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IDENTIFYING ENVIRONMENTAL FEATURES FOR LAND MANAGEMENT DECISIONS

National Aeronautics and Space Administration
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Center for Remote Sensing and Cartography
Applied Technology Division
University of Utah Research Institute

Salt Lake City, Utah

INTRODUCTION

The past few months have seen more progress toward making the Center for Remote Sensing and Cartography (CRSC) a well-organized and productive professional research entity than the several preceding years. CRSC's move from the Geography Department to the University of Utah Research Institute (UURI) has produced dramatic changes in management organization and facilities: the result of which has been a tremendous boost in the confidence of the staff that CRSC, indeed, has a viable and deliverable remote sensing capability to offer.

CRSC WITHIN THE UURI ORGANIZATION

CRSC has made significant progress in augmenting its technical capabilities, and a report of such progress will follow, but we wish first to articulate important philosophical advances which have been an outgrowth of the physical relocation of CRSC. Over the past few months, we have found working within the administrative structure of the UURI to be very productive: the policies and procedures here are entirely in harmony with our objectives. UURI is a viable and vigorous research organization, with a healthy fiscal and administrative foundation. It is clear that at UURI we have but one mission: to develop, apply, and extend state-of-the-art remote sensing capabilities to as many land management decision-making situations as possible.

At UURI, we are not obligated to expend our resources to promote academic programs or keep harmony among an independent faculty, and we are relatively unaffected by the ephemeral flux of students and consequential setbacks to CRSC's research projects. CRSC finds itself in an environment where the prevailing attitudes and policies promote positive growth and marketing of the technical capabilities which CRSC has built up over the past several years through its seed grants from NASA. At UURI, we continue to have access to on-campus professionals. In recent interactions with private industry administrators we have found that such administrators would prefer to do business with the UURI because of our applied research mission, rather than academic departments who emphasize instructional and graduate thesis pay-offs.

In short, we have found the UURI administrative officers delightful to work with and as anxious as we are in establishing a productive and financially viable remote sensing center. We are confident that as we continue to adjust to our new home, tie down loose ends of past projects, and increase our abilities to market CRSC, we will find our dependence on the NASA seed grants to lessen with time.

FACILITIES

The physical setting of the UURI offers attractive advantages. At present, CRSC has administrative offices for its director, manager, and secretary, as well as modest, but practical, laboratory facilities. We have access to the PRIME 400 computing equipment of the Earth Science Laboratory (ESL), a division of UURI, and have been interacting with ESL's computer technicians to become operational with the ELAS software package. Within the past few weeks we received ELAS and are making progress toward bringing it up to fully operational capacity.

Several components of the ELAS package make it particularly attractive to us. First, its integrated modular system and its easy access on a moderate size computing system enhance its flexibility for our use in our new quarters. Secondly, the modular routines encompass most of the capabilities we desire and have been building toward. These include multi-temporal digital registration, interfacing with varieties of GIS data (a growing need in our arena), interfacing with digital terrain data (also in growing demand), and various statistical routines for classification. We had already developed in our own lab (partly with NASA money) several powerful statistical routines (mentioned below), which we find now are integrated into ELAS. The capabilities give us the confidence that we will have the technical tools for staying with and contributing to the state-of-the-art in the foreseeable future. Until we become operational on ESL's computer, we will continue to perform our digital processing via a direct line to the University of Utah Computer Center's Univac computer. Even after we are fully operational on ELAS and PRIME, we will continue access to the UNIVAC with our present programs as a back-up system.

Being located across the hall from ESL results in other economies and conveniences. We have ready access to their professional illustrations department and equipment, their reproduction facilities, and their library. Also, in their computer operating room we have access to such equipment as a STATOS electrostatic printer-plotter, a drum plotter, Tectronics display screens coupled to map digitizers, and all of this interfaced with the PRIME. In addition we plan to purchase jointly with ESL, in due time, a copy camera and darkroom facility, and an interactive color display system (such as COMTAL). Meanwhile we access camera facilities of the Department of Geography and a COMTAL system (linked to a PDP 11) in the Computer Science Department, where we have done our contrast enhancement work. Our contrast enhancement products have been further enriched by the department's precision color display CRT coupled to a high quality camera system and a first rate color photo lab in the Computer Science Department, which we have utilized.

We have also been interacting with the Medical School, Department of Medical Physics and Radiological Research, to share in the use of new facilities being installed there. Such facilities are a high quality film writer, a microdensitometer, and associated periferals. We are planning an association whereby we will help purchase a terminal for them, and thereby gain access to the equipment as needed.

In short, we are optimistic about having a broadly based and highly flexible, integrated capability across a full spectrum of digital, optical, and mechanical remote sensing applications.

CRSC ORGANIZATION

With regard to present CRSC staff, you may have noted from the CRSC brochure sent to you that CRSC now has five professional staff members. Besides CRSC's director and manager are three recent graduates from the U of U Geography Department who have emphasized remote sensing training. All three such members of the staff are very capable and enthusiastic about the future of CRSC and its projects. John Merola has been working full time as the Center's systems analyst and is performing the primary role on several of our current projects. Lincoln Clark and Keith Landgraf have been performing much of the remote sensing technical research on approximately a half-time basis: both will work full time this summer and we plan to place both on full-time salaried employee status as soon as our budget will permit.

