapped information. The maps are relative in their accuracy. They are not planimetric maps. Our parcel level system has taken 5 years to get to a point that we can simply report back the assessor's data. Somebody here talked about having satellite imagery flown at one scale and aircraft underflights to build a hierarchy of resolution into the photographs. I think of information systems, even a data-based management system such as NIPS in Louisiana, as being in several layers. How can I do it graphically? We could have parcel-level data. That is a big ball and that ball moves very slowly. The rate of change we see between points in time is greater. Landsat data, coming out in some scanned format, are being processed more quickly because we are dealing with a much smaller number of units and getting more continuous updates. This is a small ball. And if the balls are going along at the same time, the small ball must be turning faster to keep up with the big ball. These multiple systems are never going to be replaced; there is no single magic system. There are multiple systems for multiple users.

WRAY: I think you are leading to a way to answer the last question: What is the role for Landsat or some sensing capability that acquires information from time to time in a digital form? Our image-processing techniques offer an alternative to our short supply of photointerpretation skills and inputs into information systems.

LANDINI: The best answer I have is that the city of Los Angeles has an open-space plan. It is colored with lots of different, attractive shades of green that indicate where desirable areas of open space are to be built. And when I got into my 1970 Plymouth Valiant and went up to check some of these desirable open-space plans, I found that the areas were now all terraced and under construction. I could monitor that activity from Landsat information. Somehow the information is not coming in now, because we are still coloring it as green open space.

QUERY: You indicated that NASA ought to be in the natural resource data business. What are your criteria for arriving at that conclusion, rather than suggesting that same function could be carried out by USGS, or some other place in the Department of the Interior?

LANDINI: This suggestion is based on my association with NASA personnel and seeing what is going on with Landsat technology. My bailiwick is census. One of my primary recommendations for the 1980 census is to embark upon a mapping system so that we can get line segment information only, information that could be scanned and converted to digital information also. So why burden USGS with both maps and photographs? Leave some for NASA.

QUERY: How much soul-searching have you done about the frequency, format, and resolution of the product that you would like for NASA to deliver on a regular basis, if it could?

LANDINI: As I understand it, all substances on the face of the Earth reflect or absorb light to some degree. And I can perceive these, within the visible light spectrum, with my eyes. And, generally, as a planner, I plan for things I can see. So we'll narrow down the spectrum band that way. I understand that it is possible to have equipment developed that could increase resolution down to 10 meters. That is a hardware problem; a number of people have told me they think it can be solved. The problem seems to be, then, handling the massive amount of data which goes up exponentially with that increase in resolution. I think, for a citywide pass, 5 to 10 acres would be fine.

SCHWERTZ: Ten acres per mapping unit is used in the LUDA system for urban areas. You also mentioned the desire to interface census tract data and census tract boundaries. Do you feel that the 10-acre minimum mapping unit, which is produced by LUDA, is useful to the city of Los Angeles and particularly to yourself? And, if so, would you recommend this be used by other cities?

LANDINI: I suspect a little undercurrent of political activity exists here between people who are digitally oriented and people who are cartographically oriented in producing information. As I pointed out, photointerpretation is not on the horizon in the planning process, not because photointerpretation is not a good technique, but because there are not enough trained people to do the photointerpretation. And how do you rate reliability? I have some background in testing, so I know I would not accept the judgment of one person rating somebody else's performance. I would have three people rate it and average the scores. In photointerpretation, we never even have one rater. Everybody has always put one interpreter on one photosheet, and then taken that person's judgment. In using LUDA, you are even one more step removed, because you do not even know who the interpreter was. I would favor scanning at this point, not knowing anything about scanning versus cartographic techniques, simply because scanning eliminates human error in drawing boundaries of land use.

CARLSON: Joe Carlson, from Public Technology. The recommendation of last year's summer study on Earth resources, if it finally comes from the Space Applications Board relatively unchanged from what the panel recommended, does in fact say that NASA should take the next step toward an operational system, at least in the sense of providing a lot more visibility within NASA toward the requirements of state and local government users. Could you form an opinion as to whether it is possible now, or in the reasonably near future, through some political compromise, to organize the users to tell the Federal Government what data products they would like to have? Are there now enough people who have good enough ideas about what they would like to have? Could they aggregate a market, sufficient to go to the Federal Government, or to private industry, and say, "We have differing requirements, but there is a large degree of commonality to them, and if you can deliver this kind of imagery, processed or not processed in this particular fashion, it will satisfy most of our needs"? Are we coming to this point? Is it still some time off? Or will we never get there?

LANDINI: The USDI bulletin (number 671) on land use classifications was circulated among our staff and I commented that it did not get down to fine enough detail. However, the best land use map in the entire city of Los Angeles was drawn in 1973, in the technique that I described, discriminating only among the gross categories of residential, commercial, and industrial, with some open space and some railroad yard type of activity. That type of map is already being beaten by the type of product that I have seen Jim Wray do for Washington, D.C. So I think we have reached a point that we could follow the outlines of the USDI classifications and start trying to establish a consensus. I don't know how we get to that. I think it would be more complex than having somebody turn out a land use map.

CARLSON: What is the greatest inhibitor of defining a common set of user requirements of that sort? Is it the shortage of photointerpreters? Or the differing requirements between kinds of levels of government? In other words, is it a labor problem or a requirements problem?

LANDINI: I am sure that the people who talked about state activities have no problem with photointerpreters on their staff. I am sure this is also true in the State of California, particularly in our Department of Highways. I am only talking very parochially about my one department. I don't claim to be a photointerpreter. I have nobody in the planning department who claims to be a photointerpreter. I am the person in the department most familiar with photographs, but I have never worked as an interpreter.

If I were to make land use classifications from photographs for the first time, what reliability would you, as a user, put on them?

SPEAKER: Because we have different people with different problems in different areas of the country, at different levels of government, we will not be able to define a single need. However, we are beginning to look at alternatives and narrow down the approaches to any one problem to a relatively few alternatives. In the coming months and years, we will develop a true consensus of one or two preferred alternatives for a particular type of activity. The more we learn, the more complex the problem gets, so the harder it is to come up with an ideal solution. When we were very naive, we could sit back and say, "Well, I can fly that satellite up there, and it's going to solve all my problems, from the Federal level down to Los Angeles." We are looking at just one tool, and we may need a handful of tools, but we will soon be able to define that handful.

CARLSON: After you define the needs, what forum do you think is the best means to communicate that information to the Federal Government? Should a professional society do this? Or should you have a meeting where, presumably, somebody writes down everything that gets said and sends that to somebody at NASA, or NASA and X number of other agencies, and asks them to read it? What is the vehicle for transmission here? Or are there a number of them?

LANDINI: I think the way it actually happens is through grant applications. When people ask for money and money is given them to create a land use information system of some kind, the parameters of data that they gather and classify are specified in the resulting work or in the grant application. This is where the real communication takes place.

QUERY: When you refer to grant applications, are you talking about something like section 208, which specifies you are supposed to solve a problem like storm-water runoff and if you make the decision to use remote sensing, and if EPA approves, then it allows you to use its money for that purpose? Or are you talking about the typical NASA kind of grant application, in which you as a principal investigator (PI) intend to show that, in fact, a particular sensor or processing technique or whatever can define the phenomena in which you are interested? If you mean the latter, I think you have a translation or interpretation problem. By translating that into a decisionmaking process, all the PI's who looked at that or variants of that particular technical issue can somehow aggregate the results. That is a very difficult sort of thing when, at the other end, the guy who is funding is, in fact, primarily interested only in the technical results with regard to the sensor.

LANDINI: Let me refer you to Chuck Paul's presentation (L-11, vol. I-C). He explains what was done in one man's instance. We did a study in which we asked people to rank the importance of a number of variables in their planning operations. Something like that might be appropriate. That met with a lot of kudos, and a lot of criticisms too. A lot of people have said, "Land use planners in California must be crazy to have chosen the items that they did." And other people have said, "Gee, that's great that you got it down in writing, that you know what these different agencies really want in terms of land use items."

QUERY: One of the great frustrations among NASA people is that they see this great, amorphous, unaggregated blob of users, all of whom appear, at least on the surface, to have different kinds of requirements. They have varying degrees of data processing capability in-house, or money to buy it outside. Without a way to aggregate and define common requirements amongst that amorphous blob, NASA has very little option except to continue doing what it is now doing. When, if ever, will it be possible for the users to begin on their own to break down into aggregated segments, at least?

LANDINI: Census has the same problem every 10 years about what items to put on the questionnaire. People in the Census Bureau are already conducting interviews. They go to professional organizations, hold public hearings, and communicate through two newsletter-type publications. They have a whole educational process that I think is lacking in NASA. NASA, under its charter, may not be allowed to do this. Right now, a person must be a pretty dedicated user to find out what is there.

SPEAKER: You hit a major point about education. I have the feeling that NASA is going through all kinds of gyrations, trying to find out who the users are. I think the people at NASA are doing it with some success, indicated just by the number of people here who have not been at earlier conferences. The processes must be interrelated. You must go out and educate the people first, so that they have some sense of what you are talking to them about. And then you begin to understand their problems. But the ultimate responsibility in codifying those problems into 5 or 10 areas must remain with whoever is providing the information; the provider cannot give up that responsibility. The southeastern states and some other areas have regional groups. Some people from the southeastern states have been meeting to try to define our needs so that, through our own initiative, we can come to NASA or to USGS or whatever agency is appropriate, and say, "These may not be all the needs you'll find in our area, but these are five that we can agree on." This kind of action may get those five up to a higher priority.

WATKINS: The EROS Data Center at Sioux Falls, South Dakota, does have a training mission and capability and does conduct workshops and has user contact facilities in places throughout the country.

ANDERSON: I just wanted to comment about the matter of error. I think we have to be very careful not to get a mistaken idea. What we are doing here is substituting one set of skills for another, and it is quite important that this be recognized. A great deal of skill on someone's part is required to properly choose training sites to do automatic classifications of land use and land cover patterns. We do need to take, I think, a closer and closer look at the accuracy with which we do these things. I believe it is possible to get an objective evaluation of the product. We have a human being working on automatic classification and that classification is subject to error. The better job that person does, the better the classification will be.

LANDINI: It does take the same skills for automatic or manual classification. The possible advantage of machine classification that we still need to exploit is more production per unit. The real choice of manual versus machine interpretation techniques should be based on the total pluses and minuses and on the supplementary or complementary aspects of the various systems.

QUERY: After the keys are built for machine interpretation of data, for example, for the Los Angeles area in the fall, are those keys going to remain valid fall after fall after fall? Am I correct that the greatest potential benefit of Landsat material to any user is its time sequence availability? And I would venture to say that you cannot interpret those photographs by hand.

SPEAKER: If one is comparing one system against another, he must compare the total system. In order to do that, he must identify all the parameters, such as the skills involved (photointerpreters versus computer programers, for example). But there are many other factors, such as the original cost of the system and the cost of developing and operating the system. Rather than considering accuracy in terms of the information derived from remotely sensed data, I prefer to consider the accuracy produced as the end result of the system. Other factors to consider are flexibility and time response. I cannot see that anyone can draw any conclusions about the advantage of one system over another without looking at the total system.

HILL: Chris Hill, Washington University. I wanted to return to the question of user needs aggregation. We have had at Washington University for about a year a contract with NASA Headquarters to do a user needs study in five states in the Midwest. And I understand some of our colleagues at City University of New York will soon be embarked on the same sort of thing in the East. It is clear that few players right now in this game are trying to look beyond their own discipline and trying to match, across the board, what is available to what is needed. We are trying to do this. We want to hear people tell us what we ought to be doing. But we are interested, eventually, in laying out one or more alternative systems, which would do the sort of thing you were discussing earlier: provide, on a regular basis, the kind of imagery that people need. What is the major barrier? Of course, it is, first, lack of money. However, a broad gulf of misunderstanding exists at all levels. I have yet to talk to anyone in NASA, and to very few people at the state and local level, who really appreciate what the other guy is trying to say. And I suspect that in a few smaller rooms, we could get quite a bit closer to the solution. I hope we can begin defining needs and defining systems so that we can move on.

SPEAKER: I would like to make several points on the subject of accuracy. If you assume that you have an unbiased method of determining accuracy, then the difference between accuracy and precision is simply your bias. But I do not believe we should be talking about accuracy of maps; we should be talking about precision. And that precision is measured by variances. With any type of information gathering system, we should ask: What is the probability of its being right or wrong? I do not believe it makes any difference whether you have data that are 50 percent accurate, or 60 or 70 or 80 percent. As long as you know what the risk is, you can assess the consequences of being wrong. This is true with photointerpretation. I get a photointerpreter I think is pretty good, but I have to look at the probability of his being right or wrong. And that goes back to this business of precision; that is how you estimate probability. I have yet to see a land use map with a precision level associated with it. I have heard a lot of accuracy figures, but I have never seen one with a precision figure attached to it. I mean, for any point on a map, what is the probability that when I get to that point on the ground, I will be standing on what the map told me is there? If the map says grass, what is the probability I will be standing on grass when I walk out there? There ought to be a probability associated with each map and with each class on that map. Generally speaking, some will be low and some will be high. Suppose I make the decision to buy some land because the map indicates it is a good area to build houses. What is the probability that I will go out there and find it's a pond?

LANDINI: In the LUMIS project, we actually tried to specify that the data were within 40 feet of true ground location.

SPEAKER: Positional accuracy is not what you want. It doesn't matter if a feature is mislocated by 40 feet or 100 feet if it isn't there at all. What is the probability associated with the accuracy of that point? I see two types of error. Let us consider as an example a photointerpreter who is doing forest classification. He has the problem of positional accuracy: where and how big is the forest? And he has the problem of how reliable he is in establishing the differences among forest type.

WINIKKA: I want to emphasize the importance of multilevel information: ground level, low altitude, high altitude, and satellite. We are doing two things, combining information as well as identifying it. The critical thing here is to what level this information can be identified and aggregated. If you tried to aggregate over 5000 square statute miles using field methods, you would be in a horrible mess. The ability to aggregate the total picture in a short time is, I think, the answer to the question of the efficiency of any layer. If you can aggregate what the next layer down is doing, that might be the level to be working.

LANDINI: In Los Angeles, as an example, we have had some very low-level color-infrared photography, on a scale of about 1:5000, in which we tried to evaluate the condition of backyards. We would never attempt to do that by a scanner technique. It is much faster to roll the map sheet until you get to the frame you want, look at that backyard, make a judgment, and write it down.

N76-26668

USER SERVICES

U-1. Remote Sensing, a Sketch of the Technology

David Landgrebe[a]

PREFACE

The organizing committee of this session saw it to be a very brief version of the information systems and services session. The purpose is to provide, briefly, information on how a potential user of remote-sensing technology can gain access to all of the products and services he will need to get started. It was envisioned that these include data, training, hardware, and software.

Since the assumption is that many are receiving their first exposure to this technology, the organizing committee felt it desirable to have a very brief tutorial summary of the fundamentals of the technology. The statement which follows was given to serve that purpose. This statement is abstracted from a longer presentation originally given before the International Workshop on Earth Resource Surveys held in Ann Arbor, Michigan, May 3 to 14, 1971. (This longer version is available in NASA SP-283, vol. 1, pp. 139-154.)

During this session, the chairman read into the record a statement by Senator Frank E. Moss (D-Utah), chairman, Committee on Aeronautical and Space Sciences, entitled "The Need for Expediting Landsat Data Distribution." This statement was written specifically for this symposium and is included in its entirety in the appendix to U-1.

A REMOTE-SENSING SYSTEM OVERVIEW

Before one can contemplate beginning to use remote-sensing technology in a routine or operational fashion, it is desirable to have clearly in mind an overview of what such a system is and what some of the fundamentals and theory of its operation are. Figure 1 is a diagram of the organization of an Earth survey system. It consists of several major subsystems. It is necessary, of course, to have a sensor system viewing the portion of the Earth under consideration. There will be a certain amount of onboard data processing. This will perhaps include the merging of data from other sources, such as sensor calibration and data about where the sensor is pointed.

One must next transport the data back to Earth for further processing and analysis. This may be done through a telemetry system, as in the Landsat series, or by return of a physical package, as was done with Skylab. There is then usually a need for certain preprocessing of the data before the final processing with one or more data reduction algorithms. At this point in the system, when the data are reduced to information, it is usually helpful to merge ancillary information, perhaps derived from sources on the surface on the Earth.

An important part of the system which must not be overlooked is indicated by the last block in figure 1, that of information consumption, because there is no reason to go through the whole exercise unless the information produced is to be used. In the case of Earth resource information systems, this last portion can prove to be the most challenging to design and organize, because many potential consumers of this information are not accustomed to receiving it from such a system.

The part of the physical system in front of the sensor is also part of the information system. I refer to the atmosphere and the Earth surface cover itself. As a result

[a] Laboratory for Applications of Remote Sensing, West Lafayette, Indiana.

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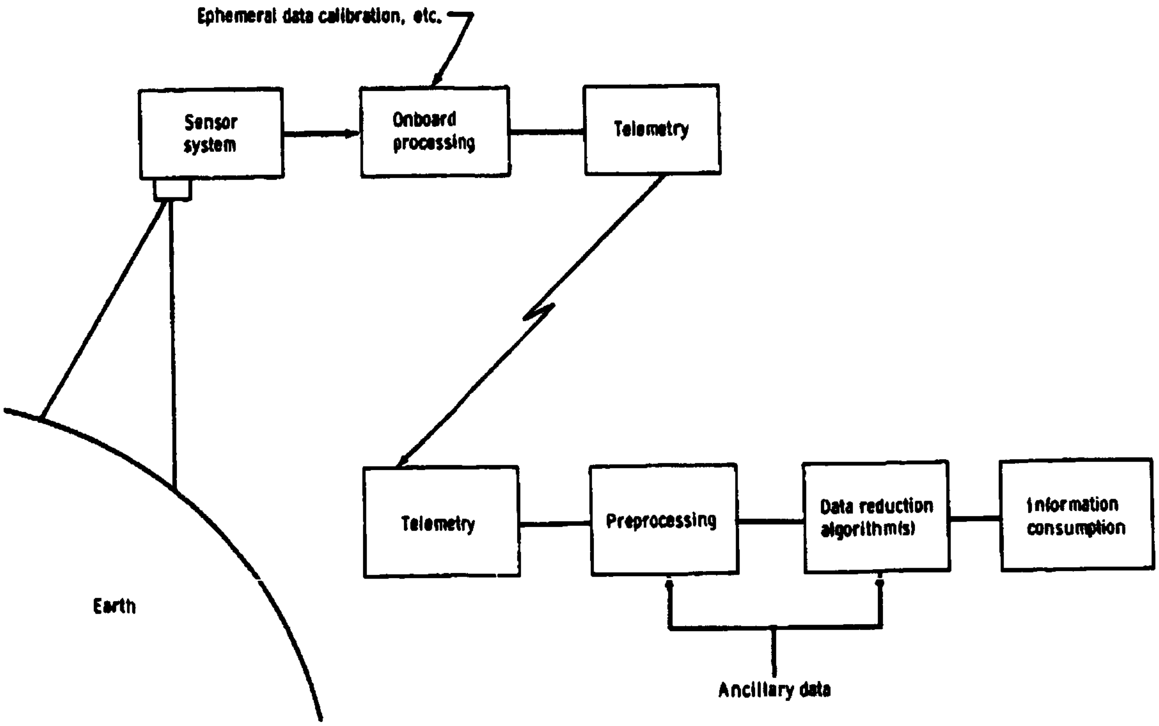

Figure 1. Organization of an Earth survey system.

of this, the operator of the system must take special precautions to be sure he understands the physical situation he is dealing with to the greatest extent possible.

THE DUALITY OF SYSTEM TYPES

When we consider the state of the art of remote sensing today, a duality of system types becomes readily apparent. Development in the field has had two major stems since it originated from two somewhat different types of technology. These two types of systems will be referred to here as being (1) image oriented and (2) numerically oriented.

An example of an image-oriented system might simply be an aerial camera and photointerpreter. The photographic film is used to measure and record the spatial variations of the electromagnetic fields, and the photointerpreter relates these variations to specific classes of surface cover. Numerically oriented systems on the other hand tend to involve computers for data analysis. Although the photointerpreter and the computer respectively tend to be typical of the two system types, it would be an oversimplification and indeed incorrect to say that they are uniquely related to these two system types. This becomes clearer upon further examination.

Figure 2 compares the organization of the two system types. Both types of systems need a sensor and some preprocessing. The distinction between the types can perhaps be brought out most clearly by noting the location of the formed image block in the two diagrams. In the image-oriented type, it is in line with the data stream and must precede the analysis block. Numerically oriented systems on the other hand need not necessarily contain a formed image block. If they do, and in Earth resources they usually do, it may be at the side of the data stream as shown. This is because its purpose is to monitor the operation of the system and perhaps to do some special-purpose analysis as needed.

THE MULTISPECTRAL APPROACH

We will illustrate further the distinction between these two system types by the following simple example which also serves to introduce the idea of the

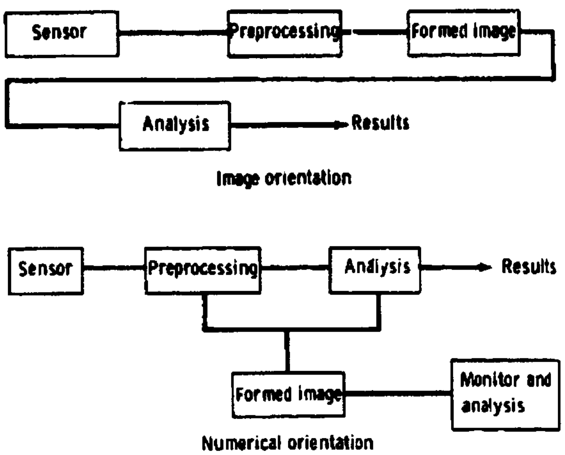

Figure 2. General organization of image-oriented and numerically oriented systems.

multispectral approach. Consider figure 3. This figure shows a small segment of an agricultural scene imaged in three different fashions. On the left is an image of the scene made with ordinary panchromatic black-and-white film; the center image was made with black-and-white infrared film. The image on the right is an artist's concept of what this same scene looks like in a portion of the thermal infrared part of the spectrum. Suppose now that the four types of Earth surface cover identified in this scene are exhaustive in a sense that for a larger area to be analyzed only these four classes of Earth surface cover exist.