CRSC OUTREACH ACTIVITIES

Since CRSC was relocated in its new home, numerous and varied contacts with local resource decision makers have been made. We have invited many persons and groups to our laboratory for formal and informal presentations. We have also reached out with numerous visits, presentations, and workshops. In our efforts thus far, we have focused on agencies within the Utah Department of Natural Resources (DNR). We view DNR as the resource and land management entity which stands to receive the greatest benefit from the remote sensing research capabilities of CRSC which have been principally created and made available through NASA. However, as we will point out below, many of the most recent policy decisions made by DNR high-level administrators do not stand to serve the best interests of such agency.

We would like to briefly review some of the formal outreach activities of the past few months. The date of each meeting, its location in Utah, and brief comments regarding attendees, format, and outcome will be presented below.

October, 1980. Salt Lake City. CRSC staff made a presentation at the Soil Conservation Service (SCS) office of the study of wetlands and water-related land use in the Uinta Basin, done on contract with SCS and the Division of Water Resources. The successful completion and presentation led to a subsequent contact on the upper Sevier River Basin.

November 25, 1980. Roosevelt. CRSC made a visual presentation to approximately twenty representatives from the Soil Conservation Service (SCS), Bureau of Land Management (BLM), Ashley National Forest, Water and Power Resource Service, and U.S. Fish and Wildlife Service. The format was primarily an abbreviated workshop: maps and overhead transparencies were used to give an introduction to remote sensing concepts and provide "hands-on" experience with digital maps and aerial photos. The purpose of the meeting was to encourage agency personnel to generate ideas about management-oriented research projects in their area.

December 17, 1980. Salt Lake City. Following a NASA-Ames slide presentation which was shown by the DNR remote sensing coordinator, CRSC made a short presentation to the assembled group of DNR directors and their assistants. The presentation led to an invitation by CRSC and acceptance by DNR director, Gordon Harmston, to visit the CRSC facilities for a tour and presentation.

January 15, 1981. Salt Lake City,at CRSC. In response to the December 17, 1980 invitation, nineteen directors and other officers from DNR and the director of the Utah Department of Community and Economic Development toured CRSC and participated in a exhibition of current and past CRSC projects and a review of present capabilities. Gordon Harmston, executive director of DNR, firmly endorsed our activities and encouraged department administrators to work with us in developing management-oriented projects. The meeting was followed by an informal discussion wherein some brainstorming was done to identify potential projects within several of the DNR divisions.

January 15, 1981. Salt Lake City, at CRSC. In a tour and meeting with three administrators from the forest supervisor's office of the Wasatch-Cache National Forest, the groundwork was laid for performing an inventory of riparian habitat forest-wide. A second visit on March 17 led to CRSC's committment to perform such a study and the outlining of a draft study plan.

January 26, 1981. Salt Lake City. In a meeting with the Great Salt Lake Board's Technical Team, we reviewed the Farmington Bay Shoreline Fluctuation Study and discussed future work. The group endorsed our plans to continue our Farmington Bay studies by studying the effects of shoreline changes on waterfowl habitat.

January 27, 1981. Salt Lake City, at CRSC. Four representatives from the Division of Water Resources received a visual overview of the techniques applied and results obtained in completing the Uinta Basin Wetlands/Land Use Study. The ability of the remote sensing techniques applied to provide needed management information was clearly accepted by the visitors, and hope for future projects of such character was expressed, budget permitting.

February 3, 1981. Delta. Two members of CRSC participated in a MATE Van display of Landsat remote sensing to three officials of nearby associations of governments. One of the guests on that occasion later visited CRSC to discuss the possibilities of remote sensing work in Juab and Millard counties.

February 13, 1981. Salt Lake City. CRSC staff made a presentation at the MX Missile Coordinator's office, promoting a comprehensive application of remote sensing technology to better define baseline data across a full array of natural resource data needs. This lead to a visit to CRSC facilities by the chairman of the Governor's University MX review team (March 10) and an invitation of CRSC staff to write a formal element of the Governor's MX review of the EIS. This has subsequently lead to the pursuit of a contract with the Air Force for a major base line study. (This is still in very preliminary stages and is somewhat problematical at this reading.)

February 19, 1981. Vernal. A slide overview of remote sensing and CRSC project work was presented to nineteen representatives from the SCS, BLM, Ashley National Forest, Water and Power Resource Service, U.S. Fish and Wildlife Service, and Utah Division of Wildlife Resources. In individual afternoon meetings with the Ashley N.F. and S.C.S. the possibilities for future project work and applications of the Uinta Basin study were discussed.

February 26, 1981. Logan. A slide overview of CRSC capabilities and project work was presented to thirteen members of Utah State University's

College of Natural Resources, and federal and state resource management agency officers. Ideas for forest resource inventories were discussed with federal and state forestry people.

March 5, 1981. Provo. Over fifty people attended a seminar on remote sensing and CRSC's projects. The group included faculty members and students of Brigham Young University, and representatives from the U.S. Forest Service, S.C.S., and Utah Division of Wildlife Resources.

March 6, 1981. Salt Lake City. Three CRSC staff specialists made a formal presentation on our remote sensing capabilities, with particular reference to the Uinta Basin study results, to the Division of Water Resources Board. Follow-up applications and studies were discussed.

March 20, 1981. Salt Lake City. CRSC met with approximately 15 high-level officers, including the director, of the Utah Division of Wildlife Resources to report on the findings of the Farmington Bay Shoreline Fluctuation and Snowpack/Mule Deer Studies and discuss new projects. This was a very valuable meeting that clarified mutual objectives and working relationships.

March 26, 1981. Logan. A slide presentation was made to approximately twenty-five members of the Bear River Soil Conservation District and various representatives from the S.C.S., Utah Department of Agriculture, and Cache County Planning Office. Slides regarding the Uinta Basin study were reviewed to illustrate the technique which could be applied to inventory water-related land use in the Bear River Basin. CRSC was invited to the meeting by Mr. James Christensen who is serving as a consultant to the Utah Department of Agriculture. Mr. Christensen is on assignment to develop a coordinated local resource planning and development program for the state. As the program evolves, it is likely that remote sensing technqiues will become a fundamental element to the formulation of area-wide planning and zoning. As a result of the meeting in Logan, a representative of the Bear River Association of Governments visited CRSC and arranged to receive technical assistance in performing a sensitive area inventory for Cache County.

April 20, 1981. Salt Lake City. CRSC made a formal presentation to the interstate Bear River Compact Commission at its semi-annual meeting in the Utah State Capitol. Some 20 representatives of all three states (Utah, Idaho, and Wyoming), including the respective state engineers and directors of the respective division of water resources, deliberated on the potential value and feasibility of a CRSC remote sensing analysis of the land use (as of 1976, the landmark date) as a common denominator for the three-state compact. The Utah State Engineer, for whom CRSC has done some work in the past, and who chairs the Engineering Committee, recommended CRSC be invited to make a proposal to supply the desired data.

In addition to the above formal outreach presentations, dozens of meetings have been held in agency offices in the line of managing ongoing CRSC projects with the respective agencies, promoting new project work, etc. Also, CRSC opened its doors to numerous visits from individuals and agency people for similar purposes. From these varied interactions, some experimental projects have been performed and many, many leads and ideas have been generated. Among them, CRSC has interacted with private firms on potential project work, and we have completed a second major project on guayule rubber plant inventories in Mexico, and submitted proposals for two additional projects in Mexico. The "Mexican connection" has resulted in a tremendous increase in both our technical capability and our professional visibility as a state-of-the-art remote sensing facility. From this activity, CRSC's director has been invited to present papers at three international symposia, with chapters in published books as tangible products.

To the extent that time and budget would permit, CRSC has been active in attending professional meetings and training sessions. CRSC's manager and one technician attended the conference sponsored by the Soil Conservation Society of America held October 28-30, 1980, in Kansas City, Missouri. Said conference, entitled "Remote Sensing for Resource Management", provided a desirable environment for training and the creation of research project and technique ideas. CRSC's manager also participated in a workshop, held November 17-21, 1981, entitled "Remote Sensing and Geographic Information Systems in the Planning Environment." Said course of study was offered on the University of California, Berkeley, and provided a valuable training opportunity.

The director of CRSC attended the Western Regional Remote Sensing Conference in Monterey, California this past March. Such opportunity permitted CRSC to continue professional acquaintances and exchange ideas. The director also attended the remote sensing session of the Association of American Geographers in Los Angeles, April 20-21, 1981, where he was appointed to the publications and program committees of the Remote Sensing Specialty Group. The director has also been appointed to the conference committee for the annual national meetings of the American Society of Photogrammetry and the American Congress on Surveying and Mapping for 1983.

STATUS OF RELATIONSHIP WITH DNR

In Utah, the Department of Natural Resources (DNR) has been designated as the state agency with responsibility for organizing a system of what DNR terms "Automatic Geographic Referencing" or AGR: a synonym for the concept generally referred to as Geographic Information Systems or GIS. As of the latest report, DNR has taken steps to submit proposals to state and federal sources to obtain funding to acquire the necessary equipment and software for the creation of AGR. In recent discussions between CRSC and various DNR officials, including Mr. Bruce Plott, who has been appointed as the AGR Coordinator, it is clear that remote sensing input is considered an important part of the AGR system. However, the manner in which remote sensing information will be obtained for AGR is somewhat uncertain at present.

Nevertheless, it has always been, and will continue to be, CRSC's goal to assist the state in the utilization of Landsat and other remote sensing resources as analytic tools to efficiently augment natural resource decision and policy making processes. Further, we aim to provide the final products of our research efforts in a format that will be most compatible with state computer systems for their AGR program. In numerous formal gatherings, and personal and telephone conversations, we have made it clear that CRSC is anxious to utilize the resources of its NASA grant to do specific decision-oriented remote sensing research of natural resources.

An assessment of the present status of our relationship with DNR may best be communicated by reviewing a few items of history. As mentioned above, in his visit to CRSC for a formal presentation on January 15, 1981, DNR Executive Director Gordon Harmston enthusiastically commended us on our facilities and project work and encouraged us to contact the directors of the several DNR divisions and set up as many projects as the combined resources of DNR and CRSC (i.e., NASA) could afford. DNR's Deputy Director, Temple Reynolds, was also in attendance but did not seem to share in Mr. Harmston's enthusiasm.

As a follow-up to the January 15 meeting, we arranged a meeting with William Dinehart, director of the Utah Division of State Lands and Forestry (a division of DNR) on January 29. During the course of discussing the role of CRSC in doing remote sensing research for DNR, we had occasion to invite Mr. Harmston into the meeting to clarify a few points. At that time, Mr. Harmston again endorsed the concept that CRSC and DNR should associate closely and that, at least for the short-term future, CRSC would perform the primary remote sensing research function for the state. We reviewed the common goal of DNR to acquire an in-house remote sensing capability, but all agreed that, especially under conditions of budgetary austerity, CRSC should interface closely with the AGR Coordinator so that State and CRSC computing systems would be as compatible as possible. Such compatibility seemed essential, considering the expense involved in acquiring an operational Landsat capability in addition to the technical training required to acquire the necessary competence. As a result of the discussion with Mr. Harmston, we received an invitation to seek and discuss specific project ideas at the DNR division directors' meeting on February 3.