Suppose our interest is to locate all the corn in the area. Thus, by examining the data of figure 3 we must devise a means for identifying corn relative to the other three classes[1]. A close inspection of the corn area shows that it has a distinctive texture that is not present in the other three classes of material. Thus, we may identify corn relative to the other classes by noting all parts of the scene that have that unusual texture.

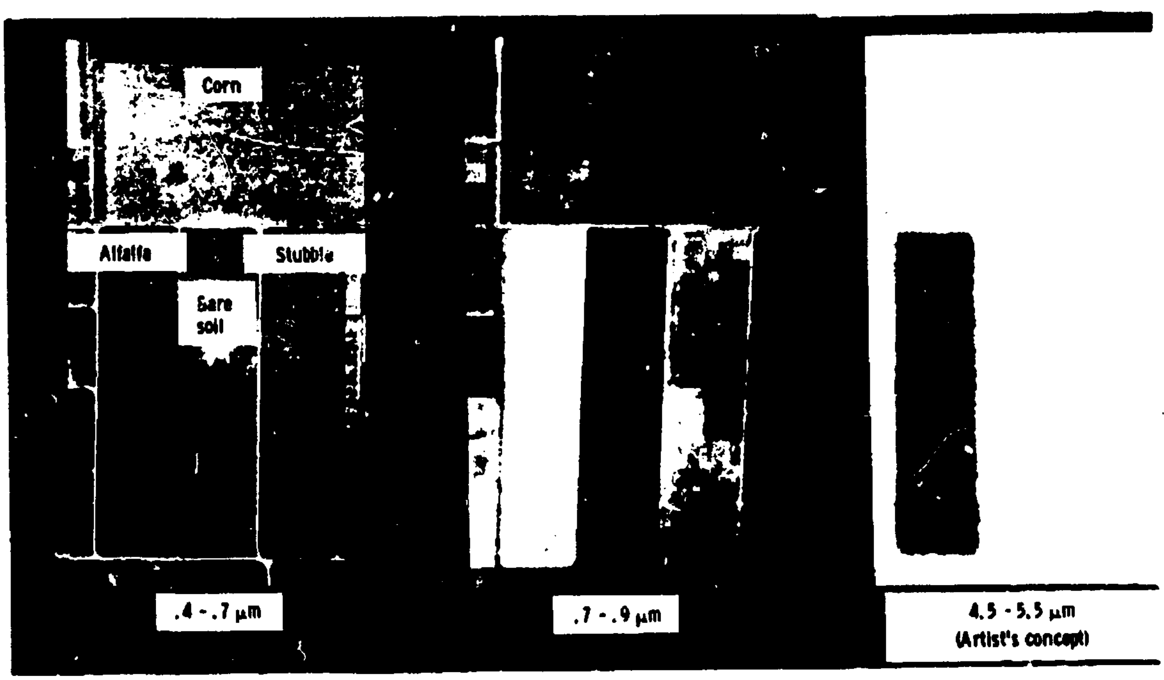

Figure 3. Multispectral response of corn, alfalfa, stubble, and bare soil. Images were recorded September 30, 1964, at 10 a.m.

[1] The data of figure 3 might then be referred to as training data, since they include labeled examples of all classes to be found in the larger scene to be analyzed, and they are used to train the analyzer to recognize the difference between the classes.

In this case, we have used an image-oriented approach. Texture is an image-oriented characteristic, one which is used extensively in the interpretation of imagery. It is, however, difficult to devise an algorithm which will define a unique quantitative relationship between "texture" and set of numbers.

This difficulty in the face of the importance of the problem, particularly with regard to analyzing Earth observational data by computer, has led to the development of the so-called multispectral approach. This approach is much more suited to numerical methods. It may be qualitatively described as follows. Notice that in viewing the corn area from band to band across the three bands, we see medium-gray, dark-gray, and light-gray response, respectively. Notice also that this same pattern of responses does not occur for any of the three other materials. This is the basis then of using pattern recognition methods on multispectral data. The relative response (degree of grayness) is very easy to quantify.

Let us explore this approach in slightly more quantitative detail. Consider figure 4. Shown at the top of this figure is the relative response as a function of wavelength for three different materials: vegetation, soil, and water. Let us choose two wavelengths, marked λ_1 and λ_2, on the wavelength scale. Shown in the lower part of this figure are response data for these three materials at these two wavelengths, plotted with respect to one another. For example, in the upper graph, soil has the largest response at wavelength λ_1. This manifests itself in the lower plot in that soil has the largest abscissa value (the greatest displacement to the right).

It is readily apparent that two materials having different responses as a function of wavelength will lie in different portions of two-dimensional space. Please note from this that the concept of spectral identifiability is a relative one. One cannot know that vegetation has a unique spectral response which makes it identifiable, for example, until one sees the plots resulting from the spectral responses of the other materials within the scene to be analyzed. Note also that a larger number of bands can be used. The response at λ_3 could be used and the data plotted in three dimensions. Four or more dimensions indeed have meaning and utility even though an actual plot of the data is not possible.

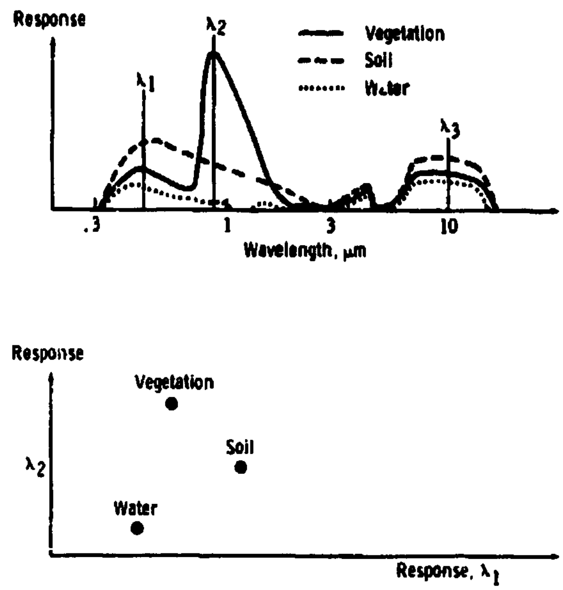

Figure 4. Spectral data in two-dimensional space.

CLOSURE

From this simple example of analysis viewed in these two ways, perhaps the distinction between these two stems of technology is apparent. It is quite important to know when considering a piece of hardware, a piece of software, a particular sensor system, or the like, which type of system the designer had in mind. These two stems of technology are indeed fundamentally different. This implies that they are optimally useful for different problems. One of the tasks of the potential user is to discern which of the technologies, and therefore which pieces of hardware, software, et cetera, will be best for the task he has in mind.

U-1 APPENDIX

THE NEED FOR EXPEDITING LANDSAT DATA DISTRIBUTION

Statement of Senator Frank E. Moss (D-Utah)
Chairman, Committee on Aeronautical and Space Sciences
At the Earth Resources Survey Symposium
June 9, 1975

I have a personal interest in the Landsat program because I believe it typifies the best of what space has to offer us. So I have been concerned that the success of the Landsat experiment might be jeopardized by a logistics problem with the data. In short, the delay in getting the data to some of the principal investigators is excessive.

Of course, for some investigators, the delay is acceptable. However, those investigators using Landsat to monitor agriculture may not be getting the information in time to conduct their experiments effectively.

Other investigators of short-lived phenomena no doubt are also adversely affected, such as in sea-ice monitoring, but agriculture is somewhat unique: agricultural benefits are part of the backbone of the potential economic return from Landsat.

Econ, Incorporated, of Princeton, New Jersey, recently released a study conducted for NASA entitled "The Economic Value of Remote Sensing of Earth Resources from Space: An ERTS Overview and the Value of Continuity of Service." In assessing the potential economic impact of Landsat, it found that the potential dollar value of benefits in agriculture constitute more than the potential value of the benefits in all other areas combined.

Now, this study is certainly not the last word on Landsat's economic worth. Some debate the report's underlying assumptions and quibble over numbers. However, a general conclusion remains unassailable: Anything that jeopardizes the effective use of Landsat data in agricultural applications severely limits the benefits of Landsat itself.

It is my understanding that the principal investigators working in agriculture receive the data several weeks after the satellite passes over a given area. And representatives of the Department of Agriculture have told my staff that this delay seriously hampers the experiments related to agriculture.

Perhaps in our excitement over launching Landsat and in our pride over its imagery, we have somewhat neglected the equally important further steps of imagery processing and immediate distribution to the investigators.

Critics have said that improvements in the speed of imagery processing and of distribution to users cannot be justified as long as the system is experimental. Wait until the system is operational, we are told. Such an approach would hobble the Landsat experiment because the work of the principal investigators is almost as much a part of Landsat as is the satellite itself. A fair test of the overall system's merits must include a sincere evaluation of the utility of its data.

I think it would be tragic indeed if a mere logistical problem over data handling impedes the success of this extraordinary system. Consequently, I plan to do all I can to expedite the imagery conversion and data distribution process. I have just written Dr. Fletcher, the administrator of NASA, expressing my views on this matter. And I have requested him to determine what steps are necessary to reduce the delay to only a few days. I believe that much better performance in data handling is feasible and that it will cost a relatively small amount compared to the overall investment in the Landsat program. I hope that a solution can be implemented rapidly.

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U-2. Data Availability and the Role of the Earth Resources Observation Systems Data Center

Allen H. Watkins[a]

INTRODUCTION

With the launch of Landsat-1 in July 1972, and the follow-on launch of Landsat-2 in January of this year, routine availability of satellite imagery and electronic data of the Earth's resources has become a reality. The U.S. Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of the Interior (USDI), cooperating with the National Aeronautics and Space Administration (NASA), have established Federal Data Centers to provide Landsat data to resource managers and the general public. These Federal Data Centers have to date provided almost 500 000 frames of Landsat data at a cost of more than $2 000 000. Data from the Landsat satellite program, along with data and information from the Skylab manned program, are available over any location to anyone for the cost of reproduction (table I).