When we arrived at the division directors' meeting, we were surprised to be met outside by the AGR Coordinator, Bruce Plott, who tried to persuade us not to attend the meeting but to meet with him the following day. Although we were permitted to discuss our NASA program for a couple of minutes at the meeting, it was obvious that Mr. Harmston had received some interim advice that CRSC should not be permitted to occupy the floor at the meeting.

On February 4 and 5, meetings were held with Bruce Plott wherein it was mutually agreed that DNR and CRSC should pool resources to foster AGR and remote sensing research in Utah. CRSC agreed to concentrate on providing the primary source of remote sensing research, especially technique research and development work, while DNR would focus on developing its AGR program. We agreed to draft up a formal cooperative agreement between CRSC and DNR to articulate the relationships between the two entities: such an agreement would serve as an information device to communicate the short- and long-term plans of the participating parties. All parties agreed that such an agreement would also maximize efficiency on projects performed through increased central coordination through CRSC and the AGR Coordinator.

During the ensuing weeks, CRSC and Bruce Plott negotiated through several drafts of a cooperative agreement. After the president of UURI approved the document in mid-March, it was delivered to Bruce Plott. Shortly thereafter, we found out that Gordon Harmston had resigned his position and that Temple Reynolds had assumed his responsibilities. We have more recently been informed that Mr. Reynolds has instructed the DNR division directors not to enter into any remote sensing work outside the Statehouse until proposals were first cleard with him and the AGR Coordinator.

The reason for this policy shift is clear; ever since NASA-Ames installed the VICAR/IBIS software on the state's computer and provided Bruce Plott and an associate with a week of training, some members of DNR appear to have the misconception that they are fully operational in Landsat remote sensing. It is clear that DNR officials naively believe that Landsat research is a simple process of reading data tapes and pushing a few buttons. Of course, such a notion is a logical outgrowth of seeing presentations in settings such as the NASA-Ames MATE Van, where Landsat processing is highly simplified in order to perform the demonstrations. The fact that DNR wishes to become immediately operational in remote sensing is commendable, and a desirable outcome of NASA's technology transfer program, but CRSC is concerned because, in a year of tight financial resources, it seems unwarranted for DNR to dabble with unfamiliar software systems when a number of projects could be performed. Further, DNR has done little to objectively evaluate whether VICAR/IBIS, as opposed to ELAS or other software packages is best suited to their long-term needs. It should be mentioned that the DNR division directors, for whom CRSC has performed projects in the past, do not support DNR policies and would prefer to work with CRSC because they have seen the results. In fact, CRSC is engaged currently in seven projects (at various stages from project planning to execution) involving five DNR divisions (some of which are partially funded by the division), because of their desire to get the work done. However, each division is subject to department policies and the current climate at DNR represents a stumbling block to effective interactions with DNR divisions at least for the immediate future. The cooperative agreement is apparently relegated to the back burner at this writing.

The irony of this unfortunate state of affairs is that, in spite of CRSC's successful interaction and performance with the four principal divisions within DNR through funding from NASA's University Affairs/Space Applications Program, the subversive tactics of NASA's Western RAP people have duped upper level state officials into a naive frame of mind that because they have a software package, they are in the remote sensing business. NASA-Ames convinced "the State" that if they would just accept installation of VICAR/IBIS they would be operational (which installation took place last November). Consequently, some people in DNR believe they need no outside help in performing remote sensing project work. The people on the firing line know differently, but they have been inhibited by a directive from a new head who has bought the Ames line. Sadly, no one above the trenches has thought to consider, let alone add up, the real costs of becoming operational -- the assignment of manpower, the acquisition of necessary skills and time lag associated with such acquisition, the overhead, the maintenance, the cost of remaining at the growing edge of a rapidly advancing technology, etc.

Nevertheless, we are optimistic. Where we already have a foot in the door we will continue with several state agencies and through contacts with multi-state compacts (i.e., Bear River Compact and Upper Colorado River Commission, etc.), and federal agencies (S.C.S., Forest Service, WAPRS, Fish and Wildlife Services, etc.). We should be able to develop sufficient work, and with supporting funding, to keep growing. Meanwhile, the state's upper echelon will learn that they have no remote sensing capability, and they can't afford to develop it, and that our friends from the West Coast sold them the proverbial pig-in-a-poke.

RECENTLY COMPLETED PROJECTS

Uinta Basin Wetland/Land Use Study

Much of the detail regarding the nature of CRSC's Uinta Basin research project was communicated in the 1980 annual report (see pages 3-5). The Uinta Basin Wetland/Land Use Study has since been enthusiastically accepted by both the Soil Conservation Service and the Utah Division of Water Resources. The final research products included thirty-eight mylar overlays to 7.5 minute U.S.G.S. quadrangles on which were delineated seven different water-related (i.e., primarily agriculture) land use types and nine wetland cover types, along with various complexes of such cover classifications. CRSC also provided a twenty-seven page technical report, which had an additional eighty-three pages of appendix material detailing the location and extent of the various water-related cover types mapped. CRSC provided both the S.C.S. and Division of Water Resources with selected digital print map overlays which were compatible with corresponding U.S.G.S. quadrangles.