TABLE I. LANDSAT DATA AVAILABILITY*

Location	Sources of material
Sales Western Aerial Photo Lab U.S. Department of Agriculture 2505 Parley's Way Salt Lake City, Utah 84109 Telephone 801-524-5856	Landsat USDA aerial photography Skylab imagery
Satellite Data Services Branch - D543 Environmental Data Service National Oceanic and Atmospheric Administration World Weather Building - Room 606 Washington, D.C. 20233 Telephone 301-763-8111	Landsat NOAA satellites Skylab imagery
EROS Data Center User Services Department Sioux Falls, S. Dak 57198 Telephone 605-594-6511, ext. 151 FTS 605-594-6151	Landsat NASA research aircraft USDI aerial mapping photography Skylab, Apollo, and Gemini imagery

*NOTE Many commercial photographic laboratories will custom process Landsat and other satellite imagery but do not have archival masters of Landsat holdings.

[a]EROS Data Center, Sioux Falls, South Dakota.

THE EROS DATA CENTER

One of the three principal Federal Data Centers, the Earth Resources Observation Systems (EROS) Data Center is administered by the U.S. Geological Survey for the USDI. The center is a principal operating element of the EROS program, which was initiated in 1966 to apply remote-sensing techniques to resources inventory, monitoring, and management. It provides products in the form of remote-sensing data acquired from NASA satellite and aircraft projects, along with aerial mapping photography held by the USDI. The center also provides services in the application of remotely sensed data to resource inventory, monitoring, and management activities. These services take the form of both domestic and international training, preparation of educational aids, the conduct and documentation of applications demonstration projects, and day-to-day applications assistance in the use of special analysis equipment.

The EROS Data Center was established in 1972, and was moved into its 125 000-square-foot complex in early 1974. The South Dakota site (16 miles northeast of Sioux Falls) was selected because of its central location and potential to receive telemetry data from satellites in a Landsat-type orbit in real time over any portion of the lower 48 states. In 18 months, the staff of the center has increased from approximately 60 to more than 300.

Data holdings at the center include over 500 000 frames of Landsat imagery; Landsat electronic data in the form of computer-compatible tapes; over 40 000 frames of Skylab, Apollo, and Gemini spacecraft data; more than 1 800 000 frames of data from the NASA research aircraft program; and almost 4 000 000 frames of USDI aerial mapping photography (table II). Products from this data base are available in color or black-and-white photographic images, ranging in size from 16 millimeters through 40 inches, and in computer-compatible tape (CCT), in 7- or 9-track and 800- or 1600-bit/in. formats. In addition, data catalogs and specialized computer search listings are available upon request. Typical prices of imagery are $2 for a 9-inch black-and-white paper print, $30 for a 40-inch color paper print, and $200 for a CCT set of the four Landsat bands.

TABLE II. EROS DATA CENTER DATA BASE SIZE AND PRODUCT AVAILABILITY

Data types	Current holdings, frames	Products available
Landsat data (multispectral scanner and return beam vidicon)	530 000	Prints and transparencies, color or black and white, 16 mm through 40 by 40 in. Computer-compatible tapes, 7 or 9 track, 800/1600 bits/in. Catalogs and search listings
Skylab, Apollo, and Gemini space data	40 000	Prints and transparencies, color or black and white, 16 mm through 40 by 40 in. Computer-compatible tapes from electronic sensors Catalogs and search listings
NASA research aircraft imagery	1 800 000	Prints and transparencies, color or black and white, 16 mm through 40 by 40 in. Search listings
USDI aerial mapping photography	3 700 000	Prints and transparencies, black and white, 16 mm through 40 by 40 in. Photographic indexes Search listings
Total	6 070 000	

At the heart of the data center is a central computer complex, which controls and accesses a data base of the more than 6 000 000 frames of Earth resources data, performs searches of specific geographic areas of interest, and serves as a management tool for the entire data reproduction process. The computerized data storage and retrieval system is based on a geographic system of latitude and longitude, supplemented by such information as image quality, cloud cover, and type of data. A customer's inquiry as to data availability may be a geographic point location or a rectangular area bounded by latitude and longitude. Based on the customer requirements and the use to be made of the data, a computer geographic search will print out a listing of available imagery from which a final selection can be made.

DATA USERS AND DEMAND

The demand for remote-sensing data from the EROS Data Center has continued to increase both in volume of frames and dollar value. In fiscal year 1973, 165 000 frames of data were supplied to the user community. The total grew to almost 300 000 frames in fiscal year 1974, and will exceed 400 000 frames in fiscal year 1975. The fastest growing product demand is in the area of Landsat electronic data provided in the form of computer-compatible tapes. From fiscal year 1974 to fiscal year 1975, the user community demand for this product increased 260 percent. Landsat imagery in this same period showed an increase of 18 percent, while Skylab and Apollo data increased 92 percent, largely as a result of the new Skylab data. Aircraft data, both NASA and USDI, showed an increase of 76 percent. This resulted in an overall 45-percent increase in frame demand for all products from the data center. At the same time, dollar income at the center increased by 124 percent from fiscal year 1973 to fiscal year 1974, and by 91 percent from fiscal year 1974 to fiscal year 1975, with total dollar income from the sale of data exceeding $1 600 000 in fiscal year 1975. Approximately 55 percent of the product demand at the center is for Landsat data. The customer profile for purchase of data shows that private industry is the largest single purchaser, with 30 percent of the total dollar value; agencies of the Federal Government come next with 24 percent. Academic and educational institutions account for 16 percent of data sales, whereas foreign customers comprise 12 percent. Individuals and state and local government agencies comprise the remainder. When we look only at Landsat data sales, we find that foreign customers comprise a larger percentage at 20 percent, second only to U.S. private industry at 24 percent. It should be recognized that there is very little foreign coverage from aircraft platforms available from the EROS Data Center.

Computer-compatible tapes or electronic data for the past 12 months comprise 1.2 percent of total frame volume, but account for 19 percent of total dollar sales.

A look at the principal users and purchases of EROS Data Center products reveals that almost all categories of U.S. industry and a wide variety of Federal, State, and local government agencies are currently using the data for a variety of applications. The principal application of the data appears to be mineral and fossil fuel exploration and related geologic base mapping activities of the major petroleum and mining companies. This area would appear to account for almost 50 percent of total sales of data from the center.

CURRENT DELIVERY AND QUALITY PERFORMANCE

Coincident with its 1974 move, the center received worldwide publicity in the technical and popular press, and, as a result, was deluged with requests for information and with orders for data. This was a particularly difficult period for the center and data delivery delays were excessive. The average delivery time for data has now decreased to approximately 2 weeks following receipt of the order at the data center, with a median delivery time of 10 days. During the period of August 1974 to March 1975, 76 percent or 16 405 orders were shipped prior to 14.7 calendar days. More than 20 000 of a total 21 500 orders were shipped in less than 33 days. In the past 18 months, the percentage of orders shipped older than 30 days has decreased from 91 percent to less than 4 percent.

All products from the center are inspected by a quality control staff before shipment. Customer feedback on prepaid postcards included with each shipment has consistently indicated good quality or better for approximately 90 percent of orders shipped.

HOW TO OBTAIN DATA

Inquiries concerning availability of data forwarded to the EROS Data Center initiate a geographic computer search to determine data available over a specified area of interest. This computer search can be initiated by mail, visit, or phone to either the EROS Data Center or one of the EROS Applications Assistance Facilities throughout the country. An inquiry form is available for you to request information on available coverage over your area of interest. Requests for a geographic search may take the form of a point search where all images over any portion of the point will be included or a rectangular method where any area bounded by latitude and longitude can be described. An eight-sided polygon can also be used to specify the geographic area of interest. Latitude and longitude coordinate specification is preferred since this is the method required for the computer geographic search. Additional information must be included covering acceptable dates and seasons of exposure, type of imagery preferred, cloud cover, quality, etc. Geographic areas must be clearly identified and should be limited in size as much as possible to avoid potentially voluminous output and the need to interpret large numbers of choices.

Following receipt of all inquiries, researchers communicate with the central computer complex, which results in a printout of all imagery meeting the specified criteria. This computer listing is then used by the researchers to screen microfilm copies of the over 6 000 000-frame data base to better select the most suitable data. The computer listing contains all images available over the area of interest which satisfy the supplemental data supplied with the inquiry. Each image is described by two printed lines on the computer listing, which detail the characteristics of the particular image or photograph. A number of entries may be listed, depending upon the size of area selected and the restriction of supplemental data. Imagery may be available from more than one source, for example, Landsat, Skylab, NASA aircraft, or aerial mapping photography. Thus, each entry on the computer listing must be carefully studied to determine the best selection for the intended application. A template for decoding the computer listing is provided for use with the printout. After researchers select the most suitable data for the intended application, an order form is transmitted directly to the computer, which initiates processing. According to the reproduction requirements, the original print masters are retrieved from the archival storage area and routed through staging to the applicable product generation line. A variety of high-quality photographic printers is available. Following printing, the exposed imagery is routed to one of 10 high-speed processors that vary in size from 16-millimeter microfilm processors to 52-inch black-and-white and color paper or film processors. The products are then 100 percent inspected and stamped with a unique code identifying the final inspector. Individual images are then cut and collated, placed in dissemination bins, and shipped upon completion of order processing.

Orders for reproductions of data from the EROS Data Center are accepted from individuals, government organizations, universities, and industries from the United States and all foreign countries. All orders must be accompanied by check, money order, purchase order, or authorized account identification, and processing cannot be initiated until valid and accurate payment is received.

Standing or open accounts may be established by repetitive users. To open a standing account, a check must be remitted for the amount to be deposited. Customers will be informed of the account number and future orders can be placed referencing this open account number. A $100 minimum is required to establish an initial standing account, and customers may obtain a refund of the unused portion at any time.

Quality of the reproduction cannot be improved over the quality of the master film. You may find that a product has certain quality defects such as small scratches, pinholes, or stains, or that color balance or density of the reproduction is not exactly as you think it should be. In these cases, you may be assured that it has been inspected against the quality of the original reproducible and everything has been done to produce as good a product as is possible. All shipments are prepaid, and no postage charges are made. With each outgoing order, a prepaid postage card is included soliciting comments.

A unique set of Landsat scenes covering the conterminous United States is available from the center. The 470 scenes required to cover the United States are available in a single black-and-white band, all four bands of black and white, and high-quality color composites. The specific Landsat scenes selected for the single Landsat coverage of the United States were chosen on the basis of quality, season, and minimum cloud cover. The scenes are cataloged on the basis of the newly adopted Landsat worldwide reference system which uniquely identifies each nominal center point based on path (orbit) number and row number. This unique worldwide reference system of nominal center points for Landsat data can be used to efficiently construct country-by-country catalogs of data, meeting user specified criteria. Maps are now being prepared and will soon be available, showing each nominal center point of Landsat imagery for the entire world.

Custom processing to special scales, formats, and processing criteria is available from the data center. These services normally require longer periods of time for completion, and pricing is based on three times the standard price. In addition, a priority system for rapid delivery of standard products is available whereby products will be shipped within 5 days from receipt of order. To provide this service, three times the standard price is charged and priority processing will only be accepted where imagery is specifically identified, standard products ordered, and payment is enclosed or credit available.

Two options are available for placing standing orders for either data or information from the EROS Data Center: (1) You may specify an area from which any new Landsat imagery received during a given period will be automatically reproduced and shipped to you; or (2) You may specify an area for which the data center will notify you of any new Landsat imagery received and the order can subsequently be placed by you.