The delivery of final mapping products to the S.C.S. was followed up with a meeting on February 19, 1981 in Vernal, Utah. At the meeting, CRSC staff reviewed the techniques and results of the Uinta Basin study with several S.C.S. biologists and technicians. In discussing the utility of the study to S.C.S. programs, we were informed that S.C.S. biologists look to the wetland mapping to allow them the basic data for complying with S.C.S. wetland management directives. The S.C.S. has adopted the policy that agency personnel should not encourage the implementation of agricultural projects which would significantly diminish wetland areas. Without the wetland inventory CRSC has provided, it would be highly impracticable for S.C.S. biologists to efficiently assess the potential for wetland impacts in project planning. The S.C.S. has since requested an additional set of mylar maps as well as two full sets of mylar overlays of the digital print maps.

On January 27, 1981 several members of the Utah Division of Water Resources (DWR) visited CRSC for the purpose of receiving a visually-assisted explanation of the Uinta Basin study. DWR's interest in the study stems from its need to be able to prepare a basin-wide water budget: such water budgets require a detailed inventory of water-related land use to enable the estimation of evapotranspiration, hence the lengthy appendix material which provided a section by section areal inventory. Water budget information allows DWR to be effective in its effort to estimate consumptive water use and plan water development projects.

On March 6, 1981, CRSC was invited to make a presentation of the Uinta Basin and irrigation studies to the Utah Board of Water Resources: the water-resource policy-making unit of the Utah government structure. Said board showed substantial interest in the Landsat-assisted procedures for basin-wide water-related resource analysis and inventories.

On another occasion, in March, two representatives for the Uinta Basin Association of Governments requested a visit to the Center for the purpose of receiving an overview of the Uinta Basin study. Such representatives, upon seeing the study's final products, requested map overlays covering ten quadrangles: the Uinta Basin AOG representatives indicated that the maps would be valuable in that, by identifying wetland areas as well as prime agricultural lands, they provided an ideal basis for defining new town siting on the basis of land capability and suitability. At the present time, planners and local government officials in the Uinta Basin are hard-pressed to accomplish local growth planning because of the energy-development boom (i.e., oil and gas). Future urban growth is assured as commercially viable procedures are developed to permit the development of sizeable Uinta Basin oil shale resources.

Another application of the Uinta Basin study occurred this past week, when a Montana-based private planning consultant for the Uintah and Ouray Indian Reservation requested a copy of the Uinta Basin report and thirty of the thirty-eight quad overlays. Land and resource development on and near Indian lands in the Uinta Basin created the need for water resource information for land and resource decision-making purposes.

Davis County Foothill Development Study

The basic background for CRSC's involvement in Davis County investigation of foothill hazards and resources was also explained in the 1980 annual report (see pages 5-7). A copy of the study was delivered to the primary funding agency, the Four Corners Regional Council of Governments in time to meet the December 31, 1980 deadline. The remote sensing dimension of this study was entirely manual, using NASA U-2 CIR film and conventional B/W aerial photography. The project involved limited amounts of NASA funding, but the CRSC role was highly visible through Merrill Ridd and Richard Jaynes, who were the key coordinating personnel in the two-year project.

Since the report was delivered, Richard Jaynes of CRSC and Gene Carr, a professional planner, have been rewriting the Model Foothill Development Ordinance to better integrate the technical details of the study: such rewriting was also necessary in order to make the ordinance more compatible with the planning needs of local officials, as expressed in a series of meetings to obtain local feedback.

We feel that the technical study represents something of a landmark in urban growth planning because of the cooperative manner in which numerous professionals interacted to prepare the study, and because the study's technical report represented a unique effort to translate technical findings into lay terms. The focal point of the study, of course, is the Model Foothill Development Ordinance which includes the special features outlined on the two-page Attachment to this report. We believe that the revised structure of the model ordinance will serve to best synthesize the technical findings of the study into a workable foothill management tool.

CRSC plans to have limited continued involvement with the Davis County study as we assist in the preparation of a presentation to explain the technical study and the ordinance to elected and appointed local government officials. Updates on the progress of implementing the results of the foothill study will be made in future reports.

Farmington Bay Shoreline Fluctuation Study

A brief summary of the Farmington Bay study was provided in the 1980 annual report: the study used Landsat digital data to map five levels of the Great Salt Lake in the Farmington Bay area. It was also mentioned in the annual report that the results of the study have already produced a vivid decision-making payoff: the digital maps of lake level locations were used effectively to turn down a proposal to convert Farmington Bay into a fresh water lake. More recently, CRSC has made visual presentations of the shoreline study to the technical team for the Great Salt Lake Board and the upper administrative officials in the Utah Division of Wildlife Resources. Both groups have endorsed the shoreline study as a valuable tool for managing the water and wildlife habitat resources of Farmington Bay. Both groups also encouraged CRSC to pursue the second phase of the Farmington Bay study: this includes mapping of waterfowl habitat on a scale of 1:24,000. The two stages can then be combined as an effective waterfowl habitat management tool since the final products will include a vegetation base map with a shoreline fluctuation overlay.

MX Environmental Impact Statement Review

Early this year, after discussing a couple of portions of the MX Environmental Impact Statement (EIS) with Dr. Frederic H. Wagner (Utah State MX Review Coordinator), CRSC agreed to review and comment on the vegetation and land use portions of the EIS. The controversy over the land basing mode of MX missile deployment in Western Utah and Nevada, although national in scope, is particularly intense in Utah. Utah Governor Scott M. Matheson requested Dr. Wagner to assemble and supervise a state-wide technical team to review the MX EIS so that the State could formulate a policy thereto. CRSC found a number of serious deficiencies with the portions of the EIS it reviewed. The nature of the deficiencies dealt with the inadequately described remote sensing techniques used to accomplish the study and the inappropriately small-scaled maps of vegetation and land use provided. In addition, the types of vegetation classes delineated were too coarse to satisfy the baseline inventory purpose of the EIS. The comments of CRSC were included in the report of Dr. Wagner to Governor Matheson, who will rely on the report in future meetings and discussions with the U.S. Air Force. CRSC is planning to pursue the possibilities of performing additional work on the project with the Air Force.

Irrigation Detection: 1979 and 1980

This project is a follow-up to the "Illegal Irrigation Study, Iron County, 1978 Growing Season," reported in April, 1979. In the original study, performed for the Utah Division of Water Rights, the objective was to ascertain if Landsat data could be used successfully to identify whether farmers were irrigating more land than their water right allowed. It was found that manual Landsat image analysis did, indeed, provide the needed information. In determining whether particular fields were irrigated or not, the study missed on only one field examined.

The original study utilized three dates of MSS data (May 14, July 7, and August 3) in false color composite print form, and one date of RBV data (July 25), all enlarged to 1:125,000. The product delivered to the Division included slides of the four images (with township/section overlays), slides from the field for verification, and tables of the acreages in violation.

With the information, the Division director presented the data to the Attorney General's office for legal proceedings. A decision was made to authorize a groundwater study before proceeding. Now that it was shown that Landsat could provide the needed data in convincing form, the issue of reasonableness of the law itself arose. A two-year study was initiated to ascertain whether the basic assumption of the law is borne out in the physical system; i.e., does the "excess" water applied in a field by flood irrigation return to downstream users, or, to speak more directly, does the more "efficient" sprinkling process deprive downstream users? The state prepared for three possible outcomes of the groundwater investigation: (1) that the recharge does occur (in which case the state would keep the law intact and prosecute violaters); (2) that the recharge does not occur (in which case the state would proceed to change the law and allow expansion of irrigated acreage); or (3) that the study is inconclusive (in which case the state would keep the law and prosecute). In cases 1 or 3, it was stated that Landsat image analysis would be the method of showing whether a field was irrigated or not.

In the interim, as the groundwater study ensued, CRSC agreed to gather limited Landsat data on the same fields (as the 1978 study) for 1979 and 1980 growing seasons. The plan was to determine the effectiveness of single date MSS image analysis. For 1979 a July 2 image was obtained. For 1980 only a May 30 date was available. The images were examined for each field, first to determine whether the field was irrigated, and than to estimate the acreage irrigated.

The result of the follow-up study showed that, while a single-date analysis may omit some fields that would show up at another date as irrigated, it provides at least a "minimum statement" of irrigated land for the season. This would be sufficient to prosecute if the allotment were shown to be exceeded by acreage statement from the single date. If the agency desired a total statement of irrigated acreage, however, then at least two dates, and preferably three, would be needed.

Satellite Investigation of Snow Cover/Mule Deer Relationships

CRSC partially supported a two-year study, conducted with the Utah Division of Wildlife Resources, in which the mule deer herd population indicators (i.e., pellet group counts, browse utilization, fawn/doe ratios, deer harvest statistics, etc.) were correlated with areal snow cover estimates from black and white Landsat images. The objective of the study was to investigate the feasibility of using Landsat-derived snow cover information as an additional or alternate factor in influencing the deer bag limits and conditions in deer herd units which are set annually by the Utah Board of Big Game Control.

It is known that a strong relationship exists between deer populations and the physical barrier presented by snow cover. Other types of natural and man-created structures or land features also influence the amount of winter range used by deer. By analyzing areal snow cover in combination with deer population indexes in the Utah study area, over a five year period, a significant relationship was detected between snow cover and the number of deer-days use per acre. It should be noted that an initial attempt to obtain such correlations based upon data for individual deer herd units was unsuccessful: such units are not generally separated by significant physical barriers to inhibit deer population movement from one area to the other. When new deer study units were created which were sensitive to deer herd ecological needs and behaviors, significant relationships began to emerge.

In conclusion, this study showed that Landsat imagery holds potential as a deer herd management tool; the extent to which deer may effectively utilize a given winter range habitat is largely a function of snow cover conditions. The study also pointed out the need for members of the Division of Wildlife Resources to rethink the manner in which deer herd units are delineated. Simply stated, deer herd units should be defined by features which influence deer herd movement and not, as is the existing case, on the basis of socio-political units. The present arrangement of deer herd unit boundaries at least partially explains why deer population indexes, collected from field data, are not necessarily a true reflection of herd condition and productivity. The study report contains recommendations as to how deer herd boundaries might be more effectively modified.

At the present time, the Division of Wildlife Resources is aware of the deer herd boundary problems as well as the limitations of population indexes. In meetings with the Division officials, we have been informed that a new series of deer mortality transects will be initiated this year. After reviewing the results of CRSC's snow cover study with Division personnel, we have been encouraged chat snow cover estimates are likely to be used in combination with such mortality transects, as field data is acquired. The hope is, within the

Division, that the new transects will be a more direct indicator of deer herd productivity. Although the bureaucratic inertia is firmly attached to traditional methods of managing deer populations in Utah, we hope that the Division will continue to explore, and eventually adopt or change to, more enlightening management techniques.