Copies of data held at the EROS Data Center are available to all individuals from all countries. All payments for foreign orders should be made in U.S. dollars and cents. In preparing payment, it is suggested that the foreign customer ask a local bank to make any necessary currency rate adjustment. The check or money order should be made payable to the U.S. Geological Survey and should be made out in U.S. dollars and cents. Payment must accompany the order. Most banks charge a nominal processing or exchange fee. Therefore, customers should ensure that this fee will not be deducted from the check which will be submitted for payment.

APPLICATIONS ASSISTANCE FACILITIES

In addition to the central facilities near Sioux Falls, the EROS Data Center operates a number of EROS Applications Assistance Facilities (fig. 1), where the

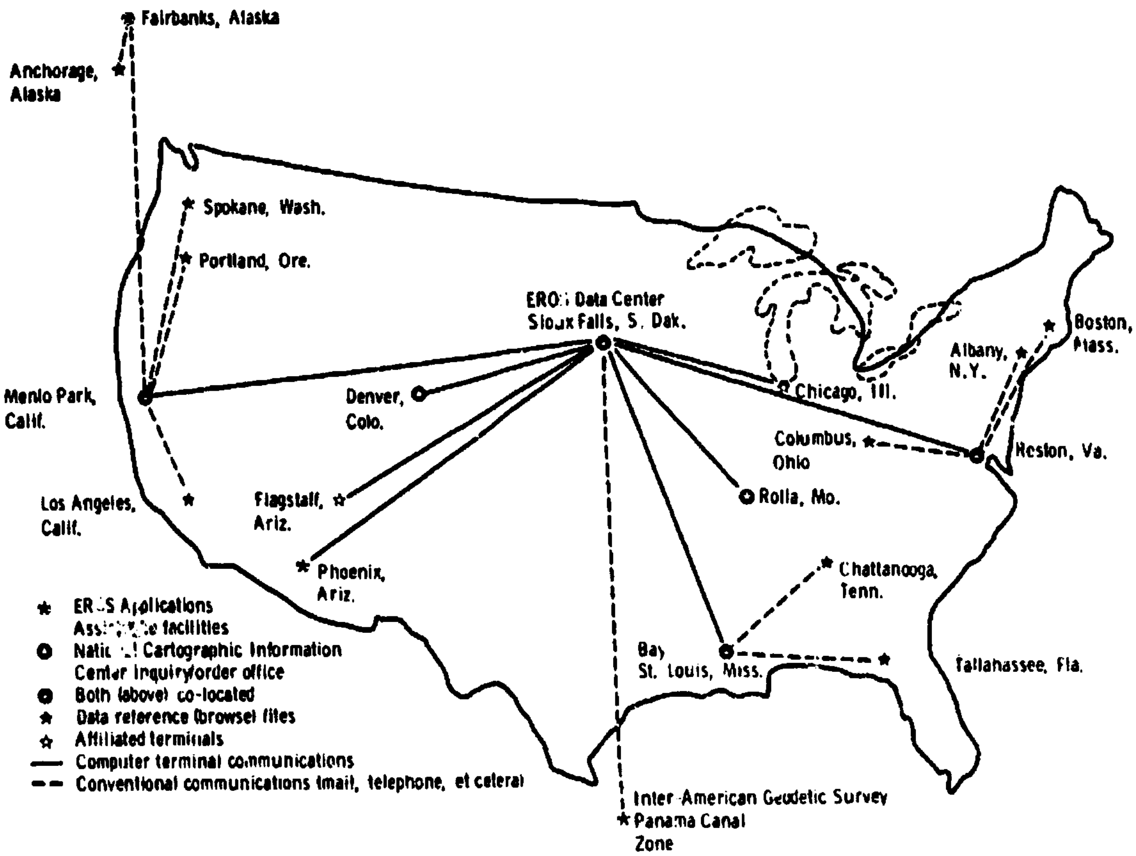

Figure 1. Earth Resources Observation Systems information network.

public may view microfilm copies of imagery available from the data center and can receive assistance in the research, ordering, and techniques of applying the data to resource problems. These Applications Assistance Facilities maintain microfilm copies and provide computer terminal inquiry and order capability to the central computer complex at the EROS Data Center. These facilities should be contacted by phone or mail in advance so that suitable arrangements can be made. Facilities are currently established in Menlo Park, California; Phoenix, Arizona; Denver, Colorado; Reston, Virginia; Bay St. Louis, Mississippi; Ft. Clayton, Canal Zone; and Fairbanks, Alaska. In addition to these offices, small Data Reference Files have been established throughout the United States to maintain microfilm copies of the most used data available from the center and to provide assistance to the visitor in reviewing and ordering data. Assistance in applying the data is not provided at these Data Reference Files. The data center also functions as an integral part of the National Cartographic Information Center (NCIC) which will provide integrated mapping, photographic, and geodetic control information and data. A number of NCIC offices are connected to the central computer complex via remote terminal throughout the country.

TRAINING OR APPLICATIONS ASSISTANCE

Training in remote sensing and assistance in techniques for extracting various information from remote-sensing data are available at the EROS Data Center. Inquiries can be made by telephone, letter, or personal visit to the Applications Assistance Branch at the center.

Periodic training programs in remote sensing are given at the center. Normally, these programs are up to 1 week in length and stress the use of data in a particular application; for example, agricultural inventory or water management. Two or three times a year, a 3- to 4-week course is offered to foreign nationals, stressing the fundamentals of remote sensing with exposure to a number of applications areas. Supplementing these formal training courses are a series of slide tape packages and educational aids covering the basic methodology in remote sensing and various applications. The principal role of the EROS Data Center in applications assistance is technology transfer.

The EROS Data Center has state-of-the-art automatic data processing equipment, which includes digital classification and analysis devices. This equipment allows the application of digital analysis techniques by classifying objects based on reflectance and/or emittance in various parts of the electromagnetic spectrum. Known objects are used to train the classification procedure, resulting in an unknown object being compared digitally with the characteristics of the known object. An unknown object which matches spectrally the known object is classified accordingly.

The center maintains a technical library of information on remote sensing of Earth resources. It is available for the use of students attending training courses, visitors to the center, and researchers on an as-need basis. The principal thrust of the data center is to document proven applications techniques and to prepare a complete technique use package which can be transferred to the user community and resource managers for consideration and possible implementation. These basics for total technique use or demonstration packages will not only provide procedural direction for information extraction, but will also provide relative costs, reliability, and accuracy figures so that intelligent decisions can be made by resource managers as to possible implementation.

ADVANCED DATA HANDLING AND PROCESSING SYSTEMS

In the future, the EROS Data Center will continue to cooperate with NASA in supplying satellite imagery and electronic products in the shortest possible time period and in flexible user-required formats. The NASA Goddard Space Flight Center (GSFC) has implemented increased computer-compatible tape production capability for Landsat-2, and the EROS Data Center is making similar changes. These changes will provide an increased throughput and more flexible format for computer-compatible tape reproduction and dissemination to users (fig. 2). For Landsat-C, now scheduled for launch in late 1977, NASA and the USGS are studying concepts for the use of communication satellites for data relay to significantly improve the timeliness of data dissemination. This concept includes the reception of data at the NASA Alaskan, Goldstone, and GSFC reception stations, with subsequent relay to Sioux Falls on a near-real-time basis for further processing, reproduction, and dissemination to users.

In addition, to more efficiently handle data from Landsat-C and subsequent satellites, NASA plans to move to high-density tape formats which will then be integrated with high-density tape product generation lines at the EROS Data Center to provide enhanced products, including imagery and computer-compatible tapes, to users in a much more timely and efficient fashion. The ultimate goal of all these changes is to provide data to the users in the unique formats required and with maximum information content within 24 to 48 hours of satellite acquisition.

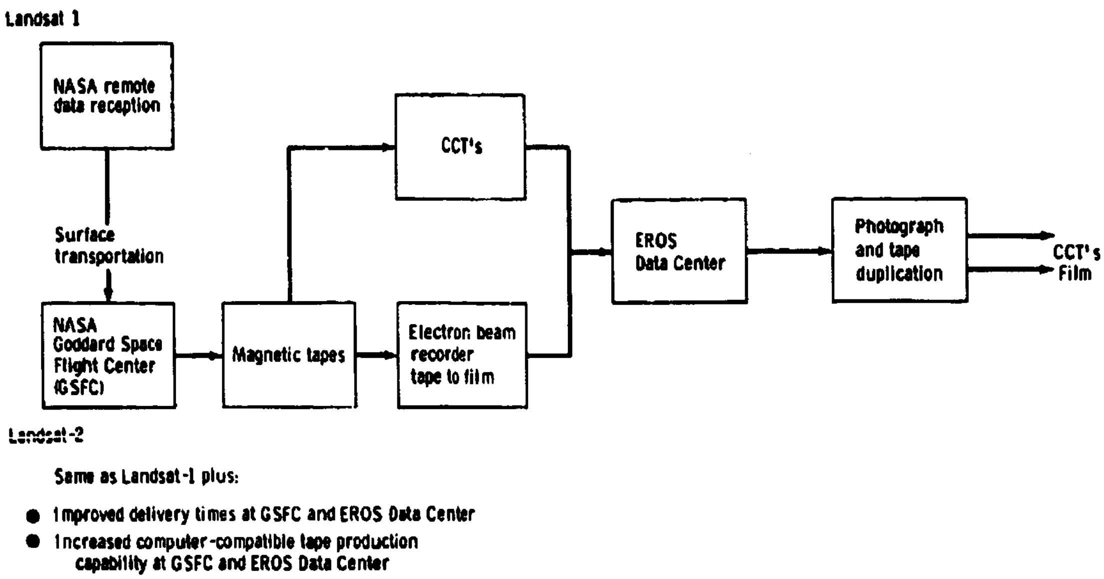

Figure 2.– Landsat data handling and processing.

U-3. Bringing Remote-Sensing Technology to the User Community

John C. Lindenlaub,[a] Shirley M. Davis,[a] and Douglas B. Morrison[a]

INTRODUCTION

Historically, there has always been a time lag between technological breakthroughs and the widespread use of a new technology. The reason is that there are several steps which must be taken before this gap can be bridged; among them are a demonstration of the "usefulness" of the technology, education of the "user community," and making the technology available to the user community. The usefulness of remote sensing has been adequately demonstrated. This paper surveys the materials and services available for educating and training individuals in the principles and operational aspects of remote sensing. Two approaches are discussed for establishing an in-house capability for the numerical analysis of remotely sensed data.

In this survey, emphasis is placed on sensor systems and analysis techniques that have developed within the past decade. These sensor systems, typified by the multispectral scanners aboard the Landsat satellites, are capable of supplying vast quantities of data, and computer-assisted analysis techniques have proved effective in handling this type and volume of data. Photointerpretation techniques are not stressed here; because this is a much more mature field, there is a relatively larger number of individuals trained in photointerpretation methods, and formal university courses have been in existence for many years.