TECHNIQUES DEVELOPMENT

In this final section, are summarized some of our recently developed and/or modified techniques. Each one has grown out of a particular need on a specific project. And each one has thus provided a special kind of answer tailored to project needs. In addition each technique has proven valuable on subsequent projects. In this way we have grown rapidly in the digital processing domain and we are committed to continuing that policy. In this way we are able to offer the client a broad and growing range of technical options across the digital realm and manual techniques, with a variety of output products, particularly as we continue to work with the Computer Science Department and the Medical School.

We should also mention our cartographic capabilities. As the name of our laboratory suggests, we take special pride in our cartographic applications and finished products. Cartographic considerations and accuracy constraints are integral with every remote sensing project and all remote sensing operations from classification to field work, to geo-referencing the classified product, to delivering the final product, whatever the format or medium. It is for this reason we chose to call our facility the Center for Remote Sensing and Cartography.

Composite Computer Mapping

Beginning with our first NASA project in North Ogden (1977) we developed the ability to sandwich multiple factor maps together for a given site, weighting the several factor maps in various ways to achieve alternative solutions to geographically-oriented problems: as in the case of North Ogden urban development hazards. This was an early application of what has come to be called Geographic Information System (GIS) mapping.

Following this, we developed the ability to add to such a set of physical development constraints, a Landsat-derived land use map to "factor out" the prime agricultural land from the path of urban development. The end-result was a practical interfacing of remotely sensed digital data with a set of GIS digitized maps (Farmington Bay Quadrangle project, 1977).

Contrast Enhancement

In late 1979, we found ourselves advising, and later performing a substantial remote sensing operation for a private Salt Lake City firm, Native Plants, Inc., to fulfill a contract to the Mexican Government on the distribution and inventory of guayule, a rubber-bearing desert shrub in northern Mexico. Out of necessity, we had to develop a way to inventory and map the guayule with Landsat data alone: the promised aerial photos from Mexico never arrived. Since the university's UNIVAC 1108 was down for conversion to a new system, we turned to the Medical School and the Computer Science Department and developed a contrast enhancement (color stretching) capability that beautifully filled the needs of the job -- on time.

Through multiple contortions (expanding, clipping, equalizing, etc.) of the histograms of brightness of bands 4, 5, and 7 (raw data) we came up with a color product of remarkable contrast, on which we were able to clearly delineate, manually, the areas of occurrence of guayule. Although the average size of the plant is about a foot in height, and its mean density is only 9% in its areas of occurrence, we felt confident that we had adequately identified and inventoried guayule habitat. Fortunately there is a close association with terrain, soil, and moisture availability. By normal interpretation the guayule environment was delineated for a 50 kilometer radius circle. Computer planimetry automatically "deskewed" the data and calculated the acreage.

This technique is now in our arsenal for appropriate application to whatever jobs may benefit from its unique capability. As we apply it each time we will improve its diagnostic potential, applying a litte R & D effort with each use.

U-2 CIR/Landsat Digital Interface

Again arising out of experimentation on the particular needs of a project, we developed a technique for interfacing Landsat digital data with NASA U-2 CIR film positives. The objective was to classify and map the pattern of wetlands and water-related land use in the Uinta Basin of northeastern Utah (1980). Thirty-eight 7½ minute U.S.G.S. quadrangles were involved.

After some field and lab reiteration, we struck on the process of photo-reducing digitized print maps from Landsat CCT's for each quad to the scale of the U-2 photography. The merger of the two media greatly improved the accuracy of classification from either technique alone (i.e., U-2 or Landsat printmaps) or the sum of the two procedures. Variations in field patterns which the eye could not detect on the U-2 photos became evident from the digital overlay (actually, underlain on the light table). From this variation it is possible not only to be more sure of the crop or wetland classification decisions, but the digital variations gave the interpreter the ability to make probablistic statements about the relative amounts of water consumption or application (in the case of the crops). This successful performance of the project (on time and within budget) led to the signing of another project in the upper Sevier River basin, as mentioned elsewhere.

Factor Analysis

Out of the Price River study (1978), searching for a finer separation of dry rangeland classes, we developed the application of a factor analysis routine. The technique was written up by a CRSC staff member/consultant, Professor Lawrence M. Harmon. Although we have not reported on it before, it has served as a springboard into a more sophisticated statistical package recently developed at CRSC by John A. Merola, which follows below.

Multivariate Statistical Package

Again, arising "out of necessity" in a study initiated by John Merola for the U.S. Forest Service, a whole array of sequential routines were developed and applied. A somewhat detailed discussion of the routines provided by Mr. Merola follows. At the conclusion of the technical discussion, the role of the technique in two projects is emphasized: (a) aspen in Utah, and (b) guayule in Mexico.

Three multivariate statistical technqiues are used to develop logical groups of spectral classes (signatures). These methods are principal components analysis, and two classification technqiues called cluster analysis and discrimination analysis. The combination of these techniques has given us a method of growing signatures which has been shown through our experience to correspond with a high degree of accuracy to the spatial distribution of land cover and land use.

The signatures are derived from the program Search, which is an "unsupervised trainer of a maximum likelihood classifier". By using this method of grouping signatures it is possible to evaluate more than the limit of 63 signatures found in the classification program MAXL63. As many as 80 to 100 signatures usually are generated.