The topics discussed here are structured in the order that an individual or organization might logically follow when learning about and applying remote-sensing technology. These topics include studying available literature, attending remote-sensing symposia and conferences, participating in intensive short courses and in-residence programs, using remote terminal networks, and implementing the analysis software. This hierarchy begins at the introductory level and extends to establishing the capability for analyzing large amounts of remotely sensed data. Cost estimates are included in the discussion when they seem appropriate.

SELF-STUDY OF THE LITERATURE

An obvious first step in entering the field of remote sensing is to consult the available literature. Appendix A provides a list of books, journals, reports, conference proceedings, and bibliographies dealing with remote sensing. To enhance the usefulness of the bibliography, addresses of publishers and professional societies have been included. Appendix A is not intended to be exhaustive but to serve as a reference to provide newcomers to the field with a logical starting point for selecting reading materials.

A search through the literature will reveal that there are only a few written pieces which present remote sensing in a tutorial way. One of the first to appear was a volume prepared in 1970 by the National Academy of Sciences, entitled "Remote Sensing with Special Reference to Agriculture and Forestry."[1] Although somewhat dated now, this report from the Committee on Remote Sensing for Agricultural Purposes presents a substantial overview of remote sensing as related to two applications areas, forestry and agriculture. Its intent is to aid communication among physical scientists, data processing specialists, agricultural scientists, and foresters, and, as such, it attempts to establish basic working vocabularies and concepts. Another book dealing with the basics, but from a broader point of view, is "The Surveillant Science: Remote Sensing of the Environment," edited by Robert Holz and published in 1973. This is a collection of 44 previously published papers selected to provide a comprehensive overview of a number of approaches to remote sensing. A third

[a] Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana.

[1] References cited in this section are listed in appendix A of this paper.

publication is actually a five-volume report written at the tutorial level prepared for the European Space Agency in 1973, entitled "Data Preprocessing Systems for Earth Resources Survey." It has as its objective "to provide information... to the earth scientist community on data correction, processing, and information extraction systems associated with the remote-sensing systems and to indicate future trends."

Frequently, governmental units and other interest groups are faced with the need to inform a large number of people about remote-sensing technology and its potential application in a specific field. Often, this is accomplished through group meetings, and a few very helpful volumes have grown out of such meetings. One of these, a volume edited by Estes and Senger in 1973 and entitled "Remote Sensing: Techniques for Environmental Analysis," is a collection of 12 papers initially presented to geographers and scientists from developing nations to give them a basic introduction to the field of remote sensing. Similarly, a tutorial seminar in 1972 resulted in a publication by the Iowa Geological Survey available under the title "Seminar in Applied Remote Sensing." And a third worth mention here is the "International Workshop on Earth Resources Survey Systems Proceedings," published in 1971 and available through NASA. This workshop was designed to acquaint people from developing nations with the potentials of remote sensing.

Most people new to remote sensing approach the technology through a particular discipline area, whether it be engineering, earth sciences, hydrology, or agriculture. Although there are very few journals devoted to remote sensing from an interdisciplinary point of view, a number of journals related to specific disciplines frequently carry articles on remote sensing. Several of these are listed in appendix A. These journals provide subject specialists an opportunity to study remote sensing from the familiarity of their own discipline.

Once a person has passed the introductory steps in learning about remote sensing, he may wish to turn to the wealth of collected information on the subject, specifically the volumes prepared under NASA sponsorship and the several sets of proceedings from remote-sensing conferences. The NASA "Annual Earth Resources Program Reviews" from 1968 through 1972 are an excellent source of information, surveying the activities of remote sensing for Earth resources during these critical formative years. The volumes published in 1972 and 1973 as a result of NASA-sponsored symposia on Landsat are also important collections for the person wishing to know about data collection methods as well as for those interested in analysis methods and possible applications of Landsat data. One of the monuments of remote-sensing literature is the proceedings of the International Symposia on Remote Sensing of Environment sponsored by the Environmental Research Institute of Michigan (ERIM). Similarly, proceedings from the Laboratory for Applications of Remote Sensing (LARS) Symposia on the Machine Processing of Remotely Sensed Data serve as collections of important papers dealing with the quantitative approach to remote-sensing data analysis.

As the volume of remote-sensing literature grows, it is not surprising to find that more bibliographic studies are becoming available. Most significant among these is the "Quarterly Literature Review of the Remote Sensing of Natural Resources," which is compiled and published by the Technology Applications Center of the University of New Mexico. This quarterly publication abstracts and gives the source for a large quantity of technical literature related to remote sensing, sensors, and the sensing of natural resources. Editors of the review tap and index abstracted technical reports, conference papers, books, foreign publications, and translations plus additional NASA governmental and engineering sources.

REMOTE-SENSING SYMPOSIA AND CONFERENCES

The next activity that might be pursued in educating oneself on remote sensing would be attending one of the conferences or symposia. Formal sessions at these conferences are designed to bring to the audience the newest techniques in remote sensing and to discuss ways the technology can be applied in various disciplines. Of equal importance, however, is the opportunity to mingle with members of the remote-sensing community, to interchange ideas on an informal basis, and to identify individuals with common problems or interests. The cost of registration and conference proceedings usually ranges from $30 to $60. Appendix B gives the name, sponsoring organization, frequency, and contact person for some remote-sensing conferences and symposia that have been held on a recurring basis. Information on proceedings is included in appendix A.

The series of conferences with the longest history is the International Symposia on Remote Sensing of Environment sponsored by the ERIM, initiated in 1962. Other regularly held conferences have been sponsored by the Tennessee Space Institute, the LARS, and the Canada Remote Sensing Society.

Conferences held by many technical societies also reflect a growing interest in remote sensing. Most notably, the American Society of Photogrammetry now has regular sessions on remote sensing. Significantly, they have recently changed the name of their journal to Photogrammetric Engineering and Remote Sensing. The Institute of Electrical and Electronics Engineers, the Association of American Geographers, and the American Society of Agronomy are among other professional groups showing increasing interest in remote sensing.

Conferences and symposia, especially those devoted exclusively to remote sensing, offer an unusual educational opportunity to someone new to the field of remote sensing.

INTENSIVE SHORT COURSES

Surveying the current literature and/or attending a symposium usually provides a person enough insight to determine whether or not remote sensing offers potential for a particular application and thus whether he wishes to pursue additional educational and training activities. If further education seems desirable, he should consider attending an intensive short course on remote sensing. Usually 1 week or shorter, these courses provide the participant an opportunity to grasp the limitations as well as the capabilities of remote-sensing technology. One advantage of these courses is that they are intensive. The participant is usually engaged in full-time study of the subject matter away from his home environment, away from the competition of other duties and interruptions. This environment provides an excellent opportunity to take full advantage of materials and presentations prepared by subject specialists. Participants in short courses often receive a collection of tutorial printed materials generally not otherwise available.

Short courses tend to follow one of two formats. The first format emphasizes lecture presentation by research specialists. In effect, these lectures are an active research worker's interpretation of the current literature in the field. Since organizers of these conferences tend to bring in expertise from various parts of the country, there is an excellent opportunity to obtain a broad overview of the field. A second way of organizing a short course is to use a smaller number of instructors, usually people from the same or nearby organizations who have worked together. This approach tends to result in a well-integrated course with a strong thread of continuity. The pote l participant will want to pay attention to the manner in which the course is organized.

Appendix C contains names and addresses of organizations which have sponsored remote-sensing short courses. Three organizations have come to our attention as offering or planning to offer courses on a regularly scheduled basis. They are the EROS Data Center, LARS, and Oregon State's Environmental Remote Sensing Applications Laboratory.

The EROS Data Center is planning annual spring and fall courses for international representatives on the general aspects of remote sensing. Quarterly offerings for general participation are in the planning stage. A publication by Reeves (ref. 1) describes EROS Data Center training programs.

The LARS offered a 2-week course in the summer of 1972 and 1-week courses in June and September of 1974. The LARS courses have emphasized numerical analysis and pattern recognition techniques. The LARS intends to offer each month a 1-week course in remote-sensing technology and applications to classes of 8 to 15 members. Included will be a series of workshops that take participants through a typical numerical analysis sequence using Landsat data.

Oregon State's Environmental Remote Sensing Applications Laboratory annually offers a 2-day course on digital processing of Landsat data, and the Oregon State School of Forestry introduces participants in its annual aerial photography remote-sensing short course to the broader aspects of remote sensing.

Costs for short courses usually range from $300 to $500 depending upon a number of factors, such as the duration of the course, the number of participants, and personnel resources for presenting the course.

RESIDENCE PROGRAMS

When an individual attends an intensive short course, he probably does so either to get a broad overview of remote-sensing technology in order to interact effectively with people working in the community or to determine whether he wishes to become a remote-sensing expert himself. In the former case, the graduate of a short course is usually equipped to enter into meaningful research or contract discussions with people working in remote sensing. In the latter case, a residence program may provide him the opportunity to increase his expertise by working at a particular organization or with a particular individual.

Within the university environment exist semester-long courses and graduate student research positions. Many university departments offer courses or series of courses in remote sensing. A survey published in 1972 by Eitel (ref. 2) lists 62 remote-sensing courses in 39 institutions. More recently (1975), Morain (ref. 3) compiled a survey of various remote-sensing courses taught in geography departments alone; the survey includes 45 courses in 33 institutions. Although full-time university residency programs usually do not lend themselves very well to industrial or government agency employees, they should certainly be looked to as a source of future graduates with training in remote sensing.

More flexible residence programs aimed specifically at the practicing professional are encouraged by a number of remote-sensing organizations within the United States. It usually takes initiative on the part of the person wishing to participate in such a program to write the organization, present his credentials, list the objectives of his visit, and negotiate an arrangement. At the Laboratory for Applications of Remote Sensing, the visiting scientist program offers residency periods ranging from a few days to a year or more.

Perhaps the best way to illustrate residence programs of the visiting scientist type is to give some examples. A Landsat principal investigator visited LARS for 8 days with the objective of comparing results of machine processing of Landsat data with classifications he had previously determined by standard photointerpretation techniques. Prior to his visit, he had gained some background in machine processing by attending a LARS short course. Working closely with an experienced analyst, he accomplished his goal, successfully classifying portions of four Landsat scenes. His organization was charged about $3000 for computer services and $680 for personnel services incurred during his visit. Another researcher, interested in the identification of subresolution targets in remote-sensing imagery, spent 9 weeks at LARS and used about $300 of computer resources and $1000 for personnel and service resources. A 1-year visit involving 4 to 6 weeks of intensive training followed by work associated with an ongoing laboratory project could cost about $2200 plus $450 for computer time. These examples reveal the wide variation possible under a visiting scientist arrangement.

The visiting scientist program at LARS can be characterized by stating that visits of a short duration re[illegible]able consulting service arrangements, whereas long-term visits more nearly approach a postdoctoral fellowship relationship between the visitor and his sponsor. Similar residence programs can be arranged at other remote-sensing organizations, including the EROS Data Center, the ERIM, the Tennessee Space Institute, and the South Dakota Remote Sensing Institute. Because of the flexible and individual nature of these programs, similar arrangements can probably be made with other organizations as well. Costs associated with residence programs vary widely depending upon the duration of the visit, the resources used, and the basic charter of the host institution.