The goal of each analysis determines the most appropriate method of applying the statistical techniques course of action. For example, if the detection of a specific ground cover is the research goal and at least several known areas of such cover's distribution can be located on a digital print map, it is possible to create a map for each of the areas (windows) which are "searched". This is done to identify the signatures in the particular windows believed to represent the type of ground cover being searched. These signatures are then given a non-exclusion status, which means they will not be eliminated in any further analysis. Usually, signatures produced in this manner number less than 30, which means there is room for 33 or more other signatures in the analysis.

If, on the other hand, the research goal is to identify and map more than one type of ground cover, and we are familiar with the study area, the goal of the analysis is to provide MAXL63 with a spectrum of signatures. If, for example, a desert area is being studied, concentration would be placed on the high reflectance signatures generated. In a wet land or marsh area concentration would be placed on the low-to-middle reflectance signatures, and in a forested area concentration would be placed on the middle range of signatures.

There are certain considerations to be made regardless of the research goal or type of analysis. One of these is to search a window that is large and covers an area representative of the entire study area. This is to generate signatures that represent the over-all light reflectance of the study area. The next step would be to search areas known to have the ground cover being analyzed in the study. The number of areas to be searched depends on how many of the ground cover types occur in the windows being searched. Generating about 100 signatures as a maximum seems to be a good rule of thumb. After the signatures to be used in the statistical routines are generated, further study of the investigation continues with an analysis of principal components. In this procedure the mean values of each signature's two visible bands and the two near infrared bands are combined into two principal components: one combining the visible and one combining the near infrared values. This is used as a data transformation technique, which gives new orthogonal, uncorrelated variables for use in cluster and discriminant analyses. The output of principal components that is used in further analyses are the component scores for each signature. The component scores are the contribution each component makes to the variance of the new variable, based on the original signature values (Johnston, 1978).*

The next step is to use cluster analysis to group the signatures into categories of similar individuals. The goal of this technique is to create a new, nominally scaled variable. The nominally scaled variable is a number assigned to each of the groups of signatures. The groups of signatures are chosen visually from the linkage tree that is produced by the program used (BMDP cluster analysis).

The next step is to pass the signature component scores and the group numbers onto discriminant analysis that we consider important: the measure of the probability of a signature being a member of a group; the closeness of a given signature to the mean of that group; the probability of a signature

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*Johnston, R.J. Multivariate Statistical Analysis in Geography, Longman, 1978.

belonging to another group, a "territorial map" of the groups; and, of greatest value, a scatter plot of the groups and their members. The scatter plot is most important because it is from this plot that decisions are made to keep or eliminate a signature from use by MAXL63 for the final classification of our study area.

The choice as to which signatures to keep or eliminate is based on the fact that every pixel will be classified by MAXL63 into one of the signature classes provided. The goal is to provide signatures that will allow the ground cover(s) in which we have the greatest interest and ground cover of lesser interest to be classified, so as to reduce the possibility of mis-classification or confusion classes. To accomplish this the output of discriminant analysis (particularly the scatter plot) is used. As stated above, at this point approximately 100 signatures are available from which choices will be made to reduce the number of signatures to 63 or less for use in MAXL63. This is begun by isolating the groups of signatures known to represent ground cover of particular interest, such as a group that represents aspen trees. It is known that there are various densities of aspen tree cover and that other deciduous trees and shrubs are easily confused with aspen. Consequently, any signatures in or around an aspen group of signatures would not be eliminated. On the other hand, there may not be interest at all in various levels of bare ground or rock in urban areas, and such signature distinctions would be lumped.

On the scatter plot there are typically several members in all groups. The groups of signatures in which we have the greatest interest are given a non-exclusion status, which means all signatures from such groups are to be used in the classification of the study area. On the other hand, the groups of non-interest signatures, such as bare ground, need to have only one or two members of their group in the classification. Thus, only one signature may be chosen from the scatter plot to represent such non-interest group, or type of ground cover, in the final classification. The methods outlined above allow us to obtain a maximum breakdown of the ground cover for which we have the greatest interest, while still allowing MAXL63 to classify the ground cover of less interest. The result is a semi-superised approach to classification of Landsat data, with maximum discriminating power through a process tailor-made to the specific detail of the job.

The above technique has served as the foundation for Landsat digital analysis of aspen site quality in northern Utah and guayule in northern Mexico. In the aspen case, a cool humid forest environment is involved. The technique derived four classes of aspen site quality that correspond very closely with a plant understory index to aspen timber site quality. A random sample of 26 Landsat derived aspen sites proved in every case in the field to be aspen. Further, the determination of the four site quality classes derived from the multivariate statistical package resulted in statistically significant class separations which correlated well with field-measured data.

In the desert application of Mexico, the package was remarkably discriminating of subtle variations in arid plant densitites and distributions. On the first pass, a general guayule environment was identifed. On subsequent passes, looking at small windows, three classes, and ultimately 16 classes of guayule production were identified. A 150 kilometer radius circle was analyzed, and the 16 classes were finally lumped into three groups -- high, medium, and low yielding quayule, for which mean percentages of density, and finally total production was estimated. While a complete verification procedure has not been applied, the discriminating power of the mulitvariate package proved indispensible. Further application and refinement will be pursued.

Looking Forward to ELAS

Most of the above-described statistical procedures are encompassed in the ELAS software. What we have developed independently should be very helpful in accessing and applying, and perhaps improving, the ELAS package as we put it on line. We are confident that over the next few months, as the programs are operationalized on the PRIME, we will develop a first rate digital capability interfacing remote sensing data with GIS operations, digital terrain data (to assist in stratification procedures), multitemporal Landsat registration (for monitoring and for better classification), and a host of statistical routines for maximum classification discrimination.