REMOTE TERMINAL NETWORKS

The next level in the hierarchy of mechanisms for bringing remote-sensing technology to the user community is providing an in-house analysis capability. For the purpose of this discussion, "analysis capability" will be defined to include hardware, software, and trained personnel. Initially, one might want to give serious consideration to providing hardware and software capability by means of a terminal connected to a data processing network capable of handling multi-image data. Advantages of this remote terminal approach include full user access to both the data bank and the processing capability of a large Earth resources data processing system, centralization and sharing of the expensive portions of the processing hardware, and centralization and cost sharing of software maintenance and updates. Perhaps of even greater importance to newcomers to the remote-sensing community is the fact that usually within several months after an agreement is made, they can be on the network, can take advantage of the newest technological developments as they are implemented, and can write their contract to terminate the agreement at a definite time.

Although the authors are aware of a program to make remote-sensing data analysis capabilities available on the Government Services Administration (GSA) network (a computer network operated for Federal agencies by the GSA) and are aware that consideration has been given to installing multispectral data processing capability on commercial time-sharing networks, at the time of this writing, there is only one operational Earth resources data processing network. This is the Earth Resources Data Processing System operated by Purdue University's Laboratory for Applications of Remote Sensing.[2]

[2]Initial development of this system was supported by the National Aeronautics and Space Administration (NASA) under grant number NGL 15-005-112.

The system provides remote access to LARSYS, a multispectral data bank, and a general purpose computer; LARSYS is a fully documented multi-image data analysis software system designed to provide for advanced research, development, and applications of remote-sensing concepts and systems. The multispectral data bank is available to all users of LARSYS and serves as its primary data base; LARSYS is implemented on a general purpose computer with time-sharing and remote terminal capabilities.

It is significant that the word "system" is used instead of the word "network" in the name of the Earth Resources Data Processing System because considerable support above hardware/software capability is provided. The main thrust of this additional support is in providing education and training materials and services, extensive software documentation, and personnel services. This support includes the following.

Educational materials and services:

1. A 2-week LARSYS Analysis for Instructors Course to train the designated remote-site specialists to become qualified instructors prior to terminal installation
2. The LARSYS Education Package, a set of instructional materials developed to train people in the analysis of remotely sensed multispectral data using LARSYS Site experts who have taken the LARSYS Analysis for Instructors Course serve as instructors at the remote sites
3. An advanced level LARSYS Analysis Workshop/Seminar offered at the remote site after users have received initial training by the remote-site instructors and have gained some experience using LARSYS

Software documentation: The LARSYS User's Manual contains a comprehensive description of the organization of the LARSYS system and the processing functions available.

Personnel services:

1. A Purdue/LARS employee designated to serve as an analysis specialist for remote terminal users
2. A Purdue/LARS employee designated to serve as a system specialist to assure smooth operation of the terminal
3. Specialized reformatting, preprocessing, and LARSYS software programing instruction services

A more extensive description of the Earth Resources Data Processing System has been prepared by Phillips and Schwingendorf (ref. 4). This document also provides the basic parameters which would allow one to estimate the cost of installing and maintaining a remote terminal at a particular location. Data on seven such installations have shown that the average annual cost for maintaining and using a remote terminal has been $70 510; terminal installation costs have averaged $9085.

IMPLEMENTING ANALYSIS SOFTWARE

Other approaches to obtain an in-house capability for the analysis of remotely sensed data range from the purchase of specialized hardware and software to implementing software on a general purpose digital machine. It does not seem appropriate in this paper to try to summarize, critique, or estimate the expense of the various kinds of specialized hardware available to the remote-sensing user community. Some of these systems are described elsewhere in these proceedings, and price information is readily available from the manufacturers. It does seem appropriate, however, to discuss some aspects of implementing analysis software on your own general purpose digital machine, because many organizations already have access to general purpose computational facilities. Three factors will be considered: software availability, training, and personnel requirements.

Computer algorithms proven to be effective for the analysis of remotely sensed multi-image data have been reported in the literature. (See conference proceedings listed in appendix A.)[3] Copies of these programs may sometimes be obtained from the authors at nominal cost. Documentation varies, ranging from nonexistent to good. A complete, well-documented software system, LARSYS, may be purchased by domestic organizations from the LARS for $1000. This price includes source tapes and over 3000 pages of documentation, consisting of the LARSYS User's Manual, LARSYS System Manual, LARSYS Test Procedures Manual, and LARSYS Program Abstracts. Nondomestic organizations may obtain LARSYS through COSMIC, Barrow Hall, University of Georgia, Athens, Georgia 30601.

The Laboratory for Applications of Remote Sensing also offers, on a request basis, a LARSYS Programing Education Course. This course, which might be more adequately described as a consulting service, is designed to take participants as far as possible into understanding how LARSYS is programed. Content and duration of the course are variable depending upon the background

[3]We do not mean to imply that existing algorithms are necessarily optimum or that continual research in data processing techniques should be curtailed. On the contrary, continued work in this area is essential.

and objectives of the participants. The course fee is negotiated on an individual basis. Sample fees are: \$2500 for a 1-week course (\$500 per day), \$3200 for a 2-week course (\$320 per day), and \$3900 for a 3-week course (\$260 per day). The thrust of the course is to prepare individuals to install LARSYS modules on their own computer.

Because it is easy to grossly underestimate the costs associated with the installation of analysis software, it seems appropriate to give some guidelines even though they may in themselves be subject to a considerable margin of error. Commentary will be restricted to estimating personnel costs only. No attempt will be made to account for computer time usage or prorated support of the computer facility. To provide a perspective, several levels of analysis capability will be discussed.

A single programer could probably implement the algorithms commonly used in remote-sensing analysis on a general purpose machine in 6 to 12 months. This implementation would not be expected to include user-oriented input-output routines or other programing "frills." Furthermore, probably only one or two individuals who were very familiar with the programs would be able to use the algorithms for analysis purposes. The personnel cost required to achieve this capability, which might be described as a minimum capability, could range from \$25 000 to \$40 000 depending upon the individual's salary and supervisory and overhead charges. Since this level of capability would be highly dependent upon one or two individuals, the associated cost is perhaps more properly interpreted as an investment in the individual rather than in the software.

Providing convenient access to a larger group of analysts, say 10 to 12 individuals, would require more careful implementation. User-oriented input-output formats as well as careful documentation would be recommended. It is estimated that this intermediate level of analysis capability would require a personnel investment of \$100 000 or more.

As a final example, consider establishing what might be called a "full service" remote-sensing data analysis capability. Such a capability would include providing preprocessing services (such as geometric correction and multitemporal overlay) and several specialized program adaptations. At least 2 to 3 years would probably be needed to build up such a capability. Success would require building expertise in preprocessing operations, system programing capability, and routine service operations. One could anticipate a \$300 000 to \$500 000 investment to achieve "full service" capability with an accompanying \$200 000 to \$300 000 annual personnel budget.

Although subject to considerable interpretation, the personnel costs quoted in these examples are estimated as realistic lower bounds. Naturally, justification of such expenditures would require large volumes of data analysis. Alternatives to such a large expenditure are the remote terminal approach, discussed in the last section, or outside contractors to analyze the data.

SUMMARY

This paper has presented a survey and discussion of the two components necessary for bringing the remote-sensing technology which has developed over the past decade to the user community. These components are education and training opportunities and the capability for analyzing the data available from current sensor systems.

Education and training opportunities range from self-study of the literature and attending conferences and symposia to participating in intensive short courses and residence programs. Options for establishing numerical analysis capability include purchasing specially designed hardware-software systems, accessing via a remote terminal the LARS Earth Resources Data Processing System, and implementing analysis software on one's own general purpose computer.

This paper, along with its appendixes, is intended to serve as a guide to potential members of the remote-sensing community seeking a deeper understanding and involvement in remote-sensing activities.

ACKNOWLEDGMENTS

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2. Fitel, D. F.: Remote Sensing Education in the U.S.A. Photogrammetric Engineering, vol. 3 ., no. 9, Sept. 1972, pp. 900-906.

3. Morain, S. A.: Geographic Education in Remote Sensing at the University Level. Compiled for the Association of American Geographers Committee on Remote Sensing, March 1975.

4. Phillips, T. L.; and Schwingendorf, S. K.: On the Access to an Earth Resources Data Processing System. LARS Information Note 031274. Laboratory for Applications of Remote Sensing, Purdue University.

U-3 APPENDIX A

REMOTE-SENSING LITERATURE

The following list of published materials was compiled as an aid to persons new to numerical analysis of remote-sensing data. The authors would appreciate knowing about other available tutorial and technical publications which might be of help to the newcomer.

Books

Alexander, Larry; Eichen, Leo; et al.: Remote Sensing – Environmental and Geotechnical Applications, Engineering Bulletin 45, 1974. Dames and Moore, 445 S. Figueroa St., Los Angeles, Calif. 90017.

Colwell, R. N., ed.: Manual of Photographic Interpretation, 1960. American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, Va. 22046.

Estes, John E.; and Senger, Leslie W., eds.: Remote Sensing – Techniques for Environmental Analysis, 1973. Hamilton Publishing Company, Santa Barbara, Calif. 93101.

Holz, Robert K.: The Surveillant Science – Remote Sensing of the Environment, 1973. Houghton Mifflin, Boston, Mass. 02101.

Johnson, P. L., ed.: Remote Sensing in Ecology, 1969. University of Georgia Press, Athens, Ga. 30601.

National Research Council: Remote Sensing With Special Reference to Agriculture and Forestry, 1970. National Academy of Sciences, 2101 Constitution Ave., Washington, D.C. 20037.

Pouquet, Jean: Les Sciences de la Terra a L'heure des Satellites (Earth's Resources from Satellite), 1974. Translation by D. Reidel Publishing Co., 306 Dartmouth St., Boston, Mass. 02116.

Reeves, R. G., ed.: Manual of Remote Sensing, 1975. American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, Va. 22046.

Rudd, Robert: Remote Sensing – A Better View, 1974. Duxbury Press, 6 Bound Brook Ct., N. Scituate, Mass. 02066.

Wolff, Edward; and Mercanti, Enrico P., eds.: Geoscience Instrumentation, 1974. John Wiley and Sons, 605 Third Ave., New York, N.Y. 10016.

Journals Devoted to Remote Sensing

IEEE Transactions on Geoscience Electronics (quarterly): Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, N.Y. 10017.

ITC Journal (five issues yearly): International Institute for Aerial Survey and Earth Sciences, Enschede, The Netherlands.

Photogrammetria (bimonthly): International Society for Photogrammetry, P.O. Box 1345, Amsterdam, The Netherlands.

Photogrammetric Engineering and Remote Sensing (monthly): American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, Va. 22046.

Remote Sensing of Environment (quarterly): American Elsevier Publishing Co., 52 Vanderbilt Ave., New York, N.Y. 10017.

Journals Frequently Carrying Articles on Remote Sensing

Agronomy Journal (bimonthly): American Society of Agronomy, 677 S. Segoe Rd., Madison, Wis. 53711.

Applied Optics (monthly): Optical Society of America, 2000 L St. N.W., Washington, D.C. 20036.

Aviation Week and Space Technology (weekly): McGraw-Hill, 1221 Avenue of the Americas, New York, N.Y. 10020.

Crop Science (bimonthly): Crop Science Society of America, 677 S. Segoe Rd., Madison, Wis. 53711.

IEEE Transactions on Computers (monthly): Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, N.Y. 10017.

Proceedings of IEEE (monthly): Institute of Electrical and Electronics Engineers, 345 East 47 St., New York, N.Y. 10017.

Journal of Forestry (monthly): Society of American Foresters, 1010 16th St. N.W., Washington, D.C. 20036.

Journal of Soil and Water Conservation (bimonthly): Soil Conservation Society of America, 7515 N.E. Ankeny Rd., Ankeny, Iowa 50021.

Optical Engineering (bimonthly): Society of Photo-Optical Instrumentation Engineers, 338 Tejon Place, Palos Verdes Estates, Calif. 90274.

Soil Science Society of America Proceedings (bimonthly): American Society of Agronomy, 677 S. Segoe Rd., Madison, Wis. 53711.

Reports

Bressanin, G.; and Erickson, J., et al.:

Data Processing Systems for Earth Resources Surveys

- Vol. 1 · Introduction to Preprocessing Techniques
- Vol. 2 · Methods of Implementation
- Vol. 3 · Technical Appendices
- Vol. 4 · Summary
- Vol. 5 · Bibliography

European Space Agency, 114 Avenue Charles de Gaulle, 92-Neuilly, France, 1973.

Laboratory for Applications of Remote Sensing: Remote Multispectral Sensing in Agriculture

- Vol. 1 Research Bulletin 831, 1967
- Vol. 2 Research Bulletin 832, 1967
- Vol. 3 Research Bulletin 844, 1968
- Vol. 4 Research Bulletin 873, 1970

Agricultural Experiment Station, Purdue University, W. Lafayette, Ind. 46207.

National Aeronautics and Space Administration:

Earth Resources Aircraft Program Status Review, 1968

- Vol. 1 NASA TM X-62564, N71/16126
- Vol. 2 NASA TM X-62565, N71/16147
- Vol. 3 NASA TM X-62566, N71/16166

Second Annual Earth Resources Aircraft Program Status Review, 1969

- Vol. 1 NASA TM X-66913, N71/19251
- Vol. 2 NASA TM X-66484, N71/11976
- Vol. 3 NASA TM X-66481, N71/11151

Third Annual Earth Resources Program Review, 1970

- Vol. 1 NASA TM X-67403, N72/12248
- Vol. 2 NASA TM X-67404, N72/12269
- Vol. 3 NASA TM X-67407, N72/12295

Fourth Annual Earth Resources Program Review, 1972

- Vol. 1 NASA TM X-68564, N72/29302
- Vol. 2 NASA TM X-68397, N72/29327
- Vol. 3 NASA TM X-68952, N72/29355
- Vol. 4 NASA TM X-68563, N72/29378
- Vol. 5 NASA TM X-68562, N72/29407

Advanced Scanners and Imaging Systems for Earth Observations, NASA SP-335, 1972

National Technical Information Service, Springfield, Va. 22161.

Also check reports from Agricultural Experiment Stations and Technical Bulletins from the U.S. Geological Survey.

Proceedings

American Society of Photogrammetry Symposia (annual, semiannual, and special), 105 N. Virginia Ave., Falls Church, Va. 22046.

Canadian Symposia on Remote Sensing:

First Symposium Proceedings, Sept. 1972, Information Center, 171 Slater St., Ottawa, Ontario, Canada.

Second Symposium Proceedings, Mar. 1974, Canada Remote Sensing Society, c/o Canada Aeronautics and Space Institute, 77 Metcalf St. Ottawa, Ontario, Canada.

International Symposia on Remote Sensing of Environment (every 18 months since 1962): Environmental Research Institute of Michigan, Ann Arbor, Mich. 48107.

Machine Processing of Remotely Sensed Data: Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Ind. 46207.

- 1973 Conference IEEE Catalog No. 73 CHO 834-2GE
- 1975 Conference IEEE Catalog No. 75 CH 1009-0C

IEEE, 445 Hoes Lane, Piscataway, N.J. 08854.

NASA (various symposia):

International Workshop on Earth Resources Survey Systems, NASA SP-283, 1971.

Earth Resources Technology Satellite-1 Symposium Proceedings, NASA TM X-66193, N73/19396, 1972.

Symposium on Significant Results Obtained From Earth Resources Technology Satellite-1, 1973

Vol. 1 (A & B) Technical Presentations, NASA SP-327

Vol. 2 Summary of Results, NASA TM X-66283, N73/28389
Vol. 3 Discipline Summary Reports, NASA TM X-66284, N73/28405
Third Earth Resources Technology Satellite-1 Symposium (Dec. 1973)
Vol. 1 (A & B) – Technical Presentations. NASA SP-351
Vol. 2 – Summary of Results. NASA SP-356
Vol. 3 Discipline Summary Reports. NASA SP-357
National Technical Information Service, Springfield, Va. 22161.

Seminar in Applied Remote Sensing, Public information circular no. 3, May 1972. Iowa Remote Sensing Laboratory, Iowa Geological Survey, 16 W. Jefferson St., Iowa City, Iowa 52240.

Shahrokhi, F., ed.: Remote Sensing of Earth Resources, 1972, 1973, 1974, 1975. Space Institute, University of Tennessee, Tullahoma, Tenn. 37388.

Thomson, Keith P. B.; Lane, Robert; and Csallany, Sandor C., eds.: Remote Sensing and Water Resources Management, 1973. American Water Resources Association, 206 East University Ave., Urbana, Ill. 61801.

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Nagy, George: Digital Image-Processing Activities in Remote Sensing for Earth Resources. Proceedings of the IEEE, vol. 60, no. 10, Oct. 1972, pp. 1196-1200.

National Aeronautics and Space Administration (NASA): Remote Sensing of Earth Resources – A Literature Survey with Indexes, NASA SP-7036, 1970.

Technology Application Center: Quarterly Literature Review of the Remote Sensing of Natural Resources, Institute for Social Research and Development, University of New Mexico, Albuquerque, N. Mex.

Telespazio: Data Preprocessing Systems for Earth Resources Surveys, vol. 5 – Bibliography, 1973. Prepared for European Space Agency, 114 Avenue Charles de Gaulle, 92-Neuilly, France.

U-3 APPENDIX B

SYMPOSIA AND CONFERENCES

The following list includes the names of organizations, contact persons, and brief remarks on several remote-sensing conferences and symposia that have been held on a regular basis in recent years. Information regarding proceedings that have been published from these conferences may be found in appendix A.

Alberta Remote Sensing Center
205 100 Avenue
Edmonton, Alberta T5J0Z6
Canada

Cal B. Bricker, General Chairman. Symposia held every 18 months. Third Canadian Symposium on Remote Sensing held in September 1975. Emphasis on applications.

Environmental Research Institute of Michigan
P.O. Box 618
Ann Arbor, Mich. 48107

Dr. Jerald J. Cook. 10th International Symposium on Remote Sensing of Environment held in October 1975. Remote sensing in general.

Laboratory for Applications of Remote Sensing, Purdue University
1220 Potter Drive
West Lafayette, Ind. 47906

Dr. C. D. McGillem, Program Chairman. Second Symposium on Machine Processing of Remotely Sensed Data held in June 1975. Emphasis on machine processing.

University of Tennessee
Space Institute
Tullahoma, Tenn. 37388

Dr. F. Shahrokhi. Fourth Annual Remote Sensing of Earth Resources Conference held in March 1975. Remote sensing in general.

U-3 APPENDIX C

REMOTE-SENSING SHORT COURSES

The information on courses regularly scheduled (table C-I) is intended to be representative rather than exhaustive. Many remote-sensing centers, while not offering short courses on a regular basis, have presented short courses in the past and are prepared to do so in the future when needed.

TABLE C-I. COURSES REGULARLY SCHEDULED

Location	Contact	Details and emphasis
District of Columbia	Ralph Bernstein c/o Director, Continuing Education George Washington University Washington, D.C. 20052	Digital image processing; 3-day course was offered July 1975. Emphasis on geometric and radiometric correction and computer configurations for image processing.
Indiana	D. B. Morrison LARS/Purdue University West Lafayette, Ind. 47907	Introductory course on fundamentals of remote sensing; offered first full week of every month; enrollment limited to 15 per course. Workshops emphasize machine processing.
Kansas	Dr. Richard Moore Remote Sensing Laboratory University of Kansas Lawrence, Kans. 66044	Radar short courses have been offered in the past and will be in the future when need and demand dictate. Course notes are available for purchase.
Michigan	Dr. Jerald J. Cook Willow Run Laboratories Environmental Research Institute of Michigan P.O. Box 618 Ann Arbor, Mich. 48107	Two courses on infrared are offered frequently in summer in conjunction with summer school, University of Michigan.
Mississippi	Dr. Gary W. North National Space Technology Laboratories EROS Program Bay St. Louis, Miss. 39520	Various applications of remote sensing. Twice each month, 4-day courses are offered on a request basis. Limited to 12 participants.
Oregon	Dr. Barry Schrumpf Environmental Remote Sensing Applications Laboratory Oregon State University Corvallis, Oreg. 97331	Digital processing of Landsat data offered yearly; 2-day course; participants limited to 30; cost $150 per person.

TABLE C-I. Concluded

Location	Contact	Details and Emphasis
	Dr. David P. Paine School of Forestry and Extension Service Oregon State University Corvallis, Oreg. 97331	Aerial photography remote-sensing short course offered annually in March; limit 40-50; cost $100 per person. Organizing aerial missions, photograph mensuration and multisampling, and introduction to broader aspects of remote sensing.
South Dakota	Dr. Donald Lauer EROS Data Center Sioux Falls, S. Dak. 57198	Remote sensing in general. Two courses for international representatives will be offered annually, spring and fall. Subsequently, a course will be offered quarterly for anyone interested.
	Dr. Donald Moore Remote Sensing Institute South Dakota State University Brookings, S. Dak. 57007	Photointerpretation especially, but all aspects of remote sensing covered; starts in 1976 initially for representatives of domestic and foreign governmental agencies; in conjunction with EROS Data Center. Training from 1 week to 1 year.
Tennessee	Dr. F. Shahrokhi The University of Tennessee Space Institute Tullahoma, Tenn. 37388	Remote Sensing in general. Courses have been offered on various aspects of remote sensing in the past and will be in the future upon demand.
Washington	Dr. Frank Westerlund Dept. of Urban Planning University of Washington 410 Gould Hall Seattle, Wash. 98195	"Remote Sensing for Planners" was offered May 1975; attendance limited to 36